ISSN: 2067-3809

Universitatea Politehnica Timișoara

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering

Fascicule 4 [October–December]
Tome XV [2022]

15 years ANNIVERSARY

Editura POLITEHNICA

15 YEAR ANNIVERSARY
ACTA TECHNICA CORVINIENSIS
Bulletin of Engineering

Edited by:

UNIVERSITY POLITEHNICA TIMISOARA

Universitatea Politehnica Timişoara

Editor / Technical preparation / Cover design:

Assoc. Prof. Eng. KISS Imre, PhD.
UNIVERSITY POLITEHNICA TIMISOARA,
FACULTY OF ENGINEERING HUNEDOARA

Commenced publication year:
2008

15 YEAR ANNIVERSARY
ACTA TECHNICA CORVINIENSIS
Bulletin of Engineering

ASSOCIATE EDITORS and REGIONAL COLLABORATORS

The Editor and editorial board members do not receive any remuneration. These positions are voluntary. The members of the Editorial Board may serve as scientific reviewers.

We are very pleased to inform that our journal ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering is going to complete its ten years of publication successfully. In a very short period it has acquired global presence and scholars from all over the world have taken it with great enthusiasm. We are extremely grateful and heartily acknowledge the kind of support and encouragement from you.

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering seeking qualified researchers as members of the editorial team. Like our other journals, ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering will serve as a great resource for researchers and students across the globe. We ask you to support this initiative by joining our editorial team.

If you are interested in serving as a member of the editorial team, kindly send us your resume to redactie@fih.upt.ro.

ISSN: 2067-3809

INTERNATIONAL SCIENTIFIC COMMITTEE MEMBERS and SCIENTIFIC REVIEWERS

The Scientific Committee members and Reviewers do not receive any remuneration. These positions are voluntary.

We are extremely grateful and heartily acknowledge the kind of support and encouragement from all contributors and all collaborators!

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering is dedicated to publishing material of the highest engineering interest, and to this end we have assembled a distinguished Editorial Board and Scientific Committee of academics, professors and researchers.

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering publishes invited review papers covering the full spectrum of engineering. The reviews, both experimental and theoretical, provide general background information as well as a critical assessment on topics in a state of flux. We are primarily interested in those contributions which bring new insights, and papers will be selected on the basis of the importance of the new knowledge they provide.

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering encourages the submission of comments on papers published particularly in our journal. The journal publishes articles focused on topics of current interest within the scope of the journal and coordinated by invited guest editors. Interested authors are invited to contact one of the Editors for further details.

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering accept for publication unpublished manuscripts on the understanding that the same manuscript is not under simultaneous consideration of other journals. Publication of a part of the data as the abstract of conference proceedings is exempted.

Manuscripts submitted (original articles, technical notes, brief communications and case studies) will be subject to peer review by the members of the Editorial Board or by qualified outside reviewers. Only papers of high scientific quality will be accepted for publication. Manuscripts are accepted for review only when they report unpublished work that is not being considered for publication elsewhere.

The evaluated paper may be recommended for:

- Acceptance without any changes – in that case the authors will be asked to send the paper electronically in the required .doc format according to authors' instructions;
- Acceptance with minor changes – if the authors follow the conditions imposed by referees the paper will be sent in the required .doc format;
- Acceptance with major changes – if the authors follow completely the conditions imposed by referees the paper will be sent in the required .doc format;
- Rejection – in that case the reasons for rejection will be transmitted to authors along with some suggestions for future improvements (if that will be considered necessary).

The manuscript accepted for publication will be published in the next issue of ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering after the acceptance date.

All the authors and the corresponding author in particular take the responsibility to ensure that the text of the article does not contain portions copied from any other published material which amounts to plagiarism. We also request the authors to familiarize themselves with the good publication ethics principles before finalizing their manuscripts.

ISSN: 2067-3809

Fascicule 4
[October – December]
tome XV [2022]

ACTA Technica CORVINIENSIS
BULLETIN OF ENGINEERING

ISSN: 2067-3809

TABLE of CONTENTS
ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
Tome XV [2022],
Fascicule 4 [October – December]

The ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering, Tome XV [2022], Fascicule 4 [October – December] includes original papers submitted to the Editorial Board, directly by authors or by the regional collaborators of the Journal.

Also, the ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering, Tome XV [2022], Fascicule 4 [October – December], includes scientific papers presented in the sections of:

— The 10th International Scientific Conference – IRMES 2022 – "Machine design in the context of Industry 4.0 – Intelligent products", organized under the auspices of the Association for Design, Elements and Constructions (ADEKO), by University of Belgrade, Faculty of Mechanical Engineering, Department of General Machine Design, in 26 May 2022, Belgrade (SERBIA). The current identification numbers of the selected papers are the **#4–7**, according to the present contents list.

— International Conference on Applied Sciences – ICAS 2022, organized by University Politehnica Timisoara, Faculty of Engineering Hunedoara (ROMANIA) and University of Banja Luka, Faculty of Mechanical Engineering Banja Luka (BOSNIA & HERZEGOVINA), in May 25–28, 2022, in Banja Luka (BOSNIA & HERZEGOVINA). The current identification numbers of the selected papers are the **#12–16**, according to the present contents list.

— International Symposium (Agricultural and Mechanical Engineering) – ISB–INMA TEH' 2021, organized by Politehnica University of Bucharest – Faculty of Biotechnical Systems Engineering (ISB), National Institute of Research–Development for Machines and Installations Designed to Agriculture and Food Industry (INMA Bucharest), Romanian Agricultural Mechanical Engineers Society (SIMAR), National Research & Development Institute for Food Bioresources (IBA Bucharest), National Institute for Research and Development in Environmental Protection (INCDPM), Research–Development Institute for Plant Protection (ICDPP), Research and Development Institute for Processing and Marketing of the Horticultural Products (HORTING), Hydraulics and Pneumatics Research Institute (INOE 2000 IHP) and "Food for Life Technological Platform", in Bucharest, ROMANIA, between 31 October – 1 November, 2021. The current identification numbers of the selected papers are the **#18–20**, according to the present contents list.

CELEBRATING 15 YEARS OF EXCELLENCE

A milestone moment for ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering!

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering is an international and interdisciplinary journal which reports on scientific and technical contributions and publishes invited review papers covering the full spectrum of engineering.

We are very pleased to inform that our journal ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering completed its 14 years of publication successfully [2008–2021, Tome I–XIV]. In a very short period it has acquired global presence and scholars from all over the world have taken it with great enthusiasm. This year, 2022, marks ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering' **15th year in scientific publishing**! Our ability to adapt has allowed us to prosper over the years. I look forward to new challenges, new technology and to seeing what the next 15 years will bring. We look forward to the next 15 years of service excellence!

We are extremely grateful and heartily acknowledge the kind of support and encouragement from all contributors and all collaborators! Our ongoing success would be impossible without you! And thank you to all of our readers and partners who continue to believe in our services and people, and who have helped us endure and thrive throughout the years.

Every year, in four online issues (fascicules 1 – 4), ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering [e–ISSN: 2067–3809] publishes a series of reviews covering the most exciting and developing areas of engineering. Each issue contains papers reviewed by international researchers who are experts in their fields. The result is a journal that gives the scientists and engineers the opportunity to keep informed of all the current developments in their own, and related, areas of research, ensuring the new ideas across an increasingly the interdisciplinary field.

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering is a good opportunity for the researchers to exchange information and to present the results of their research activity. Scientists and engineers with an interest in the respective interfaces of engineering fields, technology and materials, information processes, research in various industrial applications are the target and audience of ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering. It publishes articles of interest to researchers and engineers and to other scientists involved with materials phenomena and computational modeling.

The journal's coverage will reflect the increasingly interdisciplinary nature of engineering, recognizing wide–ranging contributions to the development of methods, tools and evaluation strategies relevant to the field. Numerical modeling or simulation, as well as theoretical and experimental approaches to engineering will form the core of ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering's content, however approaches from a range of environmental science and economics are strongly encouraged.

Publishing in ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering is free of charge. There are no author fees. All services including peer review, copy editing, typesetting, production of web pages and reproduction of color images are included. The journal is free of charge to access, read and download. All costs associated with publishing and hosting this journal are funded by ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering as part of its investment in global research and development.

ISSN: 2067–3809

Fascicule 4
[October – December]
tome XV [2022]

ACTA Technica CORVINIENSIS
BULLETIN OF ENGINEERING

ISSN: 2067-3809

[1.]Abdulrasaq Ayinla CHINDO, [2.]Fatai B. SULE, [3.]Sulyman Balogun LAITAN, [4.]Wahab A. SALAMI, [5.]Laniyi Laniran LADOKUN

A COMPLEMENTARY APPROACH TO PREDICTING MAGNITUDE OF FLOOD ALONG FOMA RIVER USING CROSS-SECTIONAL VARIABLES

[1,5] National Centre for Hydropower Research and Development, Energy Commission of Nigeria, University of Ilorin, Ilorin, NIGERIA
[2,4] Department of Water Resources and Environmental Engineering, University of Ilorin, Ilorin, NIGERIA
[3]Department of Food and Agricultural Engineering, Kwara State University, Malete, Kwara State, NIGERIA

Abstract: Flood hazards have been on the increase in recent years especially along the riverbank. The hazards tends to impact on human lives and results in severe economic damages across the world. However, forecasting the magnitude of flood especially in Nigeria across the coastal areas have been hindered by several complications, including inaccurate data, poor assessment of drainage basin, pollution, and encroachment. This study made use of the Geographical Information System (GIS) tools to derive cross-sectional variables that were significant in complementing the prediction of the magnitude of flood along Foma-river areas. Global Position System (GPS) was used to obtain the coordinate points along the river areas, Google earth imagery and topographical data of the study areas were obtained. The basin areas, streamlines, lengths of the river and its tributaries were also generated. The buffering of the river in 15 and 30 meters exposes the vulnerability status of structures along the river. Out of the 530 structures captured, 49 structures were highly vulnerable, while 105 structures were vulnerable to flood hazards. The predictive accuracy of the ordered logit model approximated 81%. While a 10% error in classification was resulting from the harmonization of the precision value (0.8026) and the recall value (0.6386). The cross-sectional variables that were found to be significant at $\alpha = 0.005\%$ are the river watersheds, the vulnerability status classification of structure across the river areas, the vulnerable structures identified, inadequate bridges and culverts along the river areas, inappropriate size of bridges and culverts, and extreme pollution along the river areas. This study is recommending the use of significant cross-sectional variables to complement the prediction of magnitude of flood along the riverbanks.
Keywords: buffering, cross-sectional, georeferenced, magnitude, spatial

INTRODUCTION

Floods are among the most periodic and overwhelming natural hazards, which tend to impact on human lives and results in serious economic damages across the world. Its intensity tends to threaten the entire world due to the underlining effect of climate change (Hasselaar, 2020). However, evaluating the possibility and magnitude of flood has been hindered by several complications including, climate change, inaccurate data, poor assessment of drainage basin, pollution, and encroachment (Ayanshola, et al., 2018). Studies have reported some difficulties in sampling technique of conventional rain and discharge measurement, which have hindered the accurate evaluation of the magnitude of flood, especially along the river areas. The work of Nassery, et al., (2017), also established that many existing prediction equations are based on experimental data having many experimental and constant parameters with an ambiguous estimate often required to be fixed. Such problems from previous predictions are the difficulty in the sampling of conventional rain and discharge measurement networks that makes it difficult to predict accurately.

The existing assessment of rivers tends to indicate that the level of flood quite differs from one river to the other even despite being in the same geographical location. This can be attributed to both natural and human factors such as watershed, drainage basin, drainage capacity, level of pollution, encroachment activities and many others (Du, et al.. 2019). Studies mostly focus on the relationship between the amount of rainfall and the magnitude of flood. This practice cannot be so accurate because, in actual sense, rainfall often not evenly distributed along the same geographical location, which may likely have the presence of several streams or rivers with their peculiar factors and determinants (Du et al., 2019).

Studies have established that Geographic Information System (GIS) is a very powerful tools that allows the collection, processing of geographically related data. The tool has been equally used as an instrument in problem-solving, decision-making processes, and as tool for visualizing data in a spatial location (Kraak, & Ormeling, 2020). The tool has several advantages, which includes, analysing geographical data to determine the location of structures and relationships to other landscapes, determination of watershed, and drainage density, what is likely to happen to an area of interest, and particularly, how and in what way an area has changed over time (Picuno, et al., 2019). The realization of data with the use of GIS techniques will give a complementary approach to determine cross-sectional variables which are significant to predicting the magnitude of flood along the river course. Cross-sectional variables can be observed at the local scale. The procedures involve numerical data about intrusion and runoff dynamics (Rogger, et al., 2017). The variables have some peculiar characteristic that dictates the direction of flow of flood in each river or stream rather than just a prediction through generalization which may not be so accurate. Figure 1 presents the watersheds of Foma river areas.

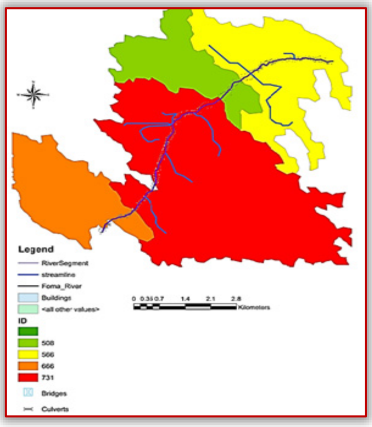


Figure 1. Foma River Watersheds

THE CHALLENGE OF FLOOD FORECASTING AND MITIGATION IN NIGERIA

Nigeria is likely to face the consequences of climate change due to its geographical location. The country is bounded by located along Atlantic Ocean to the south and the Sahara Desert to the north. This, by implication may lead to an increase in the temperature that influences the rainfall pattern and resulting in the rise of extreme drought and flood (Ayanshola, et al., 2018). Due to its location, several cases of flooding in Nigeria have been reported in recent times, mostly in Sokoto, Lagos, Ibadan, Abeokuta, Gusau, and Makurdi (Chindo, et al., 2019). Not less than 39 people were killed due to flooding in central Nigeria, Plateau State, towards the end of July 2012. The Lamingo dam had an overflow and swept across several localities in Jos, and about 200 houses were inundated or devastated after protracted rain. At least 35 people were reported missing, prompting the head of the Red Cross organization to announce that relief efforts were being initiated (Chindo, et al., 2019). The spatial distribution of areas extremely affected by the flooding in Nigeria is shown in Figure 2.

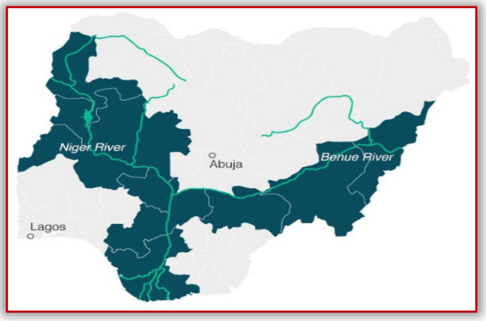


Figure 2. Distribution of Areas Affected by Extreme Floods in Nigeria

Similarly, Olorunfemi and Raheem (2013 reported that the major causes of flooding in the Ilorin are building on the floodplain, dumping of refuses in drainages and rivers, farming on the floodplain, all of which causes siltation, blocking of water ways and drainage channels and inundation. The city of Ilorin is the Kwara State capital, located in the north-central part of Nigeria. The state is found between the latitude $8^0$24'N and $8^0$36'N and between longitude $4^0$10'W and $4^0$36'E, also experienced flooding in some part of its metropolis. During the 2017 raining season, the city of Ilorin experienced a devastating flood hazard. Many residential buildings were reported to have submerged after a protracted rain that lasted for hours. The heavy rain, which was accompanied by flooding, washed away asphalt on some township road. The ravaging flood also washed away bridges and destroyed valuable properties, as reported in the Nigeria Tribune newspaper (Azeez, 2017). The Alagbado bridge along Foma river which was washed away during the 2017 heavy raining season is captioned in Figure 3.

Figure 3. Alagbado bridge along Foma-river washed away by the flood

The aim of this study is to develop a supervised model to complement the prediction of the magnitude of flood along the banks of Foma river. Other sub-objectives are to examine the river buffering in 15 meters and 30 meters across the Foma river floodplain areas, identify the cross-sectional variables in complementing the prediction of the magnitude of flood along the buffering areas of Foma river, determine the significance of the cross-sectional variables in complementing the prediction of the magnitude of flood along Foma river banks using Ordered Logistic Regression (OLR) model, and evaluate the performance of OLR in complementing the prediction of the magnitude of flood along Foma river using performance measurement metrics.

FLOOD EVALUATION USING GIS AND CROSS-SECTIONAL METHODS

Cross-sectional study is an established method to estimate the outcome of interest at a particular time, for a specified location and it is usually applied for health planning, hazard, or risk exposure. In the work of Ezzatvar, et al., (2020), cross-sectional study reflected a short period of exposition and has some characteristics associated with a specific period. Cross-section design was used to study the mental health status of adults affected from each of the flood-affected households of Koonimedu village and Tami Nadu. The Study revealed the effects of the flood evidence in relation to standard of living and economy. Similarly, a multidisciplinary evaluation on the effects of green infrastructure and flood administration on physical health, mental health, economy and flood resilience of individuals, households, and communities were carried out by Venkataramanan, et al., (2019). Among the reasons for carrying out the cross-sectional study is to describe survey exercise, which usually does not have a hypothesis. The main aim is to describe some groups or sub-groups about the outcome of risk factors. Also, the goal is to elicit the prevalent outcome of interest for a descriptive population or group at a given time (Venkataramanan, et al., 2019).

The GIS application to flood hazard evaluation and management has not been an often-used method until the year 2000. The work of Mejía-Navarro, et al., (1994), initially used the GIS to estimate several risks in many areas of Colorado, to determine the suitability of land. The development of GIS modelling for excess rainfall was the approach adopted by Schumann, et al. (2000). In Nigeria, Isma'il, and Saanyol (2013) observed that the difficulty in the sampling technique of the conventional rain coupled with discharge measurement networks makes it challenging to observe and predict flood accurately. Similarly, Ngene, et al., (2015) elicited some technical deficiencies that have been preventing Nigeria from getting preferred, and accurate, rainfall data. The research enumerated the present capacity of Nigeria's rain gauge network and the need according to the World Meteorological Organization's (WMO) guideline. Nigeria presently has 87 rain gauges, instead of 1057 (Ngene, et al., 2015). In essence, the country needs extra gauges of 970 to achieve a gauge density of 874 km^2 per gauge for the appropriate measurement of rainfall. Because of this deficiency and based on the current insufficiency of gauges, Nigeria is suffering from a 10% error in design. Because the standard condition to minimize and maximize the effectiveness for areas on the temperate Mediterranean and tropical is a range of 600-900 km^2, the inaccurate records of rain data led Nigeria to be hugely affected by the devastating flood of September 2012. This event had negative effects on the economy, roads, ports, rail lines, and most especially the water infrastructures (Ngene, et al., 2015).

METHODOLOGY

This study focused on assessment of a complementary approach to flood prediction using the GIS software. The software was initiated through Global Positioning System (GPS) to obtain the coordinates of the river channels, while the images of the earth are referenced in eastern (X) and northern (Y) coordinates. The processes elicited some cross-sectional variables from the river areas, which are significant in determining the magnitude of flood along the Foma river channel. Arc GIS 9.3® software was used to analyse high-resolution imagery from google earth.

— Research Designs

The problem-focused upon and addressed in this study is to develop a supervised model of cross-sectional variables to complement the prediction of the magnitude of flood along the Foma river. This study investigated how GIS generated variables and direct observation can be utilized to develop a supervised model in predicting the magnitude of flood (dependent variable) along the Foma river. The GIS application elicited the river buffer to determine the vulnerable areas, generate watersheds, obtain the drainage densities, and determine the vulnerable structures along the buffered areas of the Foma river. Meanwhile, site observations resulted in the location of the bridges and culverts along the river, the size of the bridges and culverts measured, the observation of specific location along the river and pollution rate. The flow chart for the study is shown in Figure 4.

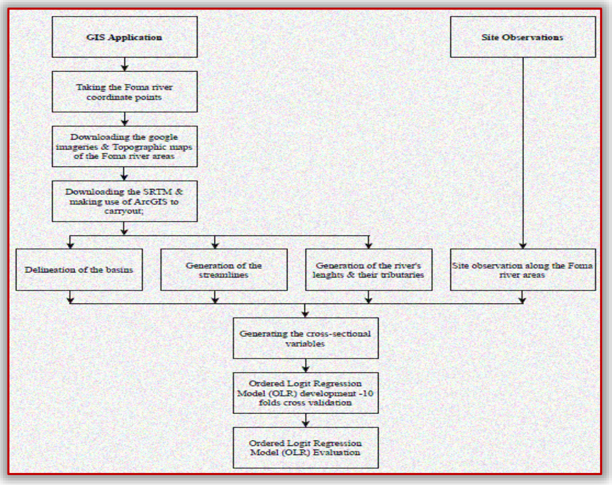


Figure 4. Flow Chart Showing the Research Design

The use of GIS tools and methods ensure the generation and observation of some cross-sectional variables that are suspected to be significant in predicting the magnitude of flood along the Foma river. Table 1 presents the cross-section variables that were derived through the application of GIS and site observations.

Table 1: Cross-sectional Variables from Foma river Areas

Variable Name	Task	Values	Data Type
River Watershed	Input	Shed1, Shed2, Shed3, Shed4	Nominal
Drainage Density	Input	0.0001, 0.0002, 0.0005, 0.0007	Ordinal
Vulnerable Status of structures	Input	Not Vulnerable, Fairly Vulnerable, Highly Vulnerable	Ordinal
Types of Vulnerable Structures	Input	Hospital, Police post, Fishery ponds, Abattoir, Educational, Commercials, Slum, Agriculture, Residentials	Nominal
Bridges and Culverts	Input	CAIS, Apalara, Oke-foma, Foma-bridge, Ajetunmabi, Oloje-bridge, Abata Baba-oyo, Alagbado Bridge, Sobi-bridge	Nominal
Size of Bridges and Culvert (m)	Input	2.1, 4.5, 7.2, 11.2, 14.9, 15, 19.5, 60.8	Ordinal
River Point	Input	Source, Middle, Extreme, Terminal	Nominal
River Pollution	Input	Fair, High, Severe, Extreme	Ordinal
Magnitude of Flood	Target	Mild, Moderate, Severe, Extreme	Ordinal

Source: Field Work (2019)

The study captured the vulnerability status of structures induced by the flood activities along the course of the Foma river using remote sensing technique. This was carried out on flood-prone areas and the buffering examined using Arc-GIS. Structures located within 15 meters of the river bank were considered highly vulnerable to flood hazards, while those structures within 30 meters to the river were considered fairly vulnerable (The map of Ilorin west was acquired to create a database for the buffering). Also, Foma river map was extracted, georeferenced and digitalized into 1:50,000 from the topographical map of Kwara state. The digitalization of the map involves the process of electronic scanning in order to convert it to points and lines using on-screen digitization. Specifications were then made to identify the objects on the map so that the Arc-GIS was linked using the spatial data with attributes of identified structures. The buffering of the river revealed the number of structures that were highly vulnerable, fairly vulnerable and those that cannot be affected by flood hazards. Figure 5 exhibits the status of vulnerable structures along the river areas, while Table 2 reflects the delineation of the vulnerable status and number of structures within each drainage area along the Foma river.

Figure 5. Showing Vulnerable status of structures along Foma river areas

Table 2: Vulnerable Status Classification along the River

ID	Description	Frequency
0	Not Vulnerable	377
1	Fairy Vulnerable	105
2	Highly Vulnerable	49

To carry out the pre-classification exercises, the original sample was split into 90/10 % repeated seed training/ testing sets. A non-exhaustive cross-validation k-fold was used with k=10 so that the original sample be randomly divided into k equal sized subsamples. Thus, taking out the subsample to be known as validation variables to test the model, where outstanding k-1 subsamples were considered as training data. The process is repeated until every k-fold serves as the test set, such that the average record scores (E) of the 10 folds become the performance metric of the model. Where E as defined in equation 1 is the addition of performance scores in the iteration.

$$E = \frac{1}{10}\sum_{i=1}^{10} E_i \qquad (1)$$

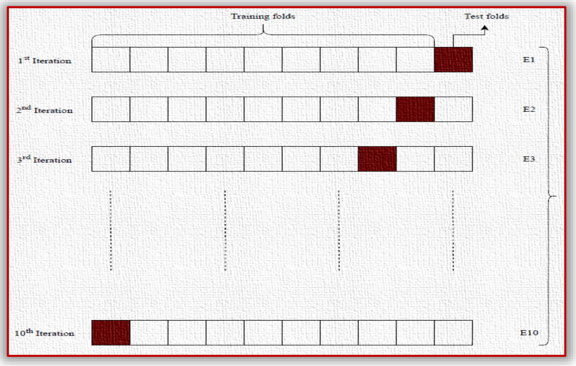


Figure 6. Cross-validation technique in the study

The cross-validation technique in the study is demonstrated in Figure 6.

However, the dependent variable (magnitude of the flood) is taking more than two categories. Thus, we employed the use of ordered logit approach due to its capability to predict the presence or absence of a dependent variable. Also, its uniqueness in predicting the probability of each character in the model because the chance is a ratio. The interpretation of results in the odd ratio, parameter estimate, and probability is quite an added advantage in the area of the results' analyses. Since the dependent variable has more than two categories, and the interval between the categories was in the relative sequential order in a way that the value is indeed higher than the previous one, then the ordered logit approach would be deemed applicable.

Ordered response models are usually applied when the dependent variable is discrete and when there is ordered measurement. In general, consider an ordered response variable Y, which can take the value Y+1, 0, 1, 2……j. Such that the general linear function

$$\hat{Y} = X\beta + \varepsilon \qquad (2)$$

The latent variable $\hat{Y}$ is not directly observed, thus, the threshold set by which the observed value change as the predicted, otherwise known as 'CUT POINT'. Cut points establish the relationship between $\hat{Y}$ and Y, let α_i be the threshold. Then.

$$Y = \begin{cases} Y_o & \text{if } \hat{Y} < \alpha_o \\ Y_1 & \text{if } \alpha_o \leq \hat{Y} \leq \alpha_1 \\ Y_2 & \text{if } \alpha_1 \leq \hat{Y} \leq \alpha_2 \\ Y_3 & \text{if } \hat{Y} \geq \alpha_2 \end{cases} \qquad (3)$$

The response variable Y takes four value categories: 0= mild flood, 1= moderate flood, 2= severe flood, and 3= extreme flood. Therefore, the unknown parameters α_i are estimated jointly with β_s via maximum likelihood. The $\hat{\alpha}_i$ estimates are reported on Gretl as cut_1, cut_2 , and cut_3 in this case. In other to apply the models in Gretl, the dependent variable must either take only non-negative integer values or be explicitly marked.

— Measurement Metrics to Determine the Performance Level of OLR

In the multi-class measurement, errors in classification have different implications. Errors in classifying Y as X may likely to have different weighted implications than classifying C as D, and many more of such errors. The accuracy measure does not take any of such problem into account. The pre-determined assumption was that the sample distribution among classes is balanced. Thus, in the case of imbalanced distribution, the most commonly used classification approach repeatedly produces a disappointing estimate. In this case, the conventional approaches need to be re-examined to address the problem of imbalanced data classification. However, the confusion matrix will create an error table to derive the measurement metrics.

In order to determine the level of accuracy of the significant classifications, the study developed 4 by 4 confusion matrices for each of the 10 folds. The matrices enabled the derivation of the measurement metrics (accuracy, F1-Score, precision, and recall). Previous studies have established that accuracy works well in describing balanced data and misleading the performance in imbalanced data. Additionally, F1-score has proven to be a useful metric when the data is imbalanced.

RESULTS AND DISCUSSION

The 10-folds cross-validation classification accuracy is demonstrated in Table 3.

Table 3: Ordered Logit Classification Performance estimate

Ordered Logit Accuracy For the Folds					
Fold1	Fold2	Fold3	Fold4	Fold5	
80.7	80.5	80.5	80.5	80.3	
Fold6	Fold7	Fold8	Fold9	Fold10	Average
81.1	81.3	80.1	81.6	80.3	80.7%

It was observed that the average number of cases correctly predicted is 80.7%. By this impression, the OLR model is said to be approximately 81% good to predict the magnitude of flood along the Foma river areas. With this classification accuracy, the variables are well fitted to complement the prediction of the magnitude along the Foma river flood. This correct percentage classification is quite high and explains how strongly significant the variables are. Similarly, this study presented eight (8) cross-sectional variables in predicting the magnitude of flood along the Foma river for classification. However, six (6) out of the eight (8) variables' average P-values were less than 0.05. The six variables were found significant and relevant to complement the prediction of the magnitude of flood along the Foma river flood channel. The 6 cross-sectional variables are the river watersheds, vulnerable status, vulnerable structures, bridges and culverts (B & C), size of bridges and culverts and river pollution. Meanwhile, the 2 other cross-sectional variables were omitted due to exact collinearity, which indicated serial linearity between the two variables; they are the river drainage density and river points along the river channel.

There was an indication of a continuous increase in the probability of the magnitude of flood along the river which was demonstrated by the cut point estimates. The estimates of P-values were highly significant all through the folds, and their coefficients were equally positive. The significance of the P-value is an indication that there is a steady and continuous rise in the level of magnitude of flood across the Foma river areas. Meanwhile, due to the imbalanced data distribution, this study further evaluates the level of significance of the cross-sectional variables using the measurement metrics.

— The Measurement Metrics

The OLR model estimate was quite high which is at 81%, this suggested a high level of classification of the cross-sectional variables in complementing the prediction of the magnitude of flood along Foma river. This study further described the classification performance of OLR using the measurement metrics due to the high disparity in the sampling distribution. Figure 7 demonstrates the level of sampling disparity in the study. There was an indication of high disparity in the magnitude of flood along the Foma river areas. Thus, the prediction of the magnitude of flood tends to favour the higher categories compared to the lower categories. In order to describe the performance of the OLR model, F1-score metric was used to measure the OLR performance and minimize the sampling disparities through the use of precision and recall.

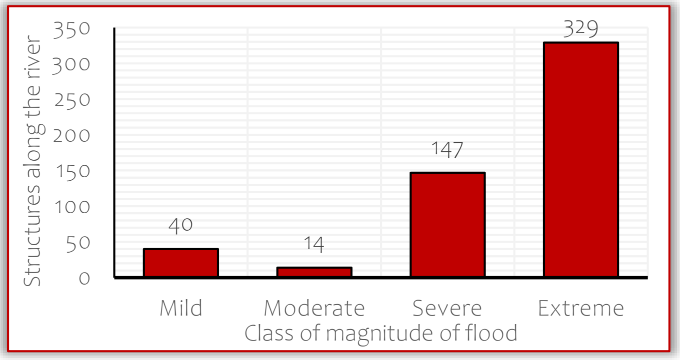


Figure 7. Level of magnitude of flood along Foma river areas

The weighted average of precision and recall was used to measure how good the OLR classification is at predicting the magnitude of flood along Foma river. The four-measurement metrics employed in this study are the accuracy, precision, recall and F1-score to determine the strength of the prediction. The results of four-measurement metrics for the models are presented in Table 4.

Table 4: Values of the Measurement Metrics

Folds	Measurement metrics			
	Accuracy	Precision	Recall	F1-score
Fold - 1	0.8092	0.8778	0.6462	0.7444
Fold -2	0.8050	0.8764	0.6390	0.7390
Fold - 3	0.8050	0.8761	0.6397	0.7394
Fold - 4	0.8050	0.6262	0.6209	0.6236
Fold - 5	0.8029	0.8739	0.6381	0.7376
Fold - 6	0.8113	0.6321	0.6259	0.629
Fold - 7	0.8134	0.8822	0.6681	0.7601
Fold - 8	0.8008	0.6224	0.6221	0.6222
Fold - 9	0.8155	0.8833	0.6463	0.7466
Fold - 10	0.8029	0.8750	0.6396	0.7390
Average	0.8071	0.8026	0.6386	0.7081

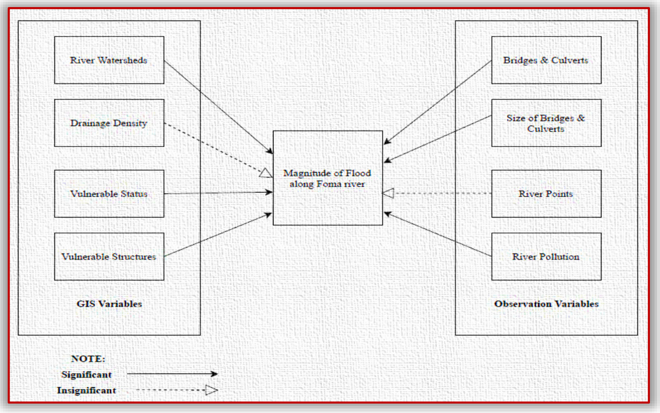


Figure 8. Supervised Model for Complementing the Prediction of Magnitude of Flood along Foma river using Cross-sectional Variables

The average values of each of the multi-class metrics derived in Table 4 were directed towards determining the performance of the OLR model in predicting the magnitude of flood along Foma river areas. Figure 8 illustrates the supervised model for complementing the prediction of the magnitude of flood using cross-sectional variables.

CONCLUSION AND RECOMMENDATIONS

This study examined the influences of precision, recall, and F1-score on the process of adjusting the inherent sampling distribution along the course of offering a significant cross-sectional variable in complementing the prediction of the magnitude of flood along Foma river areas. The ordered logit regression average prediction value 80.71% is vulnerable to error due to the high disparity in the sampling distribution. Consequently, the model was subjected to further evaluation using the F1-score analysis. The F1--score made use of the weighted averages of precision value (0.8026) and recall value (0.6386) to reduce the sampling error by approximately 10%, such that, the model's average capacity to predict the magnitude of flood along Foma river areas is 70.81%. Similarly, the model classification provided six (6) out of the eight (8) cross-sectional variables evaluated to be significant in complementing the prediction of the magnitude of flood along Foma river areas. The average P-values of the six cross-sectional variables are less than 0.05. While the other two variables were considered insignificant due to absolute collinearity.

The river buffer areas within 15 meters and 30 meters established the vulnerability status of structures along the Foma river floodplain. This exercise identified a total number of 154 structures to be vulnerable to flood hazards along the riverbank areas. One hundred and five (105) of the structures were vulnerable, while forty-nine (49) similar structures were at a very high risk of flood hazard along the river areas. In conclusion, this study is recommending the use of significant cross-sectional variables to complement the prediction of magnitude of flood along the riverbanks.

References

[1] Ayanshola, A., Olofintoye, O., &Obadofin, E. (2018). The Impact of Global Warming on Precipitation Patterns in Ilorin and the Hydrological Balance of the Awun Basin. Slovak Journal of Civil Engineering, 26(1), 40-46.

[2] Biola Azeez (2017). Flood Damages Property in Ilorin-Latest News-Tribune Online. From https//tribuneonline.com. May 28, 2017

[3] Chindo, A. A., Mohd Shaharanee, I. N., & Mohd Jamil, J. (2019). A conceptual framework for predicting the effects of encroachment on magnitude of flood in Foma-river area, Kwara State, Nigeria using data mining. TEST Engineering & Management, 81, 3913-3918.

[4] Du, J., Cheng, L., Zhang, Q., Yang, Y., & Xu, W. (2019). Different flooding behaviors due to varied urbanization levels within river Basin: A case study from the Xiang river Basin, China. International Journal of Disaster Risk Science, 10(1), 89-102.

[5] Ezzatvar, Y., Calatayud, J., Andersen, L. L., Aiguadé, R., Benítez, J., &Casaña, J. (2020). Professional experience, work setting, work posture and workload influence the risk for musculoskeletal pain among physical therapists: a cross-sectional study. International Archives of Occupational and Environmental Health, 93(2), 189-196.

[6] Hasselaar, J. J. (2020). Hope in the Context of Climate Change: Jonathan Sacks' Interpretation of the Exodus and Radical Uncertainty. International Journal of Public Theology, 14(2), 224-240.

[7] Isma'il, M., & Saanyol, I. O. (2013). Application of remote sensing (RS) and geographic information systems (GIS) in flood vulnerability mapping: case study of River Kaduna. International Journal of Geomatics and Geosciences, 3(3), 618.

[8] Kraak, M. J., & Ormeling, F. (2020). Cartography: visualization of geospatial data. CRC Press.

[9] Mejía-Navarro, M., Wohl, E. E., & Oaks, S. D. (1994). Geological hazards, vulnerability, and risk assessment using GIS: model for Glenwood Springs, Colorado. In Geomorphology and Natural Hazards (pp. 331-354). Elsevier.

[10] Nassery, H. R., Adinehvand, R., Salavitabar, A., &Barati, R. (2017). Water management using system dynamics modeling in semi-arid regions. Civil Engineering Journal, 3(9), 766-778.

[11] Ngene, B. U., Agunwamba, J. C., Nwachukwu, B. A., & Okoro, B. C. (2015). The Challenges to Nigerian Raingauge Network Improvement. Research Journal of Environmental and Earth Sciences, 7(4), 68-74.

[12] Olorunfemi, F. B., & Raheem, U. A. (2013). Floods and rainstorms impacts, responses and coping among households in Ilorin, Kwara Stat. Journal of Educational and Social Research, 3(4), 135.

[13] Picuno, P., Cillis, G., & Statuto, D. (2019). Investigating the time evolution of a rural landscape: How historical maps may provide environmental information when processed using a GIS. Ecological Engineering, 139, 105580.

[14] Rogger, M., Agnoletti, M., Alaoui, A., Bathurst, J. C., Bodner, G., Borga, M.,& Holden, J. (2017). Land-use change impacts on floods at the catchment scale: Challenges and opportunities for future research. Water resources research, 53(7), 5209-5219.

[15] Schumann, A. H., Funke, R., & Schultz, G. A. (2000). Application of a geographic information system for conceptual rainfall-runoff modelling. Journal of Hydrology, 240(1-2), 45-61.

[16] Venkataramanan, V., Packman, A. I., Peters, D. R., Lopez, D., McCuskey, D. J., McDonald, R. I., & Young, S. L. (2019). A systematic review of the human health and social well-being outcomes of green infrastructure for stormwater and flood management. Journal of environmental management, 246, 868-880.

ISSN: 2067–3809

[1.]Daniela MILOŞTEAN, [2.]Andreea NAGHI

THE CHEMICAL CHARACTERISTICS OF SETTLEABLE PARTICLES FROM THE AIR AND THEIR INFLUENCE ON THE SOIL

[1.] Faculty of Engineering Hunedoara, University Politehnica Timisoara, ROMANIA
[2.] Hunedoara County Office for Pedological and Agrochemical Studies, ROMANIA

Abstract: This study investigates the chemical characteristics of settleable particles from the air, with a diameter greater than 10 μm, which are deposited on the ground under the action of gravity. Particles can settle on any surface and, in time, influence the quality of the soil and crops. Considering that they are part of the soil, it is interesting to study them from an agrochemical point of view. Therefore, by determining the content of organic matter can be appreciated the fertility of the soil, the pH is an important characteristic since plants develop properly in neutral soils, and the insufficiency of phosphorus nutrition negatively influences all processes of plant growth and development. The aim of this paper was to determine the pH, the humus reserve and the phosphorus content in the settleable particles in the Hunedoara area. The collection points were: Răcăștie, Peştişu Mare, street Tudor Vladimirescu and street Revoluției. In order to have a more complete assessment, these determinations were also carried out on a sample of the soil from the same area such as Răcăștie. The particles samples were collected between 2018 and 2022 and the soil one in 2022. The sedimentary particles chemically analysed in this work were collected in accordance with the STAS 10195–75 recommendations.
Keywords: settleable particles, pH, humus reserve, phosphorus

INTRODUCTION

The deposited dust from the air, as a result of natural and artificial sources can travel far away from their source [1], and deposit over to any available surface. The diameter of this sedimentary particles is greater than 10μm [2]. Their settlement on the ground alter the quality of the soil, crops and life in general. For example, according to Jickells et al., iron–containing dust particles transported into the oceans through the atmosphere influence ocean's biogeochemistry and climate [3] and according to Mahowald et al. the desert dust transported on long distances is the major sources of phosphorus and iron in the atmosphere [4].

The purpose of this article was to determine the quality of this particles, from an agrochemical point of view therefore the pH, the humus reserve and the phosphorus content were determined as they influence the properties of the soil in terms of agricultural characteristics. For instance, the pH determines the mobility and accessibility of nutrients into the soil, hence the importance from the point of view of plant nutrition [5,6]. Humus reserve is also very important for the plant's nutrition process [7] as the soil fertility is closely related to the quantity and quality of humus [8]. The insufficiency of phosphorus nutrition negatively influences all processes related to the plant's growth and development [5]. Following Grant C. studies, there has been determined that, in many plant species the phosphorus supply at the beginning of the season is crucial for the optimal yield of the crop whereas a low amount of this element during early stage of the plant growth will limit crop production [9].

MATERIALS AND METHODS

The sedimentary particles chemically analyzed in this work were collected [10] in accordance with the STAS 10195–75 recommendations. The data on the collecting points and periods, respectively on the total amount of gathered particles, is presented in Table 1 and the containers with the samples are shown in Figure 1.

Table 1. Data on settleable particles collected from the air

Sample number	Collecting points	The collecting period	Total amount of settleable particles collected, g
Sample 1	Răcăștie; Peştişu Mare; Tudor Vladimirescu and Revoluției Street from Hunedoara	February to June 2018	5.72
Sample 2	Răcăștie; Peştişu Mare; Tudor Vladimirescu and Revoluției Street from Hunedoara	February to May 2019	3.58
Sample 3	Răcăștie; Peştişu Mare	April to May 2022	1.34

Sample 1 Sample 2 Sample 3

Figure 1. The containers with the samples

Figure 2. Finely crushed and homogenized sample

The homogenized and finely crushed samples (Figure 2) were chemically analyzed to determine the pH, humus and phosphorus level (samples 1 & 2) and only humus (sample 3) as the amount of dust collected was too little. For further comparison, there was used a forth soil sample taken from the same area in 2022 and subjected to the same testing as samples 1 & 2.

— The pH determination

The soil's pH is a characteristic easily determined yet it is an important parameter in assessing its fertility [5]. Considering that these particles once deposited on the soil will become part of it, by determining the pH, they were included in one of the soil reaction classes established by Florea et al. (1987) with modifications.

For the studied samples, the pH was potentiometric determined in aqueous solution with a glass electrode pH–meter. The *soil: water* ratio used was *1:2.5*. The pH measurements were done two hours after the preparation of the suspension, during which time the suspension was intermittently stirred [5]. Table 2 presents the resulted pH for the analyzed samples.

Table 2. The pH of the analyzed samples

	Sample 1	Sample 2	Sample 4
pH	8.14	9.40	7.75
Working temperature, °C	21.7	21.8	21.8

— The humus determination

The humus was determined titrimetrically using the Walkley and Black method [8] as modified by Gogoaşă. Each sample in a quantity of 0.2 g was passed through a fine sieve and put in a flat–bottomed flask. Then reagent 1 (potassium dichromate) and reagent 2 (concentrated sulfuric acid) were added, after which the samples was heated to 98°C for 30 minutes. After cooling was added distilled water and 2–3 drops of diphenylamine. The titration was done with Mohr's salt (0.2n) (Figure 3 a,b) [8].


a)


b)

Figure 3. The control sample (a) and samples 1 & 2 (b) after titration with Mohr's salt

The humus content was determined with the relationship [8]:

$$\text{Humus (\%)} = \frac{(a-b)\cdot 0{,}0010362\cdot 1{,}16\cdot 100}{m}$$

where:

m – represents the amount of soil taken in the analysis (g);

a – represents the amount of Mohr's salt 0.2 n used for the titration of the control sample (the equivalent of potassium dichromate introduced in the sample to be analyzed) (ml);

b – represents the amount of Mohr's salt used to titrate excess potassium dichromate from the analyzed sample (ml);

0.0010362 – represents the content of humus that is oxidized by 1 ml of potassium dichromate solution 0.2 n (g);

1.16=100/86 – represents the correction factor in relation to the percentage of carbon recovery;

100 – represents the factor for percentage reporting.

Table 3 indicate the results obtained in regard to the humus content for samples 1, 2 & 4.

Table 3. Humus content

	Sample 1	Sample 2	Sample 4
Humus, %	Organo–mineral material with very high humus content	5.59	3.9

The total quantity of humus in the soil can be established by *direct* or *indirect* methods. One of the direct methods consists in measuring the weight loss by slow calcination in the presence of air [8] thus the organic matter from sample 3 (where the humus content could not be determined titrimetrically) was calculated by measuring the weight loss by slow calcination in the presence of air at 600º C. The organic matter content of sample 3 after calcination (Figure 4) was 29%.

Figure 4. Sample 3 after calcination

— Phosphorus determination

The mobile phosphorus was determined using Egner – Riehm method [8]. Each sample was subjected to the following steps: extraction (I), filtration (II) and dosing (III). The extraction has been carried out by passing the samples through a 2mm sieve and then inserted in plastic bottles with lactate ammonium acetate working solution. The bottles were then placed in a mechanical shaker which rotated continuously at a speed of 30–35 spins/minute for one and a half hour, at a maximum temperature of 20°C. After the extraction time, the solution was strained through a phosphorus (P), potassium (K) and nitrogen (N) free paper filter. From the aqueous extract 5 ml was taken and diluted with distilled water, then was added Reagent 1 (reducing mixture containing hydrochloric acid, stannous chloride and ascorbic acid) and then Reagent 2 (ammonium molybdate). The reading of the results was done with a UV–VIS spectrophotometer, at a wavelength λ=715nm (Figure 5) and the resulting values of phosphorus content for samples 1, 2 & 4 are shown Table 4.

Figure 5. Reading the results with the UV–V

Table 4. Phosphorus content

	Sample 1	Sample 2	Sample 4
Phosphorus	280 ppm	250 ppm	260 ppm

RESULTS AND DISCUSSION

— pH

As specified in the specialized literature, most cultivated plants grow well on neutral soils that have a pH in the range of 6.8 – 7.2 or slightly acidic (pH = 6.3 – 6.8), but they cannot support a pH below 4.5 or above 8.3 [5].

Figure 6 shows the pH of samples 1, 2 and 4 collected in 2018, 2019 and respectively 2022, in the Hunedoara area.

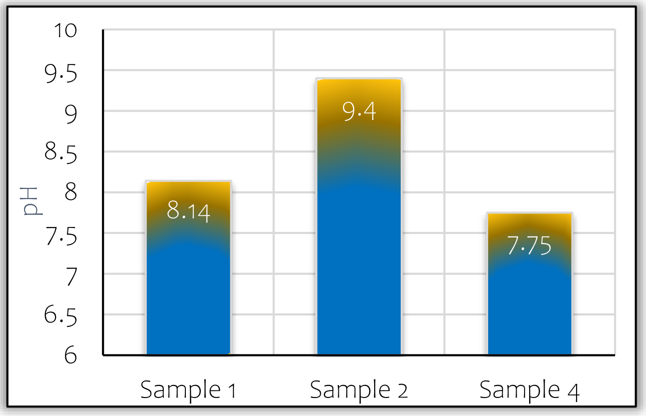


Figure 6. The pH of the analyzed samples

Analyzing the graphic (Figure 6) and taking into consideration the fact that most crops cannot support a pH above 8.3, it can be concluded that neither sample 1 nor sample 2 favors the soil in terms of pH. Even sample 4 (soil from the Hunedoara area) has a pH = 7.75 which exceeds the maximum recommended value of 7.2 suitable for an agricultural soil. Regarding the soil reaction class according to Florea et al. [5], we note that sample 1 is *weakly alkaline*, sample 2 – *strongly alkaline*, and sample 4 – *weakly alkaline*.

— Humus reserve

The humus reserve contained in sample 2 and sample 4 are shown in Figure 7. Sample 1 had an inconclusive result due to its darker tinge and the color shift from blue to green could not be perceived. However taking into account that the sample contains a rather large amount of phosphorus which is the main component of humus [5], it is accurate to conclude that sample 1 is rich in humus. For sample 3 subjected to slow calcination at 600°C, an organic matter content of 29% was obtained, so this sample also contains humus.

Considering the fact that sample 4 has a lower humus content than sample 2, a first hypothesis could be that the dust in the air contains humus and ultimately it enriches the soil.

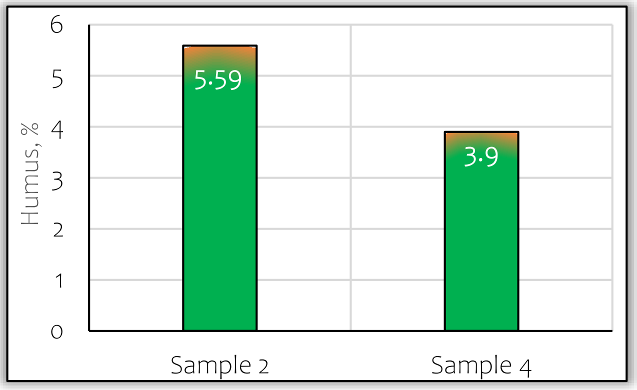


Figure 7. Humus reserve in samples 2 and 4

Regarding the evaluation of the soil according to the humus content (according to Cernescu and Florea) it can be observed that sample 1 and 2 can be included in the category of soils with a *very high content of humus*, since the reserve of humus in sample 1 is very high, and in sample 2 the resulted value is 5.59%. Also, sample 4 with a humus content of 3.9% is considered a soil with a *moderately content of humus*.

— Phosphorus

The processed samples (Figure 8) have a phosphorus content higher than 72ppm and thus are included in the class of very high mobile P content (extractable in acetate – lactate). Consequently the phosphorus reserve of the analyzed samples is very impressive.

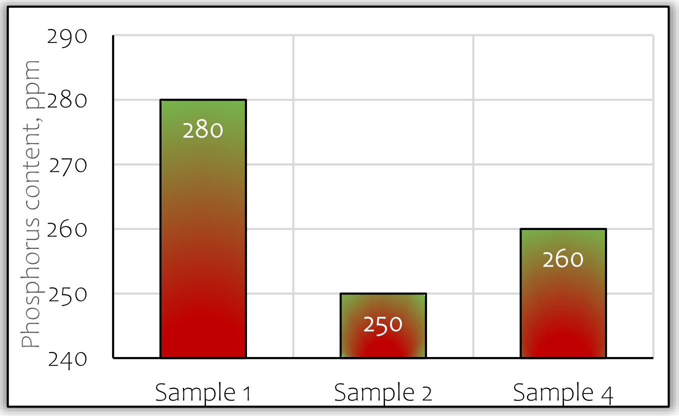


Figure 8. Phosphorus content in the analyzed samples

Given the conventional character of these determinations, the so–called limit values within which the plants react well, appropriately or not at all are valid only in the soil conditions of the country where the respective method was developed. According to Pietras, in his study on the origin of dust particles in the atmospheric air of Krakow (2016–2018) there were identified 20 chemical elements of which the most common was carbon (87.31%), but phosphorus was also identified among the other elements [11].

CONCLUSIONS

After analyzing the results of the determinations, the following can be concluded:

- From an agrochemical point of view, it seems that sample 1 & 2 do not positively influence the soil as the pH has values of 8.14 and 9.40 and crops grow well in soils with a pH of up to 7.2. Even the soil sample with a pH of 7.75 exceeds the specified suitable value;
- The amount of humus of 5.59% contained in the dust deposited on the soil in 2019 is much higher than that resulted from the soil sample. It seems that this would be due to higher pollen content in the atmosphere, considering that the collection of the powders was done in the spring;
- The phosphorus supply of the analyzed samples is very good.

In conclusion, we can assume that although the settleable particles in the air enrich the soil once deposited because of their high content of humus and phosphorus, they also do not favor it from an agrochemical point of view because of their high alkaline pH.

References

[1] van der Does M. et al., The mysterious long–range transport of giant mineral dust particles, Science Advances, 4, 2018
[2] Cao J. et al., Evolution of PM2.5 Measurements and Standards in the U.S. and Future Perspectives for China, Aerosol and Air Quality Research, 13, 2013, pp.1197–1211
[3] Jickells T. D. et al., Global iron connections between desert dust, ocean biogeochemistry, and climate, Science, 308 (5718), 2005, pp. 67–71
[4] Mahowald N. et al., The size distribution of desert dust aerosols and its impact on the Earth system, Aeolian Research 15, 2014, pp. 53–71
[5] Lăcătușu R., Lungu M., Rizeta N., Global soil chemistry. Processes, determinations, interpretations, Terra Nostra Publishing House, 2017
[6] Soti P.G. et al., Effect of soil pH on growth, nutrient uptake, and mycorrhizal colonization in exotic invasive Lygodium microphyllum, Plant Ecol, 216, 2015, pp.989–998
[7] Çelik H. et al., Effects of humus on growth and nutrient uptake of maize under saline and calcareous soil conditions, Žemdirbystė–Agriculture, Vol. 97, No.4, 2010, pp.15–22
[8] Obrejanu Gr., Soil research methods, Publishing House of the Academy of the Romanian People's Republic, 1964
[9] Grant C.A. et.al, Importance of Early Season Phosphorus Nutrition, Canadian Journal of Plant Science, Vol. 85, No. 2, 2001
[10] Miloştean D., Flori M., Strugariu L., Determination of settleable particles from the air in city of Hunedoara, Annals of Faculty Engineering Hunedoara – International Journal of Engineering, Tom XVI, Fascicule 4 (November), 2018, pp.115–118
[11] Pietras B.G., The Origin of Dust Particles in Atmospheric Air in Krakow (Poland) (Atmospheric Background). Land 2022, 11, 155

ISSN: 2067–3809

[1.]István SZTANKOVICS, [1.]István PÁSZTOR

SHAPE ERROR ANALYSIS OF TANGENTIALLY TURNED OUTER CYLINDRICAL SURFACES

[1.] Faculty of Mechanical Engineering and Informatics, University of Miskolc, Miskolc, HUNGARY

Abstract: The measure of form accuracy is an important task in the development of new and recurrent machining procedures. This requirement leads to studies of the shape error in tangential turning as well. We aimed to carry out an analysis on this property in this initial research work. We carried out cutting experiments on cylindrical workpieces with 60 HRc surface hardness, where we changed the cutting speed, the feed and the depth of cut. The experimental plan was composed according to the Design of Experiments method, where a lower and upper limit are chosen for each parameter. After the experiments we made measurement on a shape accuracy measurement device. During the evaluation, we determined equations which describe the studies parameters in tangential turning. We concluded in the analysis that the cutting speed has the most effect on the shape error values, and its value should be higher. The feed and depth of cut influences the shape error mostly according to the alteration of the chip size and chip shape, which result in different cutting forces.
Keywords: cylindricity, design of experiments, roundness, tangential turning

INTRODUCTION

Among the many requirements for the different machining procedures, form accuracy is one of the more important properties. Deviation from the designed shape can be caused by many factors, and the prediction of such errors can be a difficult task. Since inaccuracy in the shape is caused by the elastic deformation of the machining system, a proper force model can help the prediction of the deflection, thus allowing the estimation of radial, diametric and various geometric errors of the turned surface [1]. When engineers are trying to lower the shape deviation, different requirements should be prescribed during the process planning, e. g. the increased rigidity of the machine tool [2]. However, Kundrák et al. showed in their work that with the proper choice of machining procedure, the accuracy of the machined parts can be significantly increased [3]. Molnár also proved, that among the frequently analysed surface topography parameters, the extent of the shape error are equally significant [4]. However, the analysis of the form accuracy presents a new difficulty: the required time for such measurements are usually high, thus creating the choice between the lower measurement time and higher accuracy [5,6]. Many methods can be applied in the analysis of shape error, the use of the Design of Experiments method is one of these as showed by Ferencsik and Varga in the study of burnished surfaces [7]. Nagy and Varga also used the DoE method and proved after their experiments, that the feed increases the cylindricity errors in most cases [8]. Increasing the cutting speed decreased that in the case of wet machining and increases that on dry turned surfaces in their work.

In this paper, we analyse tangential turning [9] in the point of view of the achievable form accuracy. This machining procedure cam into the front due to its many advantageous properties. It can produce twist-free surfaces [10] which can be an alternative to rotational turning in machining of outer cylindrical surfaces [11]. Leichner et al. proved in their study that oil leakage, wear of the tool and machining costs can be reduced, when tangential turning is applied on sealing surfaces [12]. A good alternative can be the combined procedure, where turning and grinding is done on the same machine [13], however MQL technique can be applied when tangential turning is used as finish machining. The different insert and feed motion results in better tool life than in traditional turning [14].

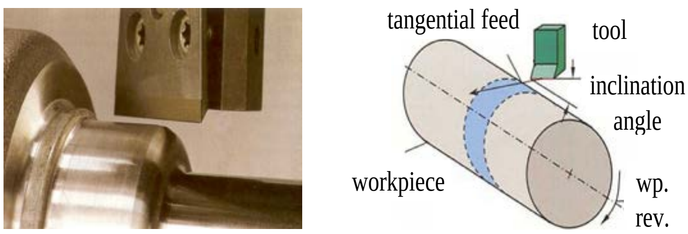


Figure 1. Tangential turning and its kinematic scheme [14]

Machining accuracy depends on many factors in this procedure as well [15], for example the value of the inclination angle, the tangential feed or the depth of cut. The application of tangential turning is widely developed by machine tool manufacturers as well (e. g. EMAG [16]).

In this paper, we study the achievable shape correctness in tangential turning by changing the cutting speed, feed and depth of cut. We analyse certain parameters of cylindricity and roundness with the Design of Experiments method.

EXPERIMENTAL CONDITIONS AND METHODS

The aim of our study was the analysis of the shape error in tangential turning. We carried out cutting experiments and theoretical evaluation using the Design of Experiments method to achieve this goal.

The equipment used during the experiments was the following. A tangential tool with 45° inclination angle was used. The indexable turning tool is made by HORN Cutting Tools Ltd. and consisted of two parts S117.0032.00 insert and H117.2530.4132 holder. The working part of the tool was an uncoated carbide insert (MG12 grade).

In the experiments, a cylindrical workpiece is machined, which outer diameter was 70 mm. The chosen material was 42CrMo4 grade alloyed steel, which processed by hardening heat treatment to 60 HRc hardness before the experiments. The tangentially turned surfaces was prepared before the experiments by turning with a standard CNMG 12 04 12-PM 4314 cutting insert made by SANDVIK Coromant, which was put into a PCLNR 25 25 M12 tool holder. An EMAG VSC 400 DS hard machining centre was applied for the study.

We intended to analyse the alteration effect of the setup parameters of tangential turnig, therefore the cutting speed (v_c), the feed per workpiece revolutions (f) and the depth of cut (a) were changed during the experiments. A lower and an upper limit value were needed to be chosen for each studied parameter according to the Design of Experiments method. We aimed to study first the lower value range of the parameters in our initial research of the topic. Therefore, the cutting speed was chosen to be 100 m/min and 200 m/min, the feed was set to 0.3 mm and 0.6 mm. Two kinds of depth of cut were also chosen: 0.1 mm and 0.2 mm. This 3x2 limit values resulted in 2^3 = 8 different setups, which can be seen in Table 1.

Table 1. Experimental setups

Setup	1	2	3	4	5	6	7	8
v_c [m/min]	100	200	100	200	100	200	100	200
f [mm]	0.3	0.3	0.6	0.6	0.3	0.3	0.6	0.6
a [mm]	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2

Shape error measurements were carried out after the cutting experiments on a Talyrond 365 accuracy measuring equipment. The setup parameters in the program were chosen according to the standard and our earlier practical experience. The analysed parameters were the following (ISO 12180-1 and ISO 12181-1) [17]:

≡ CYLt – the minimum radial separation of two cylinders, coaxial with the fitted reference axis, which totally enclose the measured data [µm]
≡ CYLv – the valley maximum departure from the reference cylinder into the material of the workpiece [µm]
≡ COAX – The diameter of a cylinder that is coaxial with the datum axis and will just enclose the axis of the cylinder referred for coaxiality evaluation [µm]
≡ RONt – the maximum deviation inside and outside the reference circle [µm]
≡ Conc – the diameter of the circle described by the profile center when rotated about the datum point [µm]
≡ Slope – average of the absolute values of the gradient dz/dφ (where z represents axial departure from the reference plane and φ represents angle) at each point in the profile [µm/deg]

The cylindricity was measured using 7 different plane with 2,75 mm separation. The roundness values were resulted by evaluating the profile in the first, fourth and seventh plane.

The results were processed according to the Design of Experiments method. In this process, the lower and upper limits were transformed according to Table 2.

Table 2. Transformed values of the studied parameters

Setup	1	2	3	4	5	6	7	8
v_c	-1	1	-1	1	-1	1	-1	1
f	-1	-1	1	1	-1	-1	1	1
a	-1	-1	-1	-1	1	1	1	1

Equations were determined for the calculation and presentation of the analysed parameters, which equations were defined in a polynomial form. This presented in Equation 1, where the analysed factors (v_c, f, a) and their products can be seen and k_i represent the constant of the different factors. The analysed cylindricity and roundness parameters is represented as y(v_c, f, a).

$$y(v_c, f, a) = k_0 + k_1 v_c + k_2 f + k_3 a + k_{12} v_c f + k_{13} v_c a + k_{23} f a + k_{123} v_c f a \quad (1)$$

EXPERIMENTAL RESULTS

The cutting experiments and the form accuracy measurements were carried out according to the description of the former section. The values of cylindricity error parameters – described in the former section – can be seen in Table 3. The valley depth (CYLv) values were also evaluated as a ratio of the cylindricity error (CYLv / CYLt) since this rate describes better the effect of the different parameters on the bearing capability of the profile.

Table 3. Results of the cylindricity measurements

Setup	1	2	3	4	5	6	7	8
CYLv [µm]	5.29	2.61	3.52	3.28	5.37	2.00	9.64	5.42
CYLt [µm]	17.58	23.66	12.80	12.06	10.62	10.58	21.50	21.97
CYLv/CYLt [µm]	0.30	0.11	0.28	0.27	0.51	0.19	0.45	0.25
Coax [µm]	0.30	0.15	0.28	0.02	0.33	0.14	0.43	0.07

Table 4. Results of the roundness measurements

Setup		1	2	3	4	5	6	7	8
RONt [µm]	1	23.24	4.97	11.21	13.37	10.52	7.97	16.04	11.14
	2	12.69	17.11	8.34	3.46	7.69	11.62	17.17	7.01
	3	8.46	1.44	4.55	1.86	11.17	6.70	13.77	15.91
	Avg.	14.80	7.84	8.03	6.23	9.79	8.76	15.66	11.35
Conc. [µm]	1	0.97	2.03	1.31	3.63	2.21	1.28	4.07	1.50
	2	2.14	2.64	0.26	1.88	1.45	1.11	2.98	1.50
	3	0.65	0.29	0.40	1.19	1.63	0.80	0.16	0.36
	Avg.	1.25	1.65	0.66	2.23	1.76	1.06	2.40	1.12
Slope [µm/deg]	1	4.60	1.52	5.03	0.50	3.11	0.96	6.89	1.01
	2	5.47	1.63	3.00	0.44	2.67	1.40	6.04	0.86
	3	3.12	0.45	0.58	0.46	3.13	0.76	4.73	1.30
	Avg.	4.40	1.20	2.87	0.46	2.97	1.04	5.89	1.05

The results of the roundness error measurements are presented in Table 4. A lesser studied parameter is the slope.

This parameter was originally developed for the bearings industry, and it is a measure of how rapidly the measured profile is changing along its periphery. Both the average and maximum value of this parameter is given by the measurement device, however in this paper we analyse its average value, because it tells more about the overall behaviour of the surface.

The measurements and their evaluation were followed by the determination of the calculation methods of the studied parameters in the form of equations described in the previous section. The function of the cylindricity error (CYLt) can be seen in Equation 2. The ratio between the maximum departure from the reference material into the material and the cylindricity error (CYLv/CYLt) is determined as seen in Equation 3. The coaxility (COAX) of the reference cylinder axis and the datum axis can be calculated with Equation 4. Equation 5 shows the determination of total roundness error (RONt). The slope of the periphery is defines as Equation 7.

$$\begin{aligned}\mathrm{CYLt}(v_c, f, a) = {} & 18.63 + 0.2635v_c - 20.97f \\ & - 91.70a - 0.4717v_cf \\ & - 1.345v_ca + 277.7fa \\ & + 2.443v_cfa\end{aligned} \tag{2}$$

$$\begin{aligned}\frac{\mathrm{CYLv}}{\mathrm{CYLt}}(v_c, f, a) = {} & 0.4155 - 0.003248v_c \\ & - 0.8491f + 2.895a \\ & + 0.00867v_cf - 0.005339v_ca \\ & + 1.375fa - 0.02421v_cfa\end{aligned} \tag{3}$$

$$\begin{aligned}\mathrm{COAX}(v_c, f, a) = {} & 0.47 - 0.0006v_c - 0.3f - 1.1a \\ & - 0.001667v_cf + 0.002v_ca \\ & + 6.01fa + 0.02v_cfa\end{aligned} \tag{4}$$

$$\begin{aligned}\mathrm{RONt}(v_c, f, a) = {} & 65.66 - 0.2647v_c - 109.9f \\ & - 319.9a + 0.4528v_cf \\ & + 1.436v_ca + 702.02k_{23}fa \\ & + 2.81v_cfa\end{aligned} \tag{5}$$

$$\begin{aligned}\mathrm{Conc}(v_c, f, a) = {} & 4.013 - 0.01437v_c - 15.9f \\ & - 13.87a + 0.09789v_cf \\ & + 0.0660v_ca + 99.89fa \\ & - 0.5867v_cfa\end{aligned} \tag{6}$$

$$\begin{aligned}\mathrm{Slope}(v_c, f, a) = {} & 20.74 - 0.08951v_c - 34.83f \\ & - 108.3a + 0.1494v_cf \\ & + 0.4966v_ca + 271.2fa \\ & - 1.232v_cfa\end{aligned} \tag{7}$$

DISCUSSION

The results of the measurements and evaluations are presented in surface diagrams, which can be seen in Figure 2-7. We analyse the cylindricity error firstly in our study. Figure 2 shows that the alteration of the cutting speed in the studied range resulted no significant change, however the alteration of the other 2 parameters shows an interesting behaviour.

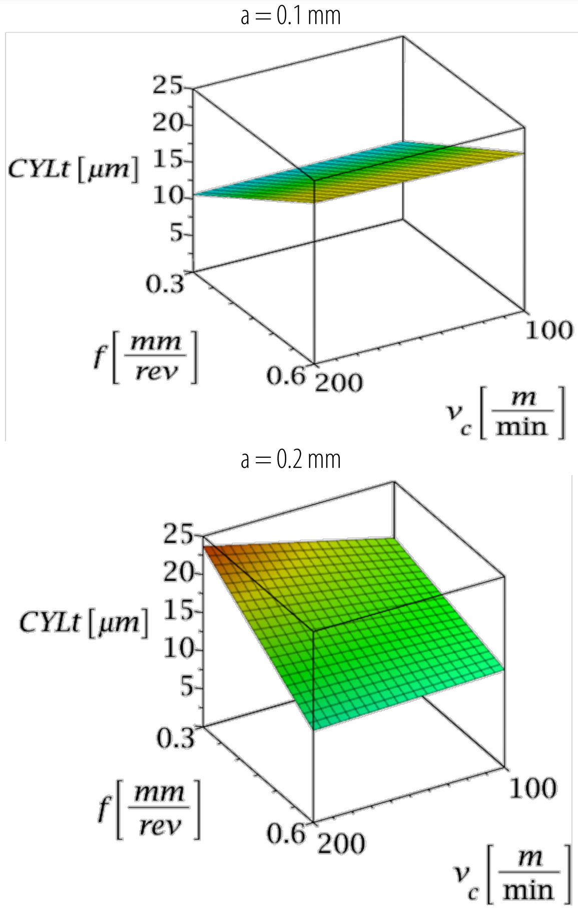


Figure 2. Cylindricity error (CYLt) as a function of the technological parameters

Increasing the feed increases CYLt when 0.1 depth of cut is set; while at 0.2 depth of cut the cylindricity decreases with the increasing feed. This phenomenon should be related to the change in the chip width and height. The former is related to the feed while the latter is calculated from the depth of cut. Low f and a values mean small chip width, height and cross sectional area, which results in a lower deformation in the machining system. If only the feed is increased, the chip width is increased, but its height remains almost the same, which leads to higher vibrations due to the longer contact. If only the depth of cut increased, the height of the chip also increases leading to lower specific cutting force, which unstabilizes the process. If both parameter is increased, the cutting force increases significantly, which stabilizes the process. However this hypothesis needs further investigation in our later works.

The ratio between the valley maximum departure from the reference cylinder into the material of the workpiece and the cylindricity error is shown in Figure 3. Increasing the depth of cut increases the studied ratio in three from the four cases, because the higher the depth of cut is the higher the chip height became. This results in larger parts of the material to break off from the surface, deepening the analysed profile. Increasing the cutting speed lowers this value in overall. The feed has a small impact on this parameter.

The coaxility is analysed in Figure 4. Here the opposite can be seen from the cylindricity error. The alteration of the depth of cut shows low impact on this parameter. The increase of the feed has a small, almost negligible lowering effect. However, increasing the cutting speed has a very good effect on the coaxility. When v_c is increased from 100 m/min to 200 m/min, the analysed parameter is halved in average. This is a result of better chip formation and less chatter.

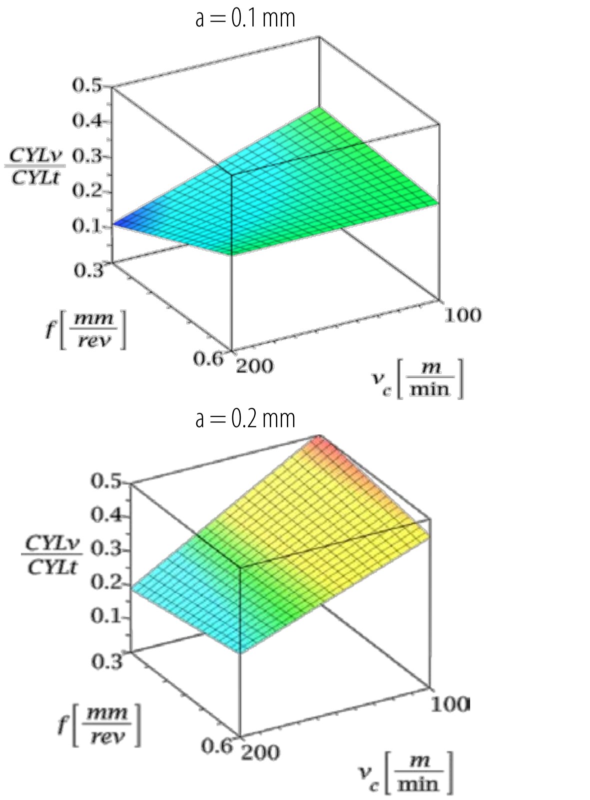


Figure 3. Ratio of the valley depth and cylindricity error (CYLv/CYLt) as a function of the technological parameters

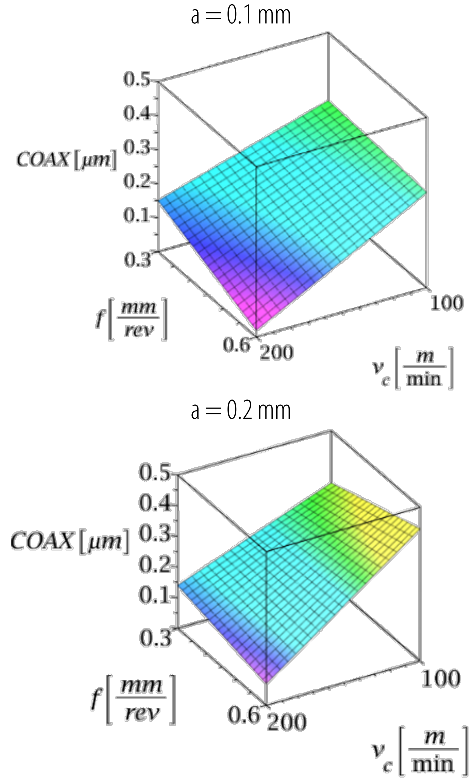


Figure 4. Coaxility (COAX) as a function of the technological parameters

Continuing with the roundness error parameters, we analyse the total roundness error on the basis of Figure 5. A better roundness can be achieved by increasing the cutting speed in overall, lower values are measured at v_c = 200 m/min. The depth of cut has an increasing effect on the analysed parameter: RONt is greater at 0.2 mm depth of cut three out of the four cases. At 0.1 mm depth of cut, increasing the feed decreases RONt, while at 0.2 mm depth of cut the feed increases the roundness error. This caused by the changing chip shape and cross sectional are. The geometry of the chip alters as the cutting tool generates the cylindrical surface (according to the run-in, constant, and run-out phase). RONt is more sensitive to this change than CYLt, which causes a deviation between the two parameters. This phenomenon needs further study, which we will continue in our future work.

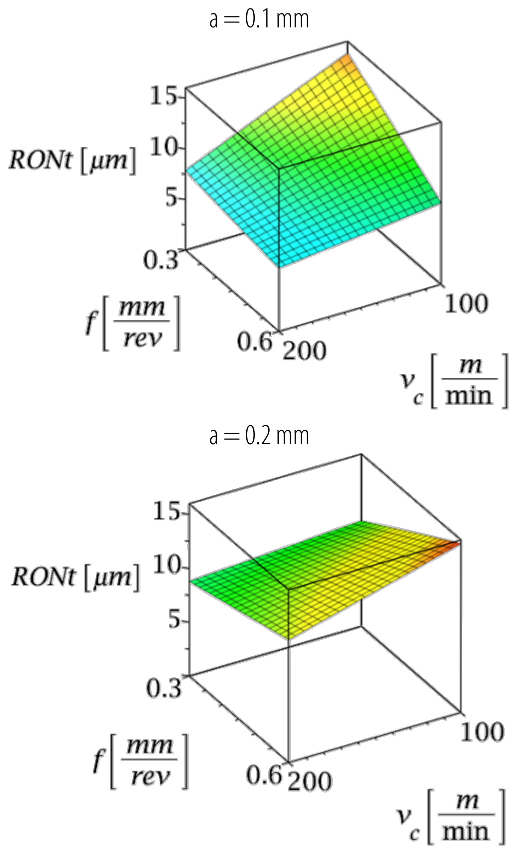


Figure 5. Roundness error (RONt) as a function of the technological parameters

We conclude from the analysing the concentricity in Figure 6, that altering the depth of cut results a different effect of the cutting speed increase. At 0.1 mm depth of cut, a two-fold increase in the cutting speed results higher error, while at 0.2 mm depth of cut this change results in lower error. The feed rate has an almost insignificant effect on this shape error parameter.

Finally, we analyse the slope of the periphery. This parameter describes the functional parameter of surfaces which turns on each other (e. g. bearings.) Figure 7 shows the reducing effect of the cutting speed on the slope: a two-fold increase of v_c results in 3-5-fold lower value, which caused by the better material removal at higher speeds. The depth of cut and feed has a varying effect. At 200 m/min cutting speed, increasing the feed lowers the slope, while at 100 m/min cutting speed its effect is not unidirectional. Increasing the depth of cut shows no clear effect on the slope.

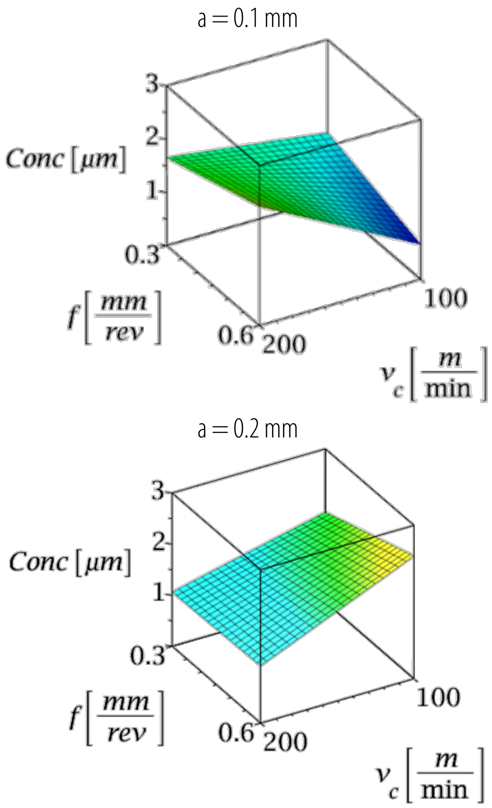


Figure 6. Concentricity (Conc.) as a function of the technological parameters

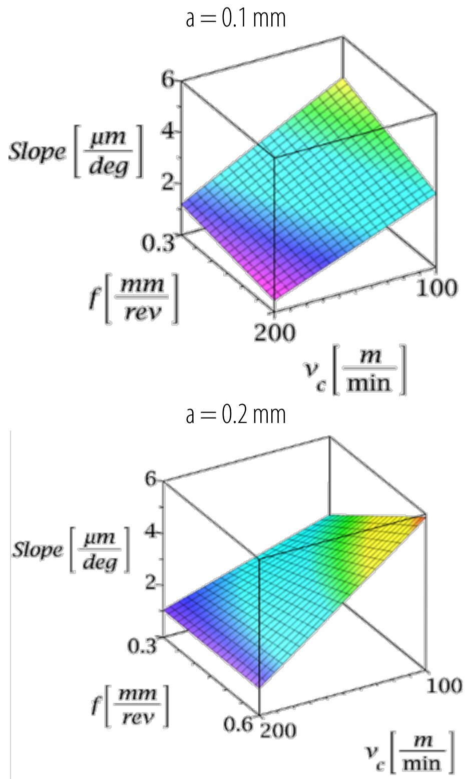


Figure 7. Slope as a function of the technological parameters

At the end of the discussion we would like to point out the following conclusions:

- Among the analysed parameters, the cutting speed has the most effect on the studied shape error values.
- Between 100 m/min and 200 m/min cutting speeds the latter is the favourable.
- The feed and depth of cut influences the shape error mostly according to the alteration of the chip size and chip shape, which result in different cutting forces.
- Functional parameters of the surface topography should be analysed.
- Cutting speed higher than 200 m/min and feed higher than 0.6 mm must be analysed in the next research step.

SUMMARY

The shape correctness of the machined parts is important in finish machining, thus the study of the effect of different technological parameters is need for better production planning. We studied several parameters of the cylindricity error and roundness deviations outer cylindrical surfaces machined by tangential turning in this paper by changing the cutting speed, feed and depth of cut. By the application of the Design of Experiments method, equations were also determined for the calculation and presentation of the analysed shape error parameters. In this study, the following parameters were measured and evaluated: CYLt, CYLv, COAX, RONt, Conc. and Slope. We showed the advantage of increasing the cutting speed, while we also pointed out further goals for our future studies.

Acknowledgement

Project no. NKFI-125117 has been implemented with the support provided from the National Research, Development and Innovation Fund of Hungary, financed under the K_17 funding scheme.

References:

[1] Hareendran M., Tufan C. B.: Modelling of dimensional and geometric error prediction in turning of thin-walled components. Precision Engineering, Volume 72, Pages 382-396 (2021)

[2] Fine, L.: Off centre turning, International Journal of Machine Tool Design and Research, vol. 10, no. 1, pp. 15-24 (1970)

[3] Kundrák, J., Karpuschewski, B., Gyani, K., Bana, V.: Accuracy of hard turning. Journal Of Materials Processing Technology 202 : 1-3 pp. 328-338. , 11 p. (2008)

[4] Molnar, V.: Tribological Properties and 3D Topographic Parameters of Hard Turned and Ground Surfaces. Materials 15 : 7 Paper: 2505 (2022)

[5] Mikó, B.: Assessment of flatness error by regression analysis. Measurement 171 Paper: 108720 , 8 p. (2021)

[6] Jian M., Yanlong C., Jiangxin Y.: Implementation uncertainty evaluation of cylindricity errors based on geometrical product specification (GPS). Measurement, Volume 42, Issue 5, Pages 742-747 (2009)

[7] Ferencsik, V., Varga, G.: Investigation of shape correctness of diamond burnished low alloyed aluminium components. Rezanie I Instrumenty V Tekhnologicheskih Sistemah 92 pp. 179-187. , 9 p. (2020)

[8] Nagy, A., Varga G.: Effect of abandonment of cooling and lubrication on surface roughness and cylindricity in turning of steel. Multidiszciplináris Tudományok: A Miskolci Egyetem Közleménye 11 : 4 pp. 395-407. , 13 p. (2021)

[9] Schreiber, L., Trott, K.: Verfahren zur drallfreien spanenden Bearbeitung von rotationssymmetrischen Flächen. Patent DE19963897A1, 1999.

[10] Schubert, A., Zhang, R., Steinert, P.: Manufacturing of Twist-Free Surfaces by Hard Turning, Procedia CIRP, vol. 7, pp. 294-298, 2013.

[11] Kundrák, J., Gyáni, K., Deszpoth, I.: Precision Hard Turning of External Cylindrical Surfaces by Rotation Procedure. Rezanie I Instrumenty V Tekhnologicheskih Sistemah 79 pp. 108-117. , 10 p. (2011)
[12] Leichner, T., Franke, V., Sauer, B., Aurich, J. C.: Investigation of the tribological behavior of radial shaft rings and soft turned shafts under the influence of abrasive particles. Production Engineering, vol. 5, no. 5, p. 531–538, (2011)
[13] Kundrak, J. ; Molnar, V. ; Markopoulos, A.P.: Joint Machining: Hard turning and Grinding. Rezanie I Instrumenty V Tekhnologicheskih Sistemah 2019 : 90. pp. 36-43. , 8 p. (2019)
[14] Schneider, J., Schreiber, L.: Mit dem Tangentialdrehen zu drallfreien Oberflächen. Werkstatt und Betrieb, vol. 6, pp. 40-45, (2002)
[15] Nee, A. Y. C., Venkatesh, V. C.: Form Accuracy of Tangentially Skived Workpieces. CIRP Annals-Manufacturing Tech., vol. 34, no. 1, pp. 121-124, (1985)
[16] EMAG: "Scroll-Free Turning from EMAG: Fast, Precise, Reliable. EMAG GmbH & Co. KG, [Online]. Available: https://www.emag.com/technologies/scroll-free-turning.html. [Accessed 16. 02. 2021.].
[17] Taylor Hobson: Exploring Roundness - A fundamental guide to the measurement of cylindrical form. Taylor Hobson Limited, Leicester, England, p. 100, (2011)

ISSN: 2067–3809

[1.]Vukić LAZIĆ, [1.]Dušan ARSIĆ, [1.]Srbislav ALEKSANDROVIĆ, [2.]Milan ĐORĐEVIĆ, [1.]Marko DELIĆ

APPLICATION OF WELDING FOR THE PRODUCTION OF BALLISTIC PROTECTIVE STRUCTURES

[1.]Faculty of Engineering, University of Kragujevac, Sestre Janjić 6, Kragujevac, SERBIA
[2.]Faculty of Technical Sciences, University of Priština, Kosovska Mitrovica, SERBIA

Abstract: In the common industry and especially in military industry there is a growing need for production of highly effective protective structures. For that purposes the most used materials are armor steels. They belong into a group of the fine-grained, increased strength steels, which are manufactured by intensive thermo-mechanical treatment at high temperatures and later quenching and low-tempering. Combination of the heat and mechanical treatments provides for the fine grains and exceptionally good properties of these steels, while the low-tempering enables relatively high hardness and good ballistic properties. However, sometimes there is a need to weld these steels in order to manufacture some specific assemblies. Since the way these steels are produced this is why the welding can negatively affect the material properties in specific zones of the welded joint, what could lead to worsening of the material's ballistic properties, as well. The aim of this paper was to determine influence of the welding procedure on that mechanical and ballistic properties. In that order the model plates were welded with the specially prescribed technology in three types of the joints: the butt-joint, corner joint and the corner joint with the shielding plate. After the welding the test plates were subjected to the ballistic tests which consisted of shooting with three types of live ammunition at different types of the welded joints. At the end the comparative analysis of the results is given.
Keywords: protective structure, welding, armor steels; ballistic properties

INTRODUCTION

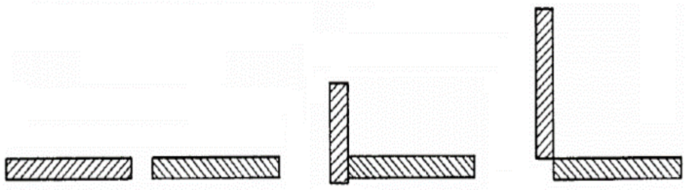
The combat vehicles for the infantry were created from the tendency to increase the efficiency of the tanks and possibilities for their survival on the combat field. The problem that appeared was how to develop the armor, which would guarantee the safety to the personnel by preventing the penetration of the projectile from the anti-armor ammunition into the vehicle, while simultaneously realizing as good as possible its tactical-technical and combat-exploitation characteristics. Taking into account these requirements, it was inevitable to develop the special group of the high-strength steels, known as the armor steels that are being improved [1].

The Swedish company SSAB Oxelösund [2] has the high-strength steels in its production program, where the especially interesting is a group of armor steels, known under the commercial brand ARMOX, which are produced according to the strictly defined manufacturing procedures, [3]. Their excellent properties are resulting from the manufacturing process. They possess a very low content of carbon what positively affects their weldability, while the strength is being achieved by application of the thermo-mechanical processing (TMP) [1, 3]. However, despite their exceptional properties, when the armor is being welded, the worsening of those properties occurs, locally, due to the entered heat. Such spots represent the critical places on the structure and the objective of this paper is to show how those places (various types of the welded joints) behave in the conditions when being hit by the projectiles of different types [4, 5].

WELDING OF SAMPLES

The welded joints on combat vehicles, made of this or some other steel, represent the most vulnerable places of the whole structure. The reason for that is the fact that in welding of the armor steels the filler metals must be applied, which produce the weld metal of the significantly lower strength with respect to the base metal. Thus, the appearance of the cold cracks can happen, since the armor steels are very prone to hardening. Besides that, this steel belongs into a group of the conditionally weldable steels, which implies that adequate measures must be taken during the welding. One of the most important measures is to control the heat input, what is explicitly presented by SSAB in specifications of this steel. The heat input is limited to 200 °C, since at the higher temperatures the excessive annealing occurs and thus the loss of all the positive properties induced by the TMP. In this paper are given recommendations that are mandatory to be followed in order to obtain as high quality welded joints as possible. The welding technologies are also proposed, all based on recommendations by the steel manufacturer, as well as the experts that have already dealt with this problem.

The experimental samples, needed for the ballistic tests of the basic zones of the welded joint, were made in the form of the butt, corner and corner-edge joints (Figure 1). The plates' dimensions of the ARMOX 500T steel were 200 × 200 × 8.6 mm and they were cut by the laser (Figure 2).



a) b) c)

Figure 1. Schematic presentation of the welded joint:
a) butt, b) corner and c) corner-edge

The welding was done using MMA welding procedure. The welding parameters are given in Table 1 while in Figure 3 are shown the plates' appearances after the welding, for all the three cases.

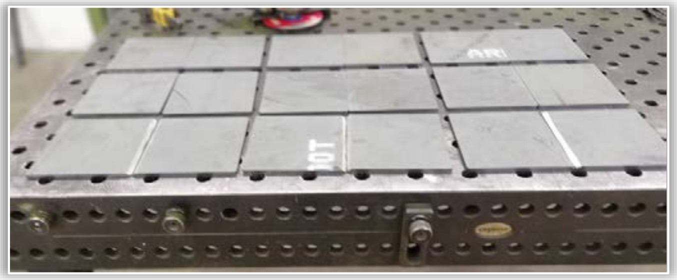
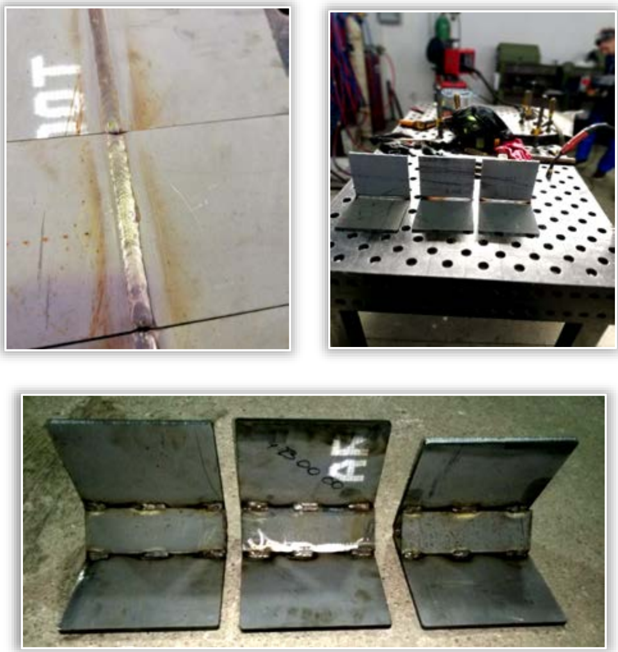


Figure 2. Plates prepared for welding

Table 1. Used welding parameters

1.	Groove type	V
	Way of preparation	grinding
2.	Wire diameter	1.0 *mm*
	Type	
	Protective gas type	Ar + 2.5
3.	Preheating temperature	125-175ºC
	Interpass temperature	150-175ºC
	Measurement procedure	Thermo-chalks
	Preheating device	Gas flame
4.	Welding procedure	135 (MMA)
	Welding position	PA
	Welding technology	To the left/75º
	Power	190-210 *A*
	Arc voltage	24.5 *V*
	Current type	DC
	Polarity	+
	Wire feeding rate	6 *m/min*
	Welding rate	21 *cm/min*
	Gas flow	18 *l/min*
	Number of passes	2
	Driving energy	≈ 11000 *J/cm*



a) b) c)

Figure 3. Welded plates: a) butt, b) corner and c) corner-edge joint.

TESTING OF THE WELDED JOINT BASIC ZONES BALLISTIC RESISTANCE

Many countries have prescribed standards regarding the levels of the ballistic protection; the most used by the ARMOX manufacturers are STANAG 4569 (Table 2) prescribed by the NATO and EN 1522, prescribed by the UN, primarily due to the customers' requests [4]. The STANAG 4569 standard refers to degrees of the protection for logistic and light armored vehicles.

The standard includes threats by the ballistic projectiles, of the small and medium caliber, as well as the fragments simulating the penetrators, in order to simulate the artillery actions. It is aimed for the repeatable testing procedures for estimate of the ballistic protection of the armored vehicles' parts and for determination of the critical zones on those vehicles. The threats are divided into five levels, where the first level is related to civilian threats, while the other levels are related for various military threats.

Table 2. Standard STANAG 4569 NATO

Level	Weapon type	Caliber	Distance, m	Velocity, m/s
I	Rifle	7.62×51-NATO Ball	30	833
		5.56×45-NATO SS109		900
		5.56×45-M193		937
II	Infantry rifle	7.62×39-API BZ	30	695
III	Sniper rifle	7.62×51-AP (WC core)	30	930
		7.62×54R-B32 API		854
IV	Machine gun	14.5×114AP-/B32	200	911
V	Automatic cannon	25 mm APDS-TM-791	500	1258

RESULTS OF THE BALLISTIC TEST

Though the three samples were made for each type of joints (the butt, corner and corner-edge), the ballistic tests were done at one sample from each group, only. That was done primarily due to the complexity of the experiment and since the obtained data were sufficient to estimate the ballistic resistance. The objective of the experiment was to estimate the degree of damage, namely the type of penetration of the basic zones of the welded joint (the base metal – BM, the heat affected zone – HAZ, the joining zone – JZ and the weld metal – WM) by ammunition of the 7.62 × 39 type: M67 Ball, 7.62 × 51 NATO Ball (Ball M80) and armor bullet 7.62 × 54R B32 API (Dragoon's). The 7.62 × 39 M67 Ball bullet is not prescribed by the NATO standards, but by the Russian standards of the ballistic protection, which is not guaranteed by the SSAB.

The experiment was performed on the test field of the "Prvi Partizan DOO" company in Užice, Serbia, which has decades' long experience in producing the ammunition and the tests of this kind. The finishing, verification and homologation (approval) tests of ammunition are being conducted on this test field. The experiment was executed by the expert staff, according to adequate safety standards. The testing equipment included:

- Test barrel with the cover for measuring the velocity, of caliber 7.62 × 39 mm,
- Test barrel with the cover for measuring the velocity, of caliber 7.62 × 51 mm,
- Test barrel with the cover for measuring the velocity, of caliber 7.62 × 54 mm,
- Stand for the test barrel
- Ammunition 7.62 x 39 M67 Ball, velocity at v25 = 725 m/s,
- Ammunition 7.62 x 51 NATO Ball (Ball M80), velocity at v25 = 830 m/s,
- Ammunition 7.62 x 54R B32 API, velocity at v25 = 790 *m/s*.

The samples of the armor steel, prior to the commencing of the experiment, were firmly positioned in the wooden frames, to prevent the loss of energy due to motion of the plates when hit by the bullet. The distance from the exit hole of the test barrel to the sample was 10 m. According to the experimental plan, the welded joints were positioned in such a way that the weldment was perpendicular to the bullet motion direction, what at the corner and corner-edge joints should present the behavior of the base metal and the heat affected zone at the bullet impact at an angle.

Appearance of the butt joint after the bullet impacts is presented in Figure 4. Total of 10 projectiles were fired of the three calibers [4].

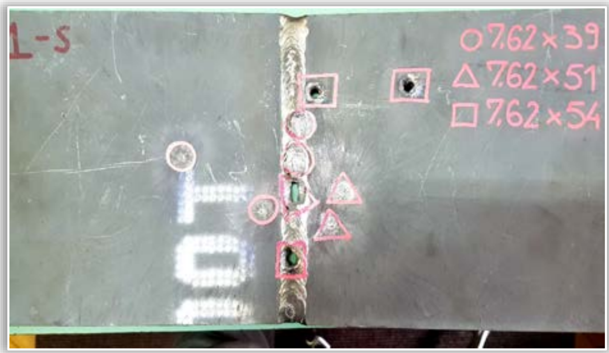


Figure 4. Appearance of the tested sample of the butt joint from the entrance side

After the tests on the butt joint, the tests of the corner joint were performed, with the samples fixed as described earlier. The total of 9 bullets was fired of the three calibers. The entrance side of the corner joint is presented in Figure 5 [5].

Figure 5. Appearance of the tested sample of the corner joint from the entrance side.

The penetrated spots – perforations were of the type characteristic for an impact by the sharp pointed projectiles into the armors of the small thickness. In some cases they also appear for the flat bullets' impacts at velocities that are close to the limiting velocities of penetration. Consequences of penetrations of this type are characteristic since the shape of the hole at the exit side resembles the flower petals.

At the end, the corner-edge joint was tested, which on the inside has little platelets made of the same material. The idea is that they should act as a protection in the case that the weld metal and its vicinity have been penetrated. The total of 8 bullets were fired of the three different calibers, into the characteristic zones of the welded joint. Results are presented in Figure 6 [4, 5].

a)

b)

Figure 6. Appearance of the corner-edge joint with protection:
a) at the entrance side, b) at the exit side.

CONCLUSION

In this paper the ballistic check the penetration resistance of three types of welded joints' zones were performed. Ammunition used was 7.62 x 39 M67 Ball, 7.62 x 51 NATO Ball, and 7.62 x 54R B32 API. Besides, the whole welding technology of the samples was presented.

Obtained results led to the following conclusions:

- The base metal, the heat affected zone and the weld metal are all bullet proof for the caliber 7.62 × 39.
- Test by the 7.62 × 51 caliber bullets showed that only the base metal is resistant to penetration.
- For the armor ammunition of the 7.62 × 54R caliber there are no obstacles, i.e. all the zones of the welded joint are threaten, even the protective plates in the corner-edge joint case.

Based on these results, one must recommend that vehicles constructions made of this steel must be so designed that all the zones of the welded joint should be well protected against penetration by any caliber projectiles. The weld metal should be hidden whenever possible, while the butt joints should be strictly avoided in any case. If these recommendations were not followed to the letter, the safety of the personnel in the vehicle, against the projectile penetrating the armour, cannot be guaranteed.

The reason that the welded joint is the weakest place at the structure can be the heat input during welding. Namely, the heat generated during welding leads to worsening of the properties of the material in the welded zone (softening of the steel). Although, the steel producer forbid the heating of the steel over 200ºC in order to preserve the good mechanical properties, during the welding that cannot be achieved. Since the welding has to be used for joining that is the reason why we tested different types of joints in order to determine the most favourable option.

Note: This paper was presented at The 10th International Scientific Conference – IRMES 2022 – "Machine design in the context of Industry 4.0 – Intelligent products", organized under the auspices of the Association for Design, Elements and Constructions (ADEKO), by University of Belgrade, Faculty of Mechanical Engineering, Department of General Machine Design, in 26 May 2022, Belgrade (SERBIA)

Acknowledgment

This research was supported by companies "DLS Special systems" Belgrade, branch Kragujevac and "Prvi Partizan Ammunition", Užice, Serbia.

References

[1] Arsić, D., Nikolić, R., Lazić, V., Hadzima, B., Aleksandrović, S., Djordjević, M., 2014. Weldability estimates of some high strength steels, *Proceedings of 42. International Conference "Zvaranie 2014"*, Tatranská Lomnica, Slovakia, ISBN 978-80-89296-17-0, pp. 11-21, 2014.

[2] https://www.ssab.com/products/brands/armox, accessed on 12. 04. 2022.

[3] Lazić, V., Arsić, D., Nikolić, R. R., Djordjević, D., Prokić-Cvetković, R., Popović, O., Application of the high strength steel HARDOX 450 for manufacturing of assemblies in the military industry, *Key Engineering Materials*, ISSN 1013-9826, Vol. 755, pp. 96-105, 2017.

[4] Rakičević, M., 2018. Estimation of weldability and selection of optimal welding technology of bulletproof steel ARMOX 500T, MSc thesis, Faculty of Engineering, University of Kragujevac, Kragujevac, Serbia. (In Serbian)

[5] Lazić, V., Arsić, D., Rakičević, M., Aleksandrović, S., Đorđević, M., Marinković, P., Ratković, N., Uticaj vrste zavarenog spoja na balistička svojstva pancirnog čelika ARMOX 500T, Zbornik radova sa 37. Savetovanja proizvodnog mašinstva Srbije, Kragujevac, 2018, 25-26 Oktobar, ISBN 978-86-6335-057-1, pp. 173-177.

ISSN: 2067–3809

[1.]Isak KARABEGOVIĆ

SENSORY TECHNOLOGY IS ONE OF THE BASIC TECHNOLOGIES OF INDUSTRY 4.0 AND THE FOURTH INDUSTRIAL REVOLUTION

[1.] Academy of Sciemces and Arts of Bosnia and Herzegovina, Bistrk 7, 71000 Sarajevo, BOSNIA & HERZEGOVINA

Abstract: Digital transformation of the production process or the entire value chain, from component to system and from supplier to customer, is the key to hidden value that can contribute to the company's productivity, compliance, profitability, and quality of the finished product. Connected production processes in the company are realized by converging information technology (IT) and operational technology into a single one, which results in the introduction of flexible industrial automation of production processes. These technologies connect the physical and virtual worlds with the Internet of Things (IoT) in order to better collect and analyze data, turning it into information that reach the decision–makers. All of the above cannot be achieved without the implementation of smart sensors that provide information at all times. Industry 4.0 can be implemented in production processes only by using smart sensors, and they, along with other technologies, are responsible for fully flexible automation of production processes, which brings a number of advantages such as shortening product development time and reducing manufacturing costs. The application of smart sensors makes production processes more efficient, and we have the ability to optimize them. The paper presents the basics of smart sensors, their role in Industry 4.0 as well as examples of their implementation in production processes.
Keywords: smart sensors, Industry 4.0, implementation, production system

INTRODUCTION

All companies in the world as facing global competition, and in order to keep up with the competition and meet the growing demands of the market, it is necessary to use new technologies in production processes, i.e. implement Industry 4.0. In other words, digital transformation is needed to make a connected company that enables production processes to discover new ways to increase productivity and improve overall business performance. Industry 4.0 helps to increase productivity as well as improve the company's overall business performance [1–3]. To ensure this, it is necessary to have a secure connection between the various production systems and processes throughout the company.

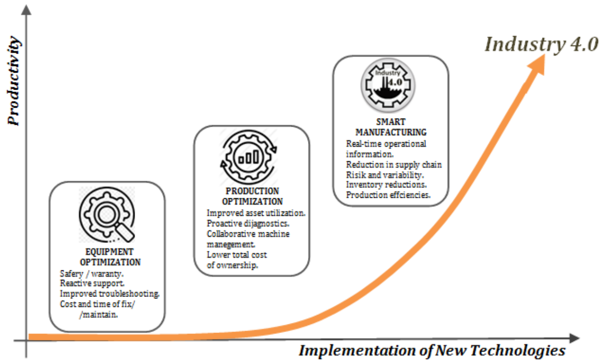
The new way of managing production processes aims to improve performance, make better use of data that already exist, and use a combination of tools that can improve the system or production process. The digitalization performed throughout the company, integration of processes, serial and discrete, drives, and movement into one connected infrastructure increases efficiency and productivity in all segments of companies. The access to production data in the production process at any time in real time allows us to monitor and improve the performance of the production process itself.

Many companies around the world have developed different sensor designs to measure different physical sizes [1,7–9]. Currently, great changes are happening every day in all industries, including the transformation of production processes, increasing flexible automation of production processes, new form of delivery of finished products, and a new way of consumption, all thanks to the implementation of Industry 4.0.

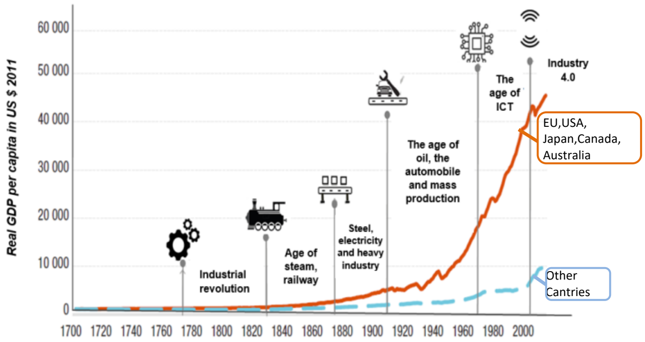
The basic technologies on which Industry 4.0 is based are: robotics and automation, smart sensors, Big Data, Internet of Things (IoT), 3D printing, radio frequency identification (RFID), virtual and augmented reality (AR), artificial intelligence (AI), advanced security systems, etc. [10–13]. The application of Industry 4.0 brings a number of advantages such as flexible automation, and bridging the physical and digital world through cyber physical systems (CPS). Greater and more open integration in manufacturing companies is enabled by cyber physical system (CPS) and Internet of Things (IoT) through horizontal integration (reflected in the exchange of information and data, networking of production processes, communication integration: procurement–production–logistics, and inclusion of customers in the production process), and vertical integration (connectivity in the company from the operational level to the production itself).

The implementation of base technologies can optimize the following: equipment in the production process so that we have greater safety, improved problem–solving, equipment safety, improved maintenance, self–production so that we improve the use of tools, proactive diagnostics, collaboration and management machines, and lower total costs [14–19].

The goal of implementation of Industry 4.0 core technologies is smart manufacturing where we have real–time operational information, reduce supply chain risk, reduce inventory, achieve the efficient production (Figure 1.a), as well as growth of GDP (Figure 1.b). It is necessary to build a set of skills both inside and out. An illustration of how to achieve smart manufacturing using Industry 4.0 implementation in companies is shown in Figure 1.



a – application of base technologies of Industry 4.0 increases productivity



b – the impact of technological change on GDP growth

Figure 1. Implementation of base technologies of Industry 4.0 –a, and their impact on GDP growth – b [6]

A graphical representation of the implementation of base technologies in Industry 4.0, their impact on technological change and inequality over the centuries, and GDP growth are shown in Figure 1. The analysis of Figure 1.b) has shown that the biggest jump in living standards due to investment in research, development and the implementation of advanced technologies happened in the last fifty years. Worldwide, many leading companies are investing and implementing advanced technologies that are key Industry 4.0 technologies. These companies have made significant progress thanks to artificial intelligence, machine learning, and an increase in available data growing exponentially, as well as the improvement of statistical methods and advanced data analysis in digitization and automation in production processes. All this has been happening in the last ten years.

The accelerated implementation of advanced technologies in Industry 4.0 has been significant since 2016, when the Fourth industrial revolution was announced at the World Economic Forum. In order to survive and be present in the global market, it is necessary for companies to optimize equipment, which must be reliable and safe, minimize equipment downtime, and improve problem solving. It is necessary to optimize the production processes (as shown in Figure 1–a) that are active in companies through improving the use of devices and machines, collaborative management of machines, proactive diagnostics, and reduction of overall costs. By introducing the technologies that form the foundation of Industry 4.0, we have real–time operational information and can act instantly which makes production efficient, reduces risk and supply chain variability, thus reducing inventory. The implementation of advanced Industry 4.0 technologies would not be possible without the use of smart sensors, defined by the IEEE 1451 Standard. The enhanced development of robotic and sensor technology, supported by information and communication technologies, is moving in the direction of communication between robots and humans, and the machines themselves.

SMART SENSORS AND THEIR CAPABILITIES IN PRODUCTION PROCESSES

Companies in the world engaged in the research, development and production of sensors for measuring different physical quantities have developed different sensor designs. Today, companies are in the phase of transformation of production processes, because they want to achieve greater automation of production processes with greater flexibility due to the higher customer requirements and survival in the global market. The implementation of advanced Industry 4.0 technologies such as: Internet of Things (IoT), Big Data, 3D printing, robotics, smart sensors, artificial intelligence (AI), virtual and augmented reality (AR), etc., provided a new way of consumption and a new form of delivery to the customer, since the customer wants to be involved in the production process. The implementation of Industry 4.0 cannot be achieved without the implementation of all the above mentioned advanced technologies. However, we must single out the basic sensor technology, because without the implementation of various smart sensors we could not monitored parameters in real time [1,3,17,18,20–22]. Since there has been a development in all segments of society in all technologies, there has also been a historical development of sensors. The schematic representation of the development of sensor technology over time is given in Figure 2.

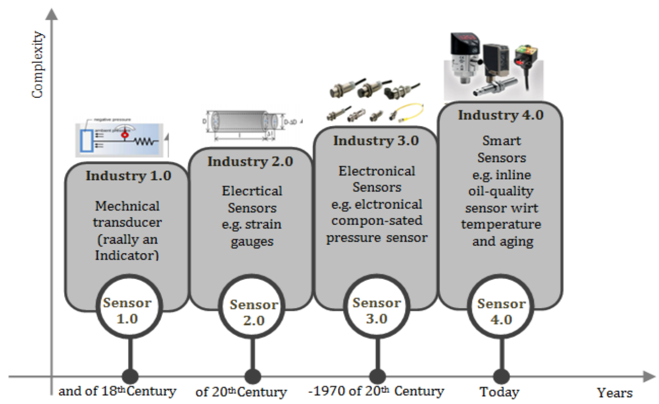


Figure 2. Schematic representation of the development of sensor technology over time

Based on Figure 2, we can conclude that sensor technology has had continuous development from the first mechanical sensors, electrical sensors, and electronic sensors. Today smart sensors are being researched, developed and implemented to support the implementation of Industry 4.0 in production processes. By implementing smart sensors in all processes, as well as in production processes, we can monitor and obtain a large amount of data on the basis of which we make decisions.

Given that the world's leading companies are in the process of implementing Industry 4.0, and they are trying to follow other companies in the world to remain in the global market, the possibility of increasing the use of sensors, and thus improving the manufacture of products is reflected in the following [1,3]:

- Sensors help to detect defects, allowing quick adjustment of settings and change of parameters to prevent downtime in future production processes.
- Based on data provided by smart sensors and insights gained from production to the delivery process, the entire supply chain is managed much more efficiently.
- Scheduled machine maintenance allows companies to more effectively plan downtime and prevent downtime or breakdowns during the manufacturing process.
- Increases efficiency and productivity by integrating smart sensors.
- We are able to quickly change the production process of one product to the production of another product.
- Adaptation of the production process for another product is simulated practically before it is physically implemented in order to adequately assess the impact and reduce the chances of errors.
- Implementation of smart sensors leads to smart machines and devices.
- Analysis of data obtained through smart sensors helps to identify and prevent dangerous situations, and thus improves the health and safety of workers.
- Their implementation ensures planned maintenance and quality control.
- Energy consumption can be optimized by using advanced analytics, because we can monitor energy consumption and make decisions by using smart sensors.

We can maintain optimal productivity and efficiency at all times if we have information about what is happening on machines that are installed in production processes minute by minute. We are also able to avoid unplanned downtime and losses that occur in the production process. The integration of smart sensors provides us with all the necessary data to create a comprehensive image of the production process at every moment. The implementation of smart sensors enables the introduction and operation of smart machines that increase the productivity and efficiency of the production process. Their installation in the production process enables all possible parameter: temperature, pressure, flow level, movement to distance, control of the accuracy of the performed operation, monitoring of the production process, and many other parameters that we have not listed. We are able to have a comprehensive overview of the production process. By knowing the current situation in the production system and the state of the sensor, we can ensure and timely identify any type of potential malfunction in the production process, as well as the sensor itself. The installation of smart sensors in the production process with other necessary equipment is shown in Figure 3 [3]

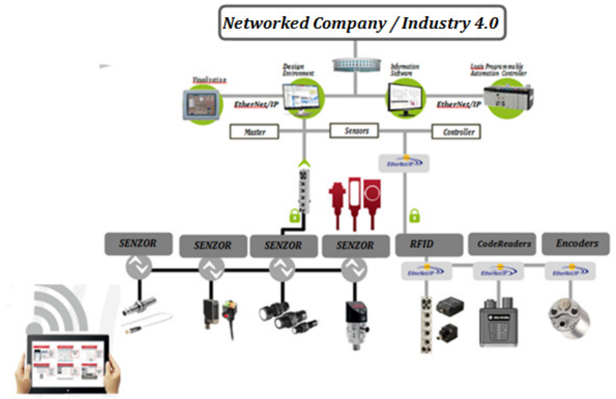


Figure 3. Scheme of installation of smart sensors in the production process with accompanying equipment

The continuous flow of valuable process and diagnostic data, and the visualization system are enabled by smart sensors with informative software and programmable controllers, as shown in the configuration diagram in Figure 1. In this way, the company is connected, which provides efficiency and other advantages. Creating a connected company using smart sensors and smart machines reduces the complexity of production processes and errors [23–25]. They simplify access to available data that can help achieve overall equipment efficiency and average time between failures. Real–time diagnostics optimizes preventive maintenance and problem–solving that arises in the production process, which enables us to reduce the solution time by about 90 % [28]. The change time for each sensor is reduced, and there is the possibility of automatic device configuration to reduce the error when replacing the sensor.

Within each production process there are many operations such as: material handling, material transport, execution of certain operations, assembly, packaging, varnishing, sorting, etc., which require smart sensor so that we can have data on the smooth performance of the operation.

When implementing sensors, we must identify key operations within the production system and define the area of focus in which we need to verify the conditions. We need to know what the system is doing or what we want it to do, such as counting products, performing quality checks, orienting parts, etc. [28–30]. We need to know what the feedback is for each function, as well as what conditions must be met after each function to confirm that the function was performed correctly. When we have identified the areas in which the action takes place in the production process, it is necessary to make an analysis of whether each area is so important from the point of view of automation of the production process and monitoring data important in the production process.

As we have seen, the application of smart sensors can occur in any production process. We need to choose the parameters to be monitored, make the right decision to install the appropriate smart sensor with other selected technology and continue to monitor the performance of appropriate tasks in the production process on mobile devices, as shown in the example in Figure 4.

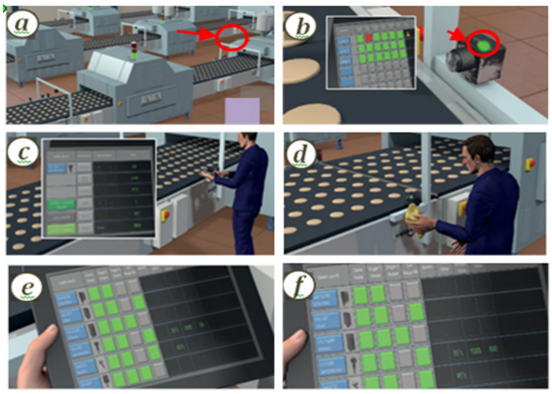


Figure 4. Implementation of smart sensors for collecting information in the production process

As Figure 4 shows, we are able to obtain information about performing operations on a mobile device. For the sake of illustration, Figure 4 shows the production process in which real–time data is monitored. The machine works normally (Figure 4.a)) and is monitored by mobile devices using smart sensors. Data is processed and monitored including activated output and measured data, the accuracy of the sensor, the state of communications, as well as data flow. It is observed that the sensor detects dust accumulation (Figure 4.b)). The operator has information about the type of sensor and where it is placed in the production process (Figure 4.c)). He provides information for maintenance, which act in a timely manner and eliminate the malfunction (Figure 4.d)), thus returning safe operating parameters (Figure 4.e)). Therefore, the monitoring of the production process can continue (Figure 4.f)). In this way, we can monitor the operation of all parameters of the production process that are important for that process at any time, so that we can take necessary measures and eliminate the shortcomings and allow the production process to work without errors. By implementing smart sensors in the production process, we are able to quickly adjust the production process for the production of another product, i.e., the transition from the production of one product to the production of another is very simple, as shown in Figure 5.

If the production process is set to manufacture one product, e.g., product (A) which we monitor using smart sensors, the setting of all parameters is defined for product (A), as shown in Figures 5.a and b). If we want to stop the product (A) and switch to the production of the product (B), we must give the command for that product on the mobile device, as shown in Figure 5.c).

The production of product (B) is initiated (Figure 5.d)) and profiles for four sensors that monitor the parameters in the production process (Figure 5.e) are downloaded. Smart sensors set new parameters for product (B) so that the machine is ready to manufacture another product. By implementing smart sensors in the production process, we can supervise, monitor, and control certain parameters when performing tasksat any time, all depending on which parameters are necessary for the production of the finished product to run smoothly.

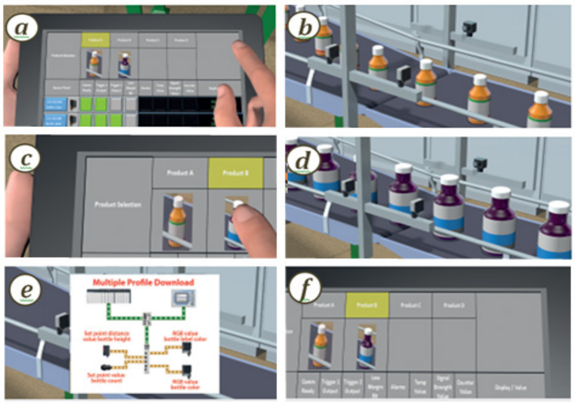


Figure 5. Adjusting the production process to manufacture another product using smart sensors

For the sake of illustration, an example is given in Figure 6.a). If we want to have information on which product is currently on the production line,we can obtain this information by implementing a radio frequency identification RFID sensor, since it is connected to PLC Logix controllers (Figure 6.b)) through a set network [30–32]. The control, information and monitoring of the current product packaging on the packaging section is shown in Figure 6. c, d), whereas the monitoring of products and raw materials at each stage from entry, production and shipment to the end customer is shown in Figure 6.e, f). We can achieve increased productivity and production efficiency by implementing smart sensors. We can also achieve detailed monitoring of products, as well as the visibility of the supply chain in order to make the right decisions on time. An example of monitoring certain positions in the production process by implementing smart sensors is shown in Figure 7. Depending on the production process, there are different positions for the application of smart sensors. In addition, the choice of information we are interested inwill influence the choice of smart sensor that will be placed to monitor and obtain information [31,32].

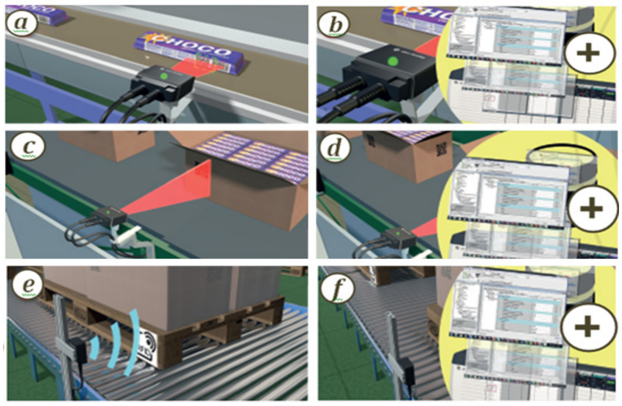


Figure 6. Monitoring of certain parameters with smart sensors in the production process

Figure 7 shows an illustrative example in which the temperature is monitored in the production process. There is a sensor that shows that the temperature is 45∘C, while the second position displays the application of pressure sensor which shows a pressure of 50 bars. In the third position, there is a proximity sensor that registers the positioning of the product on the 750 mm conveyor belt, while the power signal is 500 units. At the end of the production process, a sensor for counting parts was installed, which is now active and providing information that there are 1284 units of elements.

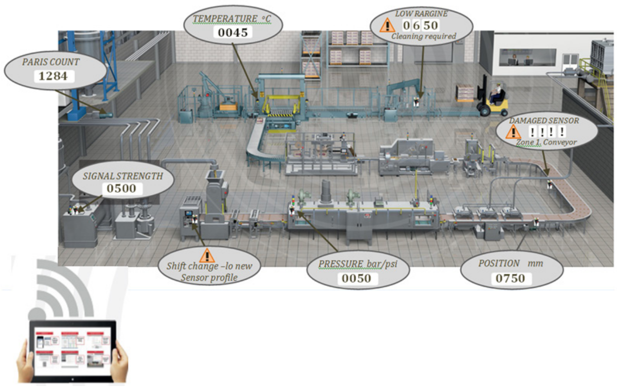


Figure 7. Mobile monitoring of production process parameters using smart sensors

Monitoring of the production process can take place on different devices, static screen or mobile device. In this particular example on the mobile device we have information about the problem on three sensors that we need to eliminate. The sensor in zone 1 is loaded on the conveyor belt, the second sensor needs cleaning, and the third sensor shows a warning that we have to change the sensor profile, i.e., we have to adjust the new sensor profile. When we have complete information given to us by smart sensors from the production process, we can act in time and eliminate errors so that the production process works normally. As we have seen in the concrete example on mobile devices in Figure 7, we can monitor the information in the production process, as well as problems on sensors that we need to eliminate. After analyzing the obtained information, we can make a decision on what actions need to be performed, such as cleaning or changing the sensor profile. In other words, we need to adjust the new sensor profile. When we have complete information given to us by smart sensors from the production process, we can act in time and eliminate errors so that the production process works normally.

CONCLUSION

Industry 4.0 is the one that provides relevant answers to the fourth industrial revolution. It is already present in all industries, from production to sales of finished products. By introducing technologies that form the basis of the fourth industrial revolution or Industry 4.0 such as: smart sensors, robotics and automation, big data (Big Data), Internet of Things (IoT), 3D printing, radio frequency identification (RFID), virtual and augmented reality, artificial intelligence (AI), advanced security systems, etc., we can change processes and technologies as well as the organization of production and sales. The fourth industrial revolution brings disruption to almost every industry in the world, because it has a greater impact than we think. The impact is reflected on all sectors and companies, including large, medium and small companies. Industry 4.0 relies on advances in the use and sharing of information, and has such potential to connect almost anything and everything on the web, thus drastically improving the company's business performance. Small and medium enterprises can benefit from what Industry 4.0 has to offer, because by using the technologies mentioned in this chapter, they can more efficiently process and store data, and improve the way they design, manufacture and deliver their products. Currently, small companies can compete with big companies in a way they never could before. It is impossible to implement Industry 4.0 without smart sensors. They are the ones that give the first information about monitoring parameters in the production process. Their implementation provides the company with advantages, some of which are:

≡ lower operating costs
≡ improved business communication processes
≡ increased productivity of companies
≡ access to the world economic market is expanding (wide user base)
≡ provides companies of all sizes with greater outsourcing opportunities (external associates)
≡ thanks to the availability of new communication tools the cooperation of company departments and individuals is easier
≡ advanced achievements, such as blockchain technology, greatly increase the security of business and personal data
≡ reduced downtime in the production process,
≡ rapid adaptation of the production process to the production of another product

As we have seen, advanced technologies that include: IoT (Internet of Things), robotics, cloud computing, smart sensors, radio frequency identification, cyber–physical systems and big data, are key in the application of the Industry 4.0 concept, because they imply full digitalization of all production processes, as well as creating an idea about a product, product engineering, production organization, process control, and the provision of industrial services. Based on all this, we can conclude that new constructions of smart sensors will be developed in the future, and their implementation in production processes, as well as in all segments of the human environment, will increase on a daily basis.

Note: This paper was presented at The 10th International Scientific Conference – IRMES 2022 – "Machine design in the context of Industry 4.0 – Intelligent products", organized under the auspices of the Association for Design, Elements and Constructions (ADEKO), by University of Belgrade, Faculty of Mechanical Engineering, Department of General Machine Design, in 26 May 2022, Belgrade (SERBIA)

References

[1] Karabegović Isak, Karabegović Edina, Smart Sensors: Support for the Implementation of Industry 4.0 in Production Processes, Chapter 7. Handbook of Research on Integrating Industry 4.0 in Business and Manufacturing, IGI

Global, USA, pp.147–163, (2020), DOI: 10.4018/978–1–7998–2725–2.ch007

[2] Schwab, K.: The Fourth Industrial Revolution, World Economic Forum, Geneva, Switzerland, (2016)

[3] Karabegović, I.,Kovačević, A., Banjanović–Mehmedović,L.,Dašić,P.:Integrating Industry 4.0 in Busniess and Manufacturing, IGI Global,Hershey, PA, USA, (2020), https://www.igi–global.com/book/handbook–research–integrating–industry–business/237834

[4] Chryssolouris, G., Mavrikios, D., Papakostas, N., Mourtzis, D., Michalos, G., Georgoulias, K.: Digital manufacturing: History, perspectives, and outlook, Journal of Engineering Manufacture, Proceedings of the Institution of Mechanical Engineers, Part B, pp.451–462(2009)

[5] Karabegović Isak and Karabegović E., The Role of Collaborative Service Robots in the Implementation of Industry 4.0,International Journal of Robotics and Automation Technology,Vol.6., 40–46, (2019) (https://www.zealpress.com/);

[6] UNCTAD (2018) Technology and innovation report 2021, United Nations conference on Trade and Development; based on data from Maddison Project Database, version 2018, Bolt et al. (2018), Perez (2002), and Schwab (2013). https://unctad.org/system/files/official–document/tir2020overview_en.pdf

[7] Muller, J.M., Buliga, O., Voigt, K.I.: Fortune favors the prepared: How SMEs approach business model innovations in Industry 4.0. Technological Forecasting and Social Change, Vol.132,Iss.C, pp.2–7 (2018)

[8] Isak Karabegović The Role of Industrial and Service Robots in Fourth Industrial Revolution with Focus on China ,Journal of Engineering and Architecture ,Vol. 5, No. 2, pp. 110–117 , (2017)

[9] Edina Karabegovic, Isak Karabegovic, Edit Hadzalic (2012),Industrial Robot Application Trend in World's Metal Industry Inzinerine Ekonomika–Engineering Economics, , 23(4), 368–378

[10] Hermann, M.; Pentek, T.; Otto, B. Design principles for industrie 4.0 scenarios. In Proceedings of the IEEE 2016, 49th Hawaii International Conference on System Sciences (HICSS), Koloa, HI, USA, pp. 3928–3937 (2016)

[11] Thoben, K.D.; Wiesner, S.; Wuest, T. Industrie 4.0 and smart manufacturing—a review of research issues and application examples. International Journal Automation Technology , Vol.11, pp.4–16 (2017)

[12] Karabegović,I.: The Role of Industrial and Service Robots in the Fourt Industrial Revolution, ACTE Technica Corviniensis–Bulletin of Engineering, University Politehnica Timisoara, Tome XI, Fascicule 2. April 2018. Hunedoara, Romania, pp.11–16 (2018), http://acta.fih.upt.ro/pdf/2018–2/ACTA–2018–2–01.pdf

[13] Karabegović. I., Karabegović, E., Mahmić, M., Husak, E.: The application of service robots for logistics in manufacturing processes, Advances in Production Engineering & Management, Vol. 10. No. 4. 2015,Maribor, Slovenia, EU, pp. 185–194 (2015)https://www.apem–journal.org/Archives/2015/APEM10–4_185–194.pdf

[14] Karabegović, I., Karabegović, E., Mahmić, M., Husak, E.: Implementation of Industry 4.0 and Industrial Robots in Production Processes In: Isak Karabegović (eds) New Technologies,Development and Application II 2019. Lecture Notes in Networks and Systems. Springer Nature Switzerland AG 76, pp.96–102 (2020)

[15] Karabegović, I., Husak, E.: Industry 4.0 based on Industrial and Service Robots with Application in China, Journal Mobility and Vehicle,44(4), pp.59–71 (2018)

[16] Karabegović, I.: The Role of Industrial and Service Robots in Fourth Industrial Revolution with Focus on China,Journal of Engineering and Architecture, 5(2), pp.110–117 (2017)

[17] Byeong, W.A. , Jung, H. S., So–Yun, K., Joohee, K., Sangyoon, J., Jihun, P., Youngjin, L., Jiuk, J., Young–Geun, P., Eunjin, C., Subin, J. & Jang–Ung, P. (2017). Smart Sensor Systems for Wearable Electronic Devices, Journal Polymers, 9(303),1–32

[18] Johan, H.H.,Frank R.R., Gertvan H. (1994). Developments in integrated smart sensors, Sensors and Actuators A: Physical,43(1–3), 276–288

[19] Karabegović I.,Husak E.,Predrag D.:The Role of Service Robots in Industry 4.0 – Smart Automation of Transport,International Scientific Journal Industry 4.0, Vo.4. Iss.6. pp.290.292 (2019), https://stumejournals.com/journals/i4/2019/6/290

[20] Andreas, S., Nikolai, H., Tizian, S. (2018). Sensors 4.0 – smart sensors and measurement technology enable Industry 4.0, Published by Copernicus Publications on behalf of the AMA Association for Sensor Technology,359–371.

[21] Gary, W. H., Joseph, R. S., Peter, J. H., Chung–Chiun L. (2010). Smart Sensor Systems, The Electrochemical Society Interface, Winter 2010, 29–34.

[22] Karabegović Isak, Karabegović Edina, Mahmić Mehmed, Husak Ermin, The Implementation of Industry 4.0 by Using Industrial and Service Robots in the Production Processes, Chapter 1. Handbook of Research on Integrating Industry 4.0 in Business and Manufacturing, IGI Global, USA, pp.1–30, (2020)

[23] Randy, F. (2013). Smart Sensors, Series: Artech House Remote Sensing Library, Massachusetts, Publisher–Artech House,

[24] Clarence, W. S. (2017). Sensor and Actuators, Engineering System Instrumentation, Second Edition, 2nd Edition, Florida,CRC Press.

[25] Bunse, B., Kagermann, H., & Wahlster, W. (2017). Industrie 4.0: Smart Manufacturing for the Future, Brochure, 20750. Germany Trade and Invest, Gesellschaft für Außenwirtschaft und Standortmarketing mbH, Berlin, Germany.

[26] Karabegović, I., Karabegović, E., Mahmić, M., & Husak, E. (2015). The application of service robots for logistics in manufacturing processes, Advances in Production Engineering & Management, 10(4); 185–194.

[27] Karabegović I., & Husak, E. (2018) Industry 4.0 based on Industrial and Service Robots with Application in China, Journal Mobility and Vehicle,44(4), 59–71

[28] Rockwel Aotomation. (2016). Condition Sensors and Switches,Publication 836E–BR001C–EN–P ,USA.

[29] Rockwel Aotomation. (2017). Get Smart,Key considerations for developing smart machines and equipment,Publication: OEM–SP019B–EN–P,USA.

[30] Rockwel Aotomation. (2016). Smart Sensors, Enabling Smart Machines for The Connected Enterprise, Publication IOLINK–BR001B–EN–P, USA.

[31] Rockwel Aotomation. (2011). Sensor Application Guide, PublicationSENS–AT001B–EN–P–May2011, USA.

[32] Rockwel Aotomation. (2016). Integrated Smart Sensors, Publication SENSOR–BR002A–EN–P, USA.

ISSN: 2067–3809

[1.]Sasa ZIVANOVIC, [1.]Nikola VORKAPIC, [2.]Stefan MITROVIC

MACHINE SIMULATION OF ADDITIVE MANUFACTURING TOOL PATH

[1.] University of Belgrade, Faculty of Mechanical Engineering, SERBIA
[2.] LOLA Institute, Belgrade, SERBIA

Abstract: The application of new additive technologies is based on models STL models of prototypes that will be build. This paper discusses two additive technologies: Fused Deposition Modeling – FDM and Laser Metal Directed Energy Deposition – Laser DED in terms of program preparation and its verification by simulation of material addition, i.e. machine simulation for these procedures. The paper presents the programming and program verification using machine simulation of additive manufacturing tool path in CAD/CAM and Vericut environment. A procedure for configuring and preparing of a virtual machine for several additive process simulations has been proposed. Simulation is a key technology for program verification. Machine simulation and digital twin are the primary simulation–based approaches in the context of the Industry 4.0. The paper analyzes the available programming software for generating G code from the STL file as well as the possibility of simulating the virtual machine when working according to the generated program.
Keywords: additive manufacturing, machine simulation, CAD/CAM

INTRODUCTION

Industry 4.0 has an initiative that aims to digitalize industrial manufacturing via the exploitation of innovative technologies [1]. In this regard, this paper will present the possibilities of applying the machine simulation of additive manufacturing processes in the era of Industry 4.0. The machine simulation of the additive manufacturing tool path aims to configure the digital twin of the machine for additive processes and simulate its work. Whatever happens on screen during simulation, will also occur identically on the real machine for additive processes.

Additive technology (AT) has emerged as a key enabling technology, with its ability to shorten product design and development time. AT is used for quick fabrication of physical models, functional prototypes and small series of parts directly from CAD models [2,3]. Rapid prototyping is used in a variety of industries to fast fabrication of parts, and representation before final realization or commercialization [4]. The main advantage of rapid prototyping technologies is that almost any shape can be produced.

The application of new additive technologies is based on models STL models of prototypes that will be build. This paper discusses two additive technologies: Fused Deposition Modeling – FDM and Laser Metal Directed Energy Deposition – Laser DED in terms of program preparation and its verification by simulation of material addition, i.e. machine simulation for these procedures.

Simulation is a key technology for program verification. Machine simulation and digital twin are the primary simulation–based approaches in the context of the Industry 4.0.

OUTLINE OF CONSIDERED ADDITIVE MANUFACTURING PROCESSES

Within this paper, the machine simulation of additive manufacturing machines based on the FDM (Fused Deposition Modelling) and Laser DED (Direct Energy Deposition) methods will be considered.

— Fused Deposition Modeling – FDM

Fused deposition modeling (FDM) is one of the most widely used additive fabrication technologies. FDM is the same as fused filament fabrication (FFF), but the term "Fused deposition modeling" and the abbreviated "FDM" were trademarked by Stratasys in 1991, creating the need for a second name [5].

A plastic filament is unwound from a coil and supplied as a material to an extrusion nozzle, which moves along the programmed path of material addition. The possible movements of the nozzle are defined by the machine's own kinematic configuration. The nozzle is heated to melt the plastic, has closed–loop temperature control and is coupled with a mechanism which allows the deposition of the melted plastic to be turned on and off. As the nozzle is moved over the table in the active layer, following the programmed path, it deposits extruded plastic, thus forming each layer.

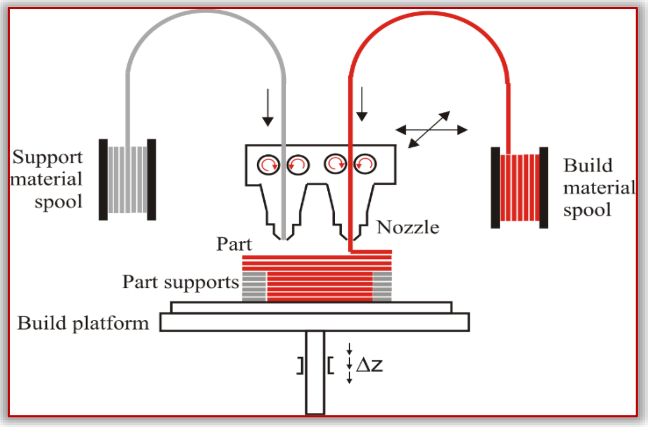


Figure 1. Schematic of FDM system

FDM approach demands fully controlled extrusion of material through a nozzle. Two extrusion heads are often used so that support structures can be fabricated from a different material to facilitate part cleanup and removal, Figure1.

FDM 3D additive machine is a type of a CNC machine that has 3 axes of movement and usually implements Cartesian (serial) or DELTA (parallel) mechanisms, although machines with hybrid kinematics are also possible. This paper considers Velleman Vertex K8400 additive manufacturing machine – 3D printer with 3–axis Cartesian serial kinematics.

— Laser Metal Directed Energy Deposition (DED)

Directed energy deposition (DED) is a group of AM processes that adds material alongside the heat input simultaneously. The heat input can either be a laser, electron beam, or plasma arc, while the material feedstock is either metal powder or wire [6]. This paper discusses laser and powder DED processes. A schematic of the laser powder DED process is shown in Figure 1.

Powder DED machines often have powder–feeding gas blown together with the powder from the nozzles, thereby sheathing the melted region, and reducing the oxidization rate. Powder DED systems can use single or multiple nozzles to eject the metal powders [6].

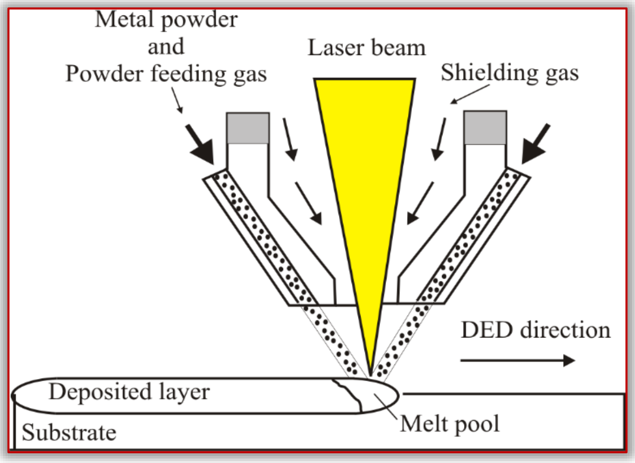


Figure 2. Schematic of a Laser powder DED process

Phillips has taken the innovative laser metal deposition technology of Meltio, and integrated it with the Haas CNC vertical machining centers, bringing the best value of additive hybrid machines to the market [7]. Supported Haas Machine Models are Haas VF Series, Haas UMC Series and Haas TM series. These machines can combine benefits from both additive and subtractive technologies. In this regard, the real challenge is the simulation of their work, which can be realized in the Vericut environment.

This opens the access to hybrid manufacturing processes that include additive and subtractive operations. Additive processes allow increased design flexibility, customization and part complexity, while subtractive processes enable higher production speeds, improved accuracy and surface finish [8]. Figure 3 shows a metal powder directed energy deposition (DED) process which can be combined with a multi–axis CNC milling process.

Figure 3. Laser DED extruder in a testing setup
in a Haas VF series CNC machine [8]

CONFIGURING VIRTUAL MACHINES FOR ADDITIVE MANUFACTURING

The simulation of additive manufacturing machines and processes, in the era of Industry 4.0, is one of the most important verification steps prior to the actual production. This section will show procedures and examples of configuring virtual machines for additive manufacturing using available software environments (PTC Creo and Vericut).

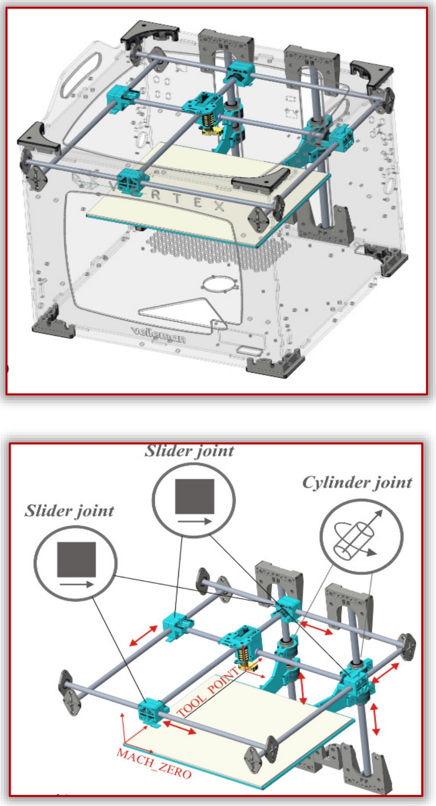
— PTC Creo

Most CAD/CAM systems are used for the simulation of the subtractive technologies, simulating virtual machine tool along a given tool path, while offering no similar alternatives for additive manufacturing.

In contrast, CAD /CAM system PTC Creo has a module for Additive Manufacturing, but it must be used in an indirect way, by configuring the machine for additive manufacturing as an equivalent milling machine with the same kinematics [9].

This paper presents the configuration of an additive manufacturing machine Velleman Vertex K8400 [10,11]. The configured virtual machine offers a virtual prototype with graphic structural elements that move as a rigid body system, aiming to be used in the simulation of the tool path [12]. All kinematic connections between structural elements of the virtual prototype must be defined in accordance with the real machine. The required kinematic connections for the considered 3–axis Velleman Vertex K8400 are three translations with slider and/or cylinder connection type, Figure4.

During configuring of the complete virtual model of the machine, based on the available machine components [11], it is necessary to define the kinematic connections for all the moving parts. Next, need connect the coordinate systems of the workpiece, the tool with coordinate systems on virtual machine within the used PTC Creo 8.0. On virtual machine tool need to define the coordinate system MACH_ZERO, on the machine table and TOOL_POINT on top of the nozzle (Figure 4b). Also, workpiece and tool have the same coordinate systems. By matching the appropriate coordinate systems of tool and workpiece with coordinate systems on virtual machine is prepare a set–up for simulation [12,16]. The virtual machine prepared in this way is ready for the needs of simulation according to the programmed tool path within the layer, which will be specified in section 5.



a)

b)

Figure 4. Virtual machine Velleman Vertex K8400 with defined kinematic connections and coordinate systems

— Vericut

Vericut provides CNC machine simulation according to a given program, program verification and process visualization. Vericut now offers the Additive module that provides CNC machine simulation for directed energy deposition (DED), laser sintering, 3D printer and powder bed layups from their build files, wire–fed additives, thermo–plastic composite additives, welding, and other layup processes that add material [13].

A very important advantage of the simulation is collision detection between the expensive machine elements and the additive part being built [13].

Vericut uses G–code as one of its basic inputs, so to simulate an additive technology operation, one of the existing machines from the Vericut library that supports additive technologies can be selected, or a new machine can be configured.

To configure a new virtual machine in the Vericut environment, it is necessary to define the machine's kinematics – type and order of joints/axes according to the structural formula. For example, the Haas VF3 machine has a kinematic structure (X'Y'OZ), Figure5.

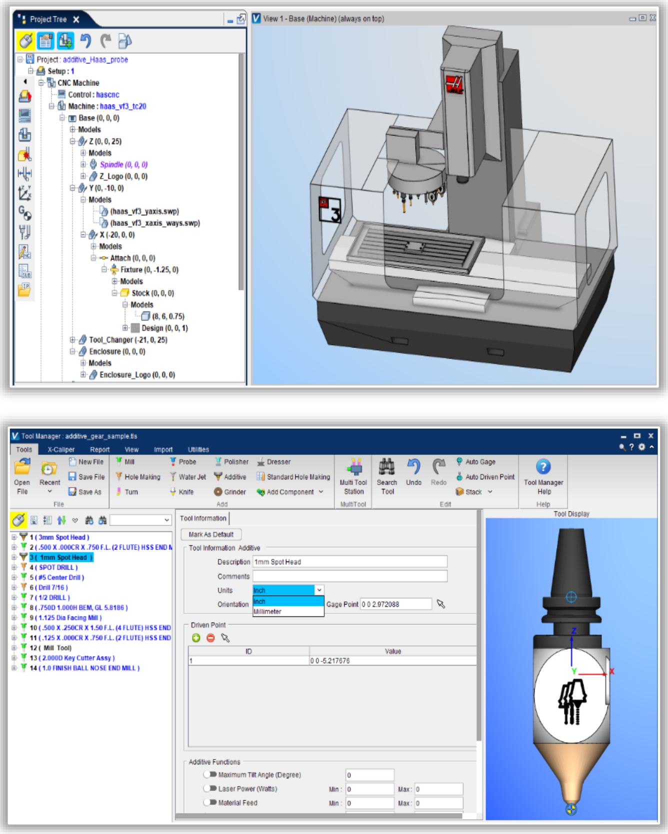


Figure 5. Selected virtual machine Haas vF3 and Laser DED extruder

The basic structure of the machine tool in Vericut consists of a BASE, TOOL, and STOCK. The configuration of the virtual machine starts from the base (O), as a fixed component. The vertical translational axis Z (Z Linear) was first added to the base, on the tool side. The horizontal translational axis Y '(Y Linear) was first added to the base in order, and then the horizontal translational axis X' (X Linear) was added to it, on the workpiece side.

On the spindle that moves along the Z–axis, there is the main spindle (Spindle) and a tool (Tool), which completes the kinematic structure of the machine. The hierarchical tree structure of the Haas VF3 machine is shown in Figure 5. The machine has the name *haas_vf3_tc20* with control *haascnc*. This machine supports additive technologies and will be used as an example for simulation of additive technology in section 5.2.

PROGRAMMING OF MACHINES FOR ADDITIVE MANUFACTURING

Programming of machines for additive manufacturing can be realized using various specialized software, such as Slic3r, Replicator G, Catalyst EX, Repetier–Host, and others. These programs represent an interface for communication with additive manufacturing machines. The input into these programs is a 3D model file, upon which we prepare additive layers and the required paths for material addition. Such programs usually allow [10]: (i) 3D model display; (ii) model scaling to the desired size; (iii) model orientation in the workspace; (iv) automatic or manual basing of the model when several parts are produced at once; (v) slicing and forming of additive layers; (vi) layer addition simulation and display of each layer; (vii) G– code generation for the specified machine.

In this paper, the Slic3r software was tested as a programming software of the considered machines for additive processes. Slic3r translates digital 3D models into instructions that are understood by a 3D printer (G–code). It slices the model into horizontal layers and generates suitable paths to fill them. Slic3r accepts the following 3D model files types: STL (Stereo Lithography), OBJ, Additive Manufacturing File Format (AMF), while 3MF is an XML–based file format, similar to AMF [14].

A typical procedure for additive manufacturing includes the following stages: (1) obtain the model in STL format, (2) load model into software, (3) set the parameters for 3D additive manufacturing (print, filament, printer), (4) export to G–code (5) simulate 3D additive manufacturing, (6) build prototype on the machine.

The first example for programming additive processes was tested on the example of the champions league cup model in pendant form, given in STL format, Figure6.

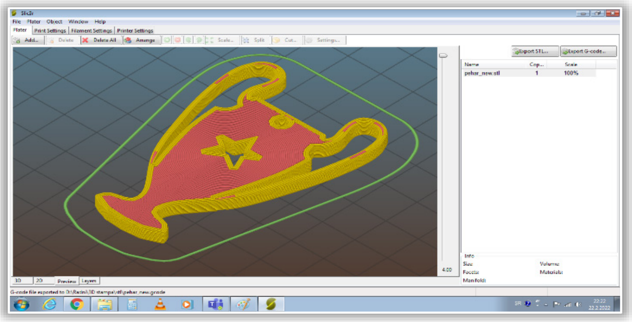


Figure 6. The example of the champions league cup in pendant form in slic3r environment

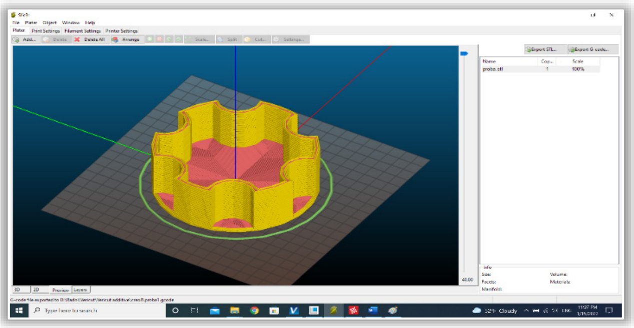


Figure 7. The second example of CNC machine simulation for laser directed energy deposition

For this example, machine simulation was prepared in CAD/CAM system PTC Creo (section 5.1), and finally this part was made on Velleman Vertex K8400 machine for additive manufacturing using FDM. Model for the first example is prepared in PTC Creo 8.0 and exported in the STL format that was loaded into Slic3r, where G–code is obtained for additive manufacturing. Prior to generating the G–code – print, filament and printer settings are adjusted. After generating the G–code, options are available for simulating the addition of material with the possibility of displaying toolpath for each individual layer.

The second example of programming additive processes, utilizing laser directed energy deposition (DED), is prepared for CNC machine simulation, Figure7. Here also, the model is produced in PTC Creo, exported in STL and loaded into Slic3r, where the G–code is obtained for additive manufacturing. This example was checked in Vericut environment.

MACHINE SIMULATION AND TOOL PATH VERIFICATION

This section presents a machine simulation of additive manufacturing for two considered methods: FDM and DED in two different environments (PTC Creo and Vericut).

— Machine Simulation of Additive Manufacturing in Creo

An example of programming additive processes for FDM was tested on the example of the champions league cup in pendant form and printed on Velleman Vertex K8400.

CAD/CAM system PTC Creo can simulate additive manufacturing in an indirect way. The configuration of the considered additive machine Velleman Vertex K8400 is shown in section 3. The configured machine can move along the tool path for each individual layer. The simulation of the last layer was chosen for the illustration.

To obtain the toolpath (nozzle path) in additive processes, it is necessary to convert the nozzle path into G code, using appropriate software, Slic3r in this case, Figure8. Obtained G–code can be converted into DXF file using CIMCO software. After that, the DXF is loaded into PTC Creo, where it is saved as a part, including nozzle path as a curve. This part is used in the CAM Manufacturing module (CAM–MFG), where the nozzle path serves to generate tool paths for simulation. During the simulation, the CAD model of the complete virtual machine can be loaded in PTC Creo environment, as shown in Figure 8, and Figure 9.

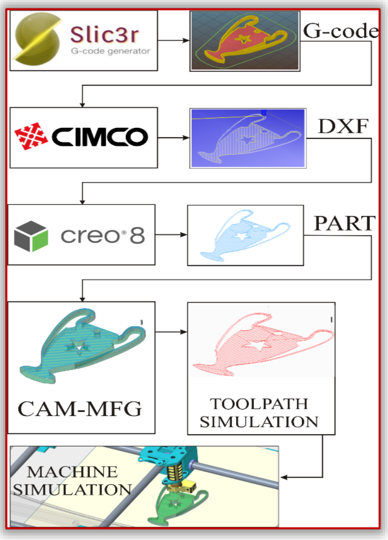


Figure 8. Procedure for indirect machine simulation of additive tool path on each layer

An illustration of the work done on Velleman Vertex K8400 during 3D printing of the first example is shown in Figure10.

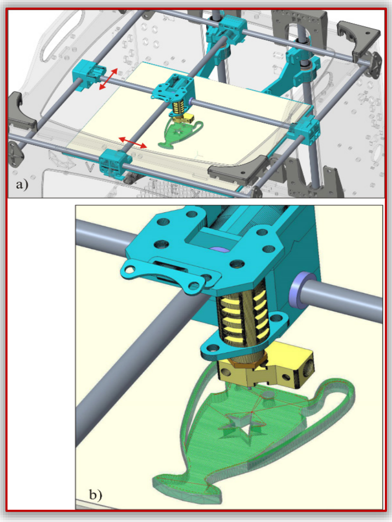


Figure 9. Machine simulation according to the given tool path within the last layer in PTC Creo environment

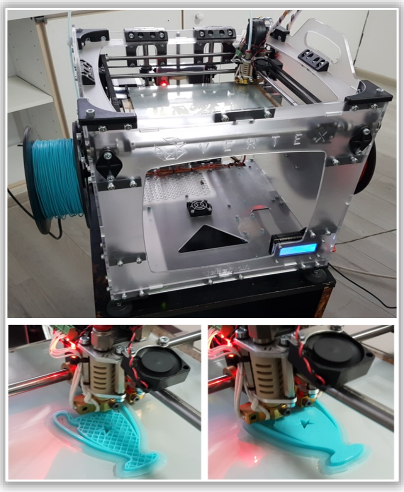


Figure10. Velleman Vertex K84000 during the printing of model champion league cup in pendant form in STL format

— Machine Simulation of Additive Manufacturing in Vericut

Simulation of the virtual machine tool in the VERICUT environment, according to the given program, allows the simulation of the operation of the machine based on G–code [15]. Virtual machines can be loaded from the available library or configured from scratch by the user, as explained in Section 3. The following is a procedure for additive technology simulation based on G–code with an example of adding material by directed energy deposition (DED). The project hierarchical tree of Vericut has already been discussed in the description of the virtual machine configuration, and now the other parts it contains are presented, referring to the basic tools needed to prepare a simulation project according to the given program, Figure11, with specifics that are characteristic for additive technology.

At the beginning, it is necessary to choose the control system and the virtual machine to perform the simulation. For example, in this paper, the chosen machine is haas_vf3_tc20 with its control haascnc.

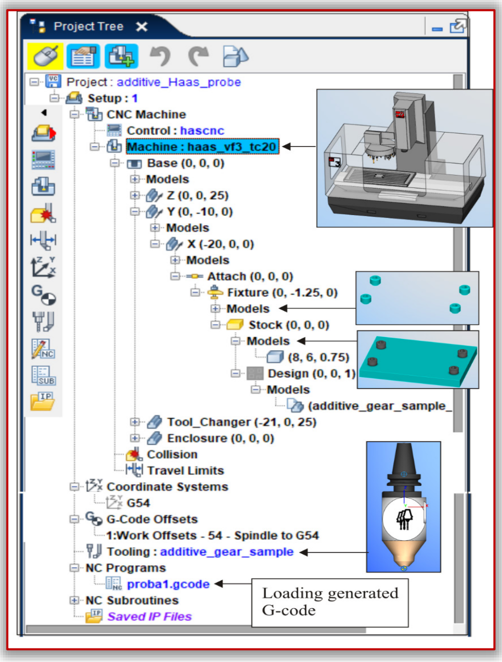


Figure11. VERICUT project hierarchical tree, an example of for additive technology

To continue with the definition of the simulation project, in this case, for additive technology, it is necessary to define: (i) stock as the platform on which the model will be based, and which is here connected to the worktable by means of a fixture; (ii) coordinate system (Program Zero Point), here G54, (iii) zero–point position adjustment on the virtual machine (G–code Offsets), (iv) tools which are used for additive technology (Laser DED extruder) and (v) G–code for additive technology.

In order to connect the virtual machine to the zero point of the program, it is necessary to select the appropriate offset of the G–code. Work offset was chosen from Spindle to CSYS Origin–G54.

G–code is prepared in software for additive manufacturing (Slic3r), and loaded in Vericut environment for simulation. When all the previously mentioned stages for the preparation of the simulation project are completed, the G–code is loaded and the additive technology is simulated, Figure12.

The simulation display of the virtual machine operation can be organized in several views, namely: Stock (workpiece)–view, where we can see the material being added layer by layer; Machine Base (Machine) – view, where the simulation of adding material can be followed on the virtual machine.

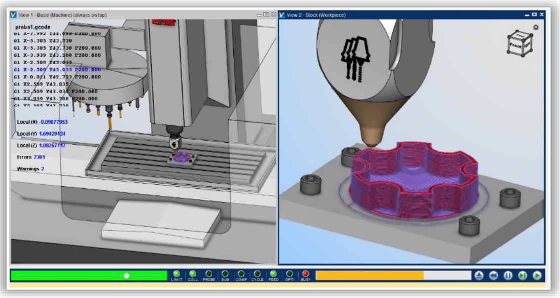


Figure12. Machine simulation of Haas vF3 virtual vertical machining center operation on example of additive technology

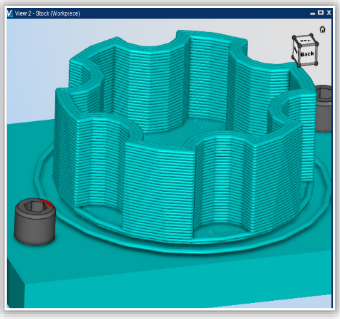


Figure13. Finished simulation example of additive technology

During simulation, its speed can be controlled using the slider on the bottom–left of the screen. Also, the display of the G–code can be included, that also marks the line being executed. The final result of the simulation and the look of the obtained part is shown in Figure13.

CONCLUSION

This paper provides an overview of programming and program verification using machine simulation in two environments for additive technology. Two methods for rapid prototyping by adding material were considered: fused deposition modelling and laser direct energy deposition.

In the age of Industry 4.0, an important research direction is digitization and virtualization of processes, enabling better verification and process monitoring.

Currently, there is ongoing research in the field of adding metallic materials in combination with milling, the so–called hybrid manufacturing, uniting additive and subtractive technology.

The importance of machine simulation for additive processes refers to the detection of possible collisions of various extruders with machine parts or the part to be made, thus gaining a higher degree of safety for people and equipment.

Our further research relates to the configuration of new virtual machines that combine additive and subtractive technologies – virtual hybrid manufacturing.

Note: This paper was presented at The 10th International Scientific Conference – IRMES 2022 – "Machine design in the context of Industry 4.0 – Intelligent products", organized under the auspices of the Association for Design, Elements and Constructions (ADEKO), by University of Belgrade, Faculty of Mechanical Engineering, Department of General Machine Design, in 26 May 2022, Belgrade (SERBIA)

Acknowledgment

The paper is a part of the research done within the projects that were supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia by contract no. 451–03–68/2022–14/200105 dated 4 February 2022 and by contract 451–03–68/2022–14/ 200066 dated 4 February 2022.

References

[1] Zivanovic, S., Slavkovic, N.: Programming of machine tools and robots for machining using STEP–NC in the era of Industry 4.0, Keynote Lecture, Proceedings of the 15th International Conference on Accomplishments in Mechanical and Industrial Engineering DEMI 2021, 28–29 May, University of Banjaluka, Faculty of Mechanical Engineering, pp. 3–26, 2021.
[2] Pham, D., Dimov, S.: Rapid Manufacturing: The Technologies and Applications of Rapid Prototyping and Rapid Tooling, Springer Verlag, London, 2001.
[3] Pham, D., Dimov, S.: Rapid prototyping and rapid tooling– the key enablers for rapid manufacturing, Proceedings of the Institution of Mechanical Engineers, Part C, 217, pp 1–23, 2003.
[4] Gibson, I., Rosen, D. and Stucker, B.: Additive Manufacturing Technologies, 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing, 2nd Edition, Springer New York Heidelberg Dordrecht London, 2010.
[5] https://all3dp.com/2/fused–deposition–modeling–fdm–3d–printing–simply–explained/, Craftcloud, Accessed on 2022–03–27.
[6] Harbaugh, K., McClain, A.: 3D printing of metals in rapid prototyping of biomaterials: Techniques in additive manufacturing, In: Rapid Prototyping of Biomaterials, Editor Roger Narayan, pp.17–40, Elsevier Ltd, 2020.
[7] https://meltio3d.com/phillips–additive–hybrid–haas–cnc–meltio/, Phillips Additive Hybrid integrates Haas CNC with Meltio, Accessed on 2022–03–22.
[8] Weaver, J., Jones, J.: Characterization of high–deposition polymer extrusion in hybrid manufacturing, Proceedings of the 29th Annual International Solid Freeform Fabrication Symposium – An Additive Manufacturing Conference, August 13–15, The University of Texas at Austin, Austin, Texas, USA, 2018.
[9] Zivanovic, S.: Rapid prototyping and manufacturing for model of human head, Proceedings of the 8th International Scientific Conference IRMES 2017– Machine elements and systems in energy sector Development of power production systems, 07–09. September, Trebinje, Bosnia and Herzegovina, pp. 271–276, 2017.
[10] https://vertex3dprinter.eu/downloads/vertex–downloads/, VERTEX ORIGINAL (K8400), Accessed on 2022–03–26.
[11] https://github.com/Velleman/Vertex–CAD, Velleman Vertex–CAD, Accessed on 2022–03–26.
[12] Tabakovic, S., Zivanovic, S., Dimic, Z., Zeljkovic. M.: Programming of 3–Axis Hybrid Kinematics CNC Machine for Rapid Prototyping Using Subtractive and Additive Processes. Journal of Mechatronics, Automation and Identification Technology, Vol. 6, No. 4, pp. 16 – 21, 2021.
[13] https://www.cgtech.com/products/product–line/85–additive.html, VERICUT's Additive module simulates both additive and traditional machining (milling or turning) capabilities of new hybrid CNC machines, Accessed on 2022–03–22.
[14] https://slic3r.org/about/, Slic3r – Open–source 3D printing toolbox, Accessed on 2022–03–22.
[15] Zeljković, M., Tabaković, S., Živković, A., Živanović, S., Mlađenović, C., Knežev, M.: Basics of CAD/CAE/CAM, University of Novi Sad, Faculty of Technical Sciences, ISBN 978–86–6022–120–1, 2018.
[16] Živanović S., Slavković, N., Kokotović, B., Milutinović, D.: Machining simulation of virtual reconfigurable 5 axis machine tool, Annals of Faculty Engineering Hunedoara, International Journal of Engineering, Tome XV, Fascicule 2 , pp.189–194, May 2017.

ACTA TECHNICA CORVINIENSIS
Bulletin of Engineering
ISSN: 2067–3809

[1.]Dejan JEREMIĆ, [1.]Nebojša RADIĆ, [1.]Nikola VUČETIĆ

BUCKLING ANALYSIS OF SIMPLY SUPPORTED SQUARE SYMMETRIC LAMINATED COMPOSITE PLATE

[1.] University of East Sarajevo, Faculty of Mechanical Engineering, Department of Applied Mechanics, Vuka Karadzica 30, East Sarajevo, BOSNIA & HERZEGOVINA

Abstract: To use the laminated composite plates efficiently, it is necessary to develop appropriate analysis theories to predict accurately their structural and dynamical behavior. The analysis of the behavior of the laminated plates is an active research area because of their complex behavior. The structural instability becomes an important concern in a reliable design of composite plates. The majority of the investigations on laminated plates utilize either the classical lamination plate theory (CLPT), or the first-order shear deformation theory (FSDT). Various geometries of the plates subjected to compressive load are studied. The present work deals about a buckling analysis of simply supported symmetric composite plate with four layers. It is assumed that composite plate is surrounded by external elastic fundation. Composite plate is modeled by the finite element method and subjected to biaxial compression load. Governing equations are derived based on Classical Laminated Plate Theory (CLPT) and computed critical buckling loads were compared with numerical results.
Keywords: buckling; symmetric composite plate; orientation of layers; compression load

INTRODUCTION

A composite laminate is composed of reinforcement (fibres, particles, flakes, and/or fillers) embedded in a matrix (polymers, metals, or ceramics). A laminate is called symmetric if the material angle, and the thickness of plies are the same above and below the midplane. The matrix holds the reinforcement to form the desired shape while the reinforcement improves the overall mechanical properties of the matrix.

To use the laminated composite plates efficiently, it is necessary to develop appropriate analysis theories to predict accurately their structural and dynamical behavior. The analysis of the behavior of the laminated plates is an active research area because of their complex behavior. The structural instability becomes an important concern in a reliable design of composite plates. Several studies on laminated plates stability were concentrated on rectangular plates [1-3]. It is known that buckling strength of the rectangular plates depends on the boundary conditions, plies orientation and geometrical ratio [2-4]. The thin composites structures which are largely used become unstable when they are subjected to mechanical or thermal loadings which leads to buckling. The buckling of the composite plates is a very complicated subject and more details can be seen in references [1-4]. To predict buckling load and deformation mode of a structure, the linear analysis can be used as an evaluation technique [5]. The buckling analysis of rectangular laminated composite plate with and without cutouts for the effects of fiber angle orientation and cutout shapes on critical buckling load are determined [12]. The effect of aspect ratio, orthotropic ratio and fiber orientation for antisymmetric laminated composite plates subjected to in plane loading are discussed to obtain critical buckling load [13].

The majority of the investigations on laminated plates utilize either the classical lamination plate theory (CLPT), or the first-order shear deformation theory (FSDT). Various geometries of the plates subjected to compressive load are studied. In [10] buckling analysis of the laminated composites is performed by using finite element analysis software ANSYS. Buckling analysis of a simply supported rectangular plate subjected to various types of non-uniform compressive loads has been studied [15]. The effect of fibre orientation on buckling behavior in a rectangular composite laminate with central circular hole under uniform in-plane loading has been studied by using finite element method [16].

In this paper, buckling behavior of symmetric laminated composite plates under biaxial compression load using ANSYS software is studied. The main contribution of this work is to perform a composite laminated plates analysis by using the Classical Laminated Plate Theory (CLPT) and ANSYS ACP. The ANSYS results are validated with the results predicted by classical laminated plate theory. The composite plate is modeled as shell model and then it is loaded by compression load. Then the obtained critical loads are compared for two different orientations of layers calculated using CLPT.

The laminated composite plates are thin shell elements composed of fibre lamination and epoxy resin is used to bond the lamina. The strength of these composite plates depended on type and properties of fibre material used along with epoxy resin. In structural designing field ANSYS, COSMOS, ABAQUS and so on are the most used finite element analysis software's. ANSYS is most trusted finite element software as it provides ease of work to analyse the laminated composite plates under buckling in biaxial loading. Where as in experimental study the biaxial loading is complicate to perform and requires energy and resources.

THEORETICAL FORMULATION

The buckling analysis of the symmetric square composite plate with 4 plies made of two types of materials and two different layouts of plies is performed (Figure 1).

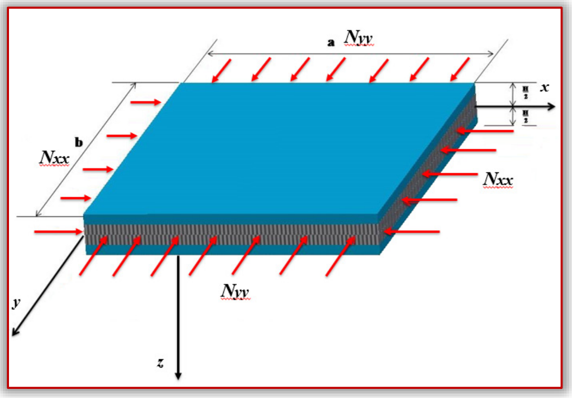


Figure 1. Symmetric square composite plate with 4 plies

The material properties of composite plate are kevlar 49/CE 3305 as material 1 (M1): E1 = 82 GPa, E2 = 4 GPa, G12 = 2.8 GPa, υ_{12} = 0.25 and graphite-epoxy AS-1/3501-5A as material 2 (M2): E1 = 127.6 GPa, E2 = 11 GPa, G12 = 4.5 GPa, υ_{12} = 0.25

The thickness of one ply is h = 0.25 mm. The symmetric orientations of plies α in composite are defined as M10/M230/M230/M10 and M20/M130/M130/M20.

For laminates of total thickness of 1mm with four sheets of individual thickness of 0.25mm, bending stiffness matrix D has the following form [8]:

$$D_{ij} = \frac{1}{3}\sum_{k=1}^{N}\left(\overline{Q}_{ij}\right)^{k}\left(h_k^3 - h_{k-1}^3\right)$$

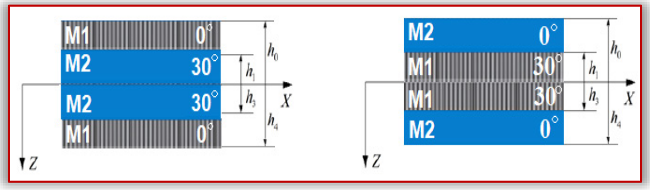


Figure 2. Symmetric orientation of plies and bending stiffness matrix

Based on the above material properties and using the MATLAB software package, bending stiffness matrix for selected laminate schemes $\theta = 0°, 30°$ are obtained.

$$[D] = \begin{bmatrix} 6,7954 & 0,3167 & 0,3990 \\ 0,3167 & 0,4800 & 0,1298 \\ 0,3990 & 0,1298 & 0,4841 \end{bmatrix} \quad [D] = \begin{bmatrix} 9,8649 & 0,3548 & 0,2588 \\ 0,3548 & 0,9093 & 0,0941 \\ 0,2588 & 0,0941 & 0,5000 \end{bmatrix}$$

— Governing equations of biaxially compressed composite plate

The governing equation for biaxially compressed orthotropic composite plate [14], which is based on Classical Laminated Plate Theory (CLPT), have following form

$$D_{11}\frac{\partial^4 w}{\partial x^4} + 2\left(D_{12}+2D_{66}\right)\frac{\partial^4 w}{\partial x^2 \partial y^2} + D_{22}\frac{\partial^4 w}{\partial y^4} + N_x\frac{\partial^2 w}{\partial x^2} + N_y\frac{\partial^2 w}{\partial y^2} = 0 \quad (1)$$

We assume that composite plate is biaxially compressed in the directions of x and y axes, N_x=N_y. Now we can define compression ratio which equals the ratio between the forces acting in y and x directions

$$\delta = \frac{N_{yy}}{N_{xx}} \rightarrow N_{yy} = \delta N_{xx} \quad (2)$$

Substitution of equation (2) in equation (1) we derive the general form of governing equation

$$D_{11}\frac{\partial^4 w}{\partial x^4} + 2\left(D_{12}+2D_{66}\right)\frac{\partial^4 w}{\partial x^2 \partial y^2} + D_{22}\frac{\partial^4 w}{\partial y^4} + N_x\left(\frac{\partial^2 w}{\partial x^2} + \delta\frac{\partial^2 w}{\partial y^2}\right) = 0 \quad (3)$$

It is assumed that all edges on composite plate are simply supported. This means that both the displacements and moments at the composite plate edges are zero. This can be expressed by following equations

$$w_i(0,y,t) = 0, \quad w_i(a,y,t) = 0,$$
$$w_i(x,0,t) = 0, \quad w_i(x,b,t) = 0 \qquad i = 1,2 \quad (4)$$
$$M_i(0,y,t) = 0, \quad M_i(a,y,t) = 0, \quad M_i(x,0,t) = 0, \quad M_i(x,b,t) = 0 \quad (5)$$

We assume that the buckling mode of the composites system as

$$w = \sum_{m=1}^{\infty}\sum_{n=1}^{\infty} W_{mn}\sin(\alpha x)\sin(\beta y) \quad (6)$$

In the upper equation:

$$\alpha = \frac{m\pi}{a}, \quad \beta = \frac{n\pi}{b} \quad (7)$$

where m and n are the half wave numbers.

Substituting equation (6) into equation (3), we get critical buckling load

$$N_{cr} = \frac{D_{11}\alpha^4 + 2(D_{12}+2D_{66})\alpha^2\beta^2 + D_{22}\beta^4}{(\alpha^2 + \delta\beta^2)} \quad (8)$$

Each composite plate had the length, a and width b. We assume that composite plates are biaxially compressed by forces N_{xx} and N_{yy} in the directions of x and y axes (Figure 3).

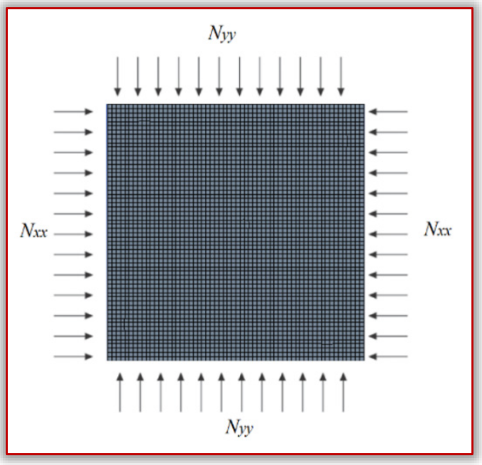


Figure 3. Composite plate loaded by biaxial compression load

RESULTS AND DISCUSSION

Non-dimensional buckling load was calculated for the number of half waves m=1, n=1 and m=2, n=2, while the compression ratio was δ=1. The thickness of one composite plate is h = 0,25 mm, while the length and width take values a=0,3m and b=0,3 (square plate). We investigated buckling behavior of square symmetric composite plate under biaxial compression load using Classical Laminated Plate Theory (CLPT) and computed critical buckling loads were compared with results obtained in ANSYS 19.2 ACP (Ansys Composites PrepPost). The present ANSYS model validation has been obtained for two different laminated composite plates and are presented in Table 1.

Table 1. Validate the ANSYS results with reference [9] for 4-layer symmetric square plate

Biaxial compression		Ncr		
Composite plate	Half wave numbers	CLPT	ANSYS	% error
M10/M230/M230/M10	m=1 n=1	7,1496	5,288	26
	m=2 n=2	28,5982	21,673	24
M20/M130/M130/M20	m=1 n=1	6,7451	7,0868	4,82
	m=2 n=2	26,980	28,738	6,11

The present ANSYS ACP model (Figure 4 and Figure 5) is being validate by comparing the results with references [9] by taking the same material properties, geometrical parameters and boundary conditions.

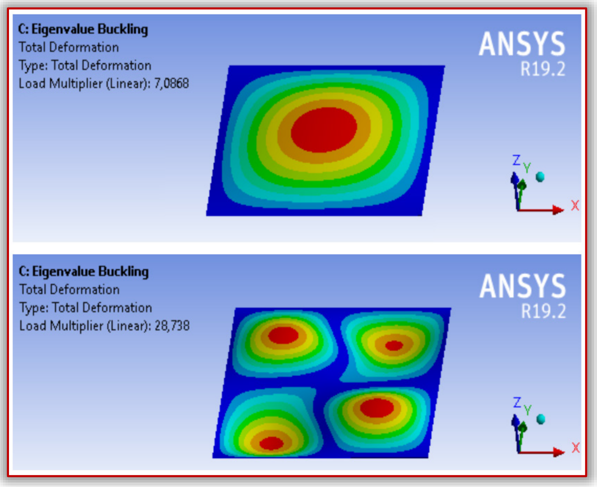


Figure 4. ANSYS results for laminate M10/M230/M230/M10

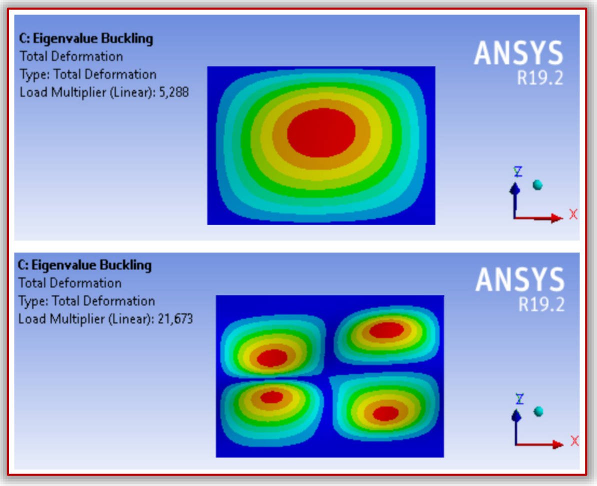


Figure 5. ANSYS results for laminat e M20/M130/M130/M20

In Table 1 the present ANSYS results are showing good agreement for laminate M20/M130/M130/M20 and the values are max 6,11% error compared to the reference [9]. The values for laminate M10/M230/M230/M10 are higher with max 26% error compared to the reference [9]. It is because of the fact that the present model is developed in the finite element analysis software ANSYS whereas in the reference the model is developed based on analytical solution using CLPT. For biaxial compressive loading the values are obtained for all edges simply supported (SSSS) boundary condition. The critical buckling load of the composite plate is almost the same for all two laminates.

CONCLUSION

The paper studied the buckling behavior of the square symmetric composite plates with two different layer orientations and four layers. The all composite plates were modeled using finite element method in ANSYS 19.2 ACP. The finite element model of composite plate consisted from shell elements, which had defined the material of composite plate, the thickness of composite plate and layout of layers. The composite plates were loaded by biaxial compression load. The boundary conditions on the parallel edges with *x* and *y* were applied. The computed critical buckling loads for all configurations showed that:

- the orientations of composite layers effect the value of critical buckling load, for example the composite plate with orientation of layers M20/M130/M130/ M20 is more sensitive to compression load than the composite plate with orientation of layers M10/M230/M230/ M10
- the buckling shapes are slightly effected by position of layer in composite plate.
- for value of half wave m=2 and n=2 we get higher value of non-dimensional buckling load.

It has been shown that with the change of layer position and angle of fiber orientation the value of the non-dimensioning critical load is changed. Laminate have different minimum and maximum values of non-dimensional critical force.

Note: This paper was presented at The 10th International Scientific Conference – IRMES 2022 – "Machine design in the context of Industry 4.0 – Intelligent products", organized under the auspices of the Association for Design, Elements and Constructions (ADEKO), by University of Belgrade, Faculty of Mechanical Engineering, Department of General Machine Design, in 26 May 2022, Belgrade (SERBIA).

References

[1] Kaw, K.: Mechanics of Composite Materials, 2nd Edition, Taylor & Francis, Group, CRC Press, New York, 2006
[2] Muc, A.: Optimal fibre orientation for simply-supported angle-ply plates under biaxial compression, Composite Structures, 9:161–72, 1988
[3] Nemeth, MP.: Buckling behavior of compression-loaded symmetrically laminated angle-ply plates with holes, AIAA Journal, 26:330–6, 1988
[4] Zor, M., Sen, F., Toygar, ME.: An investigation of square delamination effects on the buckling behavior of laminated composite plates with a square hole by using three-dimensional FEM analysis, J Reinf Plast Compos, 24:1119–30, 2005

[5] Shufrin, I., Rabinovitch, O., Eisenberger, M.: Buckling of laminated plates with general boundary conditions under combined compression, tension, and shear-A semi-analytical solution, Thin-Wall Struct, 46:925–38, 2008
[6] Reddy, JN.: Mechanics of Laminated Composite Plates and Shells: Theory and Analysis, CRC Press LLC, London and New York, 2004
[7] Spencer, A.J.M.: Constitutive Theory for Strongly Anisotropic Solids in Continuum Theory of the Mechanics of Fibre Reinforced Composites, Springer-Verlag, Wien, 1984
[8] Powell, P.C.: Engineering with Fibre-Polymers Laminates, Chapman & Hall, England, 1994.
[9] Jeremić, D.: Analiza stabilnosti laminantnih kompozitnih ploča, Master Thesis, East Sarajevo, 2013
[10] Buket Okutan Baba and AysunBaltaci: Buckling characteristicsof symmetrically and antisymmetrically laminated compositeplates with central cutout, Applayed Composite Materials, 14 pp. 265–276, 2007
[11] Rund Al-Masri and Hayder A. Rasheed: Analytical and Finite Element Buckling Solutions of Fixed-Fixed Anisotropic Laminated Composite Wide Plates Under Axial, SPE ANTEC Anaheim, pp. 550-557, 2017
[12] Ramesh N. R., Thyagaraj. N. R., Prema Kumar W. P., and Prathap Kumar M. T.: Experimental and Finite Element Studies on Buckling of Laminated E-Glass Woven Fabric Epoxy Composite Plates, International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181 Vol. 3 Issue 7, 2014
[13] Liecheng Sun., P.E., M.ASCE; and Issam E. Harik., M.ASCE.Buckling of Stiffened Antisymmetric Laminated Plates, Journal of Engineering Mechanics, Vol. 139, No. 8, August 1, ISSN 0733-9399/2013/8-1110–1123, 2013
[14] Priyanka Dhurvey and N D Mittal.: Buckling Behavior of an Orthotropic Composite Laminate using Finite Element Analysis, International Journal of Scientific Engineering and Technology, ISSN : 2277-1581, Volume No.1, Issue No.4, pp. : 93-95, 2012
[15] Jana P., Bhaskar K.: Stability analysis of simply supported rectangular plates under non-uniform uniaxial compression using rigorous and approximate plane stress solutions, Thin-Walled structures, 44, pp. 507-516, 2006
[16] Priyanka Dhurvey and Mittal N. D.: Buckling Behavior of an Orthotropic Composite Laminate using Finite Element Analysis, International Journal of Scientific Engineering and Technology, ISSN : 2277-1581, Volume No.1, Issue No.4, pp : 93-95, 2012

ISSN: 2067–3809

[1.]Ioana FĂRCEAN, [1.]Gabriela PROŞTEAN, [2.]Ana SOCALICI

METHODS AND TECHNIQUES USED IN RECYCLING PROJECTS FOR WASTE CONTAINING IRON

[1.]Department Management, University Politehnica University Timisoara, Faculty of Management in Production and Transportation, Timisora, ROMANIA
[2.]Department Engineering and Management, University Politehnica University Timisoara, Faculty of Engineering Hunedoara, Hunedora, ROMANIA

Abstract: Waste management is a problem faced by many countries of the world and its storage is no longer a reliable solution, which is why many European Union states have decided to practice the export and import of the waste they have generated. An efficient management of ferrous waste does not provide for the export or import of waste as a saving solution, and this waste must be regarded by the states of the world as a resource generating added value. The Romanian steel industry currently operates at a quarter of what it represented in 1989; however, in Romania there are still huge amounts of waste containing stored iron. Therefore, it is imperative that the Romanian steel industry adopts a cyclical model for the reintroduction of most of the waste generated (slag, agglomerated, scrap metal waste) into the manufacturing process. The paper presents methods and techniques used in planning and conducting a research project on the recovery of waste from the steel industry and the level of impact that the implementation of the obtained results could have.
Keywords: research project, ferrous waste, recycling, steel industry

INTRODUCTION

Under Directive 2006/12/EC on waste, adopted on 12 December 2010, any substance or object which the holder intends to dispose of, discards or is forced to dispose of is considered to be waste. Those substances and materials that represent residues of production or consumption processes are not necessarily considered waste, which is why it is important to distinguish between the notions of 'residues' and 'waste'. "Production residues" are considered to be materials that are not intentionally produced in a production process, but which may or may not be considered waste [1].

Ferrous metal waste is wastes that have in their chemical composition a high content of iron (Fe). Correlation Table 1 shows the types of ferrous waste, which is made according to the statistical waste nomenclature established on the basis of substances and the European list of wastes established by Decision 2000/532/EC of the European Commission.

Table 1. Classification of ferrous waste [2]

Cod	Type of waste
06	metallic wastes
06.1	metal waste, ferrous
06.11	ferrous metal waste and scrap
0	non-hazardous
10 02 10	mill scales
10 12 06	discarded molds
12 01 01	ferrous metal filings and turnings
12 01 02	ferrous metal dust and particles
16 01 17	ferrous metal
17 04 05	iron and steel
19 01 02	ferrous materials removed from the bottom ash
19 10 01	iron and steel waste
19 12 02	ferrous metal

The Romanian steel industry is currently operating at almost a quarter of what it operated at the end of 1989. At the moment, the Romanian steel industry is facing problems related to capacity and lower prices, the demand for steel depending on the economic and financial situation of some key industrial areas, which hinders the economic performance of domestic steel plants. The pandemic has also made the situation in plants even more difficult, making steel demand even higher. About 90% of the country's total steel production goes to export.

Due to the fact that Romania has been a highly industrialized country, significant amounts of ferrous waste have been generated (waste with high iron content, especially from the steel industry), the evolution of the amounts of these types of waste is shown in the graph in Figure 1. The graph was based on a set of data downloads from the Eurostat site, according to which the amounts of ferrous waste in Romania exceeded the threshold of 1,600,000 tons in 2018, being the highest amount recorded since 2010.

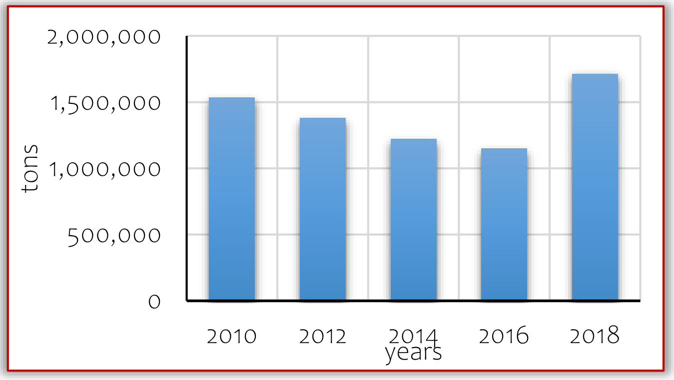


Figure 1. Evolution of ferrous waste quantities in Romania

In Romania, there are many historic waste deposits with iron content, to which are added landfills generated by the technological flows that currently operate. Most of the waste is not recycled, and the recovery rate of the waste is low. Such landfills are predominant in the western part of Romania (slag dump in Hunedoara, red sludge deposit in Oradea, tailings dump in Ghelari, Teliuc, etc.) and non-use and lack of maintenance activities cause a high degree of pollution. According to statistics made at the 2020 level, ferrous waste exports (iron and steel) from the European Union amounted to approximately 17.4 million tons, representing more than half (53%) of total waste exports. In 2020, the main export destination of the Union was Turkey (70 % of the Union's iron and steel exports). The EU also focused on imports, with 4.1 million tons of ferrous metal waste imported in 2020, with a third (32%) coming from the UK [3].

At the level of 2020, according to statistics, the export of ferrous waste represented about half of total waste exports from the EU. The quantities of ferrous waste (iron and steel), according to figures 2 and 3, occupy the first place in the hierarchy of imports and exports of different types of waste from and into the EU, according to Eurostat statistics.

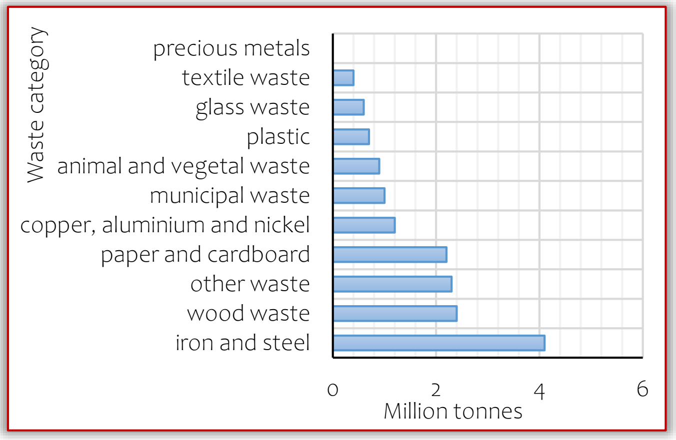


Figure 2. Statistical data on EU imports by waste category in 2020 [3]

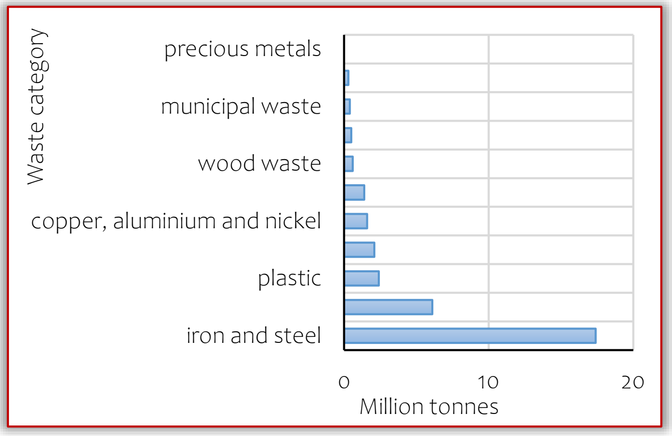


Figure 3. Statistical data on EU exports by waste category in 2020 [3]

In 2020, the main export destinations for "ferrous waste and scrap, iron and steel rebutting, iron or steel ingots" from Romania were: Turkey, Bulgaria, and Moldova. Ferrous waste and scrap, iron or steel scrap from Romania, in 2020, were imported by countries such as Bulgaria (with a share of 46%), Hungary (with a share of 24%) and Italy with a share of 11.4% (1.89 million USD) [4].

METHODOLOGIES

The methodology followed was to study, within a research approach, the applicability of specific management methods and techniques within the field of recovery / recycling of waste with iron content, following the identification of existing quantities of waste deposited in kind, located on the territory of Romania. Everything was done in order to study the way of waste management and to improve the management systems of waste generators (steel plants, metallurgical plants), carrying out the planning and development of a waste research project on waste.

Within the initiated research approach, a series of methods with high applicability in the field of industrial waste recovery were analyzed, identifying the causes that led to the generation of high quantities of waste, the strengths and weaknesses of the waste management process of these waste, the opportunities and threats that can arise in this field, respectively, the issuance of recommendations necessary to remedy or improve the situation encountered.

Management methods and techniques are those tools that are available to decision makers and are used to achieve the predicted objectives. The category of specific management methods and techniques is used when it is necessary to solve specific problems as efficiently as possible specific problems, in this case the problems and impediments that may arise within the research projects on the recovery of ferrous waste.

In the specialized literature, there are many management methods and techniques that have applicability in any field or some specific only to a certain field. Here are some methods and techniques that can be applied successfully in all research projects on the recovery of all types of waste, but in particular on the recovery of ferrous waste (small and powdery), the main subject of the paper.

THE METHOD OF DIAGNOSIS is characterized by the fact that it has a strong anticipatory character, its completion consists of the formulation of recommendations, and the essence of its application lies in the cause-effect analysis. The method results in corrective decisions on the malfunctions found. The application of the method in a waste recovery research project involves the steps listed in Table 2.

Table 2. Exemplification of the diagnostic method

1. Choosing the domain to be researched ≡ the field to be investigated shall take into account the recyclability of industrial waste, in particular of waste with a high iron content; ≡ in the area of Hunedoara County (Romania) there are many historical landfills, because historically the county was a mono-industrial area specialized in extractive industry and ferrous metallurgy.
2. Creating documentation on the investigated field ≡ it is necessary to carry out a study from the specialized literature on the typology of waste (types of waste deposited in the area: slurry from agglomeration-blast furnaces, steel dust, sideritic waste, slag), to make quantitative estimates of the waste obtained on streams that currently no longer work, as well as of the waste that is currently produced on technological streams; ≡ industrial waste landfills are located throughout Hunedoara County (e.g. in Teliuc there are sideritic waste deposits, in Hunedoara there is a slag dump, in Ghelari there is a dump of waste that contain iron, the waste are resulting from mining); ≡ waste from industry, in particular waste with a high iron content (slag, steel

dust) must be physically, chemically and mineralogical characterized for the purpose of establishing a concrete database and which will prove useful for further research to be undertaken; ≡ during the investigation process of the chosen field, answers are sought regarding the intrinsic value of the waste and the specific elements it contains (e.g. high iron content, useful mineral element iron), which recommends it in order to be the subject to a recovery process or to design, develop a specific recycling process; ≡ it imports the analysis of the form under which the useful element is found, following its study being able to choose the optimal form of extraction; ≡ after the characterisation of the waste, one can proceed to the study of the recycling processes and processes or even the development of proposals, as a result of which the obtained products can be used in the steel industry or in other industries (e.g. identify the recycling solutions to steel dust for zinc recovery); ≡ the documentation will be done from the specialized literature, but also on the spot by sampling and performing experimental analyzes.	
3. Identifying the strengths and causes that led to their appearance	
Strengths	Causes
≡ highly industrialized area based on mining (iron ore, coal) and processing in the metallurgical and steel industry; ≡ economics in full momentum since the years 50' – 60', the main flow of the Hunedoara metallurgical plant operating for almost 100 years; ≡ worldwide there is an extremely high demand for products made of steel or cast iron (e.g. in the territory of Călan city, there was in the past a gray cast iron foundry whose elaboration used white cast iron as a raw material).	≡ industrial waste is generated as a result of manufacturing processes, it is impossible to produce cast iron or steel without generating such waste (e.g. slag resulting from the steelmaking process, sideristic waste resulting from the process of enrichment of the iron ore concentrate present in the Ghelari area); ≡ increasing the iron content in the ore through the process of magnetic concentration and using only that concentrate, the rest being considered sterile, this material being stored in nature, currently in the county there are three such tailings ponds.
4. Identifying the weaknesses and causes that generated them	
Weaknesses	Causes
≡ large quantities of industrial waste deposited and currently unused (sideritic waste, slag); ≡ currently, the Hunedoara slag dump from Hunedoara, which is under concession, is being processed, but the processing speed, consumption is not very high; ≡ lack of new ways in which the ferrous fraction of the slag (with a grain size below 10mm) can be used.	≡ the correlation between legislation and rules on industrial waste management, so that waste producers benefit from the fact that they process their waste and no longer store it in kind; ≡ the frequency of waste generation by the technological processes carried out, plus the historical landfills.
5. Issuing recommendations	
≡ identification of economic entities that are specialized in processing industrial waste, especially those with a high iron content (e.g. Ecoremat, Econet Romania); ≡ in the context of sustainable development, future generations will have to use industrial waste, currently in storage, as secondary raw materials to be able to produce more, as natural resources will be depleted; ≡ designing and developing a technology for the recovery of small and powdered ferrous waste (such waste exists in Hunedoara County); ≡ the research, once materialized, will be used and implemented in other monoindustrial areas in Romania, such as Galați and Reșița.	

Annually, across the world, nearly 630 million tons of steel waste are recycled, thus preventing the emission of almost 950 million tonnes of CO_2 emissions, making "a decisive contribution to climate protection" [5].

Some reports by the Joint Research Center of the European Commission attest to the existence of a market and demand for the use of iron and steel waste in Europe, respectively, as a raw material in steelworks and smelters related to the production of metals and metal products.

Table 3. SWOT analysis applied to research on the recovery of iron-containing waste in Romania

Strengths	Weaknesses
≡ the existence of historic industrial waste landfills and the landfilling of the resulting waste in current streams; ≡ the presence of useful elements in the waste, elements which can still be recovered, the waste thus turning into secondary raw materials; ≡ the application of the principle of sustainability or sustainable development through the processing and recovery of waste with a high iron content and its reintroduction into the steel industry; ≡ the existence of large quantities of waste that are currently not processed, used (e.g. steelworks dust); ≡ when products are obtained based on the useful element of a type of waste, the products can be used in industry, this being a way of saving natural resources.	≡ industrial landfills that are not recovered and maintained (most of the landfills in the Hunedoara County area) pollute the environment, damaging natural ecosystems; ≡ the lack of interest of the entities that are managing such landfills, and implicitly of the generators, in the processing or recovery of that waste; ≡ substantial investments are needed to develop and implement a recovery technology to cover the very high costs generated by that process; ≡ not accessing European funds to create a recycling stream for landfill waste.
Opportunities	**Threats**
≡ processing of industrial waste deposited in kind produces secondary raw materials that are cheaper than raw materials obtained from natural sources; ≡ the research that will be undertaken locally will be able to be applied by other processors at national or even international level; ≡ by processing and recovering industrial waste and reintroducing it into the economic circuit, the number of landfills will decrease considerably, the degree of pollution caused by these sources will also decreasing.	≡ processing and recovery technologies can generate high costs that would generate a decrease in the interest of processors or investors; ≡ the finding by the beneficiaries of the recycling process of the need to make some changes in the production flow, changes due to the implementation of the respective process or technology of recycling/ recovery; ≡ obtaining low yields on the production side makes the technological process more difficult.

SWOT ANALYSIS is a specific management technique that each company can use to assess its internal environment, identifying strengths and weaknesses, and its external environment, identifying opportunities and threats from outside. The SWOT model can be applied not only to any managerial process but also to a concept, which is not directly related to the internal and external environment of a company. The SWOT model applied to the recovery process of industrial waste, particularly waste with a high iron content, is shown in Table 3.

According to the representatives of the International Recycling Bureau (BIR), the only global federation of the recycling industry, this industry is facing enormous challenges, with representatives of the organization trying in recent years to convince the executive branch, the European Commission (EC), that it should no longer consider processed, clean waste with high metallic content as "waste" [6].

As is the case for those iron and steel waste generated that have a sufficient degree of purity and which comply with the standards applicable to the category to which it belongs, namely the specifications required by the metallurgical industry. According to the legislation in force, both ferrous and non-ferrous waste in Europe can no longer be sold abroad, unless buyers are able to demonstrate that their waste processing standards comply with those of the countries of origin and do not generate additional pollution, as proposed by the EC [6].

Therefore, in the first month of 2020, China redefined important scrap metal as recyclable material, and since then there has been a massive acquisition of the highest quality scrap metal.

THE METHOD OF MORPHOLOGICAL RESEARCH is based on the decomposition of a complex objective into structural parts, whose evolution in the future will be independently researched, thus obtaining data on their future improvement, taking into account the forecasts of the technique and technology in the field in question. The steps and way of exemplification of the method in the field of recycling waste containing iron are presented in Table 4.

Table 4. Exemplification of the method of morphology research

1. Specifying the problem and identifying the main parameters involved in solving it ≡ the problem lies in the identification or development of processes for the recovery of industrial waste containing iron; ≡ the parameters to be identified are regarding the type of waste (ferrous or nonferrous waste), the chemical composition (high iron content or high value of other elements such as silicon, manganese, carbon), the physical composition, the mineralogical structure, and also the form in which the respective waste or class of waste is found (waste to pieces, small waste, powdery waste).
2. Careful analysis of the parameters and setting the values that each parameter can take ≡ after identification of the parameters mentioned in Step 1, the waste is thoroughly analyzed in terms of its chemical composition, mineralogy structure, and physical form under which it is found it; ≡ in view of the above characteristics, an attempt is made to find and develop those processes which can be successfully applied; ≡ for example, if it is found that the dimensions of the waste and, respectively, of the waste under analysis, are large, the recovery process by pelletization cannot be applied (pelleting is applied to powdery waste); ≡ if the waste is presented in an irregular (sharp) form following microscopic analysis, its recovery may be problematic. However, it was found, in some research conducted within the Faculty of Engineering Hunedoara (Politehnica University Timisoara), that in the case of producing briquettes from waste of 5-10mm granulation, low values were recorded for the cracking resistance of the briquettes, the breaking/cracking appearing where the large pieces of the ferrous waste were used [7,8]. ≡ the physical form under which the waste is found can cause the physical occurrence of phenomena, inappropriate events (e.g. briquette breakage, appearance of structural defects: air gaps).
3. Choosing the optimal solution, taking into account the conditions and possibilities that exist at a time ≡ in the framework of the research, to remedy the inconvenience that arose, regarding the cracking of the briquettes in the places where there were larger pieces of a particular ferrous waste, it was opted to crush them in a ball mill. After the use of this type of ferrous waste in the production of briquettes, the resistance to cracking and crushing of the samples made [9,10]; The waste used in the investigation is the result of the continuous pouring process and is called scale. ≡ sometimes, with relatively minimal efforts, nonconformities in products resulting from the application of recovery/recycling processes can be corrected.

The criteria for determining the conditions under which certain types of scrap metal are no longer considered waste, established under Directive 2008/98/EC of the European Parliament and of the Council, are set out in Regulation (EU) No. 333/2011 of the Council of the European Union. The criteria for determining the conditions under which iron and steel waste are no longer considered waste are closely linked to the activity of transferring it from the producer to another holder, the conditions to be met by the waste are set out in Regulation (EU) No. 333/2011 of the Council of the European Union adopted on 31 March 2011, on the establishment of criteria for determining the conditions under which certain types of scrap metal are no longer considered as waste, are the following:

≡ waste used as input of raw materials for the recovery operation contains iron or recoverable steel and should not contain hazardous waste, filings, fluids, pressure vessels;
≡ waste used as raw materials for the recovery operation has been properly treated for final use as input to steelworks and foundries;
≡ the iron and steel waste resulting from the recovery operation must meet the following criteria: the amount of tailings must be ≤ 2% by weight, do not contain excess iron oxide, do not contain oil, oily emulsions, lubricants or fats, toxic / radioactive/ hazardous substances.

The reports of the Joint Research Center of the European Commission have shown that the proposed criteria for waste used as inputs of raw materials in the recovery operation, for treatment processes and techniques, as well as for scrap metal resulting from the recovery operation meet those objectives and should lead to the production of iron waste, steel without hazardous properties, and with as few nonmetallic compounds as possible.

By applying the methods and techniques presented above within any type of research project, especially those projects concerning the recycling of waste containing iron, it is possible to identify, forecast and remedy the inconveniences that have occurred (the morphological method) and an exhaustive knowledge of the entire process (SWOT analysis, diagnostic method), can be identified, forecasted, and remedied, thus generated extraordinary results. The examples of the methods presented, including the implementation of the aspects and solutions identified following the application of the methods, are currently in the planning phase and will be put into practice in the near future.

RESULTS

According to recent data, all activities carried out on the recycling of iron-containing waste reduce energy consumption by 33% and CO_2 emissions by up to 32%. According to the statement of the statistics adviser of the Ferrous Division of THE BIR on 4 November 2021, adding ferrous waste back to the foundry sector would generate annual savings in CO_2 emissions that would amount to more than 1 billion tons. At the international level, as a result of the previous data, the waste with iron content generated by the steel industry is reintroduced into the production streams, it is desired to implement this concept in Romania, first locally (Hunedoara County) and then at national level.

According to the latest Eurostat data, the EU is one of the largest exporters of ferrous waste in the world. The 27 member states exported 17.45 million tons of waste to non-EU countries, in 2020. Over time, Romania has completed international collaboration projects on the implementation of an integrated waste system with Germany. Regarding the ferrous content, Romania does not have significant projects to collaborate with other countries, as landfills are still significant. A concrete example of this kind is found in Hunedoara County, where the recovery works for the deposited slag are completed in a proportion of 62%, while in Tulcea County, the recovery works have been completed up to 66%.

The problem of the aspects identified and detailed after the application of the methods could help to carry out a critical analysis generating a much clearer and more precise situation of the entire industrial waste management system, also highlighted the correlation with the legislation in force and with the regulations and directives of the Commission of the European Union.

The results obtained on the territory of Romania represent an applicative model also in the case of other states that face large amounts of industrial waste. Certain ferrous deserts generated on the territory of Romania that comply with the conditions of REGULATION (EU) No.333/2011 of the Council of the European Union are frequently exported to neighboring countries (Bulgaria, Moldova).

CONCLUSIONS

In the context of sustainable development, efficient use of resources, reuse, and recycling of steel and small and powdery ferrous waste is very important for the metallurgical industry. Currently, all raw materials must be used to their fullest capacity, ensuring zero waste in steelmaking. Each coproduct resulting during steelmaking, in the context of the circular economy, must be used in new products, this approach minimizes the amount of waste deposited, reduces emissions, and preserves raw materials. The recovery of waste regardless of the industrial branch, respectively, its expansion, leads to the minimization of the consumption of natural resources, the development of business opportunities, the optimization of costs, and the creation of new jobs.

It would be beneficial for Romania to process its waste generated from the steel industry by reintroducing it into the economic circuit. Romania could conclude collaboration projects with recycling institutions and centers located in the country or abroad, provided that this approach is supported and boosted by the country's leadership.

At the international level, many countries have decided to focus on the field of industrial waste recovery with the aim of increasing steel production. An example of this is Turkey, which in recent years has been heavily importing ferrous scrap (scrap iron), which has subsequently been recovered as part of the steel manufacturing process.

Acknowledgement

The authors would like to thanks the Politehnica University Timisoara and the Doctoral School for financial support.

References

[1] Eurostat. Methodologies and Working Paper. 2010 edition. Manual on Waste Statistics A Handbook for Data Collection on Waste Generation and Treatment. pp. 14-15, visualized at https://ec.europa.eu/eurostat/.
[2] Regulation European Commission No. 2150 of the European Parliament and of the Council of 25 November 2002 on waste statistics, pp. 35, as viewed at https://op.europa.eu/ro/.
[3] Eurostat. 2021. Where does EU waste go? visualized at https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20210420-1.
[4] Romania Imports and Exports of Ferrous waste and scrap. 2021. visualized at https://trendeconomy.com/data/h2/Romania/7204.
[5] Kinch D., Shah V., Fox J. 2021. EC to announce waste shipment regulation. visualized at https://www.spglobal.com/platts/en/market-insights/latest-news/metals/110421-ec-to-announce-waste-shipment-regulation-nov-17-eu-h1-ferrous-scrap-exports-soar-493.
[6] Luk J. 2021. EU could announce scrap metal export ban by December despite industry protests. visualized at https://www.metalbulletin.com/Article/4013559/BIR-2021-EU-could-announce-scrap-metal-export-ban-by-December-despite-industry-protests.html.
[7] Mititelu C.P., Hritac M., Constantin N. 2015. Laboratory experiments for the determination of the optimal characteristics of ultrafine ferrous waste

briquettes to be used in the cupola furnace. Scientific Bulletin Series B-Chemistry and Materials Science, 77(1), 157-16.

[8] Project no. 31-098/2007: Prevention and fight for pollution in steelmaking, energy, and mining industrial areas through the recycling of small and powder wastes, Responsible: Prof. Dr. Eng. Hepuț T. Beneficiary: CNMP, Romania.

[9] Crișan E. 2013. Research on the Valorization of Pulverulent Waste containing Iron and Carbon in Siderurgy. Ph.D. Thesis, Politehnica University Timisoara, Romania.

[10] Todoruț A. 2014. Research on the management and capitalization of small and powdery waste from the materials industry, in the context of sustainable development in Hunedoara County. Ph.D. Thesis, Politehnica University Timisoara, Romania.

ISSN: 2067–3809

[1.] Ifechukwude Israel AHUCHAOGU, [2.]Udo IME, [1.]Akindele Folarin ALONGE,
[1.]Ayobami O. OLADEJO, [1.]A.M. OJELADE, [1.]U.N. ETUK, [1.]G.M. AKPAN

GREENHOUSE (GH) TRENDS IN AGRICULTURE: A REVIEW

[1.]Department of Agricultural and Food Engineering, Faculty of Engineering, University of Uyo, NIGERIA
[2.]Department of Soil Science, Faculty of Agriculture, University of Uyo, NIGERIA

Abstract: Greenhouse (GH) technology has been employed in the production of selected crops under a controlled environment for maximum yield. Most often, flowers, medicinal plants and short-duration arable crops are most favoured for cultivation in greenhouses for research and commercial production purposes. Greenhouse is beginning to gain acceptance and usage in crop production in Nigeria in particular. This paper focused on the: origin of greenhouse, type of GH, general research trend in GH development/technology, adaptable irrigation type for GH farming, design criteria for GH, trends in smart GH/farming and GH development and utilization across the globe to produce food crops sufficiently and for future food scarcity. Site selection is a key factor for profitable and sustainable greenhouse production where factors like climate, topography, irrigation water, soil characteristics, flooded areas, air pollution, expansion, labour availability, communications network and orientation affect the utilization of greenhouses for research and production purposes. The types, styles, materials selection and uses, sizes of greenhouses, should be considered in conjunction with factors that determine the siting of greenhouses. Existing localized irrigation methods commonly utilized for crop cultivation include surface (Sprinkler), subsurface (Drip, emitter). The selection of types of GH and irrigation method depends on influencing factors.
Keywords: greenhouse, agriculture, IoT, artificial intelligence, smart agriculture

INTRODUCTION

Greenhouse (GH) is a farm structure that could be made of glass (glasshouse), plastic material of various types (greenhouse), and or of screen materials (screen house) (Bartok, 2000). Greenhouse (also called glasshouse, hothouse, screen house, shade house and crop top structure) is a system for modification and management of environmental factors that allows plants to be grown in suitable climates that may not well be suited for their growth and development. In brief, a greenhouse farming optimizes growing conditions and protects the crops from extreme weather events, protect crops from pests and diseases, enables effective crop managements. In the 17th – mid 19th century, greenhouses are commonly made of brick or timber with normal proportion of window space and some means of heating, Samapika, *et al.,* 2020, Tiwari, 2003. No matter the type or material used in the construction of these types of structures, they are all generally referred to as greenhouses (FAO, 2011; Bartok, 2000; Castilla and Baeza, 2013). The purpose of employing any type of greenhouse in agriculture is to prevent undue interference of the environment and prevent diseases and pest from influencing or altering the physiological makeup of the crop(s) intended to be planted for research or commercial production. Greenhouses are important in agriculture, horticulture and botanical science. The modern greenhouse is usually a glass or plastic enclosed frame structure, used for the production of fruits, vegetables, flowers and any other plants that require controlled environment for it survival. Components such as cover materials, climate-control systems, and irrigation and fertilization equipment are regularly evaluated by growers, designers and researchers, to improve their efficiency, lower inputs, and reduce undesired environmental effects, Samapika, *et al.,* 2020, Rajender, *et al.,* 2017; Tiwari, 2003. There are different type of greenhouses, however, polyethylene or polyvinyl, fiberglass, plastic films, transparent and translucent are commonly used as cover materials while the frame structure could be made of aluminum, galvanized steel or such woods as redwood, cedar or cypress. A greenhouse can become too hot or cold, some type of ventilating system is usually needed to provide optimum environment for growth and production of given plant. The plants cultivated in greenhouses fall into several broad categories based on their temperature requirements during nighttime hours. In a cool greenhouse, the nighttime temperature fall to about 7 – 10 °C. Among the plants that thrive in cool greenhouse are azaleas, cinerarias, cyclamens, carnations, fuchsias, geraniums, sweet peas, snapdragons and various types of bulbous plants like daffodils, irises, tulips, hyacinths and narcissi. A warm greenhouse has nighttime temperatures of 10 – 13°C. Begonias, gloxinias, African violets, orchids, roses and many kinds of ferns, cacti and other succulents are adaptable to such temperatures. In the tropics, greenhouse has nighttime temperature of 16 – 21 °C, variety of palms and orchids can be grown, Rajender, *et al.* (2017)

Greenhouse farming is a broad term that involves various types of sheltered structures. Important elements that are associated with this type of farming include shape of the structure, lifespan, cover material, size of the farm and level of farm management technology. Each greenhouse structure is inclusive of aspects that react differently then and to other management aspects. These include: the amount of sunlight, the amount of natural ventilation, the size of the farm, heating requirements, condensation run-off, efficiency of materials and costs, Samapika, *et al.,* 2020, Tiwari, 2003.

Montero *et al.* (2013) and Connellan (2002) reported that greenhouses could be categorized as low cost, medium cost or high-cost technology depending on the design and materials used. To design and construct an efficient and effective greenhouse for best management practice (BMP), the location, topography, soil characteristics, water quantity and quality, labour availability, etc. must be considered (Kumar *et al.*, 2006; Cox *et al.,* 2010; Brian *et al.,* 2015; Sabin *et al.,* 2020).

In Nigeria, the use of greenhouses is still obscured and probably restricted to farms in research institutions like IITA, Obasanjo farms, etc. or in the Universities/ research institutions. Crops planted for study are protected from extreme weather conditions that affect their growth while crops' environments are better managed to reduce the harmful effect of pest and diseases, therefore, these plants can be grown and made available throughout the year. Greenhouses are classified as either domestics, plastics or commercials, in Nigeria (agricdemy, 2020).

The use of irrigation technology in farming in Nigeria, especially in the southern region is very limited compared to the northern region. Irrigation technology still remains the available option to supplement natural rain-fed agriculture, particularly in a greenhouse. However, the choice of a particular irrigation system is affected by factors like climate, topography, soil characteristics, water quality and quantity (Arora, 2012; Waller and Yitayew, 2016).

The effects of greenhouse gas emission, its effects on the environment as well as the drying mechanism of greenhouse are not considered in this review. This review is focused on the greenhouse for farming purposes; types of greenhouses and their evolution over the years, general research trends in GH technology and current trends in the utilization of greenhouse for food security and sustainability.

MATERIALS AND METHODS / GREENHOUSE

Published articles (Literature) ranging between year 1989 – 2020, over three decades, were downloaded and used for the review. The downloaded literature were sorted out and categorised into those that reported on the origin of greenhouse (GH); type of existing GH; general research trends in GH development; adaptable irrigation type for GH farming; design criteria for GH; trends in smart GH/farming; special GH design methods and innovations in GH technology.

RESULTS AND DISCUSSION

— Types of greenhouses

Classification of greenhouses is done based on different parameters, such parameters includes: cost investment – Low technology greenhouses, medium technology greenhouses and high level greenhouse; based on shape – Lean-to, Even span, Uneven span, Ridge and furrow, Saw tooth, Quonset, Interlocking ridges and furrow type Quonset, Ground to ground; based on roof shape – Gothic, slant, saddle, round arch, hoop, gable, saw and flat; based on utility – active heating system, active cooling system; based on construction frames – Wooden framed, Pipe framed, Truss framed; based on covering materials – Glass, Plastic films, Rigid panel, shading net; based on cladding materials – Transparent glass, Fiberglass reinforced plastic/ polycarbonate, UV-stabilised low density polyethylene film; based on climate control mechanisms – naturally ventilated and forced ventilated. Generally, the structural components for greenhouse construction include framing, covering (cladding) materials, gutter, and foundation pipe, Bartok, 2000; Connellan, 2002; Tiwari, 2003; Samapika, *et al.* 2020; Rajender, *et al.* 2017; Montero, *et al.* 2013; Brian, *et al.* 2015; Kumar, *et al.* 2016; Waller and Yitayew, 2016 and Agricdemy, 2020; Cox, *et al.* 2010; FAO, 2011; Arora, 2012 and Castilla and Baeza, 2013. Figure 1 below shows the typical slanting roof shaped greenhouse with prominent parts labelled.

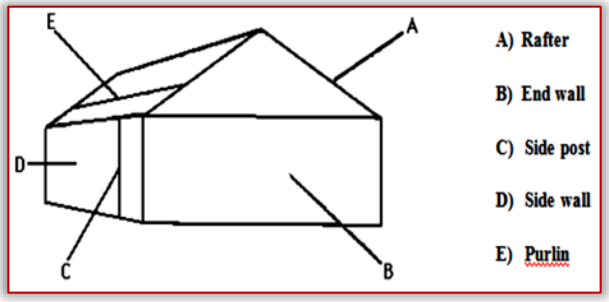


Figure 1: Primary components of a typical greenhouse. Source: Samapika, *et al.* 2020.

— Greenhouse Development and Utilization

In Nigeria and elsewhere, Greenhouse farming is the business of working on and managing the growing of crops and plants inside a greenhouse. Akpenuun and Mijinyawa (2020) worked on split-gable greenhouse developed for tropical conditions and equipped with humidifiers and circulating fan for climate control. Five varieties of Irish potato were cultivated in- and outside the greenhouse in two rainy and dry seasons using three seedlings of each variety planted with 10 replicates using Completely Randomised Design (CRD). They concluded that climate data and yield in and outside the greenhouse differed significantly. In trying to establishing the potential of a greenhouse (GH) for the production of crops like irish potato in the tropics, Akpenuum and Mijinyawa (2018) showed that the yield and growth data in and outside the greenhouse were significantly different at 0.01. Mijinyawa and Osiade (2011) again conducted a survey in Oyo State aimed at establishing the present status of the use of greenhouse in the region. Infrequent research activities, prohibitive cost of construction and maintenance were among reasons given for the abandonment of most of the greenhouse studied in the region. The introduction of greenhouses in crop production was concluded to be one of the ways of combating the effects of climate change on crop production. Ale, *et al.* (2019) designed and constructed a greenhouse for the evaluation of the performance of Okra in the Sahel region of Ondo State, Nigeria. The evaluation process was carried out in the dry season to determine the effects of greenhouse and liquid organic fertilizer on the performance of Okra. Results revealed that greenhouse has potential to improve the growth performance Okra while inorganic fertilizer has no significant influence of the yield of okra fruit.

Omobowale and Sijuwade (2019) opined that greenhouse cultivation is highly influenced by the microclimate, which affects plant growth and development. Shading is an option for ensuring a relatively cool environment within tropical greenhouses which tends to heat up due to intense solar radiations. Omobowale and Sijuwade (2019) study was aimed at comparing the microclimate between a partially shaded greenhouse and unshaded one with respect to its effect on the crops. Cucumber (*Cucumis sativus*) and Okra (*Abelmoschus esculentus*) were grown in two greenhouses during the dry season of early 2018. One greenhouse was shaded with white coloured high-density polythelene film at the roof level while the other greenhouse was left unshaded. Both greenhouses were naturally ventilated. Results showed that shading had a positive effect on the growth compared to the okra parameter observed in the unshaded greenhouse as there was significant difference in the leaf length, leaf breadth, stem girth, plant height and yield (3.71±058 and 2.56±1.21 t/ha for shaded and unshaded respectively) at P< 0.05. There was significant difference in stem height of cucumber, as well as the incoming solar radiation at P< 0.05. Partial shading had minimal but positive effect on the crops.

Omobowale, (2020) reported that sustainable agriculture is critical towards paving a way for year-round production and supply of food. He observed that cultivation of fruits and vegetables are vital due to high demand and nutritional values it provides to consumers. The rising global population especially in developing countries require other alternatives for sustainable crop production. To this, cultivation in controlled environments using functional and durable greenhouse structures presents an option. In Omobowale, (2020) study, a low-cost greenhouse was designed and constructed in Ibadan, Nigeria using locally available materials and evaluated. Afrormosia wood was used in constructing the frame while polyethylene of 2.5 mm thickness was used as sheathing material for the walls. The floor which covered an area of 24 m^2 was made of porous concrete of batching mixture 1:4 (cement to gravel) while the wall was 4 m high. Ventilation was passive with a vent area equal to 25% of total surface area; made up of 20% at the wall area and 5% as the roof vent. The roof was pitched at a 1 8° slope to allow easy drainage of rain water. Sweet pepper (Capsicum annuum, Cabernet) seeds procured from Burpee Seeds USA were cultivated with the aid of planting pots within the greenhouse in comparison with those planted in the open field for a duration of eight weeks. He based their evaluation on crop growth and yield parameters correlated with solar radiation, temperature and relative humidity in the greenhouse and ambient environments, respectively using randomized complete block design. Data were subjected to descriptive and correlation analysis. Peak temperature and RH were 31.1℃ and 91.1% respectively within the greenhouse in comparison with 29.7℃ and 89.7% respectively outside. Peak solar radiation was 413.4W/m^2 in the greenhouse compared to 690.3 W/m^2 in the ambient. Growth parameters showed that the crops in the greenhouse performed optimally when compared with plants in the open field with a yield of 18.1 t/ha in the greenhouse compared with no-yield recorded in the open field. Omobowale, (2020) concluded that utilization of greenhouses in crop cultivation can help to mitigate the problem of food shortage.

The scope of greenhouse in Agricultural Engineering (cultivation, drying and space heating) was studied by Kumar *et al.,* 2006. They agreed that greenhouse provides control environment for high value crops like flowers, medicinal plants, etc. They also agreed that crops grown inside greenhouse are healthy and give better experimental results. They pointed out that latitude and crop requirements are two factors that the design of greenhouse depends on. Different heating and cooling arrangements could be done inside a greenhouse depending on crop requirements. They further emphasized that drying of crops, fruits, medicinal plants inside a greenhouse helps in reducing postharvest losses. Brian *et al.* (2015) opined that low cost design greenhouse and its innovation have the potential to contribute to increased food security, particularly in areas where global climate change is creating additional variability in local weather patterns. They described the preliminary design of a greenhouse that uses open source control Systems. This takes advantage of the decreasing cost and size of sensors to automate systems that have the potential to increase the efficiency and yield of greenhouses.

Sabin *et al.* (2020) verified the greenhouse roof-covering-material selection using the finite element method (FEM). Heating, Ventilation, and Air Conditioning (HVAC) were used to control the situations. They observed that the covering materials of several conventional greenhouses are manufactured using polyethylene, which exhibits a limitation with respect to temperature control for ensuring optimal plant growth. Conducting the experiment using three different covering material configurations, obtained results were verified using FEM. Castilla and Baeza (2013) held that site selection is a key factor for profitable and sustainable greenhouse production. They emphasized that the main factors determining location and site selection of a greenhouse production area are: cost of production, quality of produced yield, and transportation cost to markets. They observed further that during the warm season, especially in the Mediterranean and tropical areas, where there is high solar radiation and the temperature exceeds the recommended maximum threshold level, the greenhouse effect has an adverse impact on the microclimate and crop performance. Solar radiation is the main climate parameter needed to evaluate the climate suitability of a region for protected cultivation. Other climate parameters, such as soil temperature, wind, rainfall and air composition (humidity and CO_2), influence to a lesser degree the evaluation of climate suitability (Castilla and Baeza, 2013). They opined further that the following varieties of factors must be considered in locating a greenhouse: Topography, Microclimate, and Protection from cold wind; Irrigation water, Soil characteristics, flooded areas, Air pollution, Expansion, Labour availability, Communications network and Orientation

Two greenhouse models were identified by Montero *et al.(*2013) which were the active climate control (characterized by High yields, Good quality almost all year round, regular production and High costs) and passive climate control (characterized by Limited yields, Good quality in limited periods, Irregular production and Low costs).

There are numerous options available to greenhouse operators to minimize or eliminate risks related to locating greenhouse in temperate, subtropical and tropical climate zones, environmental modification techniques. The techniques are broadly categorized into: greenhouse design (shape, dimensions and roof configuration), reducing solar load through shading and venting, forced air circulation and evaporative cooling (Connellan, 2002).

FAO (2011) listed the factors to be considered in selecting the location of a greenhouse to include: Topography, Soils, Windbreaks, Water supply and quality, Electricity, Roadways and labour force. Two basic design of greenhouse exists, namely the *Quonset* and the *A-frame*. The Quonset is based on an arched roof that permits stresses on the structure to be efficiently transferred to the ground. Quonset greenhouses are normally available in two basic designs (FAO, 2011). FAO (2011) also listed greenhouse design parameters to include light, design load, foundation, Orientation, Size, and heights. The structural materials can be grouped into floors, frames and coverings. Floors may be constructed of porous concrete, Portland cement, gravel or compacted clay covered with a strong polypropylene fabric. Figure 2 below shows the slant roof type of greenhouse with base pavement (a special future) during construction at the department of Agricultural and Food Engineering, Faculty of Engineering, University of Uyo, Nigeria.

— General research trends in greenhouse technology

Different methodologies have been used for the analysis of greenhouse technology; both quantitative and qualitative. The principal results show that there are different relevant lines of research related to different aspects of greenhouse farming: the use of water for irrigation, the design of the optimum structure of the greenhouse, conserving the soil in the best growing conditions, energy consumption of the system as a whole, climate control within the facility and pest control, Jose, *et al.,* 2020; Teitel, *et al.,* 2012.

Figure 2: Stages in the development of Greenhouse coupled with the irrigation component, University of Uyo.

Cossua, *et al.* (2020)The integration of the photovoltaic (PV) energy in the greenhouse farm has raised concerns on the agricultural sustainability of this specific agrosystem in terms of crop planning and management, due to the shading cast by the PV panels on the canopy. The PV greenhouse (PVG) can be classified on the basis of the PV cover ratio (PVR) that is the ratio of the projected area of PV panels to the ground and the total greenhouse area. In this paper, we estimated the yield of 14 greenhouse horticultural and floricultural crops inside four commercial PVG types spread in southern Europe, with PVR ranging from 25 to 100%. The aim of the work is to identify the PVG types suitable for the cultivation of the considered species, based on the best trade-off between PV shading and crop production. The daily light integral (DLI) was used to compare the light scenarios inside the PVGs to the crop light requirements, and estimate the potential yield. The structures with a PVR of 25% were compatible with the cultivation of all considered species, including the high light demanding ones (tomato, cucumber, sweet pepper), with an estimated negligible or limited yield reduction (below 25%). The medium light species (such as asparagus) with an optimal DLI lower than 17 $molm^{-2}\ d^{-1}$ and low light crops can be cultivated inside PVGs with a PVR up to 60%. Only low light demanding floricultural species with an optimal DLI lower than 10 $molm^{-2}\ d^{-1}$, such as poinsettia, kalanchoe and dracaena, were compatible inside PVGs with a PVR up to 100%. Innovative cropping systems should be considered to overcome the penalizing light scenarios of the PVGs with high PVR, also implementing LED supplementary lighting. This paper contributes to identify the sustainable PVG types for the chosen species and the alternative crop managements in terms of transplantation period and precision agriculture techniques, aimed at increasing the crop productivity and adaptability inside the PVG agro-systems.

Kimura, *et al.* (2020) upheld that environmental controls in a greenhouse improve microclimates, thereby enhancing photosynthesis, but they create spatiotemporal non-uniformity of photosynthesis, with implications for unstable crop production. They noted that there has been no research focusing on the spatiotemporal variability of photosynthesis arising from greenhouse environmental controls. They therefore visualized spatiotemporal distributions of leaf photosynthetic rate (A) and assess its linkages with microclimates [air temperature (Ta), water vapour concentration (Wa), CO_2 concentration (Ca), and leaf-boundary-layer conductance (ga)] across a strawberry greenhouse during daytime under roof ventilation and CO_2 enrichment, using physical, physiological, and biochemical models for A and mobile observations of the microclimates. Kimura, *et al.* (2020) observed that the distributions of A varied during the daytime and were non-uniform across the greenhouse under the influence of the microclimate distributions arising from the environmental controls. With the roof ventilation in particular, spatial variations of Ta and ga were most associated with non-uniformity in A through the physical process of the energy budget determining the leaf temperature and thus affecting leaf physiological properties (photosynthetic capacities and stomatal conductance). With CO_2 enrichment, in addition to the roof ventilation, spatial variations of Ca further increased non-uniformity in A through large variations of Rubisco-limited and RuBP-limited rates in the biochemical process of leaf photosynthesis. Spatial non-uniformity of A arising from the environmental controls ranged from 15% to 69% during the daytime. These findings indicated the importance of considering the spatiotemporal variability of photosynthesis with respect to its physical, physiological, and biochemical processes, in addition to the benefits of microclimates, for optimizing greenhouse environmental controls, Kimura, *et al.* (2020).

Pack and Mehta (2012) reflecting on the severity of global food insecurity, over 60% of the East African population were considered malnourished, with many regions in a state of famine. They emphasised that there is broad agreement on the need to help small-scale farmers move from subsistence to sustainable and profitable farming by boosting their agricultural productivity, reducing post-harvest spoilage losses and providing market linkages. Greenhouses, they believed can help farmers in East Africa grow and protect crops in both wet and dry seasons. Since large commercial farms, many of them owned by multi-national corporations, employ greenhouses that span several acres of land to produce high-value cash crops including fruits, vegetables and flowers for the export market. United State Botanic Garden (USBG, 2013) stated that improved types of greenhouse, cladding/covering materials, location of greenhouse as a function of site orientation, light direction and ventilation, good site selection, hydroponic and traditional irrigation systems were opined to account for their perceived new trends in greenhouse development.

Asgharipour, *et al.,* 2020, observed that the use of energy to evaluate the sustainability of greenhouse systems leads to management recommendations to increase the sustainability of production in these systems. Four greenhouse systems one each for cucumber, tomato, bell pepper, and eggplant production, located in Jiroft city, Iran, were evaluated using energy sustainability indices. To accomplish this study, 56, 31, 19, and 12 greenhouses were selected for cucumber, tomato, bell pepper, and eggplant production, respectively. Analysis of twelve energy indices and a study of the social characteristics of the producers using Analytic Hierarchy Analysis (AHA) showed that the sustainability of the cucumber production system was greater than that of the other three systems. They reported the calculated unit energy values for economic yield (UEVE) generally indicated that greenhouse systems were at least 100 times more sustainable than open farm systems for the production of different products, primarily because of drastically reduced soil erosion. The highest (5.10E+04 sej J^{-1} [4.96E+04, 5.25E+04]) and lowest (7.27E+03 sej J^{-1} [7.09E+03, 7.45E+03]) UEVE values were calculated for the bell pepper and cucumber systems, respectively. Therefore, selection of a plant with more potential to use free local environmental energy, higher yield, and more efficient use of labor will lead to greater sustainability of greenhouse vegetable production systems. Sustainability can also be increased by paying attention to the sociotechnical characteristics of the producers, the use of technologies to reduce non-renewable inputs to the greenhouse building, and by reducing the proportion of non-renewable inputs used overall, Asgharipour, *et al.,* 2020.

Yilmaz, *et al.,* 2005 examined the current status of the Turkish greenhouse industry and highlights issues important for its competitiveness. The greenhouse industry was reported to be the fastest-growing segment of agriculture in Turkey, mainly because of favourable climatic conditions. They however observed that, in recent years the greenhouse industry has been forced to adopt an increasingly competitive place in the market. The competitive market environment for greenhouse produce does not necessarily provide growers with any assurances about sales volume, a sufficient price, or favourable financial outcome. Currently, greenhouse operators in Turkey are faced with problems such as declining crop prices, price fluctuations based on over-supply, poor market systems and sales uncertainty, and lack of grower cooperatives. These problems have resulted in income uncertainty and market risks for greenhouse operators. In addition, strong dependency on imported inputs and excessive use of chemicals are other weaknesses of the Turkish greenhouse industry, Yilmaz, *et al.,* 2005.

Yongguang, *et al.,* (2007) opined that a real-time environment information acquisition system is essential if models and vegetable-crop information are to be integrated with a greenhouse management expert system for good decision making. Their designed greenhouse management expert system has four functional modules: (1) cultivation techniques, (2) pest and disease diagnosis and prevention, (3) nutrient deficiency diagnosis and fertilisation, and (4) environment control. The hardware and software of the environment information acquisition system were incorporated into the expert system, which also offers a multi-interface for sensors and is easily extended and maintained. Implementation was accomplished with the whole system to ensure its reliability and applicability for expert system, on-line decision making. The results showed that a dynamic integration of a greenhouse management system and an environment information acquisition system can supply sufficient information for good control strategies and for decision-support.

In order to improve the yield and quality of greenhouse crops, it is necessary to develop a reliable model to predict and control the microclimate of greenhouse, Hua, *et al.,* 2019 studied the problem of deterministic and stochastic modelling for greenhouse microclimate defined by the variables of temperature and humidity. Experiments were conducted in a naturally ventilated single-sloped greenhouse without crops in north China. Firstly, a mechanism model was adopted and the assumed unknown parameters were derived by using increased convergence factor particle swarm optimization algorithm. Secondly, Hua, *et al.* (2019) considered disturbance as an independent identically distributed white noise, a stochastic dynamic model was constructed and the parameters were obtained by using maximum likelihood estimate. Finally, a comparison of measured and simulated data was given to show that the proposed models can reasonably forecast internal greenhouse microclimate.

— Adaptable Irrigation type for GH farming

For an effective irrigation delivery, the design must consider parameters such as available moisture, root zone depth, allowable moisture depletion, net peak water requirements, irrigation frequency and cycle, and irrigation efficiencies in order to calculate the design flow (FAO, 1989; 2008). The maximum amount of water to be supplied has to be determined using factors such as soil type, root depth and the irrigation method. Three simple methods in determining irrigation schedules are plant observation method (including determination of soil moisture content using gypsum blocks, tensiometers and neutron probes), estimation method and simple calculation method. Determination of irrigation schedule for a given crop could be based on the total growing period, based on the months of peak irrigation, or based on a combination of the two schedules above.

According to Waller and Yitayew (2016), irrigation methods are categorized into surface, subsurface and overhead (Figure 1). Subsurface drip irrigation saves water, improves crop yields and quality, and facilitates fertilizer application; however, system performance is dependent upon skilled management. Potential disadvantages include salt accumulation near plants, restricted root development, high system costs, and restricted crop rotation. The three primary hydraulic classifications of drip emitters are laminar, turbulent, and pressure compensating while Emitters are classified as laminar flow, turbulent, orifice, vortex, partially pressure compensating, or pressure compensating. The hydraulic relationship between pressure and flow is a function of the type of emitter. This relationship is given as:

$$q = Kh^{x} \quad (1)$$

where q is emitter discharge, h is operating pressure head, k is the emitter discharge coefficient, and x is the emitter discharge exponent. Making an informed estimate of the emitter spacing along the lateral, the spacing between laterals, the emitter flow rate and lateral length. While plant spacing, plant rooting characteristics, soil texture, and lateral hydraulics are the factors that determines the selection of emitters' spacing and flow rate. It is known that calculation of the soil water holding capacity is generally not required for drip irrigation systems because drip irrigation is a high frequency irrigation system with daily or even more frequent water application.

Localized irrigation is usually comprised of drip, micro-jet (jet Spray) and micro-sprinkler irrigation while the advantages of localized irrigation system over others include: reduction in the evaporative component of evapotranspiration, reduction in weed growth due to limited wetted areas, penetration of water into problematic soil is improved by the slow rate of water application, and localized irrigation is considered as a water-saving technology. The probable disadvantages of the system include it's being prone to clogging because of very small aperture of the water emitting devices, movement of salts to the fringe of wetted area of the soil which may cause salinity problems through the leaching of salts by rain to the main root volume, the lateral lines can be damaged by rodents, dogs and other animals in search of water, not economical for the crops with very high population density due to large numbers of laterals and emitters required (James, 1993; FAO – SAFR, 2002; Grag, 2007; Arora, 2012).

Greenhouse crops are irrigated by means of applying water to the media surface through drip tubes or tapes, by hand using a hose, overhead sprinklers and booms or by applying water through the bottom of the container through sub-irrigation, or by using a combination of these delivery systems. Overhead sprinklers and hand watering have a tendency to "waste" water and also wet the foliage, which increases the potential for diseases and injury. Drip and sub-irrigation systems are the most efficient and provide greater control over the amount of water applied. Also, since the foliage does not become wet there is a reduced potential for diseases and injury, Douglas, *et al.,* 2010.

Babatunde and Mofoke (2006), explored the possibility of growing roselle (*Hibiscus sabdarriffa*. L) under irrigation without greenhouse component. The experimental treatments comprised of five irrigation schedules with irrigation intervals (*f*) of 3, 5, 7, 9, and 11 days. The corresponding gross water requirements (GWR) were 37, 56, 74, 93, and 112mm. The crops were grown under check basin irrigation during the 2001/2002 and 2002/2003 irrigation seasons in Bauchi state, Nigeria. Results showed that difference in number of leaves per plant was significant (p = 0.05) with the fifth irrigation schedule (f = 11 days, GWR = 112mm) giving the highest value of 347 leaves per plant, while the first irrigation schedule (f = 3 days, GWR = 37mm) resulted in only 192 leaves per plant. Variations in plant height, number of branches per plant and canopy diameter were insignificant (p = 0.05). The influence of irrigation schedule on the yield of Roselle measured with respect to fresh calyx weight was highly significant with a strong coefficient of determination of 97.1%. Yield soared with increase in seasonal irrigation depth, Babatunde and Mofoke, 2006. The increase followed a second degree polynomial, reaching a projected maximum of about 682 Kg/ha. The associated maximum seasonal application depth was found to be approximately 3389 mm. Results of this study indicate that maximum yield of roselle grown under irrigation could be attained with a weekly irrigation interval and a gross application depth of 188 mm.

Micro irrigation system is the best way for watering plants in a polyhouse as per the daily needs and the stage of the crop (Babatunde and Mofoke, 2006, Douglas, *et al.,* 2010, Teitel, *et al.,* 2012, Hochmuth and Hochmuth, 2018). Besides this, care should be taken that water does not trickle directly on the leaves or the flower, which may lead to disease and scorching of leaves or flowers. Fertigation equipment for providing fertilisers to the plants as per their daily needs, water-soluble or liquid fertilisers are injected in the irrigation mainlines feeding the greenhouse crops. Fertiliser dosers and tanks are used for injecting soluble fertilisers. They can also be connected to automatic mixing and dispensing unit. The fertilisers are dissolved in different tanks as per compatibility and are mixed in discrete proportions for supply to the plants through drip irrigation systems. The spraying system is used for spraying required chemicals on the crop to control pests and diseases, if any, Douglas, *et al.,* 2010, Teitel, *et al.,* 2012, Hochmuth and Hochmuth (2018),. The spraying machines are normally portable but may be equipped with high pressure motorised piston pumps and nozzles. For removing hot air from the greenhouses in forced ventilated greenhouses, cooling pads are used for cooling the air entering into the greenhouses. These systems are operated as and when the climatic parameters like temperature, humidity, etc., inside the greenhouse need manipulation as per crop growth requirement, Babatunde and Mofoke, 2006, Douglas, *et al.,* 2010. These are used for controlling light intensity falling on the crops inside the greenhouse. Various shading nets with shading capacities like 35 per cent, 50 per cent, 75 per cent are used for different crops and seasons. Sensors and Controllers they are used for controlling climatic parameters automatically inside hi-tech greenhouses. These systems are generally used for very high-value crops and sensitive activities like soil-less cultivation, tissue culture plant and hardening activities, Teitel, *et al.,* 2012.

Hochmuth and Hochmuth (2018) agreed that in a rockwool or perlite house, water enters the house directly from the well, is mixed with fertilizer stocks by proportioners or injectors and applied to each plant via drip or micro-irrigation emitters. A backflow prevention system (check valve, pressure relief, and low pressure drain) are required for systems in which fertilizer will be injected, Douglas, et al., 2010, Teitel, et al., 2012. The water from the well should be filtered (150 mesh) to prevent damage to the fertilizer proportioners. A union connection installed before all major components will allow them to be removed for maintenance. Proportioners usually operate on a pressure differential basis so that installation in parallel is probably preferred over series. They upheld that nutrient solution should be filtered (150 mesh) prior to application to the plants and that a pressure regulator should be installed to ensure the desired pressure in the greenhouse irrigation system. They concluded that Rockwool or perlite media receive water from individual emitters placed at the base of each plant enabling that each plant is irrigated from a short.

DESIGN CRITERIA FOR GREENHOUSE

Rajender, *et al.* (2017) maintained that the cultivar growing technology under the low cost greenhouse is assuming an important role in Indian Agriculture in the future years. The low cost greenhouse ensures the year round growing of different cultivar varieties. This is to ensure timely availability of cultivars with good vigour. In his study, to establish a poly house, the farmer was reported to have invest between Rs.900-1000 for one m^2 area using tubular framed structure. To reduce the installation rate of greenhouses, a low cost greenhouse having an area of 50 m^2 was constructed (10 m × 5 m × 3.5 m) with locally available casuarina wood coated with coal tar was used as structural material and bamboos were used as frame work. Wooden strips with nails were used to make the poly grip assembly. UV stabilized PVC transparent sheet was used as outer cover in place of traditional glass sheets. The drip system was installed and costs around Rs. 23811.16/-.The cost for m^2 area is around Rs. 467.6/-, whereas to construct a greenhouse for naturally ventilated tubular structure is Rs 1060/- per m^2 (MIDH). So the cost was reduced to about 56 % by using locally available material.

Hochmuth and Hochmuth (2018), Bucklin, (2020), presented suggestions and options for designing and operating a greenhouse for vegetable production in perlite or rockwool. Their suggestions are presented for growers who desire to change their nutrient film technique (NFT)-pipe house over to solid media such as perlite or rockwool media. Their recommendations also would apply to other media, such as peat or pine park mixes. Their major considerations are those pertaining to the floor design for the media system. They, in addition presented suggestions for general greenhouse design and operation for tomato culture. Many of these suggestions would apply to houses with other production systems, e.g., upright bag or trough, and in most cases would be applicable for cucumbers, eggplant, and pepper. Included in their work were details on crop culture (irrigation, fertilization, disease and insect control, etc.) which can be found at the Florida Greenhouse Vegetable Production handbook.

Sutar (2020), position basically focused on the local climate and the bioclimatic requirements of the species to be cultivated, once the proper site has been selected, it will be necessary to choose the cladding material, the type of structure and the architectural shape of the greenhouse. He further opined that if the predictable climate generated by the greenhouse is not appropriate complementary facilities and equipment for, climate control will have to be considered. He upheld that greenhouse design is very much influenced, in practice, by the local climate and the latitude of the site, and in many cases is limited by the availability of materials for the construction. He agrees that no design is perfect, thus it is necessary to prioritize in each case, the criteria to follow, these being: the maximization of the light, minimizing, if possible, the structural elements to avoid shadows, ensuring good insulation which decrease the heat losses and affordable costs.

TRENDS IN SMART GREENHOUSE / FARMING TECHNOLOGY

IoT is a new and upcoming trend in technology that finds its application in almost every field. Things, when connected to the internet and to each other, make the entire system smart. Ratnaparkhi, *et al.,* 2020 used IoT in every way of life: Smart Cities, Smart homes, Smart retail and many more. Using IoT in agriculture and farming practises is the need of the hour as the global population will hit a peak of 9.6 billion by 2050, to meet that kind of demand the agriculture industry needs to supply at an even faster rate. This feat can be achieved by using modern technology and mainly IoT, Ratnaparkhi, *et al.,* 2020. IoT makes labour free farms a possibility. Not only in major farming practices but it can also be used in maintaining livestock, greenhouse farming, managing farms etc. The most important tool used for IoT is Sensors, sensors are devices that collect essential data which is interpreted to get the desired analysis. For agriculture, sensors are mainly used to get readings used to measure NPK values, detect diseases and moisture content in the soil. Ratnaparkhi, *et al.,* 2020 in their study, explores its application in the agricultural sectors. Smart agriculture is called precision agriculture because it uses precise data to reach conclusions. It shows the various sensors which aid IoT and agriculture, their applications, challenges, advantages and disadvantages.

Kodali, *et al.* (2016) worked primarily on the improvement of current agricultural practices by using modern technologies for better yield. Their study produced a model of a smart greenhouse, which helps the farmers to carry out the work in a farm automatically without the use of much manual inspection. The irrigation of study plot was carried out using automatic drip irrigation, which operates according to the soil moisture threshold set accordingly so as optimal amount of water is applied to the plants. Based on data from soil health card, proper amount of nitrogen, phosphorus, potassium and other minerals were applied by using drip fertigation techniques. Proper water management tanks were constructed and filled with water after measuring the current water level using an ultrasonic sensor. Plants were also provided the requisite wavelength light during the night using growing lights. Temperature and air humidity were controlled by humidity and temperature sensors and a fogger was used to control the same. A tube well is controlled using GSM module (missed call or sms). Bee-hive boxes were deployed for pollination and boxes were monitored using ultrasonic sensors to measure honey and send mails to the buyers when they were filled. Further, the readings collected from storage containers are uploaded to cloud service (Google drive) and forwarded to an e-commerce company.

The Internet-of-Things (IoT) has reshaped the smart agriculture by not only given a boost to the productivity and optimized the resources, but it has also increased the efficiency and has minimized the cost of production, Tripathy, *et al.* (2020). Tripathy, *et al.* (2020) emphasised the potential of sensors and IoT in the field of greenhouse farming and presents the future of automation. The different parameters such as humidity, water nutrients solution level, pH and EC value, temperature, UV light intensity, CO_2 level, mist, and amount of insecticides or pesticides were monitored in their study through various sensors so that significant knowledge about the early fault detection and diagnosis can be done. A Decision Support System (DSS) presented in their study acts as the central operating system which governs and coordinates all the activities. Furthermore, their study also accounts for the different challenges of greenhouse Rose farming and highlights a new IoT based solution which is smart and sustainable. The model presented in study is well adapted to the changing environment, thereby redefining the terms of sustainability, Tripathy, *et al.* (2020).

Wang and Yu (2019) reported the influence of science and technology, in the progressive development of modern agricultural technology in China. The research of intelligent greenhouse control system has far-reaching significance. Wang and Yu (2019) believed that greenhouse control system should meet the function demands of data acquisition, data transmission and remote monitoring. In their study, the overall control structure of greenhouse was formulated within the framework of Internet of Things (IoT) technology, which is divided into perception layer, transmission layer and application layer. Based on the architecture of IoT and Zig Bee wireless sensor network technology, Wang and Yu (2019) designed four modules of the control system, including login management module, data display module, remote control module and system management module. The greenhouse control system of IoT was tested and analysed and the experimental results show that the system can achieve the expected effect of greenhouse.

Fedotova, *et al.,* 2020 assessed the current state of Russia's agricultural sectors in the context of restrictive sanctions and food embargo. Their attention focused on the need to intensify the production of agricultural raw materials for domestic consumption and export to the world market; while noting the low efficiency of the main branches of the agro-industrial complex in Russia. The experience of developed countries revealed that the implementation of advanced information technologies into traditional agro-business processes makes it possible to increase the profitability of agricultural sectors. The development of electronic technologies, implementation of automated data collection devices and processing of the results obtained contribute to the implementation of the Industry 4.0 concept in the transition to an information society. Fedotova, *et al.,* 2020 analyzed the developed Federal Scientific and Technical Program (FS&TP) for the Development of Agriculture for 2017–2025 being implemented. Fedotova, *et al.,* 2020 conducted their study using the generalization and analog methods, statistical and graphical analysis, vertical and horizontal analysis and methods of data comparison and collation. Their finding showed that today 3 activities are being financed in Russia, i.e., the creation of scientific and technical results and products; implementation of scientific and technical results and products into production; and commoditization of scientific and technological results and products. Based on these areas, the main trends of scientific and technological development of agriculture were identified to include "smart farm," "smart greenhouse" and "smart field." The introduction of these trends into the practice of agricultural organizations will enable meeting the basic needs of the domestic food market and increasing the volume of exported agricultural products as well as provide an opportunity to increase profitability and intensify the initiative to create "smart enterprises" in the agricultural sector.

Katzin, *et al.,* 2020 opined that Greenhouse models are important tools for the analysis and design of greenhouse systems and for offering decision support to growers. While many models are available, relatively few include the influence of supplementary lighting on the greenhouse climate and crop. Katzin, *et al.,* 2020 worked on GreenLight, as a model for greenhouses with supplemental lighting. GreenLight extends state of the art models by describing the qualitative difference between the common lighting system of high-pressure sodium (HPS) lamps, and the newest technology for horticultural lighting - the light-emitting diodes (LEDs). LEDs differ from HPS lamps in that they operate at lower temperatures, emit mostly convective heat and relatively little radiative heat, and can be more efficient in converting electricity to photosynthetically active radiation (PAR). These differences can have major implications on the greenhouse climate and operation, and on the amount of heat that must be supplied from the greenhouse heating system. Model predictions have been evaluated against data collected in greenhouse compartments equipped with HPS and LED lamps. The model predicted the greenhouse's heating needs with an error of 8 - 51Wm^{-2}, representing 1 - 12% of the measured values; the RMSE for indoor temperature was 1.74 - 2.04^{0}C; and the RMSE for relative humidity was 5.52 - 8.5%. It is hoped that it may be further evaluated and used by researchers worldwide to analyse the influence of the most recent lighting technologies on greenhouse climate control, Katzin, *et al.,* 2020.

Chen, *et al.* (2020) noted that Internet of things (IoT) technology has been constantly applied in greenhouse environmental monitoring and control in recent years. The acquisition and control parameters, network protocols are different for the various purposes of the greenhouse. These factors are the keys to the abilities to effectively communicate and transfer meaningful data in IoT infrastructures. To achieve the adaptive matching of data communication between the gateway and server in a greenhouse IoT system, Chen, *et al.* (2020) designed a data encapsulation method based on XML to enable data interoperability in a distributed greenhouse IoT system. They further used the behaviour of the Multi-Agent System (MAS) to merge the heterogeneous information and the responses for data synchronization in the greenhouse IoT system, Chen, *et al.* (2020). The data communication mechanism for real-time and cumulative data synchronization between the gateway and server based on JADE was tested in a specific greenhouse. The results showed that the data loss rate between the data acquisition unit and the gateway was 1.52%, and the data loss rate was 0.4% between the gateway and the server; therefore, the mechanism could be feasibly applied to the data communication for a greenhouse IoT system, Chen, *et al.* (2020).

CONCLUSIONS & RECOMMENDATION

Greenhouse technology in agriculture for research and commercial production purposes has been in existence and continues to be useful in the production and study of choice plants; prevented from the influence of the environment and effects of diseases and pests. Literature support the employment of greenhouses coupled with the appropriate irrigation systems in the study and production of any selected crop(s). The plants cultivated in greenhouses fall into several broad categories based on their temperature requirements during nighttime hours. In a cool greenhouse, the nighttime temperature fall to about 7–10ºC. Among the plants that thrive in cool greenhouse are azaleas, cinerarias, cyclamens, carnations, fuchsias, geraniums, sweet peas, snapdragons and various types of bulbous plants like daffodils, irises, tulips, hyacinths and narcissi. A warm greenhouse has nighttime temperatures of 10–13ºC. Begonias, gloxinias, African violets, orchids, roses and many kinds of ferns, cacti and other succulents are adaptable to such temperatures. In the tropics, greenhouse has nighttime temperature of 16–21ºC, variety of palms and orchids can be grown, Rajender, *et al.* (2017)

Greenhouse has evolved from its status as it was in the 17th century to current trend of incorporating ITC, IoT, and Drone, generally termed smart farming. The common disadvantage of drudgery, timelineness, accuracy and precision, etc hitherto witnessed in greenhouse farming have been transformed to become advantageous features through current technology trends. Further still, greenhouse phenomenon has bring farming closer to man by the ease with which vegetable crops could be grown and produce to commercial level when technology (ICT, IoT, Drone and Hydroponic) are combined. Definition of greenhouse and the required optimum operational environments were discussed in line with greenhouse development and utilization in Nigeria and globally. Types of existing greenhouses, classifications, component parts, materials used for it construction, etc were reviewed. General research trends in greenhouse technology, irrigation as source of water supply for greenhouse farming, design criteria for greenhouses and trends in smart greenhouse technology were all reviewed. The results so obtained from the study could be a source

of information to assisting stakeholders like farmers and the government who may be interested in commercializing the production and processing of Zobo into desired end products in the agricultural value chain.

The following recommendation is suggested based on the information derived from reviewed literature and the knowledge gap such review provides:

I. Usage of GH should be encouraged extensively in Africa and in Nigeria in particular. This will provide enough vegetative crops to make up for the obvious deficit in the production chain, in order to meet the soaring demand
II. Use of GH for practical purposes in higher institutions and research institutes should be enforced by relevant government to inform farmers and stakeholders alike on the importance of GH and its utilization in bridging the supply gap in vegetation production chain.
III. The application of ICT, IoT, Drone, Robotics, Hydroponic and other daily emerging technologies should be publicize in order to improve yields to meet food demand, eliminate drudgery, save time, making farming to the teaming youths in Africa, etc.
IV. Larger and Commercial GH should be encouraged in order to improve the environment and reduce incidence of all forms of environmental degradations.

Acknowledgement

This is to sincerely acknowledge the sponsorship received from the Tertiary Education Fund (TETFUND), Nigeria, towards the execution of this laudable project. This research is basically centered on commercialization of Zobo tea production after a pilot scheme carried in unique Greenhouse sponsored by TETFUND under the NRF-TETFUND projects, 2019.

References

[1] Agricdemy, (2020). https://agricdemy.com/post/greenhouse-farming-nigeria. Greenhouse Farming. Assessed online 14 November 2020.
[2] Ale, M. O.; J. A. Akinyoola; A. J. Fawohunre; and A. T. B. Aderibigbe. (2019). Design and construction of a Greenhouse for evaluation of the performance of Okra in the Sahel region of Ondo State, Nigeria. International Journal of Advanced Research (IJAR) 7 (9): 24 – 31. www.journalijar.com
[3] Akpenuun, T. D. and Mijinyawa, Y. (2020). Impact of a split-gable greenhouse microclimate on the yield of Irish potato (Solanum Tuberosum L.) under tropical conditions. Journal of Agricultural Engineering and Technology (JAET), Volume 25 No.1: 54 – 78. www.niae.net.
[4] Akpenuun, T. D. and Mijinyawa, Y. (2018). Evaluation of a Greenhouse under tropical conditions using potato (Solanum Tuberosum) as the test crop. Acta Technologica Agriculturae 2, Nitra, Slovaca Universitas Agriculturae Nitriae: 56 – 62.
[5] Arora, K. R. (2012). Irrigation, Water Power and Water Resources Engineering. Standard Publishers Distributors, Delhi: 1010 -1051.
[6] Asgharipoura, M. R.; Z. Amiria; E. Daniel; and D. E. Campbellb. (2020). Evaluation of the sustainability of four greenhouse vegetable production ecosystems based on an analysis of emergy and social characteristics. Ecological Modelling 424 (2020) 109021, journal homepage: www.elsevier.com/locate/ecolmodel :1 – 17.

[7] Bartok, J. W. (2000). Greenhouses for homeowners and gardeners. Natural Resources, Agriculture, and Engineering Services (NRAES), Ithaca, New York: 9 – 13.
[8] Babatunde, F. E. and Mofoke, A. L. E. (2006). Performance of Roselle (Hibiscus Sabdariffa L) as influenced by irrigation schedules. Pakistan journal of Nutrition 5 (4): 363 – 367.
[9] Brian G.; Nile K.; Kent K.; Rowen P.; Jonathan R.; Kody S.; Albert S.; Austin S.; and H. Justin. (2015). Preliminary Design of a Low-Cost Greenhouse with Open Source Control Systems. Humanitarian Technology: Science, Systems and Global Impact 2015. Procedia Engineering 107:470 – 479. Available online at www.sciencedirect.com. Retrieved on 13 November 2020.
[10] Bucklin, R. A. (2020). Physical Greenhouse Design Considerations—Florida Greenhouse Vegetable Production Handbook, Vol 2. Bulletin HS776, IFAS Extension, University of Florida, publications: 1 – 5. http://nfrec.ifas.ufl.edu/index.
[11] Castilla, N and E. Baeza. (2013). Greenhouse site selection, In: Good Agricultural Practices for greenhouse vegetable crops (Principles for Mediterranean climate areas). FAO plant production and protection, Paper 217: 21 – 34.
[12] Chen, M.; J. Zhou; and P. Li. (2020). Data communication mechanism for greenhouse environment monitoring and control: An agent-based IoT system. Information Processing in Agriculture 7 (2020): 444 – 456. Journal homepage: www.elsevier.com.locate/inpa. Available at www.sciencedirect.com
[13] Connellan, G. J. (2002). Selection of Greenhouse Design and Technology Options for High Temperature Regions. Proc. IS on Trop. Subtrop. Greenhouses: 113 – 117.
[14] Cossua, M., Yanob, A., Solinasa, S., Deligiosa, P. A., Tilocaa, M. T., Cossuc, A. and Luigi, L. (2020). Agricultural sustainability estimation of the European photovoltaic Greenhouses. European Journal of Agronomy 118 (2020) 126074, pp 1 – 12.
[15] Cox, D.; N. Clifton; J. W. Bartok; and T. LaScola. (2010). Massachusetts greenhouse Industry best management Practices guide. UMass extension. Massachusetts Department of Agricultural Resources: 1 – 2.
[16] Douglas, C.; C. Natalia; W. B. John; and L. Taryn. (2010). The Greenhouse BMP Manual: Massachusetts greenhouse Industry best management Practices guide. The Scotts Company and by Brad Mitchell, Massachusetts Farm Bureau Federation and Michael Botelho, Massachusetts Department of Agricultural Resources: 1 – 39.
[17] FAO (1989). Irrigation water management: irrigation scheduling. Training manual No. 4. Prepared by Brouwer, C., Prins, K. and Heibloem, M. Accessed online 14 November 2020.
[18] FAO (2008). Process of using and calculating irrigation design parameters. FAO papers, module 7. Accessed online 14 November 2020.
[19] FAO – SAFR (2002). Irrigation Manual; Planning, Development, Monitoring & Evaluation of irrigated Agriculture with farmer participation, Volume 1, Module 1. Prepared by Savva, P. A. and Frenken, K.: 9 – 37.
[20] FAO (2011). Rural structures in the tropics. Design and development. Prepared by Mrema, G. C., Gumbe, L.O., Chepete, H. J. and Agullo, J. O., Rome: 343 – 350.
[21] Fedotova, G. V.; I F. Gorlov; A. V. Glushchenko; M. I. Slozhenkina; and A. K. Natyrov. (2020). Trends of Scientific and Technical Development of Agriculture in Russia, In: Digital economy: Complexity and Variety versus Rationality. Lecture notes in Networks and Systems 87. E. G. Popkova and B. S. Sergi (Eds.): Springer Nature Switzerland AG 2020: 193–200. ISC 2019, LNNS 87,
[22] Grag, S. K. (2007). Irrigation Engineering and Hydraulic Structures. Khanna Publishers, Delhi: 1 – 56.
[23] Hochmuth, G. and R. Hochmuth. (2018). Design Suggestions and Greenhouse Management for Vegetable Production in Perlite and Rockwool Media in Florida. Bulletin 327. UF/IFAS EDIS Publications: 1 – 24. http://nfrec.ifas.ufl.edu/index.
[24] Hua Y.; L. Qi-Fang; and Y. Huai-Qing. (2019). Deterministic and stochastic modelling of greenhouse microclimate. Systems Science & Control Engineering, 7(3): 65 - 72.
[25] James, L. G. (1993). Principles of farm irrigation system design. Krieger Publishing Company, Malabar Florida: 36 -50, 260 – 298.
[26] José A. A.; F. V. Juan; L. Belén; and M. R. Isabel. (2020). An Analysis of Global Research Trends on Greenhouse Technology: Towards a Sustainable Agriculture. International Journal of Environmental Research and public Health: 17, 664: 1 – 22. www.mdpi.com/journal/ijerph
[27] Katzin, D.; S. Van Mourik; F. Kempkes; and E. J. Van Henten. (2020). GreenLight - An open source model for greenhouses with supplemental lighting: Evaluation of heat requirements under LED and HPS lamps. Biosystems Engineering 194 (2020): 61 – 81. Journal homepage:www.elsevier.com/locate/issn/15375110. Available online at www.sciencedirect.com
[28] Kimura, K.; D. Yasutake; K. Kaikawa; and M. Kitaro. (2020). Spatiotemporal variability of leaf photosynthesis and its linkage with microclimates across an environment-controlled greenhouse. Biosystems Engineering, 195 (2020): 97 – 115. Journal homepage: www.elsevier.com/locate/issn/15375110. Available online at www.sciencedirect.com.
[29] Kodali, R. K.; K. Jain; and S. Karagwal (2016). IoT based smart greenhouse. Researchgate. https://www.researchgate.net/publication/316448621:1 – 7.
[30] Kumar, A.; G. N. Tiwari; S. Kumar; and M. Pandey. (2006). Role of Greenhouse Technology in Agricultural Engineering. International Journal of Agricultural Research 1 (4): 364 – 372.
[31] Mijinyawa, Y; and G. I. Osiade. (2011). The status of Greenhouses utilization in Oyo State, Nigeria. Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS) 2 (4): 561 – 566. Scholarlink Research Institute Journal. jeteas.scholarlinkresearch.org
[32] Montero, J. I.; M. Teitel; E. Baeza; J. C. Lopez; and M. Kacira. (2013). Greenhouse design and covering materials, In: Good Agricultural Practices for greenhouse vegetable crops (Principles for Mediterranean climate areas). FAO plant production and protection, Paper 217: 35 – 64.
[33] Omobowale, M. O. (2020). Evaluation of a low-cost Greenhouse for controlled environment cultivation of sweet pepper. Arid Zone Journal of Engineering, Technology & Environment, AZOJETE March 2020, Vol. 16 (1): 28 – 36.
[34] Omobowale, M. O.; and T. O. Sijuwade. (2019). Comparative analysis of partial external shading on the performance of greenhouse grown Cucumber (cucumis Sativus) and Okra (Abelmoschus Esculentus). In: Innovations and Technologies for sustainable Agricultural mechanization and livestock transformation for economic growth, Proceedings of 40th annual conference and 20th International Conference-Omu-Aran 2019 of the Nigerian Institution of Agricultural Engineers, Proc, NIAE: volume 40: 952 – 959.
[35] Pack, M. Y.; and K. Mehta (2012). Design of Affordable Greenhouses for East Africa. IEEE Global Humanitarian Technology Conference. DOI 10.1109/GHTC: 104 – 110.
[36] Ratnaparkhi, S.; S. Khan; C. Arya; S. Khapre; P. Singh; M. Diwakar; and A. Shankar. (2020). Smart agriculture sensors in IOT: A review, Materials Today: Proceedings,
[37] Rajender, G.; K. Sushanth; K. Mithun; B. Devender; D. Raju; and K. Anoosha. (2017). Design and development of low cost greenhouse to raise different cultivars". International journal of agricultural science and research (ijasr) issn (p): 2250-0057; issn (e): 2321-0087 vol. 7, issue 3: 29-36.
[38] Samapika, D.; T. Barsha; M. Smaranika; S. Basabadatta; and B. P. Jnana. (2020). Green-houses: Types and Structural Components. In: Protected Cultivation and Smart Agriculture edited by Sagar Maitra, Dinkar J Gaikwad and Tanmoy Shankar. New Delhi Publishers, New Delhi: 09 - 17
[39] Sabin, M.C.; R. Ram Karthikeyan; C. Periasamy; and B. Sozharajan. (2020). Verification of the greenhouse roof-covering-material selection using the finite element method. Materials Today: Proceedings 21 (2020): 357–366.
[40] Sutar, R. F. (2020). Design and Maintenance of Green House: 31 – 35. www.AgriMoon.Com, info@agrimoon.com.
[41] Teitel, M.; J. I. Montero; and E. J. Beaza. (2012). Greenhouse design: Concepts and trends. Proceeding of Acta Horticulturae: 605 – 620.
[42] Tiwari G. N. (2003). A Text book of "Greenhouse Technology for controlled Environment" Alpha Science Publisher.

[43] Tripathy, P. K.; A. K. Tripathy; A. Agarwal; and S. P. Mohanty. (2021). MyGreen: An IoT-Enabled Smart Greenhouse for Sustainable Agriculture. IEEE Consumer Electronics magazine. February 2021: 1 – 7.
[44] USBG - United State Botanic Garden, (2013). Greenhouse manual, an introductory guide for educators. National Center for Appropriate technology: 12 – 25.
[45] Waller, P.; and M. Yitayew. (2016). Irrigation and Drainage Engineering. Springer International Publishing AG Switzerland is part of Springer Science Business Media (www.springer.com): 289 – 304.
[46] Wang, X.; and H. Yu. (2019). Research on Control System of Intelligent Greenhouse of IoT Based on Zigbee. J. Phys.: Conf. Ser. 1345 042036.
[47] Yilmaz, I.; C. Sayin; and B. Ozkan. (2005). Turkish greenhouse industry: past, present and future. New Zealand Journal of crop and horticultural science, Vol. 33: 233 – 240.
[48] Yongguang, H.; L. Pingping; Z. Xiliang; W. Jizhang; C. Lanfang; and L. Weihong. (2007). Integration of an environment information acquisition system with a greenhouse management expert system, New Zealand Journal of Agricultural Research, 50(5): 855 - 860

ACTA TECHNICA CORVINIENSIS
Bulletin of Engineering
ISSN: 2067–3809

[1.]Boban KUSIGERSKI, [1.]Zoran PANDILOV, [2.]Goran KUSIGERSKI

DESIGN AND PRACTICAL REALIZATION OF A SCARA ROBOT

[1.]Institute of Production Engineering and Management, Faculty of Mechanical Engineering, SS. Cyril and Methodius University in Skopje, N. MACEDONIA
[2.]Replek Farm LTD, Municipality of Skopje, Kozle 188, Skopje, N. MACEDONIA

Abstract: This research presents the design and prototyping of a SCARA robotic arm with 3 degrees of freedom. This student project is sponsored by the Faculty of Mechanical Engineering, Skopje, Republic of N. Macedonia. Therefore, there are certain prerequisites that need to be fulfilled, in terms of cost and functionality, without sacrificing structural rigidity and functionality. For this reason, standardised elements and 3D printed components are used for the structure and transmission. The motion of the robotic arm is achieved by using inverse kinematics and path control. Multiple graphic models of velocity profiles (trapezoidal and S – curve) are compared for calibrating the motion smoothness. The end effector uses a pneumatic vacuum system for gripping and transferring objects with weight less than 250 g. Drive and control elements such as stepper and DC motors, sensors and encoders allow for the implementation of a feedback loop for more precise functioning of the SCARA robotic arm. Multiple control modes are further detailed. The study at the end gives a review of the obtained precision and achieved motion capabilities, considering the cost-efficiency and proposing steps for further improvement of realisation and replication on a larger scale.
Keywords: SCARA robotic arm, inverse kinematics, velocity profiles, acceleration, jerk, 3D printing

INTRODUCTION

Throughout history, the standard methods of manufacturing were subject to intensive changes. The use of industrial robots begins in the 1960's with CAD (Computer Aided Design) and CAM (Computer Aided Manufacturing) systems, which continuously expanding. The advantages [1] for introducing industrial robots in manufacturing are:

- increased productivity;
- reduced labour costs [2];
- eliminating routine tasks with repetitive work cycles [3];
- increased worker safety;
- completion of processes that can't be done manually or are done in a dangerous environment [4];
- reduced use of raw material;
- increased flexibility [5];
- improved manufacturing quality and tolerances [6];
- improved repeatability.

The use of robots in various industries is becoming more and more prevalent, and the number of robots implemented in manufacturing, military, food preparation, etc., continuously rising [7]. The goal of this research paper is the analysis of the issues that arise in the design and prototyping of a SCARA robotic arm. The type of SCARA robotic arm developed in this research work contains 3 degrees of freedom, due to the simplicity for its realization. Nevertheless, the basic components and principles applied are the same as in a higher complexity industrial robot.

SCARA is an acronym for Selective Compliance Assembly Robot Arm. The acronym refers to the design of robot arm which enables relatively ease positioning in the x, y plane, while it is still enough rigid in the z-axis. This characteristic has proven itself fairly sufficient in assembly and loading/unloading processes.

Most industrial robots use mechanical components and materials with high costs and their electronics is commercially designed. Due to the fact that this project is sponsored by the Faculty of Mechanical Engineering, Skopje, Republic of N. Macedonia, there were certain prerequisites that need to be fulfilled:

- The use of standard mechanical elements and 3D printed elements;
- The use of standard electronic components and a low-cost microcontroller.

The prototype is for a robotic arm with 3 degrees of freedom, more precisely 2 rotations of the links (shoulder and elbow) and one translation in the vertical direction (Figure 1). The shoulder and elbow allow precise positioning in the x,y plane, and the translation is used for exact positioning in vertical z – axis, i.e., pick and place the objects.

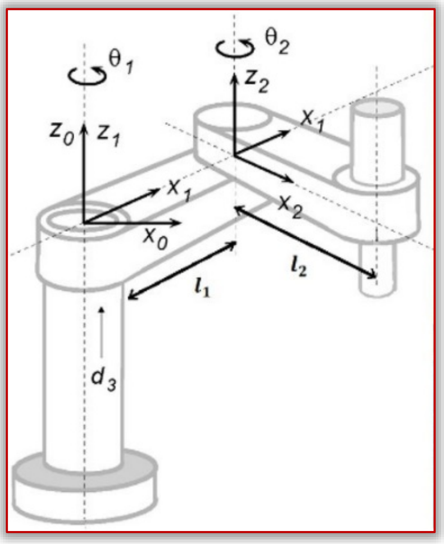


Figure 1: Coordinate systems and concept of the robotic arm [8]

KINEMATICS AND MOTION CONTROL

The positioning of robots is done by using direct kinematics, where the length of the links and the rotational angle of each of the joints of the robotic arm is used in order to calculate the position of the end effector in a Cartesian coordinate system.

Inverse kinematics is used during the positioning of robotic end effectors in order to calculate the angular rotation of each of the joints for a known length of the links. This allows to calculate the rotational angles S, Q and E (Eq. 1, 2 and 3), for known x and y coordinates, which represent the coordinates where the end effector should be positioned at the end of the movement (Table 2).

Table 1: Precision (resolution) calculations by using different parameters

Link length (mm)	Number of microsteps for 1 rotation of the motor	Pulley reduction	Arc resolution (mm/step)	Torque (Nm)
300	1600	1:5	0,24	Shoulder motor 11,5
600	1600	1:5	0,47	Elbow motor 4,5
300	800	1:20	0,12	Shoulder motor 46
600	800	1:20	0,24	Elbow motor 18
300	200	1:20	0,47	Shoulder motor 46
600	200	1:20	0,94	Elbow motor 18

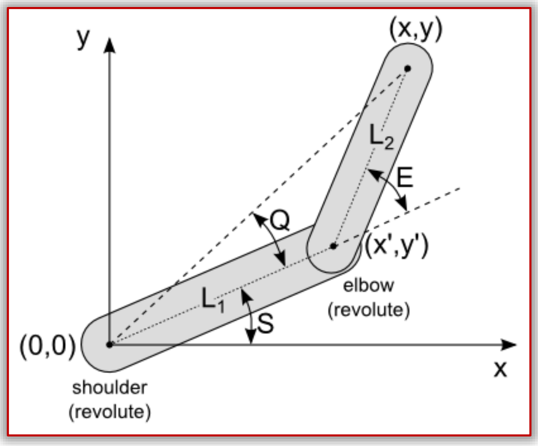


Figure 2: Trigonometry angles of SCARA inverse kinematics [9]

In order to calculate each of the angles, the following trigonometric formulas [9] are used:

$$E = \arccos\left(\frac{x^2+y^2-{L_1}^2-{L_2}^2}{2L_1L_2}\right) \quad (1)$$

$$Q = \arctan\left(\frac{L_2 \sin E}{L_1+L_2 * \cos E}\right) \quad (2)$$

$$S = \arctan\left(\frac{y}{x}\right) - Q \quad (3)$$

where: x, y – the known coordinates of the end effector at the end of its path;

L_1 and L_2 – length of each of the links (shoulder and elbow).

Table 2: Inverse kinematics calculations for given x and y coordinates

x	y	L_1 (mm)	L_2 (mm)	Q	Q (°)	S	S (°)	E	E (°)
10	50	32,7	32,7	0,67666312	39,0	0,6929506	39,7	1,3609	78,0
10	-50	32,7	32,7	0,67666312	39,0	-2,053851	-117,7	1,3609	78,0
50	30	32,7	32,7	0,46996783	27,3	0,0644843	3,7	0,95187	54,5
65,4	0	32,7	32,7	$1{,}75 \cdot 10^{-6}$	0,0	$-1{,}75 \cdot 10^{-6}$	0,0	$3{,}49 \cdot 10^{-6}$	0,0

To achieve higher precision, the actuation of the links is done by using stepper motors (satisfying the above-mentioned prerequisites) with 200 steps per revolution with stepper drivers that allow each step to be additionally divided into smaller microsteps. Additionally, the belt and pulleys used to transmit motor revolutions to the link shafts allow an increase in the precision and torque (M=2.3 Nm on the shoulder and M=0.9 Nm for the elbow) (Table 1).

The use of 1:8 microstepping ratio (1600 microsteps) and pulley transmission ratio of 1:5 allows for a high precision and torque compared to other combinations of microstepping and transmission, without compromising the positional speed of the robotic arm to a great extent. The robotic arm is set to work in the first and forth quadrant for the angles E and Q (Figure 2) in order always to have a positive value, while the value of the angle S dictates in which quadrant the end effector will be positioned. The movement of the robotic arm is done by using a point-to-point path. For this kind of control, the current (start) and end point of the end effector are inputs and the processor generates the path between them, meaning that during the movement between start and endpoint, no useful operations can be performed.

Hence, the trajectory between start and end point, is not as important as the position at the end of the movement. In order robotic arm to position itself, as fast as possible, all the joints move at the same time. The time necessary for the joint with the biggest angular rotation to position itself, is taken as the reference time needed for positioning [10]. If it is required for the robotic arm to complete multiple movements in one sequence, then the inverse kinematics is calculated from the start point to the first point of movement. After the first point of movement is reached then the current coordinates are replaced as the start point and the inverse kinematics is calculated for the second point of movement. This calculation repeats itself in accordance to how many points the end effector has to move to.

SPEED, ACCELERATION AND JERK

The efficiency of robots [11] is measured by their speed and positional precision. The errors that happen during operation, most often are due to overloading or high accelerations, which causes the motors to lose their positional accuracy because of the system inertia. Jerk is defined as the change of acceleration with respect to time. It is the first derivative of acceleration (the third derivative of position).

$$\text{Speed: } \lim_{t\to 0}\frac{dx}{dt} = x'(t) = V\left(\frac{m}{s}\right)$$

$$\text{Acceleration: } \lim_{t\to 0}\frac{dV}{dt} = x''(t) = a\left(\frac{m}{s^2}\right)$$

$$\text{Jerk: } \lim_{t\to 0}\frac{da}{dt} = x'''(t) = j\left(\frac{m}{s^3}\right)$$

The relationship between position and the first, second and third derivative of position with respect to time is graphically presented in Figure 3. In the time frame t_0-t_1, the travel distance linearly increases, which means that the speed increases following a certain function. The increase and decrease of speed indicate a change in acceleration in the time frames t_0-t_1 and t_2-t_3 while during t_1-t_2 the change in acceleration is not existing. During the time frames when there is a change in the acceleration, the jerk has the highest value. If there is no change in acceleration then the jerk has a value of 0.

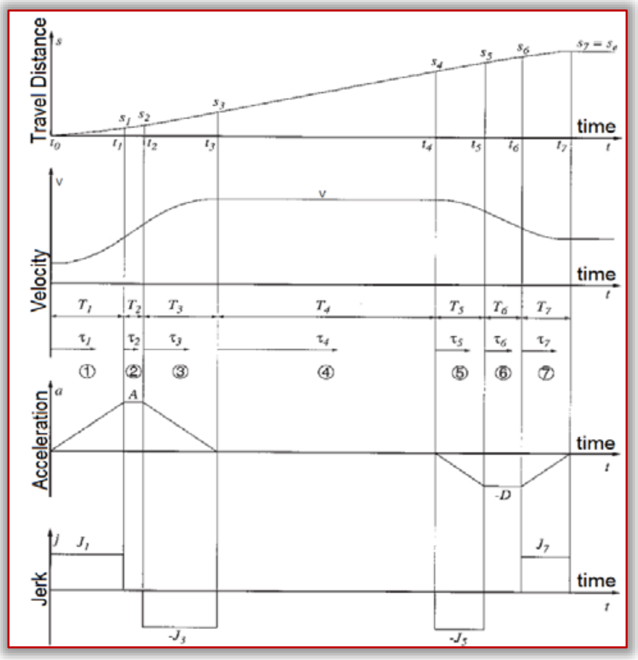


Figure 3: The relationship between position, speed, acceleration and jerk [12]

The problems that jerk causes in physical systems [13] affect motion and stability, more specifically it excites oscillations that increase the settling time and decrease position accuracy. This increases the need for the jerk to be lowered as much as possible without hindering the functionality at great extent (making the robot to have very slow accelerations/decelerations), which is accomplished by using trajectory profiles. A trapezoidal trajectory profile (Figure 4), has a sudden acceleration to a certain value, keeps the value for a certain period, then suddenly decelerates to 0. This generates a trapezoidal curve for the velocity with respect to time. The corners (α=90°) of the rectangle that point to the changes in acceleration correspond with time when the jerk theoretically has an infinite value, because of the sudden change of acceleration from 0 to maximum value or from maximum value to 0. This kind of profile is used in milling, dispensing and painting applications where the change in speed needs to be linear.

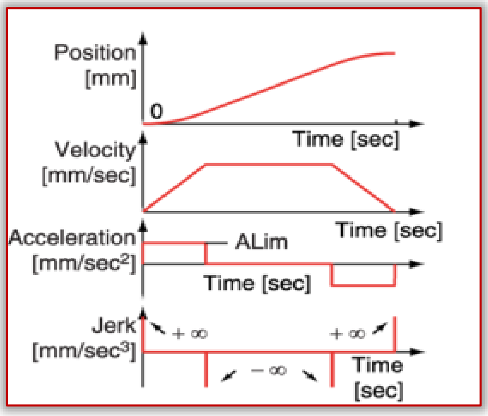


Figure 4: Trapezoidal velocity profile and its effect on acceleration and jerk [14]

To reduce the high jerk values, the move profile is done by using an S-curve velocity profile (Figure 5). The acceleration in S-curve velocity has a trapezoidal profile (α<90°), meaning that the change in acceleration is linear, which enables reducing the jerk.

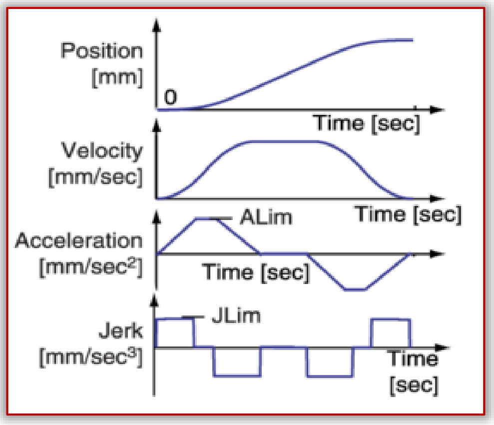


Figure 5: S–curve velocity profile and its effect on acceleration and jerk [14]

In this case study, multiple velocity S-curves have been calculated and compared in order to choose the most suitable one which satisfies the needs of the robotic arm. The trapezoidal profiles represent the change in acceleration from initial (0 mm/s^2) to maximal, with increments of 0.01 mm/s^2 multiplied by their corresponding acceleration coefficient. The four velocity S-curves have different acceleration coefficients: a_4=0.75, a_3=0.8, a_2=0.9 and a_1=1 (Figure 6) and different frequencies at which the increments are sent to the motor: a_4=250 Hz, a_3=240 Hz, a_2=220 Hz and a_1=200 Hz, meaning that in the same period, a different number of increments can be sent i.e., different maximum accelerations and speeds can be reached. The a_1 curve has the biggest increments in acceleration, but the number of increments sent to the motor is the lowest, while opposite, the a_4 curve has the smallest acceleration increments, but the highest number of increments. The a_1 curve increases the acceleration in the first 50 impulses with 0.01 mm/s^2 increments, in the next 100 impulses the acceleration has a fixed value and in the last 50 impulses the acceleration is reduced by 0.01 mm/s^2 increments until the maximum speed is reached. The a_4 curve increases the acceleration in the first 75 impulses with 0.0075 mm/s^2 increments, in the next 100 impulses the acceleration is stable, and in the last 75 impulses the acceleration is reduced by the same incremental value which was used for acceleration. Then the movement continues with the maximum speed, until reaching about 200 impulses of the end position for the a_1 curve (or 250 for the a_4 curve), when the inverse process of the above-explained starts, following a symmetrical curve. The profile ends when the starting speed is reached.

Comparing the four trapezoidal acceleration curves, we can observe the change in acceleration is highest in the a_1 curve and lowest in the a_4 curve. Thus, the goal of reducing the jerk is achieved. Also, due to the bigger number of increments, the maximum speed (V_4=98.4 mm/s) that the a_4 curve can reach, is bigger than the maximum speed (V_1=75 mm/s) that the a_1 curve can achieve. Both the reduced jerk and the higher maximum speed (Figure 7) allow the reduced oscillations and wear of the mechanical elements. For the above-mentioned reasons the a_4 curve is selected as the move profile for the robotic arm.

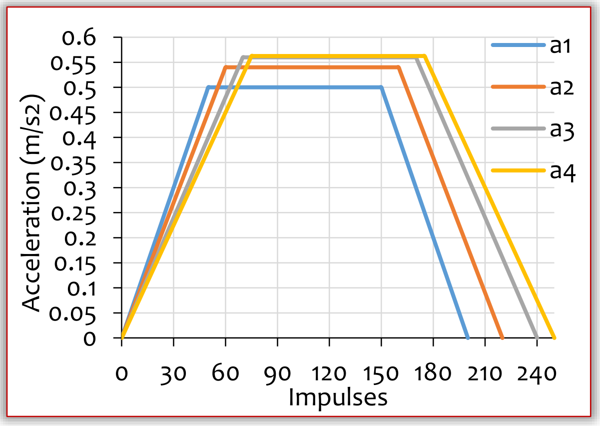


Figure 6: Comparison of trapezoidal acceleration curves

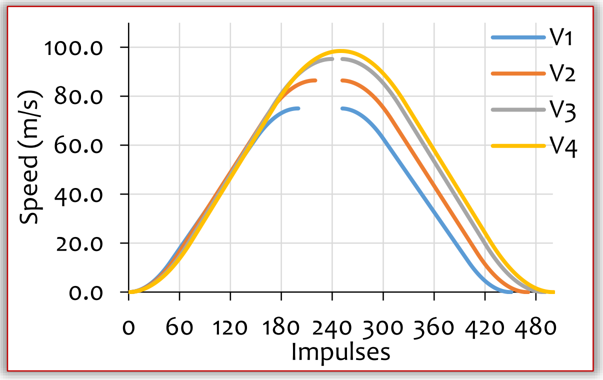


Figure 7: Comparison of different S velocity profiles

MECHANICAL ELEMENTS

The mechanical components used in the robotic arm assembly (Figure 8) can be divided by their purpose in three categories:

- Structural components, which comprise the robotic arm and allow better rigidity;
- Transmission elements, which transmit motor drives torque to the shafts;
- Fasting and standard elements, such as bolts, nuts, bearings, etc.

The structural elements are: extruded aluminium profiles, platform, 3D printed components and linear rails. Aluminium is chosen for its easy machining, availability and lesser density than steel (2.7 gm/cm^3 versus 8g/cm^3).

The assembly uses 4 profiles (2 for the shoulder and 2 for the elbow) with dimensions 20x20x300 mm made from aluminium 6063-T5. The profiles are vertically interlocked by specially designed 3D printed components that increase the rigidity of the assembly.

The aluminium platform, which travels in the z-axis direction is used as the base for the robotic arm. The linear rails on which the whole platform travels are type SBR-12 (l=400mm) and the linear bearings that travel on them are fastened with bolts to the aluminium platform. This allows movement of the whole robotic assembly of 300 mm in the z-axis.

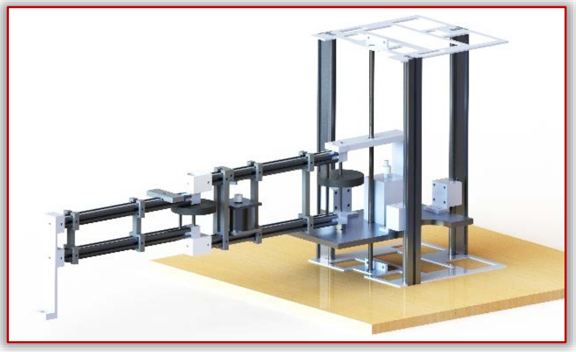


Figure 8: CAD of the robotic arm assembly modelled in Solidworks

The 3D printed components are made by using a FDM (Fused Deposition Modeling) 3D printer using PLA (Polylactic Acid) plastic, which is the cheapest, most available and easiest to use for prototyping purposes, while also having fairly satisfactory mechanical properties [15].

The structural 3D printed components (Figure 9) in the assembly are: frames that interlock the aluminium profiles together (1), housings for the ball bearings that connect to the elbow shaft (2), limit switch support (3), motor, encoder and vacuum suction cup bases (4), frame for precise positioning of the linear rails (5), etc. These components were designed in Solidworks [16] and sliced in Cura, using 0,2 mm layer height and 15-40% infill, for a combination of fast prototyping and low mass.

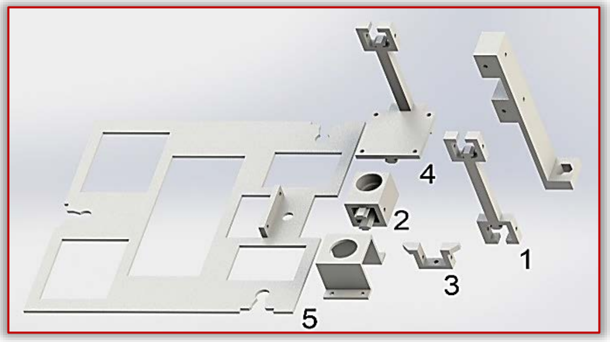


Figure 8: Solidworks CAD models of 3D printed components

The use transmission elements are: threaded rod, belts and pulleys and elastic shaft couplings.

The threaded rod used for the z-axis movement is with an 8mm pitch and is connected to the platform via a threaded nut. The threaded rod is driven by a DC motor using an HTD (High Torque Drive) profile belt, and a pulley reduction ratio of 1:5. This allows speed reduction, higher torque and increased precision. If a lower transmission ratio is used, the motor would not have enough torque to move the aluminium platform and the robotic arm attached to it, while a bigger transmission ratio would reduce the speed of the z-axis movement to a greater extent. The pulleys are 3D printed and parametrically designed by using Solid 3D CAD modeller OpenSCAD. The other 2 pairs of pulleys for the shoulder HTD (High Torque Drive) and elbow (XL – extra light) drive are designed using the same method. The encoders on the z-axis and the elbow are connected to the shafts by elastic couplings which allow compensation for axial misalignment.

Figure 10: DC motor connected to a threaded rod via belt and pulley mechanism

DRIVE ELEMENTS

The electric drive elements in the robotic arm are stepper motors and DC motor.

The stepper motors used in the robotic arm have 200 steps (1.8°/step), and the drivers are configured for 8 microsteps for each step. This increases the resolution of the movement to 0.225°/step. The stepper motor used for driving the shoulder (Figure 11) has a torque of M=2.3 Nm and the motor for the elbow (Figure 12) has a torque of M=0.9 Nm. Because the elbow motor is mounted on the shoulder member, there are weight restrictions. It has to be with low mass, which results in low torque. The possibility of missed steps due to jerk, low torque, high speed or weight is compensated by installing an encoder with a positional feedback loop.

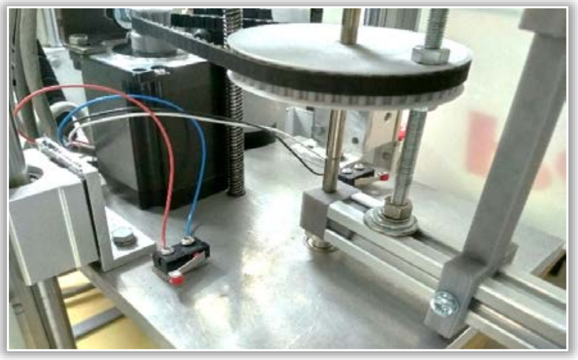


Figure 11: Pulley and motor assembly for shoulder

Figure 12: Pulley and motor assembly for elbow

The DC motor used in the robotic arm is used for moving the platform and the end effector in the z-axis. It has a torque of M=0.94 Nm and is driven by PWM (Pulse Width Modulation) using an H-bridge, which switches the polarity of the motor and allows rotation in both directions. The DC motor, just like the elbow drive motor is coupled with an encoder for positional feedback loop, to allow for precise real-time positioning of the robotic arm.

PNEUMATICS

The end effector of the robotic arm uses a pneumatic system comprised of several parts: pneumatic compressor, pneumatic tubes, pneumatic solenoid valve 5/2, vacuum generator and vacuum suction cup [17]. The compressor creates vacuum that can either stay trapped (closed valve position) or go to the vacuum generator (open valve position). The vacuum generator creates a vacuum (P= - 0.9 bar) and it is connected to the vacuum suction cup which has an outer diameter of d=14 mm and can lift objects with mass less than m < 250g. The activation of the valve is done by the microcontroller.

SENSORS

Several sensors are applied in the robotic arm, like incremental positional encoders, limit switches and optical limit sensors.

Due to the fact that the position of the incremental positional encoders mounted on the elbow and z-axis is unknown after each start of the robotic arm, each of the links have to return to their reference position (going to zero point procedure) in order encoder to obtain data from where to start the counting the rotational angle. The encoders have a resolution of 2000 impulses/rotation i.e., a resolution of $\frac{360°}{2000} = 0.18°$. The mechanical limit switches on the robotic arm are placed on the start and end position of the rotational angle (2 limit switches for the shoulder and 2 limit switches for the elbow) (Figure 11 and 12). They are used as a security devices which will not allow motors to do a larger movement than the assembly physically allows, preventing collisions and deformations. The other use for the limit switches is mentioned above for the finding the "zero point" of the links.

The optical limit sensors used in the robotic arm find application in limiting the minimum and maximum move of the z-axis platform. They are positioned in the lowest and highest move points of the platform, not allowing colliding with the other elements. When the L-profile attached to the platform, interrupts the laser beam of the sensor, the DC motor gets a command to stop the rotation and the movement of the platform. This is also used for the above-mentioned procedure of finding the "zero point" the platform.

CONTROL ELEMENTS

The main control element in the robotic arm is the Arduino Mega microcontroller. For supplying voltage to the stepper motors and the pneumatic valve a 230 V AC to 24 V DC power supply is used, with a limiting current of maximum 10A. For supplying voltage to the z-axis DC motor, the voltage is additionally lowered to 18 V DC. The Arduino microcontroller and the limit switches have a working voltage of 12 V DC, and the encoders are directly connected to the microcontroller using its 5 V DC output pins.

The control of the robotic arm is done on two levels.

On the first level, the robotic arm is controlled by the microcontroller performing the following tasks:

≡ Reading inputs from the mechanical limit switches and optical limit sensors and reading the positional feedback from the encoders;
≡ Driving the stepper and DC motors;
≡ Controlling the pneumatic solenoid valve;
≡ Communicating with the second (higher) level of control via USB.

The second control level is done on a PC, by using a SCADA (Supervisory Control And Data Acquisition) application with the following tasks:

≡ Communicating with the microcontroller;
≡ User interface for manual input of coordinates for the end effector (Figure 13);
≡ Automatic movement of the robotic arm to coordinates input from computer vision or text files;
≡ Sequence activation (teach mode) in which the robotic arm positions itself in manually defined positions and afterward calculates its path;
≡ Inverse kinematics calculations i.e., the number of impulses needed for rotating each of the links to the end coordinates of the end effector.

On the user interface (Figure13) the X_1 and Y_1 are the starting coordinates of the end effector and X_2 and Y_2 are the coordinates which have to be input as the end-of-path coordinates. L_1 and L_2 are the link lengths, the microstep field is for the multiplication factor of microstepping characteristic of the stepper drivers, and the offset field is for defining an offset, so that the number of steps the motors have to realize is not negative. These values have to be an input for the inverse kinematics calculations. With the "calculate" button, the inverse kinematics are calculated and all of the angles E, Q, S, E_2, Q_2, S_2 are shown in degrees.

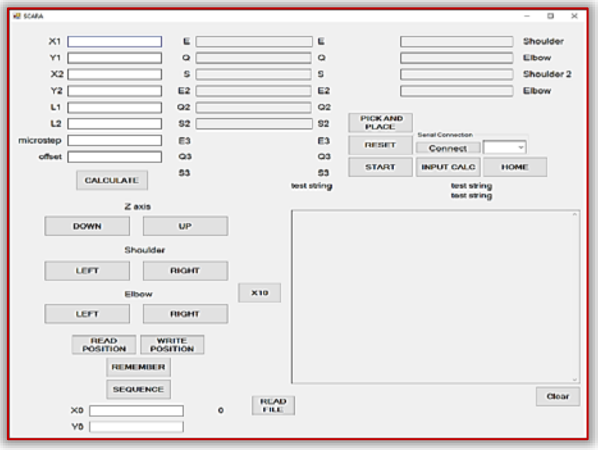


Figure 13: SCADA application for control of the robotic arm

For manual control there are separate jog buttons with variable speed (X1 or X10) for the shoulder, elbow and platform. For automatic control of the robotic arm and doing pick and place operations, there are 2 different operation modes, with previously entered coordinates or with teach mode.

By pressing "read file", the text file (which is automatically generated by using computer vision or by manually inputting coordinates of objects that need to be moved) is loaded into the application. Then by pressing the "pick and place" button the robotic arm first position itself by hitting all 3 home limit switches (minimum rotation elbow and shoulder and minimum z-axis position) and afterwards it goes to the first point, picks the object up, and takes it to a previously defined end coordinate (X_0,Y_0) where all of the objects need to be placed. Then the robotic arm continues from the X_0,Y_0 position to the second object, and repeats the process for all objects.

The other operation mode is sequential control in teach mode. The robotic arm, in fact the end effector is positioned above the object that needs to be moved (point 1), the "remember" button is pressed and afterwards the robotic arm is manually jogged to the end position where the object needs to be positioned (point 2) and the "remember" button is pressed again. With the press of the "sequence" button the robotic arm "finds zero position" and goes to the point 1, picks the object up, moves to point 2 and puts the object down. Afterwards the end effector goes to point 1 and repeats the process according the instructions of the operator of the robotic arm.

CONCLUSIONS

The final assembly of the SCARA robotic arm (Figure 14) satisfy all the criteria mentioned at the beginning of this paper: the use of low cost and standard components and the use of 3D printed parts.

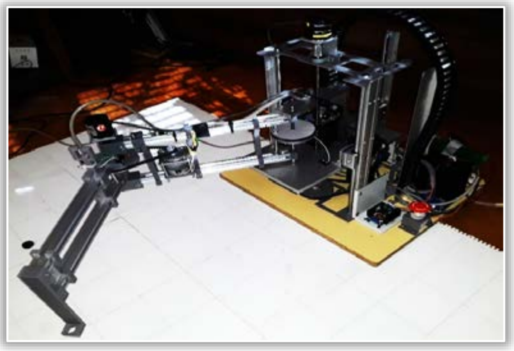


Figure 14: Final look of the SCARA robotic arm

The results that are achieved are similar and within tolerance of the results obtained through the calculations. The maximum z-axis movement of the robotic arm is 300 mm, the maximum rotational angles of the shoulder and elbow are 180° and more than 185°, respectively. The repeatability is less than 2 mm in teach mode, and less than 4 mm in sequence mode due to the mechanical limitations of the robotic arm. These values are convenient for uses such as spraying or painting, spot-welding, assembly or transport to a conveyor belt. For industrial needs the SCARA robotic arm can be replicated with bigger dimensions and work area as well as a larger load carrying capacity.

Additionally, the robotic arm can be further improved by:

- Increasing the rigidity of the mechanical assembly for better precision;
- Decreasing the position time by replacing the stepper motors with servo motors;
- Introducing a system of laser measurement of the objects height for more precise z-axis positioning;
- Fully integrating a computer vision system, which along with the laser measuring system will make the robotic arm almost fully autonomous;
- Finding a commercial use of the robotic arm.

References

[1] R. Miller and M. R. Miller, Robots and Robotics : Principles, Systems, and Industrial Applications. 2017.

[2] J. H. Jung and D. G. Lim, "Industrial robots, employment growth, and labor cost: A simultaneous equation analysis," Technol Forecast Soc Change, Vol. 159, Oct. 2020

[3] A. A. Wasique, D. Paritosh, P. Sahishnu, and P. Sunita, "A Review on Robotic Process Automation," International Conference on Advances in Science & Technology, 2019

[4] J. Petereit, J. Beyerer, T. Asfour, S. Gentes, and B. Hein, ROBDEKON: Robotic Systems for Decontamination in Hazardous Environments. Würzburg: 2019 IEEE International Symposium on Safety, Security, and Rescue Robotics (SSRR), 2019.

[5] A. C. Bavelos et al., "Enabling flexibility in manufacturing by integrating shopfloor and process perception for mobile robot workers," Applied Sciences (Switzerland), Vol. 11, No. 9, 2021

[6] A. Verl, A. Valente, S. Melkote, C. Brecher, E. Ozturk, and L. T. Tunc, "Robots in machining," CIRP Annals, Vol. 68, No. 2, pp. 799–822, Jan. 2019

[7] M. Guerry and C. Müller, "World Robotics 2021," 2021.

[8] M. E. Uk, F. B. Sajjad Ali Shah, M. Soyaslan, and O. Eldogan, "Modeling, control, and simulation of a SCARA PRR-type robot manipulator," Scientia Iranica, Vol. 27, No. 1, pp. 330–340, Jan. 2020

[9] N. Surapong and C. Mitsantisuk, "Position and Force Control of the SCARA Robot Based on Disturbance Observer," in Procedia Computer Science, 2016, Vol. 86, pp. 116–119

[10] K. (Kevin M.) Lynch and F. C. Park, Modern robotics : mechanics, planning, and control. 2017.

[11] F. Stuhlenmiller, S. Weyand, J. Jungblut, L. Schebek, D. Clever, and S. Rinderknecht, "Impact of cycle time and payload of an industrial robot on resource efficiency," Robotics, Vol. 10, No. 1, pp. 1–18, Mar. 2021

[12] K. Erkorkmaz and Y. Altintas, "High speed CNC system design. Part I: Jerk limited trajectory generation and quintic spline interpolation," Int J Mach Tools Manuf, Vol. 41, No. 9, pp. 1323–1345, Jul. 2001

[13] J. J. Craig, P. Prentice, and P. P. Hall, "Introduction to Robotics: Mechanics and Control Fourth Edition," 2022.

[14] C. H. Yeung, Y. Altintas, and K. Erkorkmaz, "Virtual CNC system. Part I. System architecture," Int J Mach Tools Manuf, Vol. 46, No. 10, pp. 1107–1123, Aug. 2006

[15] S. A. Raj, E. Muthukumaran, and K. Jayakrishna, "A Case Study of 3D Printed PLA and Its Mechanical Properties," 2018.

[16] David C. Planchard, Engineering Design with SOLIDWORKS 2020. 2020.

[17] E. Papadakis, F. Raptopoulos, M. Koskinopoulou, and M. Maniadakis, "On the Use of Vacuum Technology for Applied Robotic Systems," International Conference on Mechatronics and Robotics Engineering, Vol. 6, pp. 73–77, 2020.

ISSN: 2067–3809

Fascicule 4
[October – December]
tome XV [2022]

ACTA Technica CORVINIENSIS
BULLETIN OF ENGINEERING

ISSN: 2067-3809

[1.]Dan Iulian CUJBESCU, [1.]Mihai Gabriel MATACHE, [2.]Gheorghe VOICU, [1.]Mariana EPURE, [1.]Constantin VÂLCU, [1.]Iulian Florin VOICEA, [1.]Alexandru IONESCU

CONCEPT OF MULTIFUNCTIONAL AGRIDRONE TYPE 4.0-MHRT

[1.]National Institute of Research - Development for Machines and Installations Designed to Agriculture and Food Industry – INMA Bucharest, ROMANIA
[2.]University Politehnica Bucharest, ROMANIA

Abstract: Aerial monitoring of agricultural crops involves the creation of reliable measurements for which specialized equipment onboard UAVs are needed. This equipment consists of data acquisition systems from mono, multi or hyperspectral sensors, modularly integrated systems in the agridrone that move, position and orient them above the surface of agricultural crops in the monitored area. The components of the abiotic environment (air, water, soil) are vital for sustainable agriculture. The current trend is to make an intelligent and precision agriculture. All these operations become possible real if and only if we look at the agridrone as a unitary system, a mechatronic system formed by the meeting of several subsystems: mechanical, electronic, IT, communication, hardware and software. This involves the introduction of high-performance technologies, machines and equipment to make the agricultural process more efficient and ensure production control in ecological conditions. Thus, farmers try to get as much agricultural production as possible with the lowest costs. Drones used in agriculture as operational tools (agridrones) are UAS (Unmanned Aerial Systems) air platforms equipped for monitoring the health of crops, for spraying phytosanitary substances or carrying out logistical operations in areas difficult to access or dangerous for the human operator. The paper presents a concept of a multi-functional agridrone type 4.0-MHRT, which is in the category of high-capacity professional drones (heavy lift drones).
Keywords: agridrone, tricopter hexa-rotor, agriculture 4.0

INTRODUCTION

By combining the information provided by the last generation integrated technologies (drones, satellite images, variable application algorithms, multi-parameter sensors and probes, mobile GPS applications, etc.) with the farmer's experience and instinct, effective information is obtained for the farm manager, which will be better informed and will make optimal choices to increase agricultural productivity yields [1].

Aerial monitoring of agricultural crops involves the creation of reliable measurements for which specialized equipment onboard UAVs are needed. This equipment consists of data acquisition systems from mono, multi or hyperspectral sensors, modularly integrated systems in the agridrone that move, position and orient them above the surface of agricultural crops in the monitored area. All these operations become possible real if and only if we look at the agridrone as a unitary system, a mechatronic system formed by the meeting of several subsystems: mechanical, electronic, IT, communication, hardware and software. These subsystems interfaced and commanded by a central unit (controller) can make the drone an autonomous UAS (Unmanned Aerial Systems) system. The current trends are learning these drones by implementing artificial intelligence (AI) in order to obtain dedicated Agent (AS) or MAS systems for certain work operations in agriculture [2-5].

The integration of these technologies in agriculture have taken shape today at a global level and are slowly but surely turning classic agriculture into precision agriculture (agriculture-4.0). The use of aerial drones in agriculture makes it possible to map arable land, to obtain the scanned fingerprint of agricultural crops by recording multispectral maps, as well as to maintain a real record of the health of crops with the possibility of rapid updating as well as of the areas that require attention from farmers [6-11].

Farmers are generally interested in optimizing their return on investment (ROI). ROI is the ratio between the net profit and the cost of the investment or between the earnings and the expenses made to secure certain resources. The return on investment is good, in economic terms, when a ratio results in the advantage of profit, compared to the investment, or in other words, when the way to produce profit from the invested capital is chosen well. As a performance measure, ROI is used either to evaluate the effectiveness of an investment or to compare different investments. Therefore, farmers are interested in finding and using methods and technologies to monitor crop health, spot missing plants, monitor livestock, inspect farms, and more. Thus, the advantage of these devices is the ability to capture information to observe a large number of environmental parameters, continuously: 24 hours a day, 365 days a year, and the values obtained can be monitored in real time. Also, information can be stored and transmitted at any time as long as there is an internet connection in the monitored area [12-14].

The paper presents the design and experimental research carried out on the experimental model of the agridrone (MHRT) for carrying out phytosanitary treatments in field crops.

MATERIAL AND METHOD

The experimental agridrone model for carrying out phytosanitary treatments in field crops, MHRT, is a Y-type hexarotor drone powered by a Tattu Plus 1.0 22000mAh 44.4V 25C 12S1P Lipo battery, equipped with 6 1955 W motors, type KDE5215XF -220, whose rotation speed is controlled by 6 KDE-UAS55HVC electronic speed controllers (ESC), three engines having two CCW type propellers (they rotate in the opposite trigonometric direction) and the other three engines having propellers with two CW type blades (rotate trigonometrically), all the propellers are of the KDE-CF215-DP type with dimensions of 21.5", it has a 20 liter tank from which an electric pump at 12 Vdc pumps with a pressure of up to at 5.5 bar phytosanitary substances to a circular spray ramp on which 3 nozzle holders equipped with calibrated spray nozzles are mounted. The drone is equipped with Pixhawk 4 autopilot, power management board and GPS module for precise positioning in the field and can be programmed to operate the electric pump to spray agricultural crops only on predefined areas.

Figure 1. MHRT experimental model 3D project

A structural analysis was carried out in static mode, using the solid discretization type. The discretized structure totaled a number of 1429473 nodes, with 789629 standard elements. The minimum element size was 0.982496 mm and the maximum element size was 4.91248 mm. The finite element analysis was done in the Solidworks program. Figure 2 shows the discretized structure.

Loads and boundary conditions were imposed, as follows: the three fixings in which all three translations are canceled correspond to the landing gear soles, and were applied according to the following figure (Figure 2).

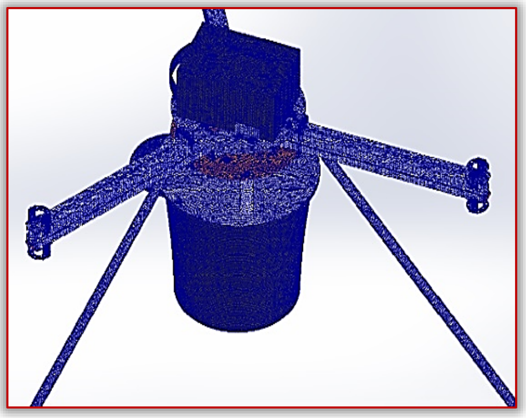


Figure 2. The structural model of the MHRT experimental model: discretization

The loading forces were applied to the drone battery in a vertical direction. The loading force had the value of 150 N. Thus the total reaction force from the fixing points had a value of 323,499 N.

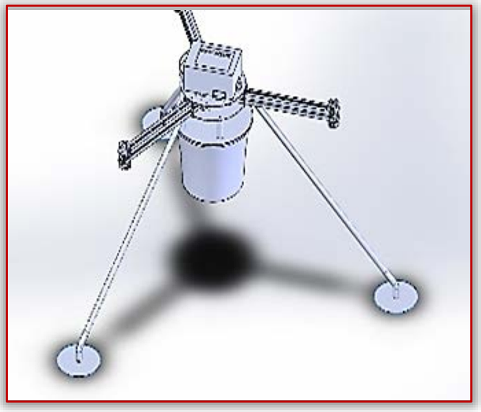


Figure 3. Structural model of the experimental model MHRT: fixings

RESULTS

The minimum and maximum values of the state of equivalent stress (Von Mises) in the structural model of the drone were determined after performing the static analysis according to the fixations and loads presented previously. The maximum value of the equivalent stress is 1,444e+12 N/m^2 and is located at the contact point between the drone arm and the landing gear leg, node 1298283. The minimum value recorded was 7,319e-01 N/m^2 and is located in node 88613 of the discretized structure.

Fig. 4 shows the distribution of the resulting relative displacement field values in the structural model of the experimental model. The representation is made on the deformed shape of the structure.

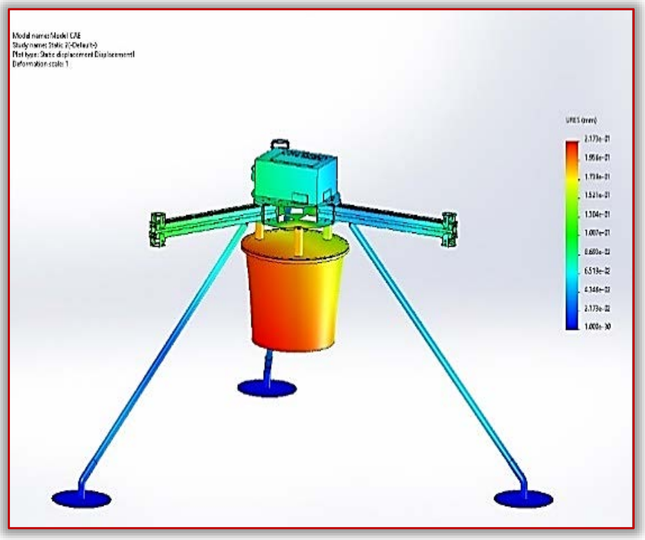


Figure 4. Equivalent displacement

Experiments were carried out in the laboratory and on the experimental fields, in order to determine the maximum take-off mass, the dimensions of the drone, the flight capacity and the sound pressure level. The dimensions of the MHRT experimental model measured are as follows:

— Diameter: 1.58 m
— Height: 0.94 m
— Own weight without battery: 12.5 kg
— Battery weight: 6 kg
— Maximum weight: 38.5 kg

The noise measurement was made on a clean and dry horizontal surface, the microphone being placed at a height of 1.2 m from the ground. The background noise was at least 10 dB(A) lower than the measured one.

Figure 5. Testing the MHRT drone in the lab

Table 1: Drone noise

Acceleration (%)	Acoustic power (db)
25%	73
50%	86
75%	88
100%	95

The maximum take-off mass was determined by measuring the maximum take-off force between the drone and a fixed point on the ground by means of a 1KN load cell placed between the drone and the ground.

Table 2 shows the average values obtained for the MHRT experimental model in terms of the maximum lifting force.

Table 2: Average values obtained for the MHRT experimental model in terms of maximum lift force

Acceleration (%)	Curent ESC(A)	Lifting force 1 engine (N)	Lifting force 6 engines (N)	Engine speed (rpm)
25%	2,5	1330	7900	2520
50%	11	3860	23080	4240
75%	26.4	7520	45000	5750
100%	52.4	11350	67850	7000

The maximum lifting force corresponds to a maximum level of current through the ESC of 52.4 A at a battery charge level of 52.2 V and a maximum electric power of 2735.28 W/motor, having a total power of 16411.68 W. Taking into account the battery capacity of 976.8Wh, this represents an autonomy of 0.06 hours.

In reality, the experimental model will not be operated at full capacity, but will be used with a maximum speed of 75%, which means a total electric power of 8268.48 W and an autonomy of 0.12 hours with the drone charged at full capacity. A series of tests were carried out with the experimental drone model in the field, in order to test the simple functions of take-off, landing and autonomy.

Figure 6. MHRT drone field testing

CONCLUSIONS

Following the design and testing of the MHRT experimental model, the following conclusions were identified:

- the tripod landing gear model provides stability to the drone;
- the length of the drone's arms must be doubled, and the material from which they will be made must be adapted to the attachment of the motors on it;
- the solutions for the autopilot and the radio control had an optimal operation;
- the 12-cell battery is not sufficient to achieve the required autonomy, so it is necessary to replace it with two 14-cell batteries;
- the circular spray ramp pattern provides both uniform spray distribution and undercarriage stiffening;
- for better balancing, the tank should be placed above the central frame and will have the shape of a truncated cone with a cylinder at the base.

Acknowledgement

This work was supported by a grant of the Romanian Ministry of Education and Research, CCCDI - UEFISCDI, project number PN-III-P2-2.1-PED-2019-4123, within PNCDI III and of the Ministry of Research, Innovation and Digitalization through Program 1 - Development of the national research-development system, Subprogram 1.2 - Institutional performance - Projects for financing excellence in RDI, Contract no. 1PFE/30.12.2021.

References

[1] Caruso A., Chessa S., Escolar S., Barba J., López J. C. Collection of Data With Drones in Precision Agriculture: Analytical Model and LoRa Case Study, in IEEE Internet of Things Journal, vol. 8, no. 22, pp. 16692-16704, 2021

[2] DaponteP., De Vito L., Glielmo L., Iannelli L., Liuzza D., PicarielloF., Silano G. A review on the use of drones for precision agriculture. IOP Conf. Ser.: Earth Environ. Sci. 275 012022, 2022

[3] Fontanella R., Vetrella A. R., Fasano G., Accardo D., Moriello R. S. L., Angrisani L., Girard R. A standardized approach to derive system specifications for drones operating in the future UTM scenario 2017 5th IEEE International Conference on Models and Technologies for Intelligent Transportation Systems, pp 250–255, 2017

[4] Vikram P., Anand N., Linesh R. Agriculture drones: A modern breakthrough in precision agriculture, Journal of Statistics and Management Systems, vol.20, no.4, pp. 507-518, 2017
[5] Ipate G, Voicu Gh. Dinu I. Research on the use of drones in precision agriculture. U.P.B. Sci. Bull., Series D, Vol. 77, Iss. 4, pp. 263-274, 2015
[6] Huuskonen J., Oksanen T. Soil sampling with drones and augmented reality in precision agriculture. Computers and Electronics in Agriculture, vol. 154, pp. 25-35, 2018
[7] Veroustraete F. The Rise of the Drones in Agriculture. EC Agriculture 2.2, pp. 325-327, 2015
[8] Stehr N. J. Drones: The Newest Technology for Precision Agriculture. American Society of Agronomy, Natural Sciences 44.1, pp. 89-91, 2015
[9] Urbahs A., Ieva J. Features of the use of unmanned aerial vehicles for agriculture applications. Aviation 17.4, pp. 170-175, 2013
[10] García L.; Parra L.; Jimenez J.M.; Lloret J.; Mauri P.V.; Lorenz P. DronAway: A Proposal on the Use of Remote Sensing Drones as Mobile Gateway for WSN in Precision Agriculture. Appl. Sci. 2020, 10, 6668. 2020
[11] Toth C.; Jó´zków G. Remote sensing platforms and sensors: A survey. ISPRS J. Photogramm. Remote Sens, 115, pp. 22–36, 2016
[12] Maes W. H.; Steppe K. Perspectives for Remote Sensing with Unmanned Aerial Vehicles in Precision Agriculture. Trends Plant Sci., 24, pp. 152–164, 2019
[13] Urbahs A. Jonaite I. Features of the use of unmanned aerial vehicles for agriculture applications. Aviation, 17, pp. 170–175, 2013
[14] Stehr, N. J.; Justen V. Drones: The Newest Technology for Precision Agriculture. Nat. Sci. Educ., 44, pp. 89–91, 2015

ISSN: 2067–3809

[1.]Qariburahman MASHAL

A STUDY ON RISK MANAGEMENT OF CONSTRUCTION PROJECTS IN AFGHANISTAN

[1.] Khurasan University, Civil Engineering Department, AFGHANISTAN

Abstract: Construction risk is a common phenomenon over the world. As consequence of those risks; globally most of the construction projects fail to meet their predefined quality standards, timely completion, safety and cost regulation. The construction industry in Afghanistan has no exception; in almost all the cases the risk factors are amongst the factors which contribute to time and cost overruns of the construction projects in the country. Unfortunately, only few numbers of previous researches have been carried out on the risk management process in the construction environment of Afghanistan; the focus was on risk assessment processes and evaluation of risks. The main aim of this study is to evaluate the frequency and impact of risks in one hand, and on the other hand to evaluate the influences of the risks contributed by owner, contractor, consultant and external. A review of the pertinent past literature was carried out in order to further discover the trends and governance of risks in different countries and in different project atmospheres. Furthermore, a questionnaire survey was designed and distributed to 110 individuals involved in the construction industry of Afghanistan. Risk Value equation was used to rank the risk factors on the basis of their frequency and impact. In addition, the risk assessment matrix was used to further evaluate the frequency and Impact of the risks. The ten most significant risks result in time and cost overrun of construction projects in Afghanistan were obtained by employing of the above methods.
Keywords: Afghanistan, Construction Risk, Management, Risk Matrix

INTRODUCTION

Risk management is the process of risk recognition, categorization, mitigation and monitoring. It is essential in order to manage the quality of the project products and deliverables, avoid the time and cost overrun of the projects and to minimize the environmental and site safety risks. Risk management is an economical and systematic approach to manage construction risks. Construction is the riskiest industry across all the industries. Hence, it requires proper risk management processes in order to ensure the success of project in terms of time, cost, quality, safety and environmental sustainability. [1]. Risk management is considered one of the most important tools and received international popularity in construction industry due to vast interest of researchers. Although, this approximate new tool requires more new work in order to bring new and working features to eliminate the negative impacts of risks on the progress of construction projects. [2].

The management of multidimensional risks directed to construction projects have significance importance in international construction business, particularly in developing countries. Hence, to ensure work in one hand and to make economic advantages at the other hand. [3]. Most of the construction projects in Afghanistan failed to meet the contract requirements. Many of them facing time and cost overruns and poor quality. In this juncture to prevent the delay and cost overrun of the construction projects in Afghanistan and to bring improvement proper risk management is essential. Risk assessment process as a part of risk management resulted in eliminating of most of the threats associated to construction industry in Afghanistan. [4]. In majority of the cases in developing countries the phenomenon of risk did not achieve the required popularity. The risk management process is systematically divided into three main stages in construction projects. Which is identification of risk, analysis and evaluation of risk and risk response. Risk with higher extent will harm all the parties involved in construction industry [5].

Risk can be seen all over the world in all types of construction works. In present era of globalization, the possibility to face risks is very high in all aspects of live in particular in construction industry. The effective risk management does not include only the resignation of risks. However, the aim is to protect adverse effects of risk on the one hand and to gain the maximum benefits of the decision at the other hand. [6]. One of the main responsibilities a construction manager must possess at managing construction sites is the management of risk. However, the process has to be started and followed right from the initiation of the project prior to the execution of any construction activity in order to overcome the complex and tricky process of risk management. Aside with knowledge and experience the methodology should be systematic and appropriate [7]. Construction industry is the most tricky, dynamic and risky industry. Unfortunately, it is strongly believed that the industry do not have better reputation in risk management. Hence, number of construction projects failed to meet their time, cost and quality requirements and limitations. [8]. Prior to the commencement of any practical activity of projects the owner of the project has to choose along with the procurement process the proper risk management practices. Because, the three major components of construction procurement have their effects on project risk management. Project delivery method, payment form and utilization of partnering arrangements imparts prominent influences on the progress of construction projects. [9]. Risk management is almost a new practice in the field of construction industry in developing countries. Therefore, there is the need of an unite and join risk management practice. In Pakistan construction is considered as the most risky and tricky industry. However, the industry did not follow best risk management practices to achieve better reputation in handling of construction risks. [10].

LITERATURE REVIEW

A number of past studies relevant to the study has been studied and the findings are listed below:

The main aim was to study the risk management practices deployed in Afghanistan Building Construction Projects. The objectives were to evaluate the level of risk management techniques used in Afghanistan building projects, to examine the levels of understanding of the involved parties and to analyze the impacts of risks relevant to each category and party. In order to discover the understanding and response of different categories of firms and companies involved in Afghanistan building construction projects a questionnaire survey was conducted. Based on the higher probability of occurrence and impact poor construction management considered as the major risk in Afghanistan building construction projects. The respondents of the survey were: global and national construction companies, local and governmental agencies, sponsors and consultants. SPSS was used with object to analyze data and SWOT analysis model was used to evaluate the data. Based on the sources risk were classified into 6 major categories: design, technical, community and political, construction, financial, environmental and administrative categories of risk. The financial category of risk was found to be the extremely occurring aspect of risk categories. In majority of the cases the fund for many of the construction projects in Afghanistan is provided by external financiers; whereas, even in most of the cases due to delay in submitting of the invoices some of the construction projects have been terminated before the attainment of their planned objectives. [1]

The base for this research was a questionnaire survey on risk management in Pakistan construction industry. The aim of questionnaire was to report the significance of various categories of risk, responsibility recognition for their efficient management and the effectiveness of major risk management techniques used in the construction sector. The two categories of risk management techniques preventive and remedial techniques were considered. Found that financial complications, site accidents and Time overrun were the most common risks. Moreover, the contractor was mainly responsible of managing the site related risks and the client was responsible for the financial, design, change orders and scope related issues. Further, the proper schedule management and instructions and experience from the similar past projects were the most suitable preventive risk management strategies. The objective of the research was to identify common risks in construction industry and their preventive managing techniques practiced currently in Pakistan construction industry. A supplementary risk assessment tool was used in order to develop the risk assessment model for various types of construction projects in Pakistan. After the discussion the most common 10 risks were categorized as follows; delay in progress payments, difficulties in project funding, accidents in sites, Time overrun, improper schedule management, weak performance by sub-contractors, inflation and fluctuations in money exchange rates, faulty scope identification, poor material and equipment quality and delay in the supply of material. Based on the results of the data preventive risk assessment technique was found to be the most suitable technique in order to manage the construction risks in an efficient style. [2]

The goal of research was to reveal and asses the existing risks in construction industries of developing countries and their prevention strategies to develop a well-organized risk management framework prior to the conducting of contract relationship with international financiers, developers and contractors. The 28 major risks were included in questionnaire survey. The evaluation and ranking of risk in a hierarchical level was done based on the three country, market and project categories. Working solutions were suggested and assessed for all the major risks. To achieve the objectives of the research four major research activities have been carried out through review of past literature, international survey, interviews and discussion. Out of 11 major risks, 7 risks were associated to country level which validate that country level is the most causing group. Besides, except the quantitative analysis a well-organized qualitative analysis by considering 6 steps was also put into practice. The steps for qualitative analysis are: definition of the nature of risk, determination of risk criticality, identification of the mutual influences, relationship amongst risks, mitigation measures based on the higher priority. 11 critical risks were: approval and permit, law changes, reinforcement of justice, local partner's wealth, political issues, cost overrun, corruption, interest rates and inflation, government policies and the influence of government on termination of JV and disputes were concluded and their mitigation strategies were developed. [3]

21 major risks were analyzed evaluated. 5x5 probability matrix was used to evaluate the major risks. In this study the process of risk assessment was carried out in three stages: risk identification, risk analysis and risk evaluation. Also found that during evaluation stage risk was categorized into acceptable, unwanted and unacceptable categories. At the conclusion of this study found that out of 21 risks considered for analysis, 20 of them fell in the categories of unacceptable and unwanted. [4]

The main aim of the paper was reviewing of the existing literature on construction project risk management process in developing countries. The most popular techniques used to identify risks in developing countries are: checklists, past experience, interviews and brainstorming. Moreover, the most risk mitigation strategies used in developing countries are: risk retaining, risk reduction, risk distribution, risk control, risk avoidance and risk transfer. [5]

In this study based on the utility theory a method for the analysis of risk was presented. The risk analysis procedure of the suggested method included the following: data regarding the construction conditions and economic situation and the relationship amongst supply and demand. [11]

Reference [6] Classified the most common risks based on their frequency of occurrence and impact. The most common risks based on frequency are: systematic and specific risks; and based on impact are: fixed risk and variable risks. Besides, risks were classified into following more types: financial risks time related risks, technical risks, market risks, nature risks, external risks and risks related to workplace safety and human.

The aim of paper was to discover the problems in the process of risk management by using knowledge-based approach. Moreover, to suggest a methodology based on the modeling of risk management, evaluation and best practice model. It is predicted that by using of the above three-fold procedure the clients and contractors will be able to promote the risk management performances. Motivation for the conduction or research was as a result of very little number of research done on the subject in Chilean construction industry. At the conclusion 5 levels of organizations were developed based on the major characteristics of each level of risk management [7]

The study reviewed systematic risk management approaches. The main emphasis was to manage the risk right from the very earliest stages of the project such as procurement and so on. Further, a small project as analyzed as a case study. The risk was allocated based on the various sources such as: owner, contractor, external and undecided. Also, the importance levels of most important and least important were specified to each source. The case study reports and analysis indicates that risks of different types affected the project. The risk identified in case study were classified into following 4 types: planning risks, design and construction risks, site-related risks and market risks, and the risks from the design and construction category were on the top of the list. [8]

The three variables in construction projects' procurement have been studied and their effects have been investigated. Eleven projects from the Swedish construction projects have been selected for the collection of data, interviews have been carried out with clients, contractors and consultants. The objective of the paper was to indicate the importance of proper selection of the procurement option over the risk management. Client is the main player of the project and has the immense responsibility in the process of risk management. In order to promote the construction efficiency and to safeguard the project objectives client is responsible to allocate the risk management processes formally from the very early stages of the construction projects. The limitations of the study were three procurement options: lump sum general contracts, design-bid-build with lump sum and partnering with cost-reimbursing type of payment. [9]

The aim of the study was to explore the risk management practices used in Pakistan. Thereby, a survey was developed and distributed. The survey forms were distributed to 22 contractor companies worked on 100 different projects. As resulted, there has been always a strong co-relation between project success and proper risk management. Unfortunately, in the local construction projects the lack of required importance to risk management is always feasible in the construction industry of Pakistan. The study was analyzed as the base for evaluation of the effects of risk management in Pakistan construction industry. Definitely the research is useful for the construction companies in order to recognize their weakness and improve it by application of the efficient risk management processes. The most used risk management technique for the analysis of risks in Pakistan were found as follows: expert judgement, work break down structure, risk index method and data collecting and representing techniques. Also, the most used risk management mitigation strategies in Pakistan were found as follows: risk management plan and decision making, sharing of risks and cost benefit analysis and risk transferring. [10]

RESEARCH METHODOLOGY

The review of relevant past literature has been conducted. Besides, a comprehensive questionnaire survey was developed in order to examine the current and future state of construction industry in Afghanistan in term of risk management. The following figure shows the flow chart of research methodology adopted in the study.

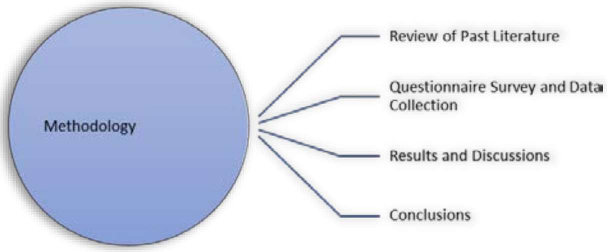


Figure 1. Flow chart of research methodology and research approaches.

— Questionnaire Survey

A comprehensive questionnaire was conducted in order to collect the necessary information for data analysis.

46 Risks were observed after the literature review and were considered for the evaluation by the utilization of 5 Point Scale Likert Survey. The questionnaire survey was designed to assess the responses of the respondents in two major qualities: Impact of risk and frequency of occurrence.

— Risk mapping

Based on the frequency and impact of risks a 5x5 risk analysis matrix was deployed in order to evaluate the level of risks. [04] and others used the risk value equation (1) for the determination of potential risk levels.

$$R = P \times S \quad (1)$$

where, P= Frequency of occurrence, S= Risk impact.

— Frequency classifications of risks

The 5 categories of frequency illustrated in risk analysis matrix are as follows:

- Don't Know: Risks with zero probability of occurrence.
- Never: Rare risks which have very little chances of occurrence.
- Sometimes: Risks which poses 50 percent probability of occurrence.
- Often: Risks which have higher probability of occurrence.
- Always: Risks which are expected to occur always, they are the first priority risks.

— Impact classification of risks

The 5 categories of impact illustrated in risk analysis matrix are as follows:

- Don't Know: Risks with zero negative impact on the project or organization.
- No Effect: Risks that do not impart any notable effect on the success of the project/organization. But, still have some effects.
- Some What High: These risks are the threats which imparts negative effects on the project.
- High; This category of risks possesses strong chances of opposed effects which have the potential of adverse impacts on the completion of the project.
- Very High: This category can harm the project on a large scale and results on the failure of the overall success of the project or affecting the daily activities seriously.

Table 1. Risk categorization and evaluation of acceptance.

Category of risk (Levels)	Evaluation of acceptance
Very low (1 to 4)	Acceptable
Low (5 to 6)	Unwanted (Acceptable but should be reduced)
Medium (8 to 9)	
High (10 to 12)	
Very high (15 to 25)	Unacceptable

— Risk evaluation matrix

Risk evaluation matrix is used in order to determine the level of risk on the basis of the probability and impact rating by respondents from level 1 to level 25.

Table 2. Categories of risk based on the risk levels

Probability (P)		Impact (S)				
		Don't Know	No effect	Some What High	High	Very high
		5	4	3	2	1
Don't Know	5	Very high (25)	Very high (20)	Very high (15)	High (10)	Low (5)
Never	4	Very high (20)	Very high (16)	High (12)	Medium (8)	Very low (4)
Sometimes	3	Very high (15)	High (12)	Medium (9)	Low (6)	Very low (3)
Often	2	High (10)	Medium (8)	Low (6)	Very low (4)	High low (2)
Always	1	Low (5)	Very low (4)	Vey low (3)	Very low (2)	Low low (1)

RESULTS AND DISCUSSION

A compressive questionnaire survey was designed and survey forms were distributed to various categories of construction professionals and experts in Afghanistan.

After the review of literature 46 risks were obtained and were preferred for the further critical analysis in this study. Risks were classified based on their frequency and impact evaluation by respondents. Risk values for each risk was determined by the multiplication of frequency and impact of each risk. The acceptance evaluation of risks was performed based on the risk levels obtained from the risk values. The very low-level risks from level 1 to level 4 were considered as acceptable risks.

The low-level risks from level 5 to level 6, medium level from level 8 to level 9 and high-level form level 10 to level 12 were considered as unwanted risks. And very high-level risks form level 15 to level 25 were considered as unacceptable risks.

Table 3. Indicates the risk value and ranking of each risk based on the risk value.

Risk	Risk Code	Impact mean (S)	Frequency mean (P)	Risk value (R=PxS)	Ranking based on risk value
Risks Related to Owner					
Delay in Invoices	01	3.89	4.20	16.34	3
Improper scope definition or changes in scope	02	2.85	4.06	11.57	43
Delay in funding of the projects by donor	03	3.74	4.08	15.26	12
Excessive change orders during execution phase of the project	04	3.82	4.16	15.89	7
Mistakes in bidding and contract award	05	3.69	3.51	12.95	36
Changes in drawing during construction	06	3.41	3.74	12.75	39
Risks Related to Consultant					
Late approval and provision of work permits	CL3	3.83	4.09	15.66	9
Justice reinforcing	CL4	3.64	3.73	13.58	29
Faulty design	CL5	3.95	3.92	15.48	10
Late approval of design documents	CL6	3.51	3.66	12.85	37
Risk Related to Contractor					
Bureaucracy in project teams	C1	3.61	3.81	13.75	25
Lack of enthusiasm	C2	3.82	3.25	12.42	40
Lake of key skill labour	C3	3.77	3.51	13.23	32
Problems in financing of the projects	C4	3.92	3.89	15.25	13
Safety accidents in construction sites	C5	3.81	4.03	15.35	11
Scheduling and execution	C6	3.77	4.03	15.19	14
Poor performance by sub-contractors	C7	3.65	3.88	14.16	21
Delay in material supply	C8	3.68	3.73	13.73	26
Cost overrun	C9	3.97	4.30	17.07	1
Cost fluctuation of material	C10	3.81	3.69	14.06	22
Lasey sub-contract work	C11	3.89	3.59	13.97	23
Insufficient coordination by contractors' technical staff	C12	3.85	3.61	13.90	24
Excessive changes in sub-contracts due to their work failure	C13	3.75	3.82	14.33	19
Time overrun	C14	4.02	4.10	16.48	2
Inappropriate planning	C15	3.97	4.07	16.16	4
Risks related to External					
Insufficient coordination amongst parties	E1	3.75	3.98	14.93	15
Difficulties in law	E2	3.53	3.75	13.24	31
Lack of regular staff meetings	E3	3.69	3.31	12.21	41
Political changes	E4	3.65	3.73	13.61	28
Social changes	E5	3.75	3.81	14.29	20
Security	E6	3.82	4.15	15.85	8

Fluctuation in the material rates	E7	3.44	3.99	13.73	27
Lack of key resources	E8	3.38	3.89	13.15	34
Working under the condition of projects in unsecure areas	E9	3.98	4.01	15.96	6
Fluctuation in money exchange rates	E10	3.82	3.55	13.56	30
Lack of high-quality materials and equipment	E11	3.47	3.70	12.84	38
Changes in law	E12	3.64	3.07	11.17	45
Local partners preferences	E13	3.28	3.44	11.28	44
Poor communication and coordination amongst involved parties	E14	3.72	3.86	14.36	18
Interest rates	E15	2.86	3.53	10.10	46
Governmental policies	E16	3.56	4.08	14.52	17
Government influences on disputes	E17	3.38	3.84	12.98	35
Corruption	E18	4.08	3.94	16.08	5
Inflation	E19	3.47	3.80	13.19	33
Bureaucracy in government entities	E20	3.38	3.61	12.20	42
Improper pre-contract coordination	E21	3.58	4.13	14.79	16

— Risk evaluation matrixes

The criticality of the risks related to all the categories owner, consultant, contractor and external have been evaluated by the deploying of risk evaluation matrix. The numbers from 1 to 5 in both vertical and horizontal axis indicates the level of risk based on the mean values of impact and frequency.

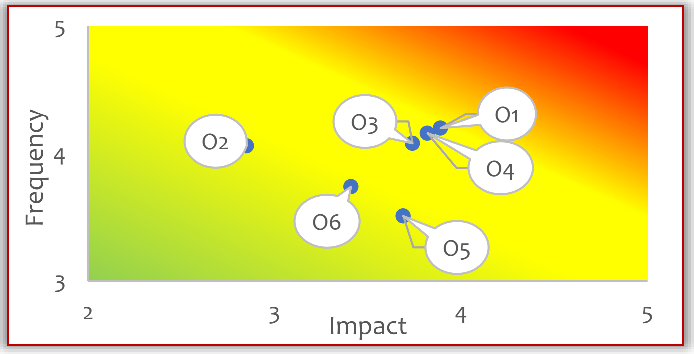


Figure 2. Risk matrix related to owner.

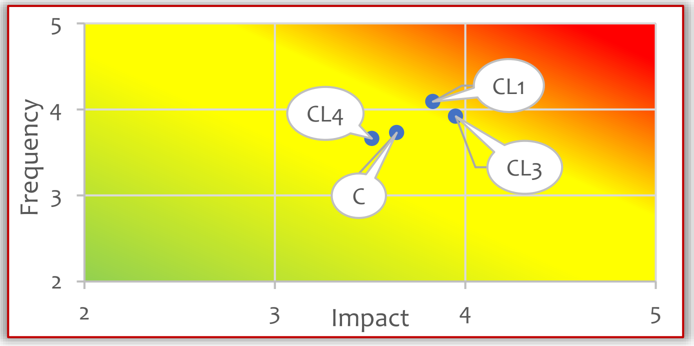


Figure 3. Risk matrix related to consultant.

Cost overrun with risk value of (17.07) found to be the most critical risk which disrupted the progress of most of the construction projects in Afghanistan. Due to many reasons most of the construction projects in Afghanistan have been not completed by their pre-budgeted cost. Furthermore, in some of the cases this particular risk prevented the successful accomplishment of the construction projects across the country.

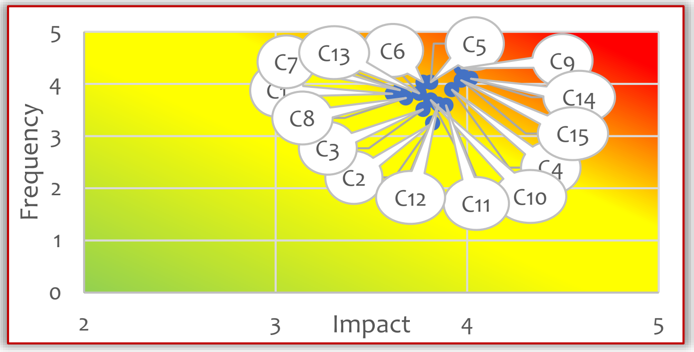


Figure 4. Risk related matrix related to contractor.

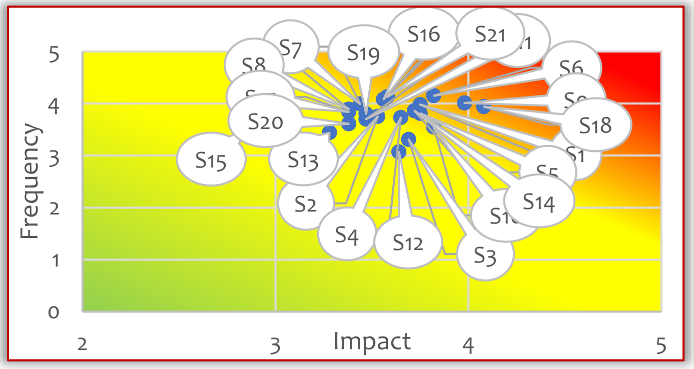


Figure 5. Risk matrix related to external.

Time overrun with risk value of (16.48) founded to be the second most critical risk. Progress delay or late completion of the construction projects is the global challenge in construction industry. Proper and well-organized risk management practices reduce the chances of construction delays. However, in most of the cases the contractors fail to provide resources and budget for proper utilization of risk management. Besides, some of the contractors even do not consider risk management in their priority lists of the construction techniques.

Delay in invoices by owner with risk value of (16.34) obtained to the third most critical risk in the study. Owners do not pay the invoices on time to contractors which resulted in time and cost overruns of most of the construction projects in Afghanistan.

Inappropriate planning with risk value of (16.16) found to be the fourth most critical risk. Improper or inappropriate planning is one of the main causes of projects' failure; replanning always requires some extra time and extra budget. As a result, inappropriate planning has been considered one of the major reasons of construction delays and cost overruns.

Corruption with risk value of (16.08) found to be the fifth most critical risk. Corruption is obtainable in almost all of the project phases from Pre-bid qualification to project closure. Hence, corruption is considered as one of the major obstacles for the foreign investors and NGOs to invest in the construction industry of Afghanistan.

CONCLUSION

Relevant past researches have been reviewed and the findings were analyzed. Unfortunately, only few researches have been carried out on risk management of construction projects in Afghanistan.

The core aim of this paper was to evaluate the frequency and impact of risks in one hand, and on the other hand to evaluate the influences of the risks related to various parties involved in construction such as: owner, contractor, consultant and external. Risk management is the process of risk identification, evaluation and mitigation. Therefore, 46 risks have been identified after literature review and were considered for further critical evaluation in this paper through questionnaire survey.

The most common risks existing in construction industry of Afghanistan were evaluated by the using of risk assessment matrix, and ranked by risk value. In addition, recommendations were given in order to minimize the impact of risks on the progress of construction projects so as to prevent construction delays and cost overrun.

The top 10 risks achieved in this study are: cost overrun (risk related to contractor), time overrun (risk related to contractor), delay in invoices (risk related to owner), inappropriate planning (risk related to contractor), corruption (risk related to external), working under the condition of projects in unsecure areas (risk related to external), excessive change orders during execution phase of the project (risk related to owner), security (risk related to external), late approval and work permissions (risk related to consultant) and faulty design (risk related to consultant).

From the overall results it can be concluded that the contractors' category is the most causing party of risks in construction industry of Afghanistan followed by external category.

RECOMMENDATIONS

Following recommendations are given in order to minimize the impact of risks on the accomplishment of construction projects in Afghanistan. In order to minimize the impact of risks and increase the possibility of successful completion of the construction projects in Afghanistan the contractors should deploy proper risk management practices. Moreover, efficient risk management will assure the timely and on budget completion of the construction projects. Thus, the two major reasons of project failure time and cost overrun will be prevented.

Delay in invoices is another risk which disrupts the progress of construction projects. If owner take his responsibility and pay the progress payment to contractor on-time this attribute can also be prevented. Besides, in order to minimize delays and cost overruns the consultant is also required to approve and report the construction works timely and concisely.

Inappropriate planning also prevented many of the construction projects to achieve their predefined objectives. Owner is suggested to conduct the feasibility study of the construction projects properly and consider all the involved and influential aspects. Also, the contractor should improve the planning and scheduling abilities of their teams.

Corruption is considered as another external risk leads to arguments and disagreements in the construction industry of Afghanistan. The government has to be very strict in this regard and the legal processes and lawsuits should be firmly considered and followed. So as to absorb funds and sponsorships of international community and external investors the government has the extremist obligation of fighting against corruption.

Note: This paper was presented at International Conference on Applied Sciences – ICAS2022, organized by University Politehnica Timisoara, Faculty of Engineering Hunedoara (ROMANIA) and University of Banja Luka, Faculty of Mechanical Engineering Banja Luka (BOSNIA & HERZEGOVINA), in May 25–28, 2022, in Banja Luka (BOSNIA & HERZEGOVINA).

References

[1] A. Faqiri and A. Rasool, "Role of Risk Management in Construction Project in Afghanistan," Int. Educ. Appl. Res. J., vol. 2, no. 9, pp. 1–9, 2018.
[2] S. Iqbal, R. M. Choudhry, K. Holschemacher, A. Ali, and J. Tamošaitienė, "Risk management in construction projects," Technol. Econ. Dev. Econ., vol. 21, no. 1, pp. 65–78, 2015
[3] S. Q. Wang, M. F. Dulaimi, and M. Y. Aguria, "Risk management framework for construction projects in developing countries," Constr. Manag. Econ., vol. 22, no. 3, pp. 237–252, 2004
[4] M. N. Aloko, "Risk Assessment Process for Construction Projects in Afghanistan," Int. J. Adv. Eng. Res. Sci., vol. 5, no. 8, pp. 211–217, 2018
[5] R. A. Bahamid and S. I. Doh, "A review of risk management process in construction projects of developing countries," IOP Conf. Ser. Mater. Sci. Eng., vol. 271, no. 1, 2017
[6] P. Szymański, "Risk management in construction projects," Procedia Eng., vol. 208, pp. 174–182, 2017
[7] A. F. Serpella, X. Ferrada, R. Howard, and L. Rubio, "Risk Management in Construction Projects: A Knowledge-based Approach," Procedia - Soc. Behav. Sci., vol. 119, pp. 653–662, 2014
[8] A. Mills, "A systematic approach to risk management for construction," Struct. Surv., vol. 19, no. 5, pp. 245–252, 2001, doi: 10.1108/02630800110412615.
[9] E. Osipova and P. E. Eriksson, "How procurement options influence risk management in construction projects," Constr. Manag. Econ., vol. 29, no. 11, pp. 1149–1158, 2011
[10] A. Nawaz, A. Waqar, S. A. R. Shah, M. Sajid, and M. I. Khalid, "An innovative framework for risk management in construction projects in developing countries: Evidence from Pakistan," Risks, vol. 7, no. 1, 2019
[11] O. Kaplinski, "Risk management of construction works by means of the utility theory: A case study," Procedia Eng., vol. 57, pp. 533–539, 2013

ISSN: 2067–3809

[1.]Adnan LATIC, [2.]Zlatko BUNDALO, [3.]Branko BLANUSA

MONITORING VITAL PARAMETERS OF HUMAN USING NodeMCU PLATFORM

[1.]University of Bihac, Faculty of Technical Engineering, Dr. Irfana Ljubijankica, Bihac 77000, BOSNIA & HERZEGOVINA
[2,3.]University of Banja Luka, Faculty of Electrical Engineering, Patre 5, Banja Luka 78000, BOSNIA & HERZEGOVINA

Abstract: In the recent years, it has become a widespread phenomenon to monitor various medical health parameters of patients outside hospitals. The aim of this paper is to describe the design and possibilities of a system for remote monitoring the patient body vital health parameters at any time using wireless connectivity. The system performs its function as it measures some vital medical parameter of the patient's body, like are temperature, heartbeat, blood pressure, by using appropriate sensors and then sends the recorded information online to a server through Wi–Fi connection and Wi–Fi module. All information about the patient health parameters is stored on the online server. It enables the doctors to remotely monitor and analyse patient's health and also family and friends can access data and see health status of patient using their smart phones. With this design and this system, it can be effectively used Wi–Fi technology to monitor patient health status. Also, the power consumption of used Wi–Fi module can be reduced as much as possible to make it economical. Thus, the designed system provides low complexity, low power consumption and low cost.
Keywords: remote monitoring, patient body, vital health parameter, wireless connectivity, NodeMCU platform

INTRODUCTION

With the recent advances and changes in many fields of science and technology, life becomes quite easier. Technology is always there to help people to perform their jobs and tasks with much less effort, in a more economical and simplified way. The health sector is changing rapidly, allowing digital technology to facilitate doctor–patient interaction, better understand its problems, diagnose and propose appropriate medications and conduct appropriate therapies.

In such applications sensors collect data about patient vital parameters, such as are blood pressure, temperature, heart rate. This data can be stored online on a remote server. Such, health professionals and healthcare professionals (doctors and other staff) can analyse and monitor the patient's condition in real time and perform adequate activities if it is needed.

There are already several technologies that allow the monitoring of patients who have heart disease problems. The great importance and great advantage of the technology for monitoring the patient remotely is the fact that patients spend a critical period, after leaving the hospital, alone at home, without the supervision of professional staff. Such remotely monitoring of that kind of patients, as well as of other type of patients, is of great help for medical staff and for patients.

The advantage of application NodeMCU platform technology is that it does not take interaction between the medical staff and the patient to read the values. It is enough only for the medical staff to use a web application or mobile application to check the patient's current condition and take the necessary steps in case the results are poor and require appropriate intervention.

This paper describes possibilities and the design of a system for remote monitoring vital medical parameter of the patient at any time and any place using wireless connection and mobile phone. The system measures some vital medical parameter of the patient body, temperature and heartbeat, using appropriate sensors. It then sends the recorded information online to the cloud based server via Wi–Fi connection and Internet. All information about the patient monitored body health parameters is stored on the online server. It enables the doctors to remotely monitor and analyze patient health. Also, the patient family and friends can access data and see patient health status using their smart phones. With this system it can be effectively monitored the patient health status. Also, it can be reduced as much as possible the power consumption of used Wi–Fi module to make low energy consumption and economical system. Such, the designed system has low complexity, low power consumption and low cost.

VITAL PARAMETERS OF HUMAN AND THEIR MEASUREMENT

Today's classical methods of treatment of patients are quite slow and, in many cases, diseases are detected in the late stages when treatment cannot be effective. For this reason, there is a need for a system and an algorithm that would automatically detect problems in the human body, as well as for devices and applications that can monitor the state of patient health in real time. Such systems and devices can be very useful, especially in environments where there are not adequate health institutions, that is, in geographical areas that are not easily accessible. Cases like this require an application and system that can be easily tuned and connected to the nearest medical staff who can respond to the needs of the patient. Such systems and applications can be also easily connected with patient family and enable family to monitor and check patient health state in real time. In such situations, there is a need for efficient control of the energy consumption of the system and device and that the system and device is capable of performing self–configuration to eliminate certain interferences. With increased internet availability worldwide, faster communication and less data delay, real–time value readings have become possible. Also, using of mobile phones for such monitoring of human vital health parameters is very simple and is permanently increasing.

— Physiological parameters reflecting the state of human health

Usually, the human health is defined by physiological parameters of person, which are mainly dependent on each other. They are not equally informative, but they are very important. For their measurement, special conditions are usually required, as well as expensive medical materials and treatment apparatus. Therefore, when creating a monitoring system, it is necessary to assess not only the significance of the assumed parameters, but also additional methods of their assessment and the probability of an observation in order to make a useful system. Research related to medicine has shown that the most important vital parameters are those that determine the respiratory system of the human body and the parameters related to the heart. They best show the condition of the human body and its health [1].

Table 1 presents human physiological parameters, of which there are four basic health parameters that should be observed regularly:

≡ body temperature,
≡ heart rate,
≡ breathing rate,
≡ blood pressure (this is a rare used parameter, but it is often measured in addition to other health parameters).

Table 1. Human physiological parameters

Measured parameter	Physiological parameter examined	Measured value environment
ECG	Heartbeat	Time function, numerical values
Pulse	Heart rate	Mean numeric values
Breathing rate	Breathing rate	Numeric Values
Breathing volume	Respiratory volume	Mean numeric values
Temperature	Temperature	Numeric Values
Blood pressure	Systolic and diastolic blood pressure	Time function, numeric values

These parameters are useful in determining and treating medical complications. The results of these vital parameters can be measured everywhere, at home, at work, in healthcare institutions. Most new smart phones contain health monitoring applications, which mostly have sensors to measure blood pressure, temperature and stress [2].

— Body temperature

The optimal state of body temperature of human beings differs and depends on the gender, what the person did recently and what activities he/she performed, the food and drink consumed, the time consumed, and in women from menstruation and menstrual cycle. Normal body temperature varies from 36.5°C (97.8°F) to 37.2° (99°F) for a healthy person.

Human body temperature can be measured in many ways. Some of them are:

≡ Oral – body temperature can be measured by placing the thermometer in the mouth, modern digital thermometers available today use electronic probes to measure body temperature,
≡ Rectally – for rectal temperature measurement, a classical or digital thermometer is used and usually the temperature is 0.6°C to 1.1°C higher than that measured orally,
≡ Armpit – measurement is done by placing the thermometer under the armpits. The temperature measured this way is generally 0.3°C to 0.4°C lower than that measured orally,
≡ By ear – there is a special thermometer that can quickly measure the temperature of the eardrum, which is almost equal to the internal temperature of the body (temperature of the internal organs),
≡ By skin – a special thermometer that is like a strip can quickly measure the temperature of the skin by attaching a strip principle.

Body temperature can also be abnormal due to elevated body temperature (high temperature) or hypothermia (low temperature) [3].

— Heart rate

Heart rate or pulse is a measure of the heart rate or heart beats per minute. As the body pumps blood through the arteries, they expand and narrow with blood flow. Heart rate measurement not only measures heart rate, but can measure heart rate and heart rate strength. The standard heart rate is from 60 to 100 beats per minute. The number can change and increase due to exercise, illness, wound, and emotional states. Women from 12 years of age upwards generally have a faster heart rate rhythm than men. Athletes, such as runners, who complete strenuous cardiovascular training, can have 40 heart beats per minute and have no difficulties [4].

— Breathing rate

The rate of breathing is the number of breaths that a human makes at all times (3–4 seconds). Speed is usually measured when a human is in a calm state and involves measuring only the number of breaths at one time by observing how often the chest rises. The rate of breathing may increase due to increased body temperature, illness and other therapeutic conditions. Checking the rate of breathing is also important to check whether a person feels any difficulty breathing. The rate of breathing for an adult mainly varies from 12 to 16 breaths per minute [5].

— Blood pressure

Blood pressure or the circulatory strain is the power of the blood pushing in the artery walls for the period compression and unwinding of the heart. Each time the heart thumps, it directs blood into the veins, bringing about the most elevated circulatory strain as the heart contracts. At the point when the heart relaxes, the pulse falls. Two numbers are recorded when estimating circulatory strain. The higher number, or systolic pressure, alludes to the pressure inside the corridor when the heart contracts and pumps blood through the body. The lower number, or diastolic pressure, alludes to the pressure inside the supply route when the heart is very still and is loading with blood. Both the systolic and diastolic pressures are measured and recorded as "mmHg" (millimetres of mercury). The chronicle shows that mercury blood pressure monitors (mercury sphygmomanometer or manometer) are outdated as it raises by the blood pressure. Today, the specialists' offices are equipped with modern digital blood pressure monitors. Normal values of systolic and diastolic pressures for a healthy person are 80 mmHg and 120 mmHg. High body pressure or hypertension, straightforwardly builds the danger of heart attack, heart failure or stroke. Due to the hypertension and in order to maintain a normal blood flow through the vessels the heart has to be stronger [6].

POSSIBILITIES FOR MONITORING HUMAN HEALTH AT A DISTANCE

Monitoring human health from a distance or remote patient monitoring (RPM) is an innovation to enable monitoring of patients outside of traditional clinical settings (e.g., at home), which increases the access to many areas where treatment monitoring and taking result is almost impossible. It also decreases healthcare delivery costs. With the invention of remote monitoring technology, the same monitoring as used in hospitals is available at home. Therapeutic innovation once used exclusively in hospitals and general practices is now available for use at home. Many clinical preliminaries of home distance checking the glucose concentrations by PC demonstrate improved proficiency and much better results in diabetes care. Similarly, measuring the blood pressure using home distance monitoring technology shows improved efficiency. Inability to enhance results of high–risk pregnancies through home distance monitoring shows the challenges in such medical applications. In general, electronic observing of patient health parameters and health state at home guarantees to reduce cost in health services. It also improves involvement of patients in their own care, and another feeling of authenticity in making an analysis of patients.

— Application of technology for remote patient monitoring

A large proportion of older adults suffer from many intense diseases and injuries. Consequently, the administration of chronic diseases, post–acute care administration and health checking are the three most important uses of remote monitoring technology for adults. Remote monitoring technology can encourage moderate improvement of chronic illness and guarantee continued recovery after intensive care. The advancement of patient remote monitoring technology can also alert caregivers and encourage mediation when a disabled adult is injured. After presenting the abnormal condition, each of these examples will be presented with several specific innovations. These opportunities and innovations should be seen as the initial stage of thinking and not as potential outcomes and progress of remote patient monitoring.

Figure 1 shows the remote tracking or monitoring procedure in five phases: collection, transmission, evaluation, notification and intervention. Remote monitoring technologies can efficiently or inactively collect information by connecting to a patient. The information contains vital signs and other physiological information, blood glucose levels, answers to certain health questions and questions about general well–being and additional information about the patient [7].

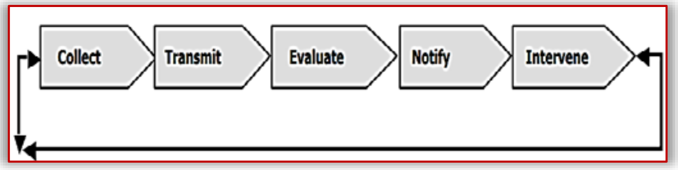


Figure 1. Remote monitoring procedure

MCU PLATFORM WITH WI–FI MODULE

Used NodeMCU platform with Wi–Fi module ESP8266 is an independent SOC (System on chip) with a coordinated TCP/IP protocol, which allows any microcontroller to access a Wi–Fi network. Each separate chip is accompanied by a pre–customized set of AT commands, which takes into account easy use.

— NodeMCU platform technology

NodeMCU platform is a very good starting stage for developers because it provides them with an interactive environment that agrees to run commands not only from those that control ESP8266's remote interface, but additionally GPIO and hardware functionalities such as i2c and PWM. In the case of a default firmware (AT Command Interpreter), the application code should be created using a programming language suitable for a microcontroller or SOC.

— Specification of NodeMCU platform

It consumes small amounts of electricity of 3.3 V and uses small processor on the board, allowing the chip to work completely independently. It is in contrast to the usual chip, which is usually an Arduino chip, and a Wi–Fi module, that costs significantly more. Despite the fact that the NodeMCU platform has only 2MB of memory, as well as a large number of chips in this group, and the amount of GPI0 needles is limited to 8, nevertheless it gives great usability.

NodeMCU platform contains a complete Wi–Fi set. It means that it can be used to host or deactivate the roles of Wi–Fi networks of other processors. For the purpose of facilitating application, it runs especially from external memory, while the coordinated cache improves system execution. It can also be used as a Wi–Fi connector and has the best Wi–Fi chip on the market [8].

— File–system of NodeMCU platform

The file system also alongside the program are put away on a similar chip, in any case, programming another venture won't change the substance of the document system. This implies we can utilize the record framework to store program information, arrangement documents or substance for a Web server. The plan used to make the executions and requirements on the chip is SPIFFS, since it was intended for a small framework, in spite the cost of a few disentanglements. PIFFS does not bolster indexes it just stores records. The good thing is that since it's anything but a customary document framework it considers the '/' character to be used in names, subsequently permitting the utilization of index posting when using the capacities [9].

PRACTICAL REALIZATION OF SYSTEM FOR MONITORING VITAL PARAMETERS OF HUMAN

For design and implementation of system to remotely monitor a patient's vital signs are used the NodeMCU platform, temperature sensor, ECG and a heart rate sensor, access to cloud based database and smart mobile phones. The system can easily achieve all requirements using NodeMCU platform and send an alert by message or email when the measured parameters are above or below normal value.

— ECG kit

The purpose of ECG electrodes is to record the electrical activity of the heart in a certain period of time. ECG detects tiny changes in the skin that originate from an electrophysiological pattern of the heart muscle depolarization and repolarisation during each heartbeat.

The ECG kit or heart monitor is a block of ECG sensors, which is conditioned by a signal coming from an ECG electrode. It is specifically designed to extract a low–voltage signal, and then delivers and filters it to suppress interference from the signal. The cause of the interference in the ECG signal is the movement of the electrode or remote setup. The advantage of a heart rate monitor is that it requires a small amount of energy to work. It was used ECG or heart monitor AD8232. Figure 2 shows right positions for placing ECG electrodes.

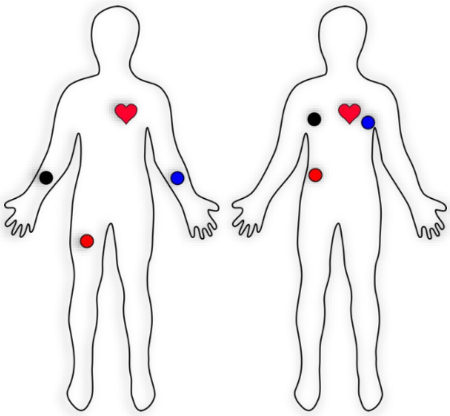


Figure 2. Right positions for placing ECG electrodes

— Temperature sensor

Temperature sensor measures body temperature of the patient. In the system it was used temperature sensor DS18B20. The device is powered by a 1–wire communication line, storing power to the internal capacitor for the time when the signal is high while for the case when the signal is low, it takes stored power from the capacitor. Alternatively, the DS18B20 can also be powered from an external voltage of 3 – 5.5V.

Figure 3 shows used temperature sensor. Sensor from Figure 3 can be used for measuring temperature of air, water and human body. Wires are covered by waterproof material and sensor can be completely drowned in the water.

Figure 3. Temperature sensor

— Schematic view of the solution

Block scheme of the solution is shown in Figure 4. Between NodeMCU platform and temperature senor and ECG kit are used wired connections. NodeMCU platform and mobile devices are connected to the Internet using wireless Wi–Fi technology.

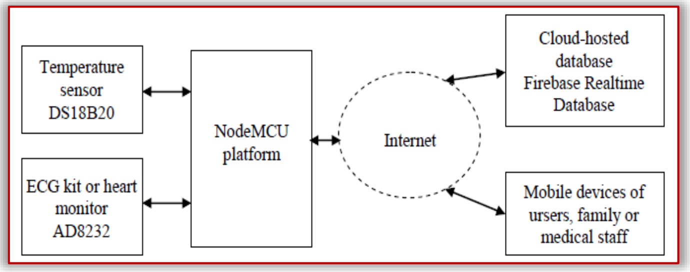


Figure 4. Block scheme of the solution

Figure 5 shows schematic view of the solution.

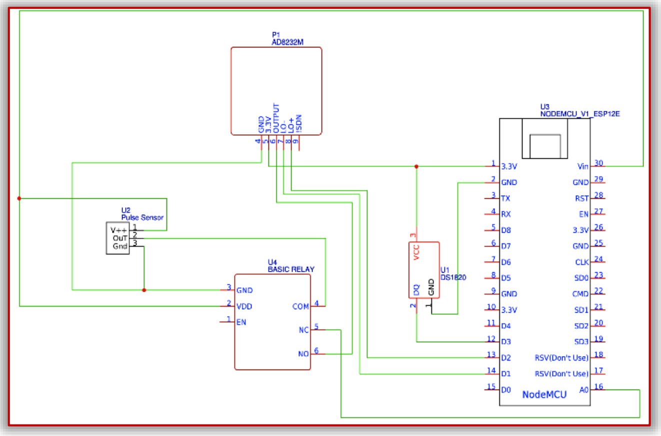


Figure 5. Schematic view of solution

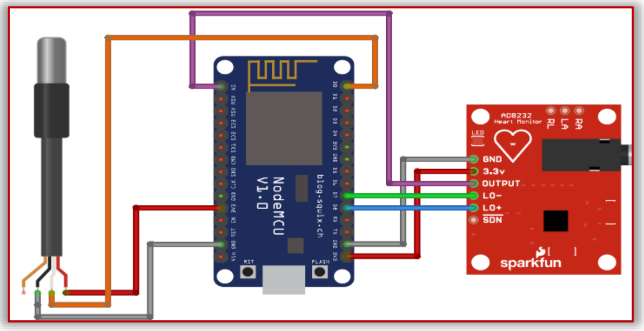


Figure 6. Practical setup of solution

Practical setup of solution that was realized and tested is shown in Figure 6. Figure 6 shows how to connect components to a functional solution that can be used to monitor patient vital health parameters. ECG sensor use two digital pins D7 and D8, and also for reading data uses analogue pin A0. Temperature sensor required only one digital pin, in this case the pin D1.

— Firebase database

In the system design and implementation it was used Firebase Realtime Database. The Firebase Realtime Database is a cloud–hosted database. Data is stored as JSON and synchronized in real time to every connected client. When you build cross–platform applications, with Apple platforms, Android, and JavaScript SDKs, all of your clients share one real time database instance and automatically receive updates with the newest data.

The Firebase Realtime Database lets you build rich, collaborative applications by allowing secure access to the database directly from client–side code. Data is persisted locally, and even while offline, real time events continue to fire, giving the end user a responsive experience. When the device regains connection, the Realtime Database synchronizes the local data changes with the remote updates that occurred while the client was offline, merging any conflicts automatically. The Realtime Database provides a flexible, expression–based rules language, called Firebase Realtime Database Security Rules, to define how your data should be structured and when data can be read from or written to. When it is integrated with Firebase Authentication, developers can define who has access to what data, and how they can access it [10].

Figure 7. Stored measured values from ECG sensor

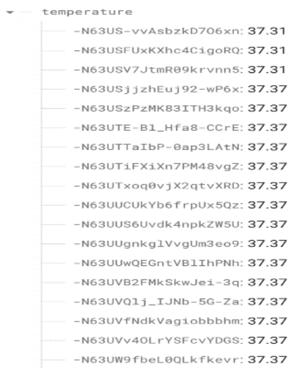


Figure 8. Stored measured values from temperature sensor

Figures 7 and 8 show stored measured data in Firebase Realtime Database. Each sensor has its own node for storing measured data.

— Comparing values and sending notification

After uploading the patient data on Firebase cloud, the data can be tracked and monitored in real–time via mobile phone and mobile application, with ability to compare measured data with normal parameter values of healthy human. Monitored parameter values can be shown to the patient, his family or his doctor by mobile phone and mobile application. Also, if it is detected value of monitored health parameter that is above or under the normal parameter value, it will be generated warning information and sent to the doctor or the family of the patient, by mobile phone or email. If the detected value of monitored health parameter is very significantly above or under the normal parameter value or not existing, it will be generated urgent emergency information and sent to the doctor or the family of the patient, by mobile phone or email.

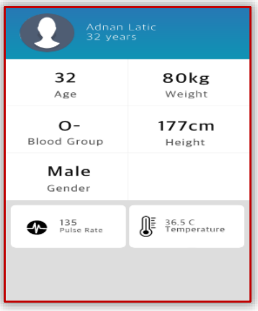


Figure 9. Example of patient monitoring record with real time tracking shown on the patient mobile phone

Figure 9 shows example of results of patient monitoring record with real time parameters tracking shown on the patient mobile phone. It can be seen that the obtained measured patient body temperature is within normal temperature range for healthy patient. But, obtained pulse rate is over normal pulse rate range for healthy patient. The reason is that the measurement was performed after patient exercise. Such was tested system operation also in such situations.

After loading data into mobile application each value fetched from the cloud server is compared with normal parameter value. If application detects sequence of increased or decreased values, it will send by mobile phone or email notification to the patient and person or medical staff responsible for monitored patient.

— Designed and implemented software

It was designed and implemented complete software needed for the system operation. The software consists of code for microcontroller and code for mobile application. Microcontroller was programmed in Arduino IDE using C++ programming language. Arduino IDE is open–source software which gives us great environment for writing code and uploading to microcontroller board. In addition to programming, it can be also used for checking results or debugging via serial monitor. Before triggering function for measuring body parameters, software checks connectivity with dedicated Wi–Fi hotspot. If connection was established successfully, software starts loop functions for collecting data from sensors and uploading results to cloud database, delay between measuring is hardcoded to 2 seconds. For formatting and uploading measured data to cloud database, software uses open–source library Firebase Arduino. Figure 10 shows program code for collecting and uploading measured data to cloud real–time database.

Mobile app was developed in Android studio using Java programming language. Android Studio is the official integrated development environment for Google's Android operating system software and designed specifically for Android development. For reading data from firebase real–time database, it was necessary to import in project all required plugins and connectors using Firebase Assistant in Android studio. After establishing connection with Firebase, user can start using developed application. Before reading data, user must have required credentials to access patient data. Logged user can track condition of patient in real–time.

```
void loop() {
  measureTemperature(); //function for measuring temperature
  measureHeartbeat();  //function for measuring heartbeat
  delay(200);
}

void measureHeartbeat() {
  digitalWrite(AD2, LOW);
  digitalWrite(AD1, HIGH);
  long now = millis();

  if((digitalRead(LOP) == 1)||(digitalRead(LOM) == 1)){
    Serial.println('!');
  }
  else{
      rythme = analogRead(A0);
  }
  Firebase.pushFloat("sensors/ecg", rythme);
}

void measureHeartbeat() {
  tempS.requestTemperatures();
  temperature = tempS.getTempCByIndex(0);
  Firebase.pushFloat("sensors/temperature", temperature);
}
```

Figure 10. Program code for measuring body parameters and storing on online cloud

CONCLUSIONS

With advances in technology, there are many possibilities to apply them in human life and to make easier many human activities. Wireless communication and mobile devices opened up new possibilities where people can easily communicate with each other. This paper proposes and describes one way of design, one possibility and application of remote monitoring systems for patient vital health parameters in health care systems.

Medical parameters are monitored with the help of sensors. Sensors are connected via a wireless communication network. In this way, doctors can get reports of patient physical health condition when they need it. Also, patient itself and his family or friends can obtain information about his health status. This system could be very effective for monitoring patients who have been left the hospital. In such situations the patients are mostly on their own and undergo a sensitive part of the recovery. Such remote monitoring of patient health parameters could be very useful for doctors, family, friends and patients itself.

With designed system it can be easily and effectively monitored the patient health status. The system is developed and implemented using open source technologies and open source hardware and software platforms. Also, the power consumption has reduced to obtain low energy consumption and to obtain economical system. The designed and implemented system is low complexity, low power consumption and low cost system.

With increased economic migration the described system can be of great benefit. Currently a large number of the elderly population has been left unattended by the family and often in places where medical staff is far from the patient or the person who needs to be supervised. The system can be further improved with using additional sensors, because the current system only uses sensors to measure body temperature and heart pulse rate.

In addition to measuring health parameters for the purpose of treating and monitoring patient chronic illnesses or recovery, this system allows patient family members or patient guardian to check whether the patient is alive or if the vital parameters are very low.

Note: This paper was presented at International Conference on Applied Sciences – ICAS2022, organized by University Politehnica Timisoara, Faculty of Engineering Hunedoara (ROMANIA) and University of Banja Luka, Faculty of Mechanical Engineering Banja Luka (BOSNIA & HERZEGOVINA), in May 25–28, 2022, in Banja Luka (BOSNIA & HERZEGOVINA).

References

[1] Sung M. and Pentland A. Minimally Invasive Physiological Sensing for Human–Aware Sensing // Proceedings of the 11th International Conference on Human Computer Interaction (HCII'05). Las Vegas NV, USA. – 2005. – 10 p.
[2] National Institute for Health and Clinical Excellence. Clinical guideline 50: Acutely ill patients in hospital. London, 2007.
[3] R. Prakash1, B.Paulchamy, "Remote Monitoring Of ECG And Body Temperature Signals", International Journal of Innovative Research in Science, Engineering and Technology, May 2014.
[4] Sandra L. Schutz, "Oxygen Saturation Monitoring by Pulse Oximetry", AACN Procedure manual for Critical Care, Fourth Edition, 2001.
[5] Rodríguez–Molinero A, Narvaiza L, Ruiz J, Gálvez–Barrón C (December 2013). "Normal respiratory rate and peripheral blood oxygen saturation in the elderly population". Journal of the American Geriatrics Society. 61 (12): 2238–40.
[6] Agarwal R, Bunaye Z, Bekele DM (March 2008). "Prognostic significance of between–arm bloodpressuredifferences". Hypertension. 51 (3):65762.
[7] Heartbeat and Temperature Monitoring System for remote patients using Arduino Vikram Singh, R. Parihar, Akash Y Tangipahoa D Ganorkar (IJAERS), International Journal of Advanced Engineering and Science eissn2349–6495
[8] https://datasheets.maximintegrated.com/en/ds/DS18B20–PAR.pdf (20.06.2022.)
[9] M.C. Paul, S.Sarkar & S.M. Reza, "Low Cost and Portable Patient Monitoring System or e–Health Services" IEEE International conerence on computer communication & inormatics (ICCCI), Jan. 2016.
[10] https://firebase.google.com/docs/database (25.06.2022)

ISSN: 2067–3809

[1.]Radu-Iulian RADOI, [1.]Marian BLEJAN, [1.]Liliana DUMITRESCU, [2.]Dorin BORDEASU, [3.]Cristian GHERA

MULTIPURPOSE STAND IN THE FIELD OF HYDROSTATIC DRIVES

[1.]Hydraulics and Pneumatics Research Institute (INOE 2000 - IHP), Cutitul de Argint str., no. 14, 040558, Bucharest, ROMANIA
[2.]Politehnica University of Timisoara, Department of Automation and Applied Informatics, Vasile Parvan str., no. 2, 300223 Timisoara, ROMANIA
[3.]Politehnica University of Timisoara, Department of Mechanical Machines, Equipment and Transports, Mihai Viteazu Bvd, no. 1, 300222, Timisoara, ROMANIA

Abstract: The reconfiguration of Romania's industrial production in recent decades, due to the opening of markets, has also had the effect of significantly reducing the national production of hydraulic components and systems. On the other hand, the demand was covered by imported equipment, which requires, after a period of time, repair or performance evaluation. The reduction of staff involved in the design of components and systems has led to a decrease in the volume of knowledge in the field of hydraulic drives, which is trying to be eliminated by training technical staff in the field in universities. Through the collaboration between the Research Institute for Hydraulics and Pneumatics in Bucharest and the Polytechnic University Timisoara, a stand was created that has a double function: it is used both in the process of training students and for testing equipment, on request, in the laboratory of hydraulic machines and systems at the university.
Keywords: test stand, hydraulic components, PLC, data acquisition

INTRODUCTION

Before 1990, the Romanian industry had a significant part of the production of hydraulic components, which were then integrated on a national level in various systems, so as to cover a large part of the demand for equipment with hydraulic actuation in the country, and to be offered for export. The component factories produced almost all types of hydraulic apparatus (pumps of various types, linear and rotary hydraulic motors, distribution and regulation apparatus, auxiliary apparatus). The penetration on the free market of some import components, from more or less famous manufacturers, at competitive prices, caused the demand for components produced in the country to decrease; at the level of 2022, Romania still produces only a few types of hydraulic components in significant quantities, as follows:

- gear pumps, at SC HESPER SA Bucharest
- distribution and regulation equipment, at SC HIDROSIB SA Sibiu
- linear hydraulic motors, at WIPRO Infrastructure Engineering Râmnicu Vâlcea

Some of the hydraulic equipment importers also offer design, execution, commissioning services for systems made with imported equipment. There are also a significant number of companies that deal with the repair of hydraulic equipment, and in particular pumps and motors.

Both for some products that have gone through a maintenance process and for those that have been repaired, a performance evaluation is necessary, which can only be done with specialized equipment, such as stands equipped with modern parameter measurement systems. Under certain conditions, the owner of such a stand can provide training services in the field, especially if he has staff with teaching capabilities. Using a performance stand in a technical university has several social and economic benefits:

- is used to deepen technical skills in the field of hydrostatic drives for students
- provide experimentation reports for equipment of beneficiaries in industry and services (the university is a provider of performance evaluation services)
- can be included by the university in the professional development process of employees from various companies that request training in the field.

In this context, the idea of a multifunctional stand appeared, to be used by the Politehnica University of Timisoara, both for didactic activity with students and to offer services to interested companies (Kheiralla, A.F. et al., 2007; Elshorbagy, K.A. et al., 2018). The services mainly consist of testing repaired pumps and hydraulic motors or new linear hydraulic motors produced by the companies (Achten, P. et al., 2017).

STRUCTURE AND CHARACTERISTICS OF THE EQUIPMENT

The structure of the stand was designed in such a way as to meet the 2 purposes, didactic and economic (Meng, F.H. and Zhang, J.H., 2013; Salah, T. and Kassem, S., 2012). Thus, a complex structure was created, which provides information about several types of devices: pumps, motors, distributors. The stand has a specialized module for testing linear hydraulic motors, a module for rotary hydraulic machines (Grama, L. et al., 2013) and an auxiliary tank equipped with devices that work together with the two testing modules. The scheme of the stand can be found in Figure 1.

The operation of the stand, as well as the acquisition of the experimental data (Chen, F. and Yan, G., 2011) resulting from the test, is managed by an electrical subassembly that has a PLC as its basic component (Grama, L. et al., 2009).

The diagram of the stand contains pumps P1 and P2, driven by electric motors EM1 and EM2, two base plates on which the limiting valves RV1 and RV2 are mounted, as well as directional control valves DCV1 size 6 and DCV2 size 10. With the help of directional control valve DCV1 auxiliary control circuits can be powered. With the help of DCV2, the testing modules for rotary machines and hydraulic devices can be powered. Through a series of ball valves (HBV) it is possible to feed or isolate the different circuits that feed the cylinder test modules, hydraulic pumps/motors or the area for testing distributors, valves, servo valves, flow regulators or throttle valves (Michelson, S. et al., 2012).

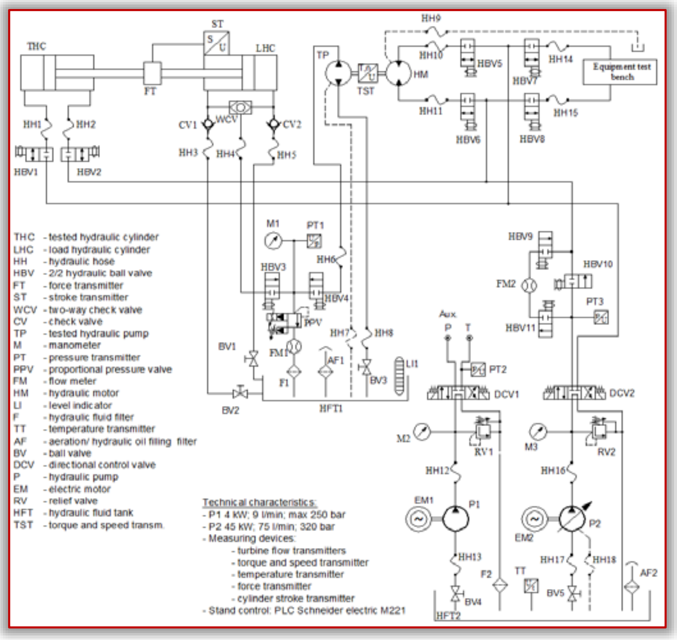


Figure 1. Scheme of the test stand used for hydrostatic drives

This work area is arranged on the cover of the main tank, in the form of a plate that has channels for the mechanical fixation of the test apparatus. The hydraulic circuits are made with hydraulic pipes and a series of HH hoses, to prevent vibrations (Castro, R.M. et al., 2014).

The auxiliary hydraulic fluid tank allows the supply of the tested pump TP or another pump used as a load for a tested hydraulic motor HM and the hydraulic load cylinder LHC, which can perform loads for the tested hydraulic cylinder THC. The load level on linear or rotary hydraulic motors can be adjusted using the PPV proportional valve.

To measure the mechanical and hydraulic parameters, the PT pressure transmitters, the FM flow transmitters, the FT force transmitter, the ST hydraulic cylinder rod position transmitter, the TST torque and speed transmitter and the TT oil temperature transmitter, are used in the stand diagram. For the direct visualization of the regulated pressure at the valves, the M pressure gauges can be used.

THE MAIN CHARACTERISTICS OF THE STAND

If in terms of the didactic nature of the stand, a very high drive power is not required, but for performing of test services the stand must have sufficient power to allow testing a significant part of the existing hydraulic equipment.

The maximum flow rate, and therefore also the pump displacement, is calculated using formula (1), and is a function of the working pressure, but also of the pump type.

$$N = \frac{Q \cdot P}{600 \cdot \eta_t} [kW] \quad (1)$$

where:

Q – pump flow, in l/min

P – outlet pressure

η_t – the total efficiency, which is calculated with the formula:

$$\eta_t = \eta_v \cdot \eta_{mh} \quad (2)$$

For pumps working at pressures of max. 210 bar (gear pumps, vane pumps, e.g.) and have lower efficiencies (0.85), the maximum flow will be:

$$Q_{max} = \frac{N \cdot 600 \cdot \eta_t}{210} \quad (3)$$

resulting in $Q_{max.}$ = 45 • 600 • 0.85 / 210 = 109.3 l/min, where total efficiency η_t was estimated at the value of 0.85, according to Table 1.

For a pump with a higher efficiency (pumps with axial pistons, η_t = 0.92), using formula (2) and considering a higher working pressure of 315 bar, we obtain a maximum flow rate of 78.9 l/min.

Through the variation of the displacement or the drive speed of the pumps, it is possible to carry out tests at pressure and flow superior to those above, under the conditions of maintaining the value of the product P • Q at values that do not lead to exceeding the power of 45 kW (taking into account and the efficiency of rotating machinery, η_t).

The total efficiency can also be appreciated with the help of the Table 1.

Table 1. Efficiency of hydraulic pumps (Internet source: Casey, B., 2011)

Pump type	Overall Efficiency %
External gear	85
Internal gear	90
Vane	85
Radial piston	90
Bent axis piston	92
Axial piston	91

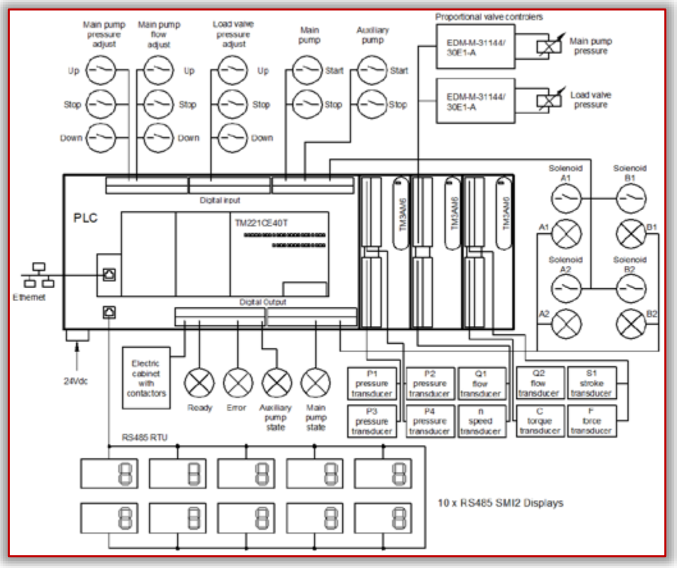


Figure 2. Block diagram of the operating console equipped with PLC

The control panel of the stand (Figure 2) is made with a programmable logic controller M221 from Schneider Electric (Figure 3). It has 24 digital inputs, 16 transistor source outputs, 2 analog inputs, a serial line port, Ethernet port, 24

Vdc power supply. To connect the transmitters and the controllers for the proportional valves to the PLC, three TM3AM6 modules were attached, which have 4 voltage or current inputs and 2 voltage or current outputs.

Stand commands are made by push buttons, with visual confirmations by means of indicator lights. To adjust the pressure and the flow rate, digital Up/Down buttons were implemented with the help of PLC. The on or off status of the pumps, stand ready or certain error codes can be visualized with the help of indicator lights. The solenoids from the 4/3 directional valves also have luminous confirmations in the control buttons. To view the adjusted values for the flow rate and pressure from the main pump and to display the values read by the transmitters, on the panel are displays with RS485 communication type SMI2 produced by Akytec.

Figure 3. PLC Schneider Electric M221 with analog input/output modules and the proportional controllers located in the electrical cabinet

Characteristics of the transmitters:

≡ Pressure: 250 bar and 400 bar ;
≡ Flow: 120 l/min and 60 l/min turbine flow transmitters;
≡ Torque and speed: 500 Nm and 360 pulses/rot;
≡ Temperature: 0…100 °C Pt 100 temperature transmitter;
≡ Force: 10000 kgf;
≡ Linear displacement: 0…1200 mm.

OBTAINING EXPERIMENTAL DATA

The results of the tests carried out on the stand, both laboratory works for students and tests of different hydraulic equipment made for various companies can be recorded graphically with the help of a PC application (Figure 4).

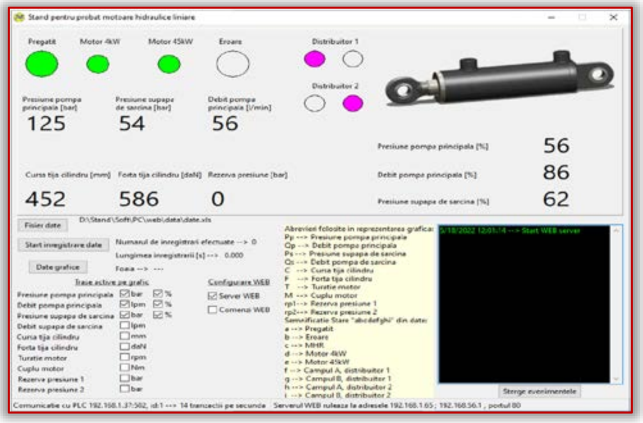


Figure 4. The main panel of the PC application

In Table 2 it can be seen the addresses assigned for the parameters used by the test stand. From address 23, information can be obtained about the solenoids of the hydraulic directional valves that are activated, the testing module that is active, the electric motors that are in operation, stand ready and various error signals.

The operator can select which parameters to be recorded depending on the tests performed. The recorded diagrams can be exported to the Clipboard and are automatically saved in a Microsoft Excel file, the file name containing the current date and time.

The stand test application also contains a Web server that can be activated to view the stand parameters on mobile devices through a web browser. The operator can also activate the Web command function so that commands can be given for the 2 directional hydraulic valves or the flow and pressure values of the main pump and the pressure of load valve can be changed. To record the diagrams, the application uses the parameter values transmitted by the programmable logic controller through the Modbus TCP/IP protocol in the local network. Parameters such as main pump pressure and flow rate, hydraulic cylinder stroke, hydraulic motor speed etc. they are identified with the help of numerical addresses (memory words in the PLC).

Table 2. Allocation of Modbus registers for the parameters monitored by the analog inputs of the PLC

Memory word	Adress	Symbol
1	%MW10	PMPPRES
2	%MW11	PMPFLOW
3	%MW12	VALVPRES
4	%MW13	STROKE
5	%MW14	FORCE
6	%MW15	FLOW1
7	%MW16	FLOW2
8	%MW17	TORQUE
9	%MW18	PRESS1
10	%MW19	PRESS2
11	%MW20	PRESS3
12	%MW21	PRESS4
13	%MW22	SPEED
14	%MW23	STATE

Figure 5 shows a fragment of the ladder diagram used to acquire data using the programmable logic controller.

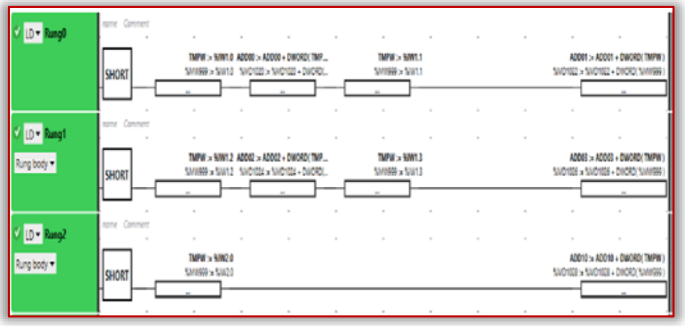


Figure 5. Ladder diagram for data acquisition from stand transmitters

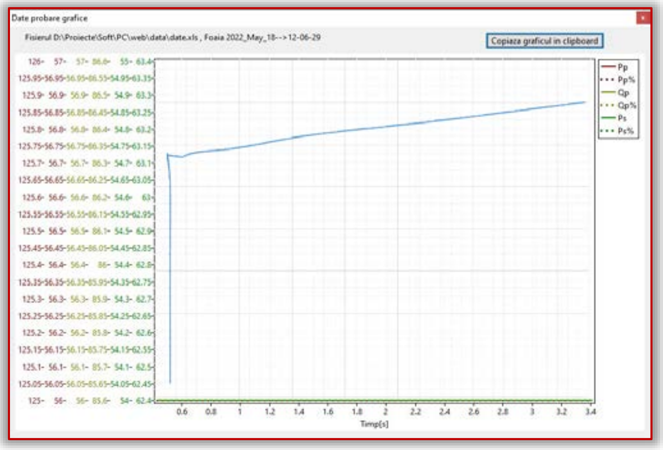


Figure 6. Graphic display of the PC application

Figure 6 shows the application window in which different graphs can be drawn for the different parameters of interest depending on the testing carried out. The recorded graphics can be selected from the main panel of the application. The graphs are displayed superimposed, each plot having a corresponding color and scale. The parameter plots in the graph can be identified with the help of a legend displayed next to the graph.

CONCLUSIONS

The stand allows the realization of laboratory works with students as well as the testing of hydraulic equipment for companies.

The modules of the stand allows the testing of different types of hydraulic devices; thus, with the help of linear hydraulic motors and rotary hydraulic motors subassemblies, linear hydraulic motors (hydraulic cylinders), pumps and rotary hydraulic motors can be tested, and to the fixing plate on the main hydraulic fluid tank, can be tested devices from the category of hydraulic regulation and control equipment: directional valves, servo valves, pressure valves, throttle valves , flow regulators etc.

The stand is modern and is equipped with measuring equipment, transmitters and software application for data acquisition and storage.

The operating parameters of the test stand are transmitted via Modbus TCP / IP protocol in the LAN network.

The monitoring of the operating parameters of the stand can be done, by the students, by a web browser through a web server that can be activated from main software application.

Acknowledgement

This paper has been financed under a project funded by the Ministry of Research, Innovation and Digitalization through Programme 1- Development of the national research & development system, Sub-programme 1.2 - Institutional performance - Projects financing the R&D&I excellence, Financial Agreement no. 18PFE/30.12.2021.

Note: This paper was presented at International Conference on Applied Sciences – ICAS2022, organized by University Politehnica Timisoara, Faculty of Engineering Hunedoara (ROMANIA) and University of Banja Luka, Faculty of Mechanical Engineering Banja Luka (BOSNIA & HERZEGOVINA), in May 25–28, 2022, in Banja Luka (BOSNIA & HERZEGOVINA)

References

[1] Achten, P.; Potma, J. and Eggenkamp, S.: A new hydraulic pump and motor test bench for extremely low operating speeds. Proceedings of the 2017 Bath/ASME Symposium on Fluid Power and Motion Control, pp. 1-6, 2017.
[2] Castro, R.M.; Neto, J.M.; Morona, Y.M.; Machado, K. and Rocha A.S.: Development of a test bench for analysis of the supply pressure variation in hydraulic systems. Hidraulica Magazine (4), pp. 7-17, 2014.
[3] Chen, F. and Yan, G.: Design of Automatic Hydraulic Test Bench Based on LabView. Proceedings of Second International Conference on Mechanic Automation and Control Engineering, pp. 1183-1186, 2011.
[4] Elshorbagy, K.A.; Kandil, H. and Latif, M.R.: Development of a Multi-functional Hydraulic Test Stand. Journal of Scientific and Engineering Research 5(1), pp. 123-132, 2018.
[5] Grama, L.; Banyai, D. and Vaida, L.: Experimental testing of a low speed hydraulic motor with axial pistons. Hidraulica Magazine (3), pp. 64-73, 2013.
[6] Internet source: Casey, B.: Hydraulic Pumps and Motors: Considering Efficiency. Machinery Lubrication (3), 2011, https://www.machinerylubrication.com/Read/28430/hydraulic-pump-motors-maintenance.
[7] Kheiralla, A.F.; Rahama, O.A.; Saadelnoor, A.A.; Abd-lkareem, D.M. and Nasr, G.M.: Design and Development of a Hydraulic Circuit Bench for Education Purposes. Proceedings of International Conference on Engineering Education – ICEE 2007, pp.1-7, 2007.
[8] Meng, F.H. and Zhang, J.H.: Optimization Design and Simulation Research of Hydraulic Test Bench. Adv. Mater. Res. 744, pp. 23–26, 2013.
[9] Michelson, S.; Mueller, M. and Schurman, B.: Hydraulic Test Bench Circuit Construction Testing and Analysis. Journal of Undergraduate Research 10, pp. 117-127, 2012.
[10] Oleiwi, M.A.; Al-Timimi, A.M.M. and Abdulhussein, A.: Design & Simulation of PLC Control and Electro-Hydraulic System for a Punching Machine Fluid Power system. Eng. Tech. J. 27(8), pp. 1559–1571, 2009.
[11] Salah, T. and Kassem, S.: Development and manufacture of a universal hydraulic test rig for proportional and servo valves and cylinders. Int. Conf. Engineering Technology ICET 2012 - Conf. Book, pp. 1–6, 2012.

ACTA TECHNICA CORVINIENSIS
Bulletin of Engineering
ISSN: 2067–3809

[1.]Amel DŽANIĆ, [1.]Amel TOROMAN, [2.]Alma DŽANIĆ

AGILE SOFTWARE DEVELOPMENT: MODEL, METHODS, ADVANTAGES AND DISADVANTAGES

[1.]University of Bihać, Faculty of Technical Engineering, Ulica Irfana Ljubijankića bb, 77000 Bihać, BOSNIA & HERZEGOVINA
[2.]University of Bihać, Faculty of Economics, Ulica Pape Ivana Pavla II/2, 77000 Bihać, BOSNIA & HERZEGOVINA

Abstract: The only constant in today's world is a change and therefore the changes are an unavoidable factor also from the aspect of software production. Poor reaction to changes in traditional software development methods has led to the emergence of a new agile philosophy, which has embraced change and put it in its focus. The agile approach essentially implements the set of values and principles given in the agile manifesto. This paper presents an agile model that can be recognized in any agile method. Furthermore, the paper presents the several agile methods that are often used today. The advantages and disadvantages of these methods are stated, and software development through each of these methods is described. The result of the paper is the discussion on the use of these methods, as well as the main problems and the possible directions of development of these methods is addressed.
Keywords: Agile software, development, advantages and disadvantages

INTRODUCTION

Software has major impact in modern life and business, and therefore it is very important to study and research those methods for software developments. Thus, until the end of the 90s of the last century, the software process, i.e. software development, was exclusively based on traditional methods of software development, which were characterized as "heavy" methods [1]. This software process generally consisted of the following steps [1]:

- The project plan must be completed first – that is why these methods are also called plan–driven methods
- All software requirements must be written down – i.e. requirement specification
- The whole project completed and met requirements
- Created source code that implements project documentation with all requirements
- Fully test the software to see if it meets all the requirements

The biggest problem with traditional methods of software development has been the way they respond to changes in requirements, i.e. the traditional way of software development did not respond well to the changes. There have been situations where changes in software specifications (requirements) have required large and expensive interventions on developed software [2].

A lot of time was spent on software development, so the customer received software that was already obsolete in some areas, and these areas required modifications. Because of all this, there was a need for the so–called an easy process where the main goal was to accelerate software development and successfully respond to changes in requirements. These methods are called agile software development methods.

The table shows the main differences between agile and traditional methods of software development

Table 1. Differences between agile and traditional approach of software development [2]

Parameter	Traditioanl methods	Agile methods
Simplicity of modification	Hard	Light
Development approach	Predictable	Adaptive
Development orientation	Orientation on process	Orientation on customer
Size of project	Large	Small or Medium
Planning scale	Long term	Short term
Mode of management	Command and control	Leadership and cooperation
Learning	Continuous learning with development	Learning is secondary to development
Documentation	High	Low
Type of organization	High income	moderate and low income
Number of employees	Huge	Small
Budget	High	Low
Size of team	Medium	Small

AGILE APPROACH OF DEVELOPING SOFTWARE

Adaptable, "light" methods have been created and promoted through the official agile alliance made up of 17 software engineers and consultants, the famous Agile Manifesto was created in 2001. In this software development philosophy, a set of 4 values and 12 principles reflect the essence of agility, and is available on the website https://agilemanifesto.org/ [3].

— Agile model

There are a very large number of agile methods that fully support the principles and values given in the agile manifesto. It is possible to determine the general form of the agile development process in four steps as show on picture 1 [4]:

- Project selection and approval – is the first phase where team consisting of developers, managers, and customers establishes the scope, purpose, and requirements of the product.

≡ Project initiation – is a second phase where a working architecture of the system is created, which is discussed by all stakeholders with the necessary deadlines and working frameworks.

≡ Construction of iterations – is third phase of this model in which iterations are made, i.e., this phase consists of planning and building the iterations. In other words, there is a successive incremental process that results in software that meets the evolution of user requirements. This is a consequence of the close collaboration of all stakeholders, and in this way the quality of the software is most effectively ensured. Also, each iteration of the software needs to be tested.

≡ Product release – is the final phase of this model. In this phase, the final software testing takes place, as well as work on necessary corrections and software documentation. Then product is realised, and end user training begins. Also, the working team may stay to maintain and improve the project as well as user support.

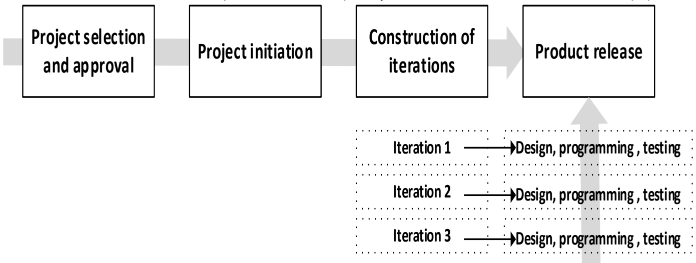


Figure 1. Agile model – general form of the agile development [4]

The advantages of this model are [4]:

≡ Fast response to the user, the first deliveries are in weeks and not in months. A project always has demonstrable results – the final version of each iteration is usable software.

≡ Great flexibility, very often combined with other existing models.

≡ Due to the use of feedback loop and small realises, a high–quality product is created with a high degree of client satisfaction.

≡ Developers are more motivated – they prefer to produce usable solutions, and they don't like to compile documentation.

The disadvantages of this model are [4]:

≡ They are problematic for larger projects. There are discussions about their applicability to larger projects.

≡ The documentation is questionable. Since the documentation is on the back burner, the question arises as to whether the necessary documentation will be compiled at all. This is a big problem, since documentation is an integral part of what developers produce.

AGILE METHODS

— Extreme programming – XP

The extreme programming method – XP is an agile software development method developed by Kent Beck in 1996. The XP method represents a lightweight, flexible, disciplined, low–risk approach to software development that has the ability to manage unclear or rapidly changing requirements. The XP method emphasizes teamwork, therefore managers, developers and clients are part of the team. Team size is one of the limitations of extreme programming, as this method is considered to be suitable for small and medium–sized teams, reportedly anywhere from 2 to 12 team members, although projects with 30 members have been reported successful [5][6].

The life cycle of XP method has six phases and they are as follows [6]:

≡ The research phase deals with requirements modelling and system architecture. In this phase, user requirements, tools and technology are defined. A schedule of system versions is created, i.e. software releases are planned. Based on the schedule, plans are made for each individual iteration. The user writes user stories that represent the software specification [7]. For each user story, it is necessary to create at least one test that will confirm the correctness of the user story [5]. According to the assessment, the user story should be implemented within 3 weeks, and if it takes longer, it should be divided into several stories.

≡ In the Planning Phase, priorities for the implementation of user stories are set, and the content of the first small release of the software is agreed upon. The developer makes an estimate of how much effort and time each user story requires, and then an implementation schedule is agreed upon. The first small release of the software should be completed within two months. If the research phase is done well, then the planning phase should last a few days. The basic goal of planning a software release is to find software functions, and to make a schedule for delivering these functions [8]. During the planning phase, the team size, schedule, and who owns the code and working hours are determined [9].

≡ The iterations to release phase includes basic development activities such as: coding, testing and integration [9]. This is an iterative phase where each iteration can last from one to four weeks. In the first iteration, the stories that make up the structure of the entire software architecture were chosen [7]. After coding, functional testing is performed, and if it is successful, then the code is integrated. If it happens that the code does not fulfil the request, then the so–called refactoring. Quick meetings are used to review development progress or to resolve any issues should they arise. After the final iteration of the code, the production phase begins.

≡ Production phase – software is delivered in small releases. A small piece of planned software is released that implements some business need or function. Frequent releases allow XP to build the desired system incrementally. The duration for one release is from one to four weeks, and it can contain a certain number of iterations. In order to check whether the software is ready for the production phase, tests must be performed [8].

- Maintenance phase – the software continues to evolve for some time. In the maintenance phase, certain new functionalities are created, while the old ones continue to work [7]. It can also lead to the introduction of a new software architecture, but then the team must be much more attentive to the software in use [9].
- Death phase – there are two possible situations in which the software reaches this phase. The first reason is that all software functionalities that users need have been developed, and users are satisfied, and there are no more user stories to implement [9]. Then it is time to carry out the final release of the software, and approach the creation of software documentation. Another reason is that the system does not provide the desired outputs, or if it becomes too expensive for further development, then it is better to stop the software development, which is called entropy death of the system.

The main advantages of the XP method can be summarized in the following few points [2]:

- Incremental development is supported through small and frequent software releases.
- Improving productivity through a feedback mechanism.
- Maintaining simplicity through constant refactoring.
- Improving quality through the creation of automated tests before installing functionality.

On the other hand, the method also has its disadvantages, namely [2]:

- Reduced capability for distributed teams as it focuses on community and co–location.
- This approach to software development requires additional training for newly joined team members.
- XP depends on informal documentation such as user stories, code, etc.
- The practice of user involvement is effective, but on the other hand, it is also very stressful as well as quite expensive because it can keep the customer away from his real work for a long time.

— SCRUM method

Scrum represents an agile method of software development that focuses on the management of the iterative process, instead of individual technical approaches. The Scrum method was developed to manage the system development process. The basis of this method is an empirical approach that applies the ideas of industrial process management theory to system development, resulting in an approach that reintroduces the ideas of flexibility, adaptability and productivity. This approach does not define any specific software development techniques for software implementation. Scrum concentrates on how team members should function to produce a system flexibly in a constantly changing environment [10].

The lifecycle of SCRUM method has three phases as follows [2]:

- The initial phase is the outline planning phase in which the general goals of the system being designed and developed are stated. The project team, necessary tools and resources are also defined. A PBL (product backlog) is generated, which is used to document requirements in the form of user stories and functionality. The requests are then analysed and given specific priorities, and the assessment of the work required for each request is carried out by the product owner, who is also responsible for maintaining a visible and transparent PBL [10]. The PBL is subject to continuous updating since user requests are implemented incrementally, and also during software development there may be a change in the priority of user requests. It is important to note that the documentation is never complete and is supplemented during the process itself in the so–called Sprint Backlogs.
- Sprint phase is a time period of one month or less (most often two weeks) in which one increment of the iterative process is made [10]. The advantage of this way of working is that it is possible to deliver part of the software product to the client at the end of the sprint and to adapt part of the product to new requirements in the next cycle based on his suggestions. In this way, it is possible to learn in the course of the work, and not at the end, based on experience and introduce changes and improvements that give a better end result, that is, a good software product with which the client will be satisfied. Sprint contains the following activities, which can be said that correspond to the traditional stages of the life cycle [10]:
  - Sprint Planning – represents a meeting that lasts a maximum one day and very often shorter at which tasks from the so–called Product Backlog are ordered by priority from the highest to the lowest. The so–called Product Backlog represents the place where the functionalities are defined by the product owner. In this activity not all stakeholders are involved, and it is estimated what needs to be done for these tasks and how many of them can be done during the engineering work.
  - Sprint – is a time–limited period, from 2 to 4 weeks, in which tasks taken from the Sprint Backlog are executed. In short, these tasks are coded, tested, integrated and documented. The goal of this agile methodology is that at the end of each sprint, functionalities have been developed that can go into production.
  - Daily Sprint Meeting – is held every working day at the same time and lasts a maximum 15 minutes. Any deficiencies or obstacles in the system development process or engineering practices are sought, identified and removed to improve the process.
  - Sprint Review – the Scrum development team and the Scrum Master present the results of the sprint, i.e. the work product increment presents to the product

owner, customers and users. Participants evaluate the product increment and decide on the next activities. The preview can even change the direction of the system being built.

- ❖ Sprint Retrospective Meeting – is a meeting where the team and the Scrum Master answer the questions: What was good in the last sprint? What was not good in the last sprint? What to do to work better? After that, the new cycle starts again with a new sprint planning.

≡ The project closure phase occurs when the user requirements are met and the required software goals are achieved based on the dialogue between the product owner and the team. The latest version of the product is ready for "release" and distribution, and the user documentation is being completed [2] [10].

The advantages of the SCRUM method are as follows [2]:

≡ The software product is divided into a smaller set of manageable and understandable components shared by teams resulting in increased communication and shared knowledge.
≡ Transparency – the development team has visibility into everything, including communication and feedback from product owners through the various meetings held throughout the development process.
≡ Self–organization – all teams share responsibilities.
≡ Self–retrospective – provides a tool to self–assess goals achieved against those needed after each iteration or sprint, increasing productivity through continuous testing.
≡ Simple process.
≡ Ignoring any change in sprint duration by prohibiting the addition of any functionality to the sprint, allowing the team to finish their current in–progress functionality.

The disadvantages of the Scrum method are as follows [2]:

≡ Violation of responsibility may occur, since there are no precisely defined responsibilities for each team member.
≡ SCRUM does not prescribe any specific practices, work methods or any guidelines on engineering practices.

— Feature driven development (FDD) method

This method manages short incremental iterations that lead to functional software. The basis of the FDD method is the management of software development based on a list of required characteristics of business needs. The FDD method is a highly adaptive software development method that can account for late changes in software requirements. The main focus of the FDD method is the delivery of high–quality outputs during all phases of the development process [2] [9].

The life cycle of the FDD method contains five sequential processes that are performed incrementally and iteratively, and in this way the final software is delivered. The listed steps are [9] [11]:

≡ Development of the overall model: In this step all team members and experts define the required context and scope of the overall project. Different teams and experts can generate many models, which are then reviewed and the optimal model is selected based on the requirements.
≡ Creation of a list of characteristics: based on the model and the required documentation an overall list of characteristics is created, i.e. a specification for the software. A list of characteristics is created, which is grouped into sets by subject areas.
≡ Planning by characteristics: a high–level plan is created based on a previously approved list of characteristics. The plan is created as an order based on the client's priorities and depending on the characteristics. The master developer assigns characteristics to a specific developer called the class owner.
≡ Design by characteristics: is an iterative step where each iteration can last up to two weeks. The master developer and the class owner create a package project for each class with sequence diagrams. Package design and diagrams are reviewed before approval.
≡ Build by Features: Designs are implemented, after which the code will be reviewed and tested. This is also an iterative step like design by features. After all the iterations are done, the developed features will be published in the main version, then a new set of features is launched, and so on.

The FDD model has certain advantages which can be summarized as [9]:

≡ FDD is a highly adaptable method that can take into account late changes in client requirements.
≡ Delivers high quality results after each stage.
≡ The results of each iteration can be delivered within one to four weeks which helps as we can have quick feedback from clients.

However, there are certain limitations and disadvantages when using the FDD model, such as [9]:

≡ There are no guidelines on requirements gathering, analysis and risk management.
≡ The FDD model requires an expert team with a high level of design and modelling skills.
≡ The FDD model does not take into account issues of project criticality.

OVERVIEW OF AGILE METHODS AND DISCUSSION

Agile methods are essentially iteratively incremental methods. Iterative nature is achieved by using user feedback with which a certain functionality is “polished” until the moment it meets user requirements. Small software releases are given always which is also iterative nature. The first release of software is essentially software with a minimum number of functionalities that it can work with. In this way, a quick response to the customer is offered, the first deliveries are in weeks, not in months.

The project always has demonstrative results – the final version of each iteration is usable software, i.e. each subsequent release adds some new functionality to the software. Due to its approach where users together with the development team choose which functionalities have higher priority, and incremental and iterative nature, this approach is adaptive and customer–oriented, not the development process–oriented. The agile methods that have been processed are suitable for small to medium–sized projects because agile methods also prefer small to medium–sized teams of highly trained professionals [5]. Due to its informal nature, documentation is weak and often not even created. Due to adaptability, there are no long–term plans. It can be said that there are only short–term plans. In agile teams there are so–called self–organizing teams that, through cooperation, communication and leadership, achieve set goals as opposed to the command and control which could be found in the traditional approach [11].

For large, long–life systems developed by a software company for an external client, using an agile approach presents a number of problems. The informality of agile development is incompatible with the legal approach to defining contracts that is commonly used in large companies. When a system user uses an external organization for system development, a software development contract is concluded between them. A software requirements document is usually part of that contract between the customer and the vendor. Because requirements and code development are intertwined, fundamental to agile methods, there is no definitive requirements document that can be included in the contract.

Agile methods are best suited for new software development, not software maintenance. However, most software costs in large companies come from maintaining their existing software systems. If maintenance involves adapting and changing systems in response to new business requirements, there is no clear consensus on the suitability of agile methods for software maintenance. Three types of problems can occur, especially with maintenance [12]:

≡ Lack of product documentation – agile methods in most cases do not care so much about documentation. The collection of requests is conducted informally and gradually. Shorter meetings and face–to–face communication are also preferred. Therefore, there is no coherent document of requirements, unlike traditional methods. This further leads to the problem of how to subsequently maintain and upgrade the system. However, this is a big problem if the continuity of the development team cannot be ensured.

≡ Keeping customers involved – initially the customer's representatives in the development team will be fully engaged. But as time goes on, their interest is lost. Thus, there will have to be adjustments and changes to try to get interest back.

≡ Development team continuity – a fundamental aspect of agile methods is that team members know the system without having to consult the documentation. If the members of this team leave, then the knowledge about the system is also lost. New members who come to the team can have great difficulties while understanding this knowledge of the system. In addition, programmers prefer to develop new software rather than maintain existing ones. Therefore, even when the intention is to keep the development team together, people leave if they are assigned maintenance tasks.

As mentioned before, agile methods are not very suitable for building large systems. That is why it is necessary to perform the so–called scaling agile methods. The fundamental purpose of scaling agile methods is their integration with a planning approach. To solve these problems, most large "agile" software development projects combine practices from plan–driven and agile approaches [12].

Recently, with the arrival of internet of things – IoT, a wide range of devices are integrated into software systems, large amounts of data become available for analysis, virtual reality systems are developed, and therefore there are increasing expectations of intelligent solutions. These new technologies have completely renewed interest and revealed new possibilities in exploring the full potential of both artificial intelligence and user interface. Because of this, a strong role of agile software development in the emergence of new technologies is predicted [13].

CONCLUSIONS

Certainly, agile methods represent an unstoppable trend in software development. As stated, they are very successful in the realization of small to medium software projects, with small teams. They have successfully responded to the changes that and have enabled software engineers to deliver quality software that meets user requirements.

Agile methods follow the presented agile model. The agile model is valid for all agile methods that are iteratively incremental by its nature. This very nature ensures success of agile methods in the fight against changes in requirements and the release of better software versions.

There is great discussion about their performance on large projects in terms of documentation, consistency of the team as well as the size of the team itself. Furthermore, teams must primarily be in the same locations due to the informal nature of the agile process, which leads to problems with distributed teams. Of course, large systems are also long–lived, so they must have maintenance as well as upgrades. Maintenance and upgrading are processes that require the existence of documentation. Agile methods do not really focus on formal documentation, even proponents of agile methods say that documentation is unnecessary, because documentation is often not updated and is therefore worthless. If there is no continuity of the team, and if there is no documentation, the big question is how such software systems could be maintained and upgraded. Because of these problems, agile methods are scaled, i.e. there is a process when the practices of planning and agile methods are combined to a certain extent.

Since the agile approach has fully justified its existence in the struggle with continuous changes and the production of high–quality software, it will certainly find its place in the future.

Note: This paper was presented at International Conference on Applied Sciences – ICAS2022, organized by University Politehnica Timisoara, Faculty of Engineering Hunedoara (ROMANIA) and University of Banja Luka, Faculty of Mechanical Engineering Banja Luka (BOSNIA & HERZEGOVINA), in May 25–28, 2022, in Banja Luka (BOSNIA & HERZEGOVINA)

References

[1] Braude, E. J., & Bernstein, M. E. 2016 Software engineering: modern approaches, Second Edition, Waveland Press, Inc., Illinois, USA
[2] Alsaqqa S., Sawalha S., Hiba A. N. 2020: Agile Software Development: Methodologies and Trends, International Journal of Interactive Mobile Technologies – Vol. 14 NO. 11
[3] Manifesto for Agile Softvware Development, https://agilemanifesto.org
[4] Isaias P., Issa T. 2015: High Level Models and Methodologies for Information Systems, Springer Science+Business Media, New York, USA
[5] Džanić A., Dujmović D. 2011: Razvoj aplikacija korištenjem agilne metodologije Extreme programming – xp, 8th International Scientific Conference on Production Engineering RIM 2011, Velika Kladuša, BiH, September 29 –October 1, pp 401 – 407
[6] Mnkandla E., and Dwolatzky B. 2004: A survey of agile methodologies, The transactions of the SA institute of electrical engineers, Vol. 95 NO. 4
[7] Beck K. 2000: Extreme programming explained: embrace change, Addison–Wesley Professional, USA.
[8] Abrahamsson P., Salo O., Ronkainen J. and Warsta J. 2002: Agile software development methods: Review and analysis, VTT publ., Finland.
[9] Anwer F., Aftab S., Shah S. S. M., Waheed U. 2017: Comparative Analysis of Two Popular Agile Process Models: Extreme Programming and Scrum, International Journal of Computer Science and Telecommunications, Volume 8, Issue 2
[10] Schwaber K. 2004: Agile Project Management with Scrum, Microsoft Press,
[11] Zaimović T., Kozić M., Efendić A., Džanić A. 2021: Self – Organizing Teams in Software Development – Myth or Reality, TEM Journal. Volume 10, Issue 4, pages 1565–1571
[12] Sommerville I. 2016: Software Engineering, Tenth Edition, Pearson Education, Inc
[13] Hoda, R., Salleh, N., & Grundy, J. (2018). The rise and evolution of agile software development. IEEE Software, 35(5), 58–63

ISSN: 2067–3809

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
Tome XV [2022] | Fascicule 4 [October – December]

[1.]Goran KUZMIC, [2.]Dusanka BUNDALO, [3.]Zlatko BUNDALO, [4.]Mirko SAJIC, [1.]Aleksandar STJEPANOVIC, [1.]Mirko STOJCIC

INFORMATION AND COMMUNICATION SYSTEM FOR OPTIMIZATION OF LENGTH, DURATION AND COSTS OF TRAVELING IN ROAD TRAFFIC

[1.]Faculty of Transport and Traffic Engineering Doboj, University of East Sarajevo, BOSNIA & HERZEGOVINA
[2.]Faculty of Philosophy Banja Luka, University of Banja Luka, BOSNIA & HERZEGOVINA
[3.]Faculty of Electrical Engineering Banja Luka, University of Banja Luka, BOSNIA & HERZEGOVINA
[4.]Atos banka ad, Banja Luka, BOSNIA & HERZEGOVINA

Abstract: The possibilities and ways of design and implementation of distributed information and communication systems for management of traffic and road infrastructure in road traffic that are used in intelligent transportation systems, are considered and described in the paper. First, such intelligent transportation systems are shortly described. Then, the basic architecture of one distributed information and communication system for intelligent management in road traffic is proposed. The system consists of a central part of the system and several modules or subsystems, responsible for certain individual functions of control. Most of the paper is dedicated to the description of one practically designed and implemented module, or system, for optimizing travel and travel costs. The design and architecture of the implemented system are described. The system is intended for optimization of the length, time and cost of traveling of users in road traffic. It offers to the user several of the most favourable routes, i.e. traveling routes, between selected travel destinations, with their lengths, expected travel times and expected travel costs, on journeys that cross state borders and use roads with toll payment. It takes into account the duration of congestion at border crossings and toll payment stations, as well as the prices of tolls on the offered traveling routes. More detailed experimental research was performed on the designed and implemented system. Situations when crossing the border between Bosnia and Herzegovina and Serbia, the border between Bosnia and Herzegovina and Croatia, and the border between Serbia and Croatia were observed practically and experimentally. Also, toll payment stations on highways in Republic of Srpska, Serbia and Croatia were observed. Some experimentally obtained results are given in the paper.
Keywords: road traffic, management of traffic, design & architecture, optimization

INTRODUCTION

The constant development of computer, information and communication technologies and systems, as well as intelligent systems based on them, enables the improvement, advancement and increase of possibilities, efficiency and economy of operation of various types of systems in many practical areas and applications. Among the very important areas in which intelligent systems based on the application of information and communication technologies are used are transport and traffic. For control and management of transport and traffic in practice are increasingly being used intelligent transportation systems (ITS – Intelligent Transportation Systems). There are many advantages and benefits that the application of intelligent transportation systems enables and gives to those who organize and implement traffic, as well as to all traffic participants [1–7].

High costs of building transportation infrastructure, lack of space in urban areas, growing criteria for preserving the quality of the environment and acceptable levels of service of the transportation system, have imposed the need for better and secure use of existing capacity of the road network. Great opportunities for solving complex requirements that users and society as a whole place before the traffic system, are in the field of traffic management.

Although the development of hardware and software in the field of transport can provide a more efficient approach to traffic management, it becomes clear that traffic management, viewed as a separate entity, cannot solve all traffic problems. Significant attention is beginning to be paid to the integration of other systems into the framework of traffic management with the application of modern technologies. This concept of integration has contributed to the emergence and development of intelligent transportation systems (ITS) [1–7].

Development in the field of ITS is a strategically necessary component of the development of a country's transport system. Many ITS applications have already entered the framework of national strategies for the development of the future, popularly called e–transport, based on a high degree of integration of modes of transport based on different information and communication systems and platforms. The information and communication technology is always there to help people to perform their jobs and tasks with much less effort, in a more economical, more secure and more simplified way [1–7].

The ways and possibilities of implementation and design of distributed information and communication systems used in intelligent transportation systems for management of traffic and road infrastructure are considered and described in the paper. Described are architecture and organization of such systems, and information and communication technologies used in such systems.

It is proposed the basic architecture of one distributed information and communication system for intelligent management in road traffic. The system consists of a central part of the system and several modules or subsystems. Each module or subsystem is performing a certain individual function of control in the system.

Most of the paper describes one practically designed and implemented module, subsystem or system, system for optimizing travel and travel costs. It is a distributed information communication system for monitoring and actively informing traffic participants, for actively monitoring and informing about the situation at border crossings, and for optimizing the length, duration and costs of travel. That system is intended for use for optimization of the length, time and cost of traveling of users in road traffic. It offers to the user several of the most favourable travel routes, between selected travel destinations, with calculated of their lengths, expected travel times and expected travel costs, on travels that cross state borders and use roads with toll payment. The system takes into account the duration of congestion at border crossings and toll payment stations. It also takes into account the prices of tolls on the offered traveling routes.

Situations when crossing the border between Bosnia and Herzegovina and Serbia, the border between Bosnia and Herzegovina and Croatia, and the border between Serbia and Croatia were observed practically and experimentally. Also, toll payment stations on highways in Republic of Srpska, Serbia and Croatia were observed. Some experimentally obtained results are given in the paper.

INTELLIGENT TRANSPORTATION SYSTEMS

Because of the rapid development, improvement of possibilities and increasing of economy of information and communication technologies, their application in traffic and transport management is constantly increasing. Systems based on these technologies are designed and implemented, which are used for many activities in traffic management: traffic infrastructure management, traffic signalization management, vehicles management, increasing traffic safety, informing traffic participants, reducing travel time and travel costs, etc. [1–7] [1–7]. Such systems for control and management of transport and traffic are intelligent systems, with a kind of intelligence, obtained using information and communication technologies, and are called intelligent transportation systems (ITS). Also, such systems are mostly distributed systems because they are based on the application of distributed information and communication systems [1–7].

The term intelligent transportation systems appeared in the 80s years of the last century, when professionals from the field of transport and traffic noticed the enormous importance and impact of developments in the field of information and communication technologies on those fields as well. Initially, the term intelligent transportation systems (ITS) referred to intelligent systems of vehicles on highways, so called IVHS (Intelligent Vehicle–Highway Systems). Later, it expanded to all systems from all areas of traffic and transport control and management [1–7].

Such systems are sets of interacting elements and established relationships between them, which have the ability to act adaptively in changing situations and conditions. System elements have some similar properties that are essential for the elements to interact or have defined relationships. Several different definitions of ITS are available in the professional literature. In general, it can be said that the term "intelligent transportation systems" refers to a system of measures and technologies applied in the transport system that combine and integrate information and telecommunication technology, with the aim of increasing the level of traffic safety, obtaining more efficient flow of traffic, without delays, with a lower level of environmental pollution [1–7].

Intelligent transportation systems apply information and communication technologies to the mobility sector. Such systems are systems in which information and communication technologies are applied in the field of road transport and traffic, including infrastructure, vehicles and users. The systems are used in traffic management and mobility management, as well as for interfaces with other modes of transport. ITS is used to improve the efficiency and safety of transport in a number of situations, i.e. road transport, traffic management, mobility, etc. ITS technology is used across the world to increase capacity of busy roads and to reduce travel times and costs. ITS services and applications create many benefits as are increased transport efficiency, sustainability, accessibility, safety and security, as well as decreased energy consumption and decreased pollution of environment [1–7].

— Architecture of intelligent transportation systems

In order to achieve maximum quality and benefit from an intelligent transportation system, it is necessary to base its architecture and implementation on a certain strategic framework. The goal of the system architecture, when introducing ITS in transport, is to provide that framework. The framework includes the principles of system design and development with observing the entire life cycle of the system [1–7]. The most common division of ITS architecture is into [1–7]:

- Logical architecture,
- Physical architecture,
- Communication architecture.

The logical architecture, which is also called functional or functionality architecture, defines the internal logic of the relationships between individual parts or units of the system. The physical architecture defines and provides descriptions of the parts of the functional architecture, which may or may not be connected, such to form physical parts or units. Communication architecture defines the ways and forms of communication between parts or units of the system, the flows of data and information. The architecture of ITS is mainly decentralized, i.e. distributed, with more interconected functional modules or subsystems. It is based on adequate application of hardware and software computer, information and communication technologies and systems [1–7].

The architecture of ITS, as well as other information and communication systems, can be viewed as [1–7]:

- System or hardware architecture,
- Software or program architecture.

There are three types of system or hardware architecture of ITS: centralized, decentralized and hybrid. ITS mainly use decentralized, i.e. distributed system architecture. It is based on the adequate application of computer hardware, information and communication hardware technologies and devices

There are several different software or programming architectures of ITS. As this are distributed systems, the most important software architectures of ITS are: layer–based architectures, object–based architectures, data–based architectures and event–based architectures. They are based on the adequate application of software information and communication technologies, on adequate software solutions and applications.

ITS architecture is primarily related to information exchange and control between systems at different levels of abstraction. Four levels of ITS architecture can be defined: Level 0, Level 1, Level 2 and Level 3. Level 0 includes the level of technical components and subsystems, and the way of their design. Level 1 relates to the level of used technologies. Level 2 refers to a level within an organization or system. Level 3 deals with the possibilities of interoperability of the work of multiple organizations or systems

Various frameworks of ITS architectures have been developed around the world. The United States of America has done the most, where the national ITS architecture focuses on the physical aspects. Next is Europe, where the focus of national ITS architecture is on user needs and functional aspects. Then comes Japan, Australia and Canada, who have used the good sides of all available architectures, and made adjustments to their own needs.

— Communication architecture of intelligent transportation system

In planning and developing the architecture framework of ITS, a very important segment is the view on communication in the system and the communication architecture. The communication architecture ensures the unity of the transport and communication system. There are more different technologies available for implementing of communication and communication architecture in ITS. Practically all communication technologies, wired and wireless, can be used. Wired technologies are mainly used for connecting and communicating of stationary parts of transport infrastructure and stationary parts of ITS. For most other purposes, wireless technologies are used, the application of which is constantly increasing. Wireless technologies are used for communication between vehicles, communication between vehicles and road infrastructure, communication between traffic participants and the system, and communication of the entire system with the central monitoring system or central station. Also, cooperation between traffic participants and road transport infrastructure requires the existence of appropriate communication possibilities, mostly wireless. Different types of communication with and from the vehicle are used, which are also wireless [1–7].

Wireless communication technologies for purposes of ITS are classified into [1–7]:

≡ General purpose wireless communication technologies (DVB, DAB, Cellular networks, WiMAX, WLAN, WPAN and IR),
≡ Dedicated wireless communication systems for vehicles (V2V and V2I based on DSRC and CALM technology).

European approach to communication architecture of ITS consists of four separate subsystems or stations, Personal Station (PS), Central Station (CS), Vehicle Station (VS) and Roadside Station (RS), and their interconnection [1–7].

INFORMATION AND COMMUNICATION SYSTEM FOR MANAGEMENT IN ROAD TRAFFIC

Here is described one proposed distributed information and communication system for intelligent management in road traffic and its design. Basic architecture of the distributed information and communication system for intelligent management in road traffic is proposed and described. The system consists of the central part of the system and several modules or subsystems. Modules or subsystems are performing certain individual functions of control in road traffic and in the system.

Basic architecture of proposed distributed information and communication system for intelligent road traffic management is shown in Figure 1. The main part of the system is the central part of the system, central monitoring system (DIKS ITS). The central monitoring system communicates with the modules and coordinates their activities and operations. Each module or subsystem performs one concrete function and activity of control in the road traffic and transportation.

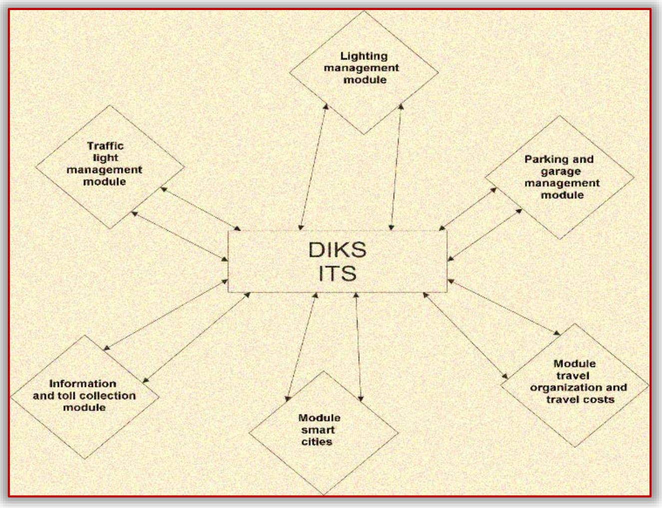


Figure 1. Basic architecture of the proposed system

The basic modules or subsystems of the proposed system are [8–11]:

≡ traffic lights management module,
≡ lighting management module,
≡ parking and garages management module,
≡ information and toll collection management module,

- module of smart cities,
- module for optimization of travel organization and travel costs.

Every module is independent and performs its specific function in the road traffic management system. All modules are coordinated by the central monitoring part of the system and they also communicate with each other.

SYSTEM FOR OPTIMIZING OF TRAVEL ORGANIZATION AND TRAVEL COSTS

It was practically designed and implemented module or system for optimizing of travel organization and travel costs. The operation of the system was also experimentally tested and verified. It is module of distributed information communication system for monitoring and active informing of road traffic participants, for active monitoring and informing about situation on border crossings and for optimization of length, duration time and costs of travel. The system suggests to the user a few the most favourable traveling routes, between selected travel destinations, for travels that could cross state borders and use roads with toll payment. It gives users calculated lengths, expected travel times and expected travel costs for all suggested traveling routes. The duration of congestion at border crossings and toll payment stations, as well as the prices of tolls on the suggested routes are taken in the account. Practically and experimentally were observed traveling routes with crossing the border between Bosnia and Herzegovina and Serbia, the border between Bosnia and Herzegovina and Croatia, and the border between Serbia and Croatia. Toll payment stations on highways in Republic of Srpska, Serbia and Croatia were also observed.

— Organization and operation of the system

Based on the analysis of user needs and wishes of interested parties, participants and users of the system, the following functions of the system were defined:

- Monitoring of current delays at the border crossings of the borders of Bosnia and Herzegovina, Croatia and Serbia by downloading and receiving data from the border crossings about the time needed to cross the border,
- Downloading and taking the current location of the travel participant (user) based on his/her GPS location,
- Estimation of the time needed for user to arrive at individual border crossings,
- Monitoring of current traffic congestions at individual toll booths along the observed road section,
- Calculation of total toll costs along the observed road section
- Informing users about the time needed to arrival at individual border crossing, about current delays at individual border crossings, about current delays at toll booths and about total toll costs that should be paid,
- Determining the optimal parameters for the travel based on the criteria given by the user (length of the travel, time duration of the travel, travel costs, etc.).

By using the application on his/her mobile phone, the user selects the destination of travel. The application determines user current location using the application GPS module, i.e., the user mobile phone. Based on the given location of the destination and the current location of the user, the application processes the given activity and sends a request to the central monitoring system (command or control centre) to update data on current conditions at border crossings and toll stations. The command centre processes the received request. On the basis of information on current conditions at border crossings and toll stations and data placed in the database on traffic congestions during the day at individual border crossings, the command centre updates the data and performs needed calculations.

The proposed system is divided into two parts:

- command or control part,
- acquisition part.

The command or control part is located in the monitoring and control centre. It processes all the data and presents it and obtained results to users via changeable traffic signs or via the application on a mobile phone.

The acquisition part is located in the field, on roads and border crossings, and collects the data. It consists of sensors and surveillance cameras at border crossings and toll booths on the highways along the road route being travelled.

Figure 2 shows the structure and principle of operation of the command, control or central, part in the monitoring and control centre.

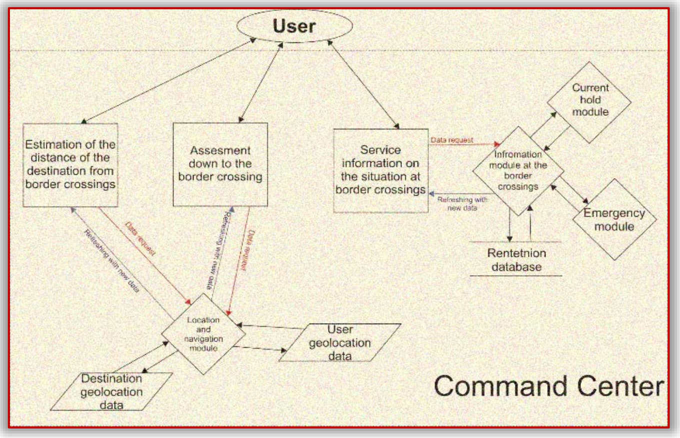


Figure 2. Structure and principle of operation of the command, control or central, part in the monitoring and control centre

Based on the initial data given by the application user, the command centre performs the following steps:

- Based on the data received from the user, calculates the approximate time needed (T1) to the user to arrive at individual border crossings, as well as the average time required to arrive at the destination from the border crossing (T2),
- Calculates the current distance of the user from individual border crossings (S1) and the distance between border crossings to the destination (S2),
- Based on the data on the current conditions at the border crossings and the average delay at the border

crossings, calculates the time needed to cross the border crossing (T3),

- Based on the data about tolls at the toll boats on the travel route, calculates the total toll cost (C) to be paid
- Returns to the user the information about individual border crossings with the data about the total time needed to arrive at the destination and cross the border (T=T1+ T2+ T3), about the total distance of travel (S= S1+ S2) and about total toll cost (C) for the travel.

Based on the obtained information, the user decides on which rout to travel and via which border crossing. Also, based on certain criteria that can be defined by the user, the system can suggest the most favourable route to the user for realization of that travel. These criteria can be: the shortest travel time, the smallest distance travelled or the minimum of travel costs. Thus, the optimization of the road route and travel costs can be achieved.

Figure 3 shows structure and principle of operation of acquisition part of the system. In the acquisition part are used cameras for the surveillance of border crossings, sensors and surveillance cameras at the toll stations. Video sensors are used to detect accidents and traffic congestion at toll stations of highways in the Republic of Srpska. Changeable traffic signs are planned to be installed on certain sections of the highways. It will be used for information of road users, on which the results of current delays at border crossings and toll stations would be presented via the control centre. The algorithm of operation of the acquisition part is as follows:

- The traffic management module sends a request to the video sensors and they, in the form of cameras, send to the module the current photo or video, as needed.
- The analysis of the obtained photograph is performed in the traffic management module, obtained information is forwarded to the information module, from where the information is further sent to traffic participants via dynamic traffic signs.
- In case an accident is detected, the information is forwarded to the call centre module, from where the information is further forwarded to the interested services.

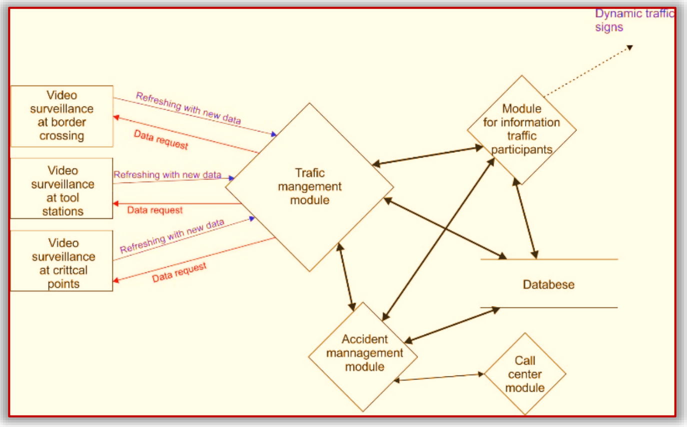


Figure 3. Structure and principle of operation of acquisition part of the system

The system that was proposed, designed and used in the experiment consists of a hardware part and a software part. The software part includes applications installed on the user's mobile phone and web applications installed on the server, which interact with the database. The hardware architecture of the system consists of the user's smartphone, computers of sensors and video surveillance installed at border crossings, and a central computer installed in the command centre for monitoring, traffic management and informing traffic participants.

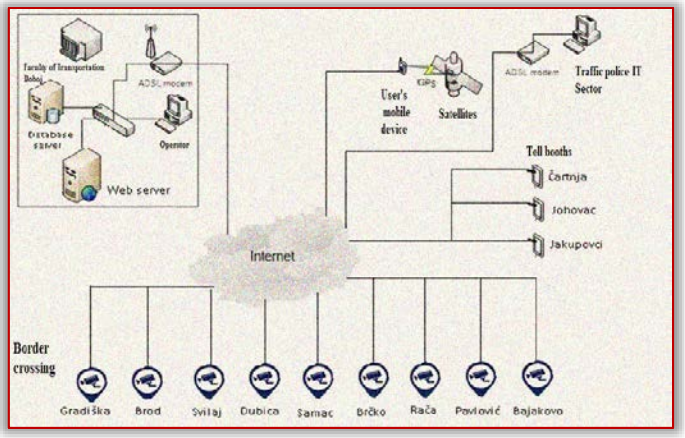


Figure 4. Architecture of distributed information communication system for traffic monitoring and actively informing traffic participants

The architecture of that system for monitoring traffic and actively informing users about congestion at border crossings and at toll booths, as well as for optimizing the travel route and travel costs, is shown in Figure 4. The system consists of following modules:

- Central monitoring system installed at the Faculty of Traffic and Transport Engineering in Doboj, Bosnia and Herzegovina,
- Multimedia devices (smart mobile phones of users),
- Computers (Raspberry PI with the necessary software) placed at border crossings with traffic surveillance cameras,
- Server with installed application for collecting and processing data from border crossings and toll booths,
- Server with installed database (MySQL).

❖ Software organization of the system

The software architecture of the system designed and used in the experimental research is shown in Figure 5. It can be seen that the software consists of two separate parts: the software for the smart mobile phone and the software for the central monitoring system.

The software for the smart mobile phones includes applications installed on the user's mobile devices and with the appropriate GUI (Graphic User Interface). By accessing these applications, users interact with the transportation system through a central monitoring system. The software for the central monitoring system consists of applications based on HTML5, CSS3, JavaScript, PHP, Google Maps technologies, which are placed on the server in the central monitoring system. Those applications have the function of connecting of all modules into a unique system. They enable active information of traffic participants and the determination and selection of the optimal travel route, taking into account the length, time duration and costs of the travel.

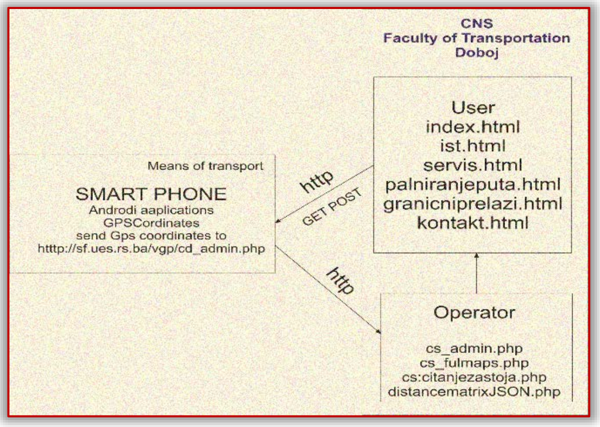


Figure 5. Software system architecture

The free phpMyAdmin tool, available at web page sf.ues.rs.ba/vgp/phpmyadmin, was used for the design and management of databases implemented in MySQL. A database (baza1) was designed, which was placed on the server sf.ues.rs.ba/vgp/baza. The database is storing data of the geolocation of individual border crossings that are included in the research and data of the geolocation of individual toll stations located on highways in the Republic of Srpska. In addition to geolocation, the database includes the time delays at border crossing locations for every hour of the day. Three tables were designed. The first table contains data of the locations of border crossings, with associated attributes–columns. The second table contains data of the delay times at border crossings and toll booths. The third table contains data about toll costs at toll booths. For database modelling, the MOL model (Model–Object–Links) was used, which is based on the concept of entities (objects and links).

An integral part of the software are applications programmed for Android OS and web applications written in HTML5 language. Some web applications are executed on the client side (written in JavaScript and Java code), and some are executed on the server side (written in PHP script and Payton). Different user interfaces (UI) have been designed to access the applications, i.e. the system. The user interface for Android applications consists of a part for display on the phone screen and the part for processing of events.

For the purpose of research, and for the needs of the experiment, a web application was designed based on publicly available opensource tools. The web application was developed using the HTML5 language, CSS3 styles, JavaScript, Java Applets that are executed on the client side, and PHP language for execution on the server side. Among other technologies, Android OS, Java, Google Maps service for displaying maps, "Distance Matrix API" service for calculating the time needed to cross a certain section of the road were used.

The developed applications perform following functions:

- The "GPSCordinates" application is installed in the client's mobile phone. Through the GPS module, it finds the GPS coordinates and sends them to the application located on the server. In addition to the GPS coordinates, the user also enters the travel destination, which is also forwarded to the application on the server. The data is sent via the HTTP protocol (GPRS technology), a text file containing the geocoordinates of the client and the destination. The web application, placed on the domain www.sf.ues.rs.ba/vgp, reads the sent data through a PHP script and sends it to the "baza1" database in the „privremenipodaci" table.
- The application located on the server downloads data from the „privremenipodaci" table. Based on the data of the current location and the location of the border crossings, from the GPiNM location table, it sends that data with a JSON query to the "Distance Matrix API" web service. From the file returned by the web service "Distance Matrix API" following data are read: distance and time duration for each border crossing. Based on the distance data, two or three border crossings are selected using the shortest distance method.
- After selecting the two or three most suitable border crossings and based on the client's destination data, the application sends this data via a JSON query to the web service "Distance Matrix API". The following data is such obtained and read: distance and time duration from the border crossings to the destination.
- The obtained data is processed, and then by the SQL code from the „vrijemezadrzavanja" table are read the data of the current delays at the border crossings and the obtained values are added to the already existing values.
- By the SQL code from the „putarine" table are read the data of the toll costs on toll boots along travel route and calculated total toll cost for the travel.
- Thus obtained the data is sent to the client in the text form, where two or three border crossings are offered, with estimated travel times, travel distances and total tool costs.

OPTIMIZATION OF TRAVEL ROUTE AND TRAVEL COSTS

For the experimental verification and testing of the proposed system, two road routes were taken and used. The first road route is Doboj – Zagreb, with border crossings Svilaj, Brod, Gradiska and Dubica. The second road route is Doboj – Beograd, with border crossings Svilaj, Samac, Brcko, Raca and Pavlovica Most.

The HP ProLiant DL320e Gen8 server was used to test the system in real conditions, which was installed at the Faculty of Traffic and Transport Engineering in Doboj. The Linux system Centos 7.5 and the following software are installed on that server:

- phpMyAdmin, intended for working with the PHP script language,
- Apache server, intended for working and testing web applications on a local server,
- MySql, which is used for database design.

Together with the software for working with databases and testing of applications, on the server are installed applications on the website (www.sf.ues.rs.ba/vgp), for user and system interaction. Access to the application is possible using smartphones, tablets, stationary and laptop computers. A method based on the application of the web service "Distance MatriX API" was used to estimate the time of arrival at the destination via individual border crossings.

❖ Case 1: Travel route Doboj – Zagreb

On this travel route, the following four border crossings between Bosnia and Herzegovina and Croatia were taken into observation: Svilaj, Brod, Gradiska and Dubica. Figure 7 shows a block diagram with practically obtained distances between border crossings and destinations with estimated travel times for this case.

Figure 6. Case 1, travel route Doboj – Zagreb

❖ Case 2: Travel route Doboj – Beograd

On this travel route, two directions with six border crossings between Bosnia and Herzegovina and Serbia were taken into consideration. The first direction is with the Svilaj, Samac, Brcko and Bajakovo crossings. The other direction is with Raca and Pavlovica Most crossings. In the first direction, it is travelled through two state borders, Bosnia and Herzegovina – Croatia and Croatia – Serbia. In the second direction, it is travelled through one state border, Bosnia and Herzegovina – Serbia.

Figure 7. Case 2, travel route Doboj – Beograd

Figure 7 shows a block diagram with practically obtained distances between border crossings and destinations with estimated travel times for this case.

— Methods for travel time estimation

Two methods were used to estimate the travel time:

- Method that uses the web service "Distance MatriX API",
- Method that uses the Kalman filter.

Web service "Distance MatriX API" of Google is a service that gives feedback information about the distance between two points and the travel time on a selected road route, based on a user given query. As input parameters of the query are defined the initial and final destinations. The input parameters can be given in the form of destinations names or in the form of geocoordinates of selected locations. Of the other parameters are chosen the way of transport and the units in which the output values will be given. For users of the free API, the number of requests per day is limited to 2500. As a response to the given query, two forms of documents can be obtained, in XML and JSON (JavaScript Object Notation) form.

The use of the Kalman filter for time prediction is based on the calculation of estimated states, based on measurements with noise, for a random process, which is described by a linear discrete model in the space of states. The Kalman filter is an optimal estimator and predictor of an unknown quantity and has found wide application in time prediction, navigation, tracking, and object trajectory prediction.

Both used methods give approximately equal results.

— Obtained results

For a simpler and faster use of the possibilities of this system, as part of the overall realized software, an application was developed and implemented for the graphic presentation of the suggested most favourable routes, with the showing of maps for all those options. The application is activated by selecting the "Planiranje puta" option. Figure 8 and Figure 9 show examples of such obtained results for one day in March 2022, for two travel routes from Doboj to Zagreb, via different border crossings. The figures show all the details for the selected travel routes: starting and ending points of the travel, suggested routes, calculated distances, times needed to travel to the given destination and total tolls for those travels.

Figure 8 shows example of obtained results for travel route Doboj – Zagreb, via the Gradiska border crossing. Figure 9 shows example of obtained results for other travel route Doboj – Zagreb, via the Brod border crossing. From the results shown, it can be seen that the travel route Doboj–Gradiska–Zagreb is shorter and that the total duration of the travel on that route is also shorter. Also, that travel route is faster to travel because most of the road is a highway. However, the time needed to cross the border crossing at the Gradiska was much longer than at the Brod border crossing. Also, the total toll that needs to be paid on that travel route is higher. Based on these given data and his preferences, the user can decide to choose one of the offered travel routes.

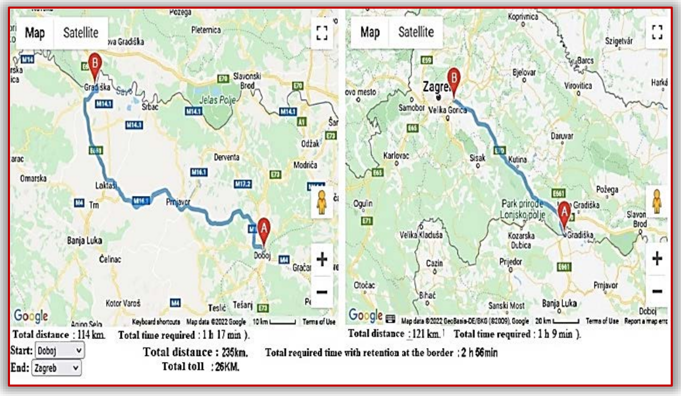


Figure 8. Obtained results for trave route Doboj – Gradiska – Zagreb

Figure 9. Obtained results for travel route Doboj – Brod – Zagreb

CONCLUSION

By implementing the distributed information communication system with dynamic web applications included, it is provided the possibility of active monitoring of current situations at border crossings, as well as on individual sections of the road selected sections. By connecting information and communication flows within intelligent transportation system and distributed information systems, it has been shown that it is possible to achieve the necessary impact by improving the performance of transport systems, in order to achieve more efficient, faster and more accurate problem solving in transport and in various dynamically complex situations. By applying distributed information systems in interaction with communication technologies, it improves multi–aspect traffic management, from real–time vehicle monitoring, monitoring of conditions on certain sections of the road, real–time monitoring of border crossings, and constant coordination of traffic participants through media in traffic.

Using such distributed information and communication system it is possible to travel participants to effectively optimize their traveling in road traffic. Very easy, using their smart mobile phones, users can obtain data about length of travel, time duration and costs of travel in road traffic for his/her traveling route. Based on his/her preferences, minimal length of travel, minimal time duration of travel or minimal costs of travel, the user can choose one of the offered travel routes, that is optimal for his/her needs and wishes.

Note: This paper was presented at International Conference on Applied Sciences – ICAS2022, organized by University Politehnica Timisoara, Faculty of Engineering Hunedoara (ROMANIA) and University of Banja Luka, Faculty of Mechanical Engineering Banja Luka (BOSNIA & HERZEGOVINA), in May 25–28, 2022, in Banja Luka (BOSNIA & HERZEGOVINA)

References

[1] E. Deakin, K. Trapenberg Frick, A. Skabardonis: Intelligent Transport Systems–Linking Technology and Transport Policy to Help Steer the Future, Journal Access, no. 34, 2009.
[2] A. Perallos, U. Hernandez–Jayo, E. Onieva,I. Julio García–Zuazola: Intelligent Transport Systems– Technologies and Applications, John Wiley, 2016.
[3] S. Ghosh, T. S. Lee: Intelligent Transportation Systems–Smart and Green Infrastructure Design, CRC Press, 2010.
[4] R. Gordon: Intelligent Transportation Systems–Functional Design for Effective Traffic Management, Springer, 2016.
[5] J. Carlos Amaro Ferreira: Intelligent Transportation Systems for Electric Vehicles, MDPI, 2020.
[6] P. Pagano: Intelligent Transportation Systems From Good Practices to Standards, CRC Press, 2021.
[7] L. Jain, X. Zhao, V. Balas: Information Technology and Intelligent Transportation Systems, IOS Press, 2020.
[8] Z. Bundalo, M. Veljko, D. Bundalo, G. Kuzmic, M. Sajic, A. Ramakic: Energy Efficient Embedded Systems for LED Lighting Control in Traffic, Proceedings of 8th Mediterranean Conference on Embedded Computing MECO2019, Budva, Montenegro, June 2019, pp.202–205.
[9] D. Pasalic, B. Cvijic, D. Bundalo, Z. Bundalo, G. Kuzmic: Embedded Systems for User Identification in Access to Objects and Services Using Mobile Phone, Proceedings of 6th Mediterranean Conference on Embedded Computing MECO2017, Bar, Montenegro, June 2017, pp.109–112.
[10] M. Sajic, D. Bundalo, Z. Bundalo, L. Sajic, D. Lalic, G. Kuzmic, (2019), Smart Universal Multifunctional Digital Terminal/Portal Devices, Proceedings of 8th Mediterranean Conference on Embedded Computing MECO2019, Budva, Montenegro, June 2019, pp.171–174.
[11] M. Sajic, D. Bundalo, G. Kuzmić, Z. Bundalo, D. Lalic (2019), Automation of teller/counter services in smart cities concept using universal digital devices, Proceedings of 27th Telecommunications forum TELFOR2019, Belgrade, Serbia, November 2019.

ACTA TECHNICA CORVINIENSIS
Bulletin of Engineering
ISSN: 2067–3809

[1.]Eugen MARIN, [1.]Dragoş MANEA, [1.]Marinela MATEESCU,
[1.]Gabriel–Valentin GHEORGHE, [2.]Imre KISS, [1.]Carmen BĂLŢATU

INNOVATIVE TECHNOLOGIES AND EQUIPMENT FOR THE MECHANIZATION OF SOIL WORKS WITH REDUCED IMPACT ON THE ENVIRONMENT. PRESENT AND PERSPECTIVE

[1.]INMA Bucharest, Ion Ionescu de la Brad Blvd., no. 6, sector 1, Bucuresti, ROMANIA
[2.]University Politehnica Timisoara, Faculty of Engineering Hunedoara, Hunedoara, ROMANIA

Abstract: Sustainable agriculture involves, first of all, the development of innovative mechanization technologies for tillage, the establishment and maintenance of agricultural crops that satisfy quantitatively and qualitatively the current needs of people without compromising the requirements or options of future generations and without causing irreversible damage to the environment. Ensuring a healthy and harmonious environment, as the quality of soil, water, air, vegetation and food depends on many factors, but the quality of the land and implicitly of the soil are decisive due to the excessive loosening of the soil, the removal of plant debris from the surface, excessive mineral fertilization, decreased content and degradation of soil organic matter. The paper presents research and perspectives on innovative technologies for mechanization of soil works without overturning the furrow and the establishment of crops by developing technical equipment for sustainable land use systems, which minimize soil degradation, prevent reducing biodiversity, restoring productive capacity and vital processes of degraded soils in order to increase the quality of life
Keywords: tillage without overturning the furrow, the establishment of vegetable crops, sustainable use

INTRODUCTION

Agriculture has a major contribution to the sustainable development of the economy and society, through the economic and social opportunities it gives to the current and future generations. This, apart from the fact that it represents the sector that ensures the food of mankind, constitutes the very basis of the existence of life. At the same time, however, agriculture must also assume the responsibility of protecting the soil and other environmental resources that it can degrade [1].

As estimated in some statistics, the population of the globe is continuously growing, estimating that by 2050 it will reach approximately 10 billion inhabitants, which will lead to an increase in the demand for food and raw materials [2], [5].

Under these conditions, through the pressure exerted by mankind due to the ever–increasing needs, the global capacity to produce food in agriculture will be greatly tested [3], [4]. In the future, the expansion of agriculture in a "horizontal" plan is no longer possible, due to the fact that worldwide the reserves of productive land are exhausted, and the uncultivated surface is no longer suitable for the development of high–performing, profitable, viable, sustainable agriculture [6].

The development of mechanized agricultural technologies, namely the use of increasingly larger and heavier tractors and machines, with advantages regarding productivity and economic efficiency, led to the appearance, intensification and expansion of some processes in the physical degradation of the soil, especially the destructuring and human compaction [7]. A particular problem is the one that occurs in areas with a drier climate, where intensive tillage and the removal of plant residues contribute to the loss of water from the soil, accentuating the processes of drought and desertification [8]. Among the most widespread negative processes of energy–intensive agriculture, we mention: the movement and deep leaching of nutrients and other chemical compounds causing the contamination of water resources, their translocation from the soil to the vegetative mass, and from here to the entire trophic chain; the excessive increase in soil compaction, the excess of surface water and the risk of erosion, the increase in emissions from the soil leading to the degradation and global warming of the atmosphere [8]. The negative influence of the agricultural technological system on the modification and reduction of biodiversity due to the excessive loosening of the soil, the removal of plant remains from the surface, the excessive mineral fertilization, the decrease in the content and the degradation of the organic matter in the soil cannot be neglected either [9].

Consequently, there must be major interest in the promotion of innovative mechanization technologies used within the technological itineraries, for systems for the sustainable use of agricultural lands, which prevent or minimize soil degradation, restore the productive capacity and vital processes of degraded soils [10].

MATERIALS & METHOD

The research materials and methods consist in the use of the reading sheets of the research phases from the research projects carried out within the research programs INNOVATION, PARTNERSHIPS IN THE PRIORITY AREAS, POC 2014–2020, ADER 2020, NUCLEU [11–19].

RESULTS & DISCUSSION

In this paper, some of the research carried out within INMA Bucharest are presented, which concern innovative technologies for the mechanization of soil works and the establishment of vegetable crops (grass cereals and fallow plants) in accordance with sustainable agriculture:

A. Technical equipment with active bodies trained for the work of loosening the soil in depth, EAA

The technical equipment (Figure 1) is intended for deep loosening works, in order to reduce the primary or secondary compaction, primarily of podzolic, reddish brown soils, vertisols, lacustrine soils and heavy alluvial soils. It can also be used on chernozems, brown soils and medium alluvial soils. It cannot be used for the execution of deep loosening works on sandy soils, soils with gravel and superficial hard rock, on flood lands and with ground water at a depth of less than 1 m depth, lands with a slope of more than 15% and on lands with slips.

Figure 1. Technical equipment with active bodies trained for the work of loosening the soil in depth

The main subassemblies of the technical equipment with active bodies driven for the work of loosening the soil in depth are the frame provided at the front with a yoke and hydraulic cylinder for coupling to the tractor's three–point suspension mechanism; the active working organ of the oscillating vertical knife type with vibrating chisel tip; the transmission consisting of cardan shaft and conical reducer with two left–right outputs; elastic couplings with bolts; right wheel and left wheel for adjusting the working depth; the support leg for stationary support; roller for aggressive shredding, placement and additional levelling of clods.

B. Multifunctional aggregate for working the soil, MATINA

The multifunctional aggregate for working the soil (Figure 2) promotes the conservative farming system, a system that ensures quantitatively and qualitatively competitive productions with those obtained in the classical system, but with low costs and high profit, under the conditions in which it is ensured:

≡ accumulation and storage in the soil of the entire amount of water from precipitation during the summer and autumn;
≡ accumulation in the soil of a large amount of nitrates by intensifying nitrification processes;
≡ obtaining a layer of loose soil, but at the same time settled to ensure a good rooting of the plants and to avoid the process of removing shoes;
≡ obtaining a germinative bed without lumps, so that the seed can make as intimate contact with the soil as possible to sprout in the shortest possible time.

The aggregate consists of the following main assemblies: battery with chisel organs; battery with independent discs; rod roller; monobeam chassis with transport train.

The battery with chisel organs loosens the soil in depth with loosening organs, to facilitate the penetration of plant roots more easily, in depth, for the necessary nutrients and water.

The battery with chisel organs consists of a metal frame on which five active organs are mounted (two organs on the front pipe and three organs on the rear pipe).

Figure 2. Multifunctional aggregate for working the soil in agricultural holdings

The battery with independent discs performs the preparation of the germinal bed with specific working organs, of the type of crenellated spherical discs.

The battery with independent discs is composed of a metal frame and two half–batteries, the front one with the active part of the discs oriented to the left and the rear one with the active part of the discs oriented to the right.

The roller with rods ensures a shredding and a slight levelling off the ground processed by the crenelated discs, being located behind them and it consists of a frame, an elastic adjustment system and the roller with rods.

The monobeam chassis with transport train constitutes the skeleton on which all the components of the aggregate mentioned above are mounted. It is composed of a crossbar, an elastic system for adjusting and maintaining the horizontality of the chassis, monobeam frame with built–in hydraulic pipes, hydraulic cylinder for the transport train.

C. Multifunctional equipment for working the soil in agricultural holdings, SCAR–ART

The multifunctional equipment for tilling the soil in agricultural holdings (Figure 3) promotes the conservative farming system, a system that ensures quantitatively and qualitatively competitive productions with those obtained in the classical system, but with low costs and high profit, under the conditions of improving the properties of the soil.

The operations performed in a single pass are as follows:

≡ intensive decompaction of soil layers;
≡ breaking the hardpan;
≡ soil preparation at working depths of 10–14 cm with independent disc–type working bodies;
≡ crushing the lumps on the surface.

The equipment additionally executes the subsoil of the soil at working depths of 0.20–0.25 m, without overturning the slices processed in the aggregate with the 150–200 HP tractors.

Figure 3. Multifunctional equipment for working the soil in agricultural holdings

D. Decompactor for deficient soils with simultaneous administration of nutrients, DECOM FERTI

The technical equipment (Figure 4) is composed of two main assemblies: DECOM, which through the specific working organs (chassis, active organs with reversible chisel knives, rollers with claws, working depth adjustment wheel) achieves the loosening and improvement of soil permeability in the purpose of storing and conserving water and FERTI which, through the distribution system and the conducting tubes, brings improvements to the complex functions of the soil by adding nutrients (solid chemical fertilizers), in order to achieve the most favorable conditions for plant nutrition to obtain spores (quantitative and qualitative) of agricultural production. The application of basic fertilizers (NPK) is carried out in such a way as to harmonize with the needs of the crop plant and the properties of the soils to be applied to ensure maximum efficiency and reduce the risk of losses or blockages through different processes.

Figure 4. Decompactor for deficient soils with simultaneous administration of nutrients

E. Harrow with independent disks, GD4

The harrow with independent discs (Figure 5) executes in one pass:

≡ weeding;
≡ the preparation of the seedbed for the purpose of sowing grassy cereals and grassy plants at working depths between 10–14 cm.

It is used summer–autumn (in certain situations spring) on fresh ploughing, in all types of soil located on flat land or with a slope of up to 6º.

Weeding is carried out immediately after harvesting grassy or leguminous cereals because the soil remains free (unshaded) and water evaporation intensifies. This reduces the rate of water evaporation from the soil by breaking capillarity. Moreover, weeding ensures the mechanical destruction of weeds, stimulates the germination of the seeds left on the ground so that they can be destroyed chemically or mechanically, and last but not least, it ensures the leveling of the soil.

The seedbed made by the harrow with independent discs, GD4 complies with the following rules:

≡ the attack angle of the disks is the same for all batteries;
≡ the front batteries work at the same depth as the rear ones;
≡ the work speed corresponds to the agrotechnical requirements.

Figure 5. Harrow with independent disks

F. Chisel, PC13

The chisel (Figure 6) is intended for the execution of the soil work without overturning the furrow, on all soils with a maximum clay content of 32%, in order to establish cereal crops, especially grass cereals with disc seeders, within the input technologies reduced. The use of the chisel is mandatory on saline lands or those with a tendency to become saline, those with a thin fertile layer, and those subject to wind erosion.

Figure 6. Chisel, PC 13

G. Technical equipment with working bodies for preparing the soil and sowing grassy cereals, SGR

The technical equipment (Figure 10) is intended for soil preparation and sowing that uses working organs for the establishment of grassy cereal crops, grain legumes, fodder plants, in prepared (Variant I) or semi–prepared land (crusted land that requires further loosening of the layer on the surface for sowing), as well as on land where basic soil processing, sowing and subsequent compaction are carried out in a single work cycle (Variant II).

The technical equipment with working organs for preparing the germinative bed and sowing, SGR by equipping vertical rotors with tooth knives is used for sowing grassy cereals in semi–prepared land for sowing. The vertical rotors with tooth knives process the soil, worked by ploughing, at depths of up to 8 cm, thus creating a suitable germinative bed for sowing.

The technical equipment with working organs for preparing the germinative bed and sowing, SGR by equipping vertical rotors with blade knives is used for sowing grassy cereals in unprepared land for sowing. The vertical rotors with blade knives work the soil at depths of up to 12 cm, thus creating a suitable germinative bed for sowing.

The technical equipment with working bodies for preparing the soil and sowing grassy cereals, SGR (Figure 11) works in aggregate with the 150 HP tractors on wheels equipped with category 3 hydraulic lifters according to SR ISO 730–1+C1.

Figure 10. Technical equipment with working bodies for preparing the soil and sowing grassy cereals

Figure 11. Technical equipment with working bodies for preparing the soil and sowing grassy cereals SGR

The technical equipment with working bodies for preparing the soil and sowing consists of a harrow with vertical rotors (Figure 12), which can work independently to work the soil or to prepare the seed bed, and a mechanical–pneumatic seeder (Figure 13) which can he worked independently sowing grassy cereals.

Figure 12. Harrow with vertical rotors

Figure 13. Mechanical–pneumatic seeder

H. The technical equipment for tilling the soil in strips, sowing weeds, fertilizing and distributing insecticides, ELS 4

The technical equipment for working the soil in strips, sowing weeds, fertilizing and distributing insecticides (Figure 14) can be used independently in one pass for processing, mobilizing, and loosening the soil on an area called a "narrow strip" and in another pass for sowing crops of creeping plants (corn–by–corn sowing, sunflower, etc.) simultaneously with the administration of chemical fertilizers and insecticides or simultaneously when tilling the soil in "narrow strips", sowing creeping plants, fertilizing, distributing granulated insecticides, incorporating into the soil, covering and light compaction is achieved in a single pass.

Figure 14. The technical equipment for tilling the soil in strips, sowing weeds, fertilizing and distributing insecticides

The technical equipment consists of a front frame, a coupling bar, some side bars, some bolts, some supports, some clamps, some nuts, a rear frame, a central tie rod, some bolts secured with a pin and an elastic safety, some left/right wheels for support, some working sections equipped with two notched discs mounted at an angle, a straight notched disc, a chisel knife, two notched spherical discs, some sowing sections that have seed distribution devices driven from a support wheel and right–hand drive by means of a chain–wheel drive, some boxes for chemical fertilizers and some boxes for granulated insecticides having in their composition dispensers driven from a left–hand support wheel by means of a chain–wheel drive, some coulters for incorporated fertilizers and insecticides, some left/right track markers operated by means of a hydraulic device IC and a vacuum installation which consists of an exhauster driven from the tractor's power take–off by means of cardan transmissions, a bearing and a multi–belt transmission.

I. Equipment to work the soil in the substrate adapted to conservative technology in the context of climate change, CONSOL

The tillage equipment adapted to conservative technology (Figure 15) is of the type carried on the three–point suspension mechanism mounted on the rear of 220–240 HP wheeled tractors, category 3, SR ISO 730:2012 and is intended to perform soil work from the arable substrate (without turning the furrow) and removing the impermeable layer of soil (hardpan) between the layer and the arable substrate.

Figure 15. Equipment for working the soil in the substrate adapted to conservative technology

The farmer using the advanced management method, which involves collecting and storing on–site weather data from a wireless weather station and receiving this information in real–time on a computer/smartphone by the farmer, can make an instant decision on the conservative work of soil, thus saving time and labor for additional checks on the farm. The conservation work is carried out with the technical equipment to work the soil in the substrate and allows the maintenance of plant remains on the soil surface or close to the soil surface and/or keeping the soil surface loose and granular, in order to reduce erosion and improve soil–water relations. During work, to avoid overlaps and replace ground marking, the operator (machinist) uses a MATRIX® 570GS manual guidance system, which consists of a console, an RXA–30 26 dB antenna, and a RealView camera with night vision. With such a system, overlaps are eliminated and the number of people needed for a job is reduced. Basically, markings are no longer used, and compasses or other methods are no longer used.

J. Weeding equipment for working in rows and between the vine trunks, EPV 2.2

Weeding equipment for working in rows and between vine trunks (Figure 16) is intended for the mechanized execution of soil mobilization work between vine stumps simultaneously with the execution of cultivation work on the interval between the rows, in plantations with management vines on the stem, vertical, with tutus at each hub.

Figure 16. Weeding equipment for working in rows and between the vine trunks, EPV 2.2

The process of tilling the soil between the hubs consists of the translational movement of the knife–type active organ with a long side wing, lifting a strip of soil and shredding it simultaneously with cutting the roots of weeds. During the movement of the active organ on the row of hubs, the feeler rod touches the hubs at a height of 10–15 cm above the ground and through the lever system transmits the command to withdraw the active organ to the hydraulic distributor. Retraction is done progressively according to the stroke of the probe. After passing the hub, the feeler rod returns to its initial position under the action of a spring, also commanding the return of the active organ to the row of hubs. In this way, by withdrawing and returning the active organ, the area between the stumps is processed on the vine row with the exception of an area around the stumps and trellis posts.

K. Spraying machine in vine plantations, MSR

The spraying machine (Figure 17) is intended for spraying with the recovery of the working substance in vine plantations planted at a distance between rows of 2–2.2 meters. The liquid that does not adhere to the leaf surface is transferred back to the reservoir and reused for work in order to obtain a significant saving of active substance and reduce environmental pollution compared to the conventional application of treatments in vine plantations.

Figure 17. Spraying machine in vine plantations

The machine is of the type carried by a wheeled or tracked tractor, with a power of 45 HP, equipped with a three–point suspension mechanism, mounted at the rear, category 1 according to SR ISO 730–1+C1:2000, for work in vineyards planted at a distance between rows of 2–2.2 meters. The technological process of the machine's operation is carried out in the following order: from the PTO shaft (APP) of the tractor, through the universal joint shaft, the shaft of the M135s Imovilli pump is driven in rotation. The liquid in the polyethylene tank is absorbed by the pump through the suction filter and sent to the flow and pressure regulator. From the flow and pressure regulator, the working liquid is sent to the ramps with nozzles mounted on the central panels and the stg/dr panels, and from here to the plants. The dispersed working fluid passes through the foliage of the plants. A part of the drops are deposited on the leaves, and the rest drips on the panels and reaches the accumulation tanks located in the lower part of the panels. Here it is filtered and transported through the solution recovery system with electric direct current pumps to the liquid tank for reuse. The machine is fed through the filling mouth of the tank, in which the filling filter is fixed. The liquid level in the tank is visualized on the level indicator located on the outside of the tank. Emptying the liquid from the tank is done through the 3–way tap located at the bottom of it.

CONCLUSIONS

≡ The research results allow useful recommendations for farmers who implement innovative mechanization technologies for soil work, the establishment and maintenance of agricultural crops that can contribute to a better protection and conservation of soil resources.

≡ Innovative technologies and equipment for the mechanization of soil work in field crops with low impact on the environment represent alternatives to the conventional system of soil work through the effects of conservation of soil properties and assured productions.

≡ The EU Soil Strategy for 2030 supports investments in preventing and restoring soil degradation because they are economically justified.

Acknowledgment

This work was supported by a grant from the MINISTRY OF RESEARCH, INNOVATION AND DIGITIZATION from Romania, through the NUCLEU Program, ctr. no. 5N / 07.02.2019, project PN 19 10 02 01– Development of innovative technologies within SMART farms and with the support of MADR through the ADER Program 2019–2022, contract no. ADER 25.1.3 / 26.09.2019, project INNOVATIVE MECHANISM TECHNOLOGY FOR THE MAINTENANCE OF VINEYARD PLANTATIONS.

References

[1] Alexandratos, N. and J. Bruinsma, World agriculture towards 2030/2050: the 2012 revision, 2012, ESA Working paper No. 12–03. Rome, FAO.
[2] Böttinger, S., Doluschitz, R., Klaus, J., Jenane, C., & Samarakoon, N., Agricultural Development and Mechanization in 2013 A Comparative Survey at a Global Level. 2013, Fourth World Summit on Agriculture Machinery, 5–6, New Delhi, India
[3] FAO. World Agriculture Towards 2030/2050, 2006, Food and Agriculture Organization, Rome, Italy
[4] Fess, T. L., Kotcon, J. B., & Benedito, V. A. Crop breeding for low input agriculture: a sustainable response to feed a growing world population. 2011, Sustainability, 3(10), 1742–1772, West Virginia University, Morgantown, WV 26506, USA
[5] Fischer, G., & Shah, M. Farmland investments and food security, 2010, Statistical Annex, Report prepared under World Bank IIASA contract–Lessons for the large–scale acquisition of land from a agricultural land use analysis, Laxenburg, Austria
[6] Grad, I., Mănescu, C., Mateoc, T., & Mateoc–Sîrb, N., Studies on the agriculture systems practiced in Romania. 2014, Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, Vol. 14, Issue 1, Timișoara, România
[7] Guș, P., & Rusu, T., Sistemele neconvenționale de lucrare a solului, alternative agrotehnice și economice pentru agricultura durabilă. 2011, In Soil Minimum Tillage Systems, 6 th International Symposium (pp. 11–23), Cluj–Napoca, România
[8] Houssou, N., Asante–Addo, C., Diao, X., & Kolavalli, S., Big tractors, but small farms: Tractor hiring services as a farmer–owner's response to an under–developed agricultural machinery market, 2015, (No. 39). International Food Policy Research Institute (IFPRI), Washington D.C., USA
[9] Karayel, D., & Sarauskis, E. Environmental impact of no–tillage farming, 2019, Environmental Research, Engineering and Management, 75(1), 7–12, Kaunas, Lituania
[10] Onisie, T., Jităreanu, G., Agrotehnica, 2000, Editura Ion Ionescu de la Brad, Iaşi, România
[11] *** Proiectul ADER 1.3.5, Tehnologie inovativă şi echipament tehnic cu organe active antrenate pentru afânarea în profunzime şi creşterea fertilităţii solurilor, 2011,,,2014, Programul ADER 2020, București, România
[12] *** Proiectul SMIS 11789, Creşterea competitivităţii MAT Craiova prin asimilarea unui agregat multifuncţional de lucrat solul în exploataţii agricole, 2010–2012, POS CCE 2007–2013, Craiova, România
[13] *** Proiectul SMIS 105551, Echipament multifuncțional de lucrat solul in exploatații Agricole, 2018–2021, Contract subsidiar nr. 251/2018, Programul Operaţional Competitivitate 2014–2020, Gologanu, România
[14] *** Proiectul 15/19.09.2007, Crearea si promovarea unui ET pentru decompactarea si aerarea, in profunzime , a solurilor deficitare, concomitent cu administrarea de elemente nutritive destinat tractoarelor de puteri mari, 2007–2010, Programul INOVARE, AMCSIT– Politehnica, București, România
[15] *** Proiectul 14/19.09.2007, Asimilarea unui ET pentru dezmiristit si pregatit patul germinativ , in toate tipurile de sol, cu capacitate marita si cu constructie ultraredusa destinat tractoarelor de 120 – 220 CP, 2007–2010, Programul INOVARE, AMCSIT– Politehnica, București, România
[16] *** Proiectul nr. 51048, Tehnică inovativă pentru înfiinţarea culturilor cerealiere în sistem durabil, care limitează degradarea solului, conservă biodiversitatea şi contribuie la creşteri calitative ale producţiilor agricole, 2008–2011, Programul PARTENERIATE ÎN DOMENIILE PRIORITARE, Bucureşti, România
[17] *** Proiectul PN 09–15.01.02: Tehnologie inovativă de lucrare a solului si înființare a culturilor de prăsitoare corespunzătoare agriculturii durabile, adaptată la condițiile pedoclimatice specifice regiunilor din România, 2009–2011, Contract nr. 15N/27.02.2009, Program NUCLEU 2009–2012, București, România
[18] *** Proiectul PN 19 10 02 01 – Dezvoltarea de tehnologii inovative în cadrul fermelor SMART, Contract nr. 5N/2019, Program NUCLEU 2019–2022, București, România
[19] *** ADER 25.1.3 / 26.09.2019, Tehnologie inovativă de mecanizare pentru întreținerea plantațiilor de viță de vie, Program ADER 2020, București, România

ISSN: 2067–3809

[1.]Ancuţa Alexandra PETRE, [1.]Laurentiu–Constantin VLĂDUŢOIU, [1.]Nicoleta Alexandra VANGHELE, [1.]Mariana Mădălina STANCIU, [1.]Dumitru Bogdan MIHALACHE, [1.]Andreea MATACHE, [1.]Iulia Andreea GRIGORE, [1.]Dragos Nicolae DUMITRU

RESEARCH REGARDING THE GRAIN DISCHARGE SYSTEMS DESIGN

[1.]National Institute of Research – Development for Machines and Installations Designed for Agriculture and Food Industry – INMA Bucharest, ROMANIA

Abstract: The scientific paper presents the properties of dry granular flows and the recent advances made by scientists in understanding their rheological behavior. The shear rheology at the steady state of granular materials is investigated quasi–statically and inertially. The difference between the low–density collision flux and the dense friction flux is clarified. Finally, the constant granular flow on a slope and its instability in low density regime are investigated and an attempt is made to find suitable design solutions to solve the problems in the flow process. The optimal parameter in which the constant collision flow is achieved is determined, when changing the angle of inclination and the density of particles (cereals).
Keywords: grains, discharge sytems, bunkers, flow patterns

INTRODUCTION

Many traditional methods, processes and tools used in grain storage are constantly being replaced by automated systems and equipment due to technological advances. Rules and regulations by government agencies based on current health and environmental concerns restrict the use of chemicals and insecticides in grain storage. Also, in order to respect the quality assurance aspects, the continuous supply of cereals as food for human society and to meet the growing global standards, it is imperative that the agricultural industry adopt new quality management systems to reduce losses and maintain quality and safety during grain storage. (Neethirajan, S., 2007)

Bunkers are often used for long–term grain storage, with minimal loss of quality and quantity of stored products. Ideal for storing various cereals, seeds and granular materials, taking into account the fact that the products are prone to fermentation, they require special attention to maintaining quality. For this, it is necessary to design and build special technological equipment. (Mircea C., Nenciu F., 2020)

For a long time, designers of silos and bunkers have been trying to complete research work to codify the rules of eccentric filling and unloading. Some experiments and investigations on silo wall pressures have been intensively studied by scientists (Borcz A., 1991; Jenike A.W., 1964) Blight G.E., (1991) has discovered that near the outlet, the Jenike theory of pressures is also valid in the case of eccentric emptying.. Ayuga F. și colab. (2001) investigated pressure distribution in the process of unloading bulk granular products in a silo with central and eccentric holes. Molenda M. și colab. (2002) investigated the loads of bunkers induced by eccentric filling and seed unloading. It was found that the eccentric discharge induced much higher dynamic moments than the static moments on the hopper wall.

Numerous attempts have been made to investigate eccentric filling and unloading in bunkers, trying to indicate the main additional problems that occur during eccentric unloading, ie asymmetric loading of the hopper wall which can lead to quite different design of the structure from what was known. until the present. These additional, unexpected problems that occur during eccentric filling and unloading are considered to be a major cause of hopper failures. (Sielamowicz I., 2004)

Nenciu F. (2021) and Mircea C. (2020) emphasized the importance of proper designing of bunkers in wheat processing facilities, especially when performing seed conditioning. The technologies used in industry have to be updated accordingly to the new technological advances regarding the use of sensors (Nenciu F., 2014), and must take into account the optimized technological flows, in accordance with the expected quality of the products, the time required for processing or the characteristics of the materials that are being processed (Mircea C, 2020).

MATERIALS AND METHODS

This paper presents the theory of bulk grain flow through a logical, theoretical approach to understanding and managing this concept. Jenike Andrew developed test methods, equipment and design techniques and performed experiments to confirm and refine innovative analysis. (Jenike A.W., 1964; Mehos, G., 2016)

Prior to Jenike's research, silos and bunkers were usually designed primarily primarily architecturally or from a manufacturing point of view (e.g., hopper walls were tilted 30 degrees vertically to reduce material waste or 45 degrees to minimize margin requirements to simplify design calculations). However, extensive experience has shown that designing equipment without regard to the actual bulk materials that are handled often leads to flow problems such as arching, ratholing, irregular flow and even lack of flow. By measuring the flow properties of a solid bulk material, the flow behavior can be predicted so that the design of the bunkers is more reliable. (Golshan S., 2019).

Two main types of flow can occur in a hopper or in a silo: mass flow and funnel flow (Figure 1). In the mass flow, the entire bed of cereal seeds is in motion when the material is discharged through the outlet. This behavior eliminates the formation of stagnant regions in the vessel and provides a constant and continuous flow sequence that provides a more uniform speed profile during operation. A uniform speed profile also helps reduce the effects of segregation. (Liu W., 2019)

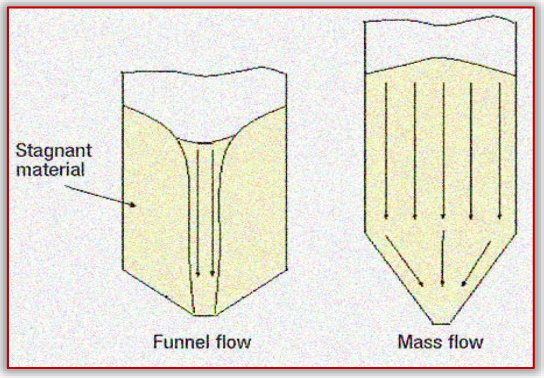


Figure 1 – Two types of flow patterns can occur when a bulk solid is discharged from a bunker, hopper, bin or silo: A typical funnel flow pattern is shown on the left, and a mass flow pattern is shown on the right (Jenike A.W., 1964)

On the other hand, in the flow of the funnel, an active flow channel is formed above the outlet, but the granular material remains stagnant (called ratholes) at the periphery of the vessel. The funnel flow can cause irregular flow, exacerbate segregation, reduce equipment processing capacity, allow particle degradation (leading to agglomeration and damage) in stagnant regions. Depending on the size of the equipment, the flow of the funnel can also induce heavy loads on its structure, due to the agglomeration of the material and the eccentric flow is formed inside the channel. (Rogovskii I., 2019)

For many powdery and granular materials, flow problems can be eliminated by ensuring a mass flow pattern in the vessel. The first step in achieving mass flow is for the designer to ensure that the converging walls are steep enough and have sufficiently little friction to allow the bulk materials to slide along them. This is done by first testing the material to measure the friction of the wall and then calculating the minimum angle of the hopper that will allow mass flow. (Al–Hashemi, H.M.B, 2018).

— Optimal angle for the mass flow

Once the results of the wall friction are known, the recommended angle for the hopper to ensure the optimal mass flow can be easily calculated. The wall friction angle (φ’) is obtained following the method described in ASTM D–6128 (ASTM–6128, 2006). The test is performed using a tool (shown in Figure 2) that involves placing a sample of powder inside a retaining ring on a flat coupon of wall material. Various normal loads are then applied to the powder, and the powdery material inside the ring is forced to slide along the stationary wall. The resulting shear stress is measured as a function of the normal stress applied.

After a series of values have been recorded, the wall efficiency is identified by plotting the shear stress against the normal stress (Figure 3). The wall friction angle (φ ') is the angle that is formed when a line is drawn from the origin of that graph to a point on the wall.

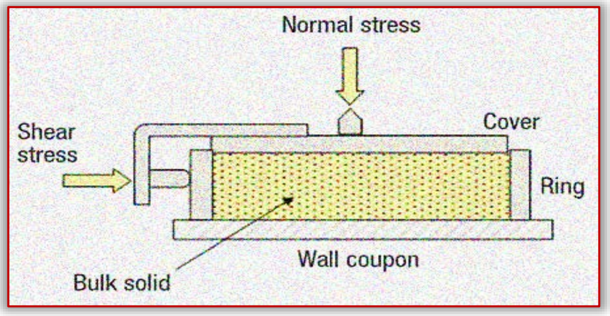


Figure 2 – By measuring the force required to slide a sample of powder along a wall coupon, the angle of wall friction can be determined (Mehos G., 2016)

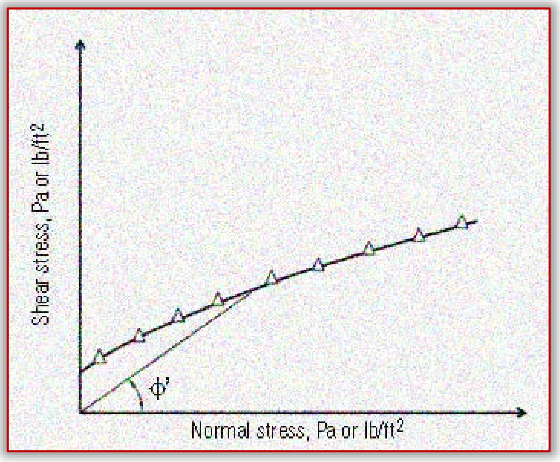


Figure 3 – The angle of wall friction (φ’) is determined by drawing a line between the wall yield locus (which is constructed by plotting shear stress against normal stress), and the origin, as shown here Δ, φ. (Mehos G., 2016)

Jenike found that the angle of the hopper needed to allow it to flow along the walls depended on the friction between the pubes and the walls, the friction between the powder particles and the geometry of the hopper. The design diagrams originally developed by Jenike provide permitted hopper angles for mass flow, given the values of the wall friction angle and the actual internal friction angle (which is determined by the shear cell testing) (Schulze D., (2007; Cui X, 2013; Armanini A., 2013).

The diagrams below are summarized in Figures 4 and 5 for conical and plane bunkers (eg wedge–shaped bunkers and transition bunkers, respectively). It is recommended that the outlet of a wedge–shaped hopper be at least three times its length to apply the relationship in Figure 5. (Jenike A.W., 1964)

The permissible values of the hopper angle θ '(measured vertically) are on the x–axis, and the values of the wall friction angle φ' are on the y–axis. Any combination of φ 'and θ’ that falls within the limiting mass flow region of the diagram will ensure the mass flow.

Bunkers with circular or square holes must not be designed at the theoretical value of the hopper angle. Otherwise, a small change in the properties of the powder can cause the flow pattern inside the hopper to change from the ground flow to the funnel flow, accentuating the risk associated with flow problems. A safety margin of 3 degrees is recommended (relative to the angle of the mass flow hopper given in Figure 4).

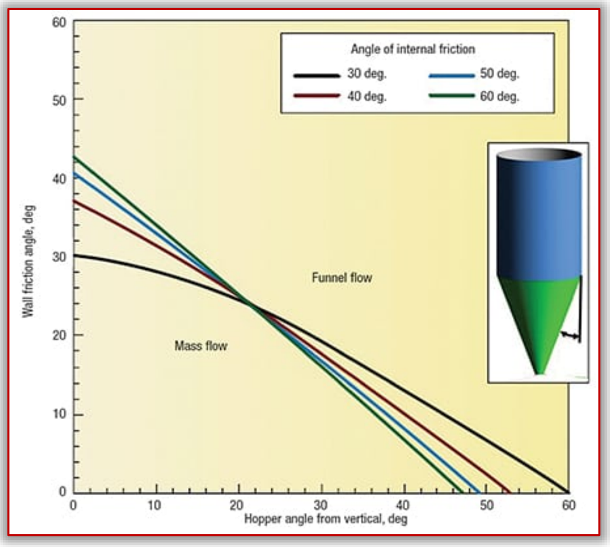


Figure 4 –Theoretical diagrama of mass–flow bunker angles for bunkers with round or square outlets. (Mehos G., 2016)

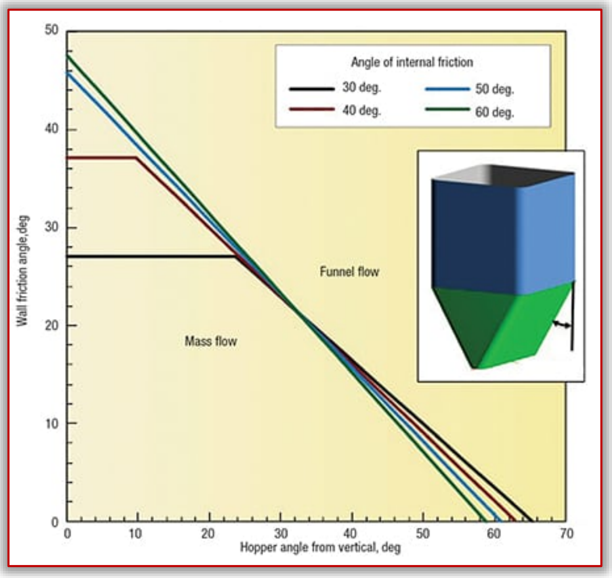


Figure 5 – This plot shows the recommended wall angles to ensure mass flow in a hopper with flat walls and a slotted outlet (Mehos G., 2016)

— Minimum outlet size

The opening of the hopper section must be large enough to prevent the development of cohesive springs or stable flows. The required size of the outlet depends on the cohesive strength and bulk density of the solid material. Cohesion strength is measured by shear cell testing, as described in ASTM D–1628 and D–6773 (ASTM D–6773, 2008). Figure 6 shows schematic diagrams for two common cell shear tests. A powder sample is placed in a cell and then pre–sheared – that is, the sample is strengthened by exerting a normal load and then sheared until the measured shear stress is stable. This is shown in Figure 7, by point (σss, τss).

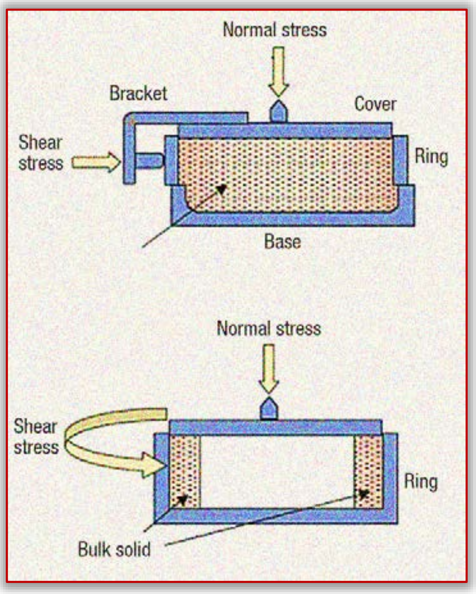


Figure 6 – Two versions of the shear cell tester — the direct shear cell tester (top) and the ring shear cell tester (bottom) — are used to measure the cohesive strength of bulk solids (Mehos G., 2016)

Then the shearing step is performed. During this stage, the vertical compaction load is replaced with a smaller load, and the sample is sheared again until it fails. These pre–shear and shear steps are repeated at the same level of consolidation for a series of reduced normal stresses, and the yield of the hopper angle is determined by plotting the shear stress against the normal stress (Figure 7).

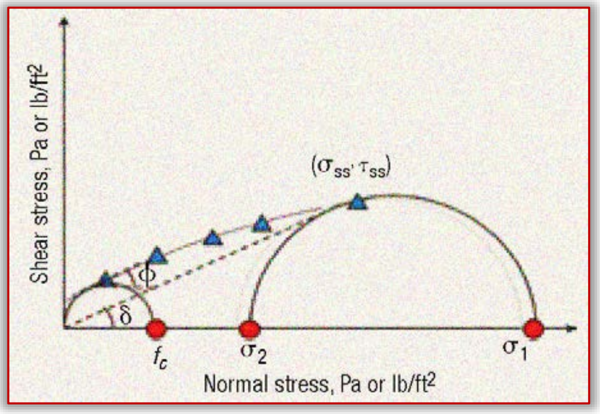


Figure 7 – A Mohr's circle drawn through the steady–state point and tangent to the yield locus gives the major consolidation stress. A Mohr's circle tangent to the yield locus that passes through the origin gives the cohesive strength. (Mehos G., 2016)

RESULTS

Cereal seeds interact, both by friction and by collision through a contact surface. From a phenomenological point of view, the material flows like a liquid with special features. To better understand this regime, different flow configurations were investigated, the most common being shown in Figure 8. These can be divided into two families: limited flows between walls as in shear cells and flows flowing on a free surface. with an inclined plane. (Forterre Y., 2009). Their characteristics in terms of speed profiles, density profiles, speed fluctuations are discussed in detail in this paper.

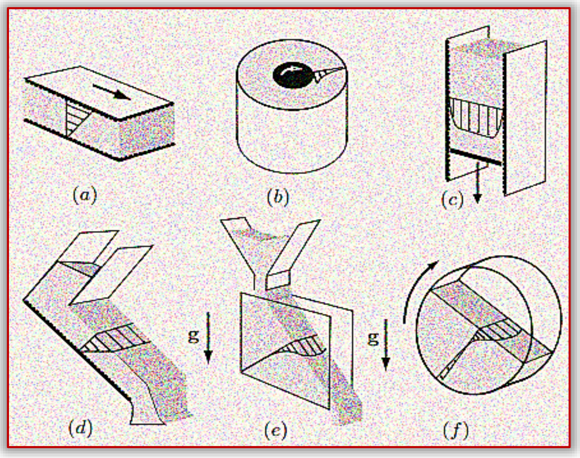


Figure 8 – Different configurations used to study granular flows. (a) Plane shear (b) Couette cell (c) vertical silo (d) Inclined plane (e) Heap flow (f) rotating drum (Forterre Y., 2009)

Dense granular flows belong to the family of visco–plastic materials, due to the two broad properties. First, there is a flow threshold, although it is expressed in friction instead of a flow voltage, as in a classic visco–plastic material. Second, when the material flows, the dependence on the shear rate is observed, which gives a behavior similar to the liquid, namely viscous. The next section presents recent advances in understanding the rheology of dense granular flows. We first present the flat shear configuration, which provides the basic ideas that allow the proposal of a constitutive law for dense granular flows. The application to other configurations is discussed and the limits of this simple local rheology are discussed. (Rogovskii I.L., 2020)

For example, it is considered a granular material consisting of particles with diameter d and density ρp under a closing pressure P. The material is bounded between two rough plates by a pressure P imposed on the upper plate.

The material is sheared at a given shear rate $\gamma = V_w / L$ imposed by the relative displacement of the upper plate at a speed V_w. (Figure 9). In the absence of gravity, the balance of force implies that both the shear stress $\tau = \sigma_{xz}$ and the normal stress $P = \sigma_{zz}$ are homogeneous throughout the cell. This configuration is simpler to study the rheology of granular flows, namely to study how the shear stress τ and the volume fraction φ vary with the shear rate γ and the pressure P.

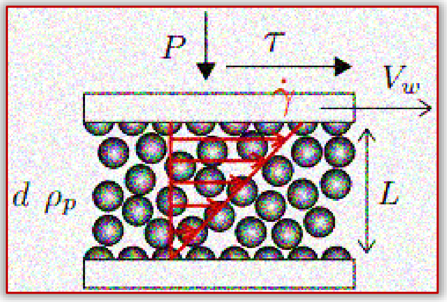


Figure 9 – Plane shear at constant pressure (Pouliquen O., 1999)

An important observation made by Da cruz F., et al. (2005) and Lois G., et al., (2005) is that in the simple shear configuration for infinitely rigid particles, dimensional analysis strongly constrains the stress / shear relationships (Midi G.D.R, 2004). For large systems (L / d >> 1) the rigid particles are controlled by a single dimensionless parameter called the inertial number:

$$I = \frac{\gamma d}{\sqrt{P/\rho_p}} \qquad (1)$$

Consequently, dimensional analysis requires that the volume fraction φ is only a function of I and that the shear stress τ must be proportional to the normal stress P, which is the only stress scale of the problem. The constitutive laws can then be written as follows:

$$\tau = P\,\mu(I) \text{ and } \varphi = \varphi(I) \qquad (2)$$

where: μ (I) is a coefficient of friction, which depends on the inertial number. The shape of the coefficient of friction μ (I) and the volume fraction φ (I) are provided by numerical simulations using discrete element models and by experimental measurements.where μ (I) is a coefficient of friction, which depends on the inertial number. The shape of the coefficient of friction μ (I) and the volume fraction φ (I) are provided by numerical simulations using discrete element models and by experimental measurements.

Figure 10 shows a summary of the results from various studies for 2D (disks) or 3D (spheres) systems. It is observed that the coefficient of friction μ is an increasing function of the inertial number. Friction increases when shear rate increases and / or pressure decreases.

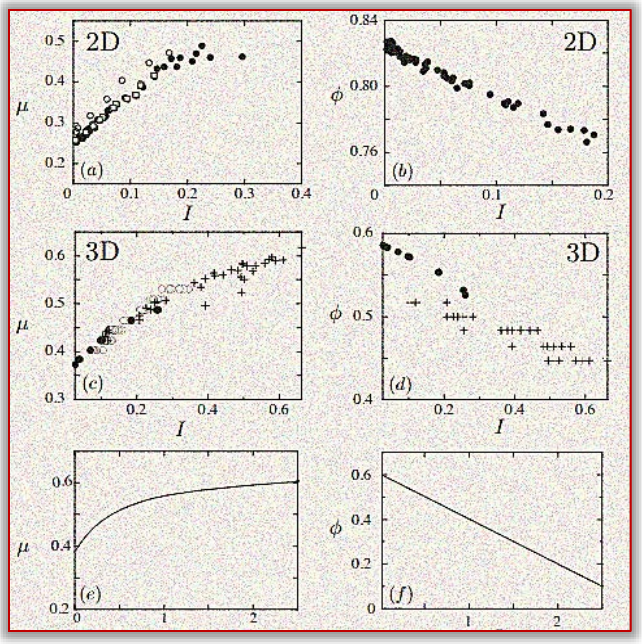


Figure 10 – Friction law μ(I) and volume fraction law (φ(I)); (a) (b) for 2D configurations with disks (c) (d) for 3D configurations with spheres; (e) (f) empirical analytical law proposed (eqs. (3) data form (Silbert, L.E., 2003)

Within the quasi–static flows (I–> 0) the coefficient of friction tends towards a constant. The volume fraction also varies with I. It starts from a maximum value when (I–> 0) and decreases more or less linearly with I. It is interesting to note that in the range of the inertial number corresponding to the dense flow regime, the macroscopic friction coefficient μ (I) and the volume fraction φ (I) do not depend on the microscopic properties of the grains. Changing the grain return coefficient or changing the coefficient of friction between the particles (as long as it is not zero) does not change the macroscopic friction. (Singh, A., 2015)

The inertial number consists of important parameters that control the rheology of dense granular regimes. It can be interpreted in terms of the ratio between two time scales: a microscopic time scale $d/\sqrt{P/\rho_p}$, which represents the time required for a particle to flow through an outlet hole of size d under pressure P and which gives the typical time interval of rearrangements; and a 1 / γ macroscopic time scale related to the mean deformation.

This interpretation allows a more precise classification of the different flow regimes. The value of I corresponds to a quasi–static regime in the sense that the macroscopic deformation is slow compared to the microscopic rearrangements, while the high values of (I) correspond to the fast flows. Dimensional analysis emphasizes that in order to move from the quasi–static regime to the inertial regime, it is due either to the increase of the shear rate or to the decrease of the pressure. This inertial number is also equivalent to the square root of the Savage number or the Coulomb number introduced by some authors as the ratio of collisional stress to total stress. (Ancey C, 1999; Savage S.B., 1984).

CONCLUSIONS

It was found that several factors affect the angle of rest, such as the static slip coefficient of friction, the rolling friction coefficient, the return coefficient, the size and shape of the particles, the amount of material used in the measurement and the method of measurement. The reported data indicate that the resting angle increases with the roughness of the particles and the affected surface, the slip and friction coefficients, the moisture content, the deviation from roundness and the increase in the speed of the rotating drum. In contrast, the angle of rest decreases with the amount of material used in the measurement, the particle size and the lifting speed of the hollow cylinder growth.

The rest angle is not always equal to the tip or the residual internal friction angle. In direct shear tests, the factors that ensure that the rest angle is equal to the residual internal friction angle are the method of sample preparation and the sample conditions, such as moisture content, maximum dry density, particle size, etc. Therefore, the resting angle should be considered as an estimate of the residual internal friction angle only in certain circumstances. Although the measurement of the angle of rest is quite simple, slight differences in the conditions of the sample or the method of measurement will lead to erroneous results.

Acknowledgement

This work was supported by one founding source the NUCLEU Program, carried out with the support of ANCSI, Project PN 5N/07.02.2019 "Integrated management of works in agricultural, vitical and pomicole ferms"

Note: This paper was presented at ISB–INMA TEH' 2021 – International Symposium, organized by University "POLITEHNICA" of Bucuresti, Faculty of Biotechnical Systems Engineering, National Institute for Research–Development of Machines and Installations designed for Agriculture and Food Industry (INMA Bucuresti), National Research & Development Institute for Food Bioresources (IBA Bucuresti), University of Agronomic Sciences and Veterinary Medicine of Bucuresti (UASVMB), Research–Development Institute for Plant Protection – (ICDPP Bucuresti), Research and Development Institute for Processing and Marketing of the Horticultural Products (HORTING), Hydraulics and Pneumatics Research Institute (INOE 2000 IHP) and Romanian Agricultural Mechanical Engineers Society (SIMAR), in Bucuresti, ROMANIA, in 29 October, 2021.

References

[1] Al–Hashemi, H.M.B., Al–Amoudi, O.S.B., (2018). A review on the angle of repose of granular materials, Powder Technology.
[2] Ancey, C., Coussot, P., Evesque, P. (1999). A theoretical framework for granular sus–pension in a steady simple shear ow, J. Rheology 43, 1673–99.
[3] Armanini, A., (2013). Granular flows driven by gravity, Journal of Hydraulic Research Vol. 51, No. 2, pp. 111–120.
[4] ASTM D–6128, (2006). Standard Test Method for Shear Testing of Bulk Solids Using the Jenike Shear Cell, ASTM International.
[5] ASTM D–6773, (2008). Standard Shear Test Method for Bulk Solids Using the Schulze Ring Shear Tester, ASTM International.
[6] Ayuga, F., Guaita, M., Aguado, P.J., Couto, A. (2001). Discharge and the eccentricity of the hopper influence on the silo wall pressures. J. Eng. Mechanics, 127(10), 1067–1074.
[7] Blight, G.E., (1991). Eccentric emptying of a large coal bin with six outlets. Bulk Solids Handling, 11(2), 451–457, 1991.
[8] Borcz, A., Abd, R.H., (1991). Wall pressure measurements in eccentricity discharged cement silos. Bulk Solids Handling, 11(2), 469–476.
[9] Cui, X., and Gray, J. M. N. T., (2013). Gravity–driven granular free–surface ow around a circular cylinder, J. Fluid Mech., Vol. 720, pp. 314–337.
[10] Da Cruz, F. Emam, S., Prochnow, M., Roux, J.N., Chevoir, F., (2005). Rheophysics of dense granular materials: Discrete simulation of plane shear ows, Phys. Rev. E 72, 021309.
[11] Da Cruz, F., Chevoir, F., Roux, J.N., Iordano, I., (2004). Macroscopic friction of dry granular materials, Tribology series 43, pp. 53–61.
[12] Forterre, Y. and Pouliquen, O. (2009). Granular Flows, Seminaire Poincare XIII, pp. 69–100, CNRS–Universite de Provence, France.
[13] Golshan, S., Zarghami R. and Saleh, K., (2019). Modeling methods for gravity flow of granular solids in silos, De Gruyter, Rev Chem Eng.
[14] Jenike, A.W., (1964). Storage and Flow of Solids, Bulletin 123, University of Utah Engineering Station (revised, 1976).
[15] Jenike, A.W., (1964). Storage and Flow of Solids. University of Utah Engineering Experiment Station, Bulletin 123, 1964.
[16] Liu, W., Hu, J., Zhao, X., Pan, H., Lakhiar, I.A., Wang, W., (2019). Development and experimental analysis of an intelligent sensor for monitoring seed flow rate based on a seed flow reconstruction technique, Computers and Electronics in Agriculture, 164, 104899.
[17] Lois, G., Lematre, A., Carlson, J., Numerical tests of constitutive laws for dense granular ows, (2005). Phys. Rev. E 72, 051303.
[18] Mehos, G., and Morgan, D. (2016), Jenike & Johanson, Hopper design principles.
[19] Midi G.D.R, On dense granular ows, Eur. Phys. J. E 14 (2004), 341–65.
[20] Mircea C., Nenciu F., Vlăduț V., Voicu G., Cujbescu D., Gageanu I., Voicea I., (2020). Increasing the performance of cylindrical separators for cereal cleaning, by using an inner helical coil, INMATEH Agricultural Engineering, vol. 62 / No.3, pp. 249–258

[21] Mircea C., Nenciu F., Voicu G., Oprescu M., Dumitru I., (2020). Review of the main equipment used for separating contaminants from wheat seeds, classification according to their functional role. Annals of the University of Craiova – Agriculture, Montanology, Cadastre Series, Vol. L/2020 (The 16th Annual meeting "durable agriculture – agriculture of the future)
[22] Molenda, M., Horabik, J., Thompson, S. A., Ross, I. J. (2002). Bin loads induced by eccentric filling and discharge of grain. Tansactions of the ASAE, v 45, 3, 781–785.
[23] Neethirajan, S., Jayas, D.S. (2007), Sensors for Grain Storage, ASABE.
[24] Nenciu F., Mircea C., Vladut V., Belc N., Berca L.M., (2021). Evaluation of wheat seed conditioning performances for a new design of rotating cylindrical sieve, equipped with a customizable homogenization coil, Engineering for rural developmenT Jelgava, pp. 1478–1483.
[25] Pouliquen, O., (1999). Scaling laws in granular ows down rough inclined planes, Phys. Fluids 11, 542–48.
[26] Rogovskii, I., Titova, L, Trokhaniak, V., Trokhaniak, O. and Stepanenko S., (2019). Experimental study on the process of grain cleaning in a pneumatic microbiocature separator with apparatus camera. Bulletin of the Transilvania University of Brasov Series II: Forestry, Wood Industry, Agricultural Food Engineering 12(61) pp. 117–28.
[27] Rogovskii, I.L., Shymko L.S., Voinash, S.A., Sokolova, V. A., Rzhavtsev, A. A., and Andronov A. V., (2020). Mathematical modeling of grain mictures in optimatization tasks of the dump bunker`s kinematic parameters, AGRITECH–III–2020, IOP Conf. Series: Earth and Environmental Science 548, 062055.
[28] Savage, S.B., (1984) The mechanics of rapid granular ows, Adv. Appl. Mech. 24, 289–66.
[29] Schulze, D., (2007). Powders and Bulk Solids – Behavior, Characterization, Storage, and Flow, Springer, New York.
[30] Sielamowicz, I., Kowalewski, T.A., Błoński, S., (2004). Central and eccentric granular material flows in bins/hoppers registered by dpiv optical technique, Acta Agrophysica 4(2)
[31] Silbert, L.E., Landry, J.W. Grest, G.S. (2003). Granular ows down a rough inclined plane: transition between thin and thick piles, Phys. Fluids 15, pp.1–10.
[32] Singh, A., Magnanimo, V., Saitoh K., and Luding S., (2015). The role of gravity or pressure and contact stiffness n granular Rheology, New J. Phys. 17, 04302

ISSN: 2067–3809

[1.]Valeriu DULGHERU, [1.]Cătălin DUMITRESCU, [1.]Ana–Maria POPESCU, [2.]Marinela MATEESCU

ECOLOGICAL DESIGN OF SYSTEMS

[1.]INOE 2000 – Subsidiary Hydraulics and Pneumatics Research Institute (INOE 2000–IHP) Bucharest / ROMANIA;
[2.]National Institute of Research – Development for Machines and Installations Designed to Agriculture and Food Industry – INMA, Bucharest / ROMANIA

Abstract: "Ecology is the science of the struggle for existence," says Greg Cooper in his paper titled "The Science of the Struggle for Existence." Indeed, the 21st century will be the century of the "science of the struggle for existence." The paper presents some exhortations to engineers, who must find solutions "before nature dies." Eco–friendly product design is one of the solutions to this global problem. Several basic concepts of eco–design, several eco–design strategies, traditional design strategies versus eco–design, are presented in this paper.
Keywords: ecology, eco–design, eco–product, conceptualization

INTRODUCTION

Engineers need to find solutions to the challenges of the millennium "before nature dies". The environment is an essential part of any development process and encompasses the links and interdependencies that exist between human beings and natural resources. As a result, the changes that the environment goes through are generated not only by natural events, but also by the practical manifestation of development patterns, practices and lifestyles. What is certain is that man has often erred in relation to nature, through the excesses made, and nature sometimes takes revenge. The great J.W. Goethe rightly said: *"Nature is always true, serious and severe. It is always right, and the errors are always those of man. "*

The effects of environmental pollution, manifested by the emergence of serious health problems and the disturbance of the ecological balance, were recognized internationally at the Stockholm Conference of 1972, held under the slogan "Only One Earth". The main document of this conference was the Final Declaration on the Environment, which highlighted the inseparable link between the quality of life and the quality of the environment, proclaiming the duty of every human being to protect and improve the environment: "The world's natural resources, including air, water, land, flora and fauna and, in particular, representative samples of natural ecosystems, must be protected in the interests of present and future generations through careful planning or management, as required." In 1986, the United Nations established the World Commission on Environment and Development, aiming to study the dynamics of environmental degradation and provide solutions for the long–term viability of human society. The document addressing the human right to a healthy environment was the *Report of the World Commission on Environment and Development* titled *"Our Common Future"*, also known as the *"Brundtland Report"*: "Sustainable development is development that seeks to meet the needs of the present without compromising the ability of future generations to meet their own needs." *(Dulgheru, 2020)*.

As a matter of fact, "ecology is the science of the struggle for existence" (G. Cooper). Ecology, defined over 100 years ago as the science that deals with the study of the interdependencies between living organisms and, especially, their interdependencies with the environment, has developed strongly in the last 15 years. It is carried out mainly through research in academic environments and specialized institutes, resulting in a large number of sophisticated ecological models and methodologies, evaluation techniques, rules and design guides, etc. It should be noted that environmental issues differ from one geographical area to another, sometimes even from one country to another, which is why no ecological model, methodology or tool has yet been imposed worldwide as being applicable to any type of product or process.

Therefore, speaking from an engineer's perspective, a problem has arisen. The environment in which we live faces many problems: global warming, water pollution, acid rain, gas emissions, which cause smog, transmissions of toxic substances, radiation. Which is the solution? How can all these harmful effects that affect the sustainable quality of life be dealt with? The solution to the problem is the ecological design of the products or the Ecodesign.

Eco–design has emerged as a growing need to protect nature. One of the first forms of eco–design was product recycling. As early as the beginning of the twentieth century, artists used collages from newspapers, packaging and other unused materials to make their works of art. Renowned artists such as Pablo Picasso and Georges Braque are among the pioneers of this initiative. There has also been a great demand in Western European countries to decorate their homes in the most "*green*" style possible. For this purpose, a series of products made of recyclable materials have been designed, which have a natural appearance.

So, eco–design can be implemented in various fields, whether it's art, building or arranging a house or designing industrial products. Eco–design is a growing responsibility of the designer to understand the ecological footprint of the planet. In connection with such global problems as overcrowding and environmental pollution, it is strictly necessary for designers, for engineers, to find environmentally friendly solutions that lead to a reduction in the consumption of materials and energy, and that the materials used are as recyclable as possible.

The range of green industrial products is very wide. It ranges from durable goods such as televisions, refrigerators, home appliances, automobiles, computers, mobile phones, to building materials and subassemblies, transportation, and industrial equipment. With the explosive development, especially in the last 30 years, of material products and, therefore, of manufacturing industries, there have been serious negative effects on the environment with major, sometimes catastrophic, implications. In connection with this, a series of measures have been taken, through which "pressure" is exerted on the economic and industrial environment in several ways: environmental taxes, directives and laws for producer responsibility, vouchers for pollution prevention initiatives. Several international (WCED – World Commission on Environment and Development attached to the UN, EMAS – European Eco–Audit and Management Scheme) and national organizations specialized in environmental issues (SETAC – Society of Environmental Toxicology and Chemistry, USA; ICME – International Council on Metals and the Environment, Canada; UBA – German Federal Environmental Agency) have been set up to implement these measures. Thanks to a well–balanced environmental policy, implemented over about 20 years, Germany, a major energy consumer, now covers more than 40% of its consumption with "green" energy.

In 2005, the EU adopted the Ecodesign Directive, which set out a framework on mandatory environmental requirements for energy–related products sold in its 28 Member States. Representatives of European manufacturers in the industry, such as Bosch, Siemens, Haushaltsgeraete and Philips, were involved in the consultations and welcomed the new rules. The directive covers more than 40 product groups, which are responsible for 40% of all greenhouse gas emissions. A further revision took place in 2009 (2009/125 / EC), which extended the scope to other energy–related products, such as windows, insulation materials and certain water–consuming products. The purpose of the Ecodesign Directive is for manufacturers of energy–using products to use, in the design stage, materials that reduce both energy consumption and adverse effects on the environment. The policy, known as eco–design, is in line with the EU's goal of reducing fossil fuel imports and greenhouse gas emissions *(*** https://www.green–report.ro/...)*.

WHAT IS ECOLOGICAL DESIGN?

The environment is seriously affected by existing products on the market, which produce a number of negative environmental effects such as: depletion of raw materials, energy consumption, water consumption, the effect of global warming, ozone depletion, photochemical fog, air acidification, air toxicity, water eutrophication, water toxicity, noise or radiation. What about artificial plastic islands (human products!) formed in the Planetary Ocean?!

Eco–design is a broad topic, but the basic idea is to reduce the negative impact on the environment throughout the entire product life cycle through improved product design. Ecodesign means "reducing the impact on the environment throughout the life cycle of a product through better product design" *(**** https://biblioteca.regielive.ro/ *…)*.

Directive 2009/125 / EC – Ecodesign states that "eco–design is the integration of environmental characteristics into the design of a product in order to improve the environmental performance throughout the life cycle".

Ecological design can also mean a configuration of products and services from both environmental and cost perspectives. Eco–designed products must meet certain criteria, such as: recyclability, low material and energy consumption, durability, avoidance of toxic materials, optimal customer benefits, use of regional resources *(Lasliu et al., 2019)*. In ecological design, the whole evolution of the product – from manufacturing to disposal – is kept under observation, the most profitable and most environmentally friendly solutions being developed.

The eco–designer assesses the impact of a product or process on the environment throughout its life cycle. He / she takes part in the technological choice of components and materials, so that maintenance and recycling are easier. The main missions of the eco–designer are the research of technical solutions and their industrial development. The basic idea in eco–design is to reduce the impact on the environment throughout the product life cycle through improved product design, while achieving similar performance and features. The life cycle of the eco–product is as follows: purchase of raw materials, manufacture of a component part, assembly of the product, distribution and sale, use of the product, repair and reuse, disposal, recycling of materials, and final disposal *(Lasliu et al., 2019)*.

All products have a certain impact on the environment throughout the life cycle, namely through the use of raw materials and natural resources for manufacturing, packaging, transportation, storage and recycling. The designer's problem is to minimize this impact. In general, about 80% of the environmental impact of the product can be determined during the design phase. Ecological design involves taking into account the environmental impacts of the product, right from the first design stage. In terms of lifecycle costs, the situation is pretty much the same. In these conditions, it is crucial to take into account the economic and environmental aspects in the very design phase of the product.

Directive 2009/125 / EC – Ecodesign sets out some generic requirements, which do not set limit values, but may impose:

- designing an "energy efficient" or "recyclable" product;
- providing information on how to use and maintain the product in such a way as to minimize its impact on the environment;

≡ performing a product life cycle analysis to identify alternative design options and solutions for possible improvement.

The general principles of European environmental policy are *(Fernández Fernández, 2018)*:

≡ Precautionary principle: If there is clear evidence of a new environmental problem, without full scientific confirmation, precaution measures will be taken;
≡ Prevention principle: Try to avoid any form of pollution or damage to the environment, instead of remedying the effects it produces when the damage cannot be avoided;
≡ Rectification of the principle of pollution at source: Immediate implementation of the resolution in due time to neutralize as much as possible the effects of the attacks produced and to prevent their progress;
≡ 'Polluter pays' principle: aiming at elaborating the regulation which establishes the responsibilities before the actions, the identification of the offender to whom the damage caused to the environment can be attributed and the damages to be repaired.

The introduction of new minimum requirements may result in a ban on the marketing of all non–compliant products in EU countries. For example, incandescent bulbs have been phased out since 2009.

Basic eco–design requirements:

≡ are adopted according to the product;
≡ set minimum standards for product performance to reduce environmental impact;
≡ must be met by all products marketed in the EU;
≡ are based on the environmental impact throughout the life cycle of the product (design, production, distribution and recycling).

The scope of the Ecodesign Directive was extended in 2009 to all products with an energy impact (the use of which has an impact on energy consumption), including:

≡ Energy consuming products (ECPs), which use, generate, transfer or measure energy (electricity, gas, fossil fuel), including consumer goods – such as boilers, computers, televisions, washing machines, light bulbs – and industrial products – such as transformers, industrial fans, industrial ovens, etc.;
≡ Energy labels show where an appliance is located on a scale from A to G, depending on energy consumption. Class A is the most energy efficient and class G is the least efficient (Figure 1);
≡ Energy labels offer consumers the opportunity to save money by choosing products that consume less energy;
≡ Other products with energy impact (ERP), which do not use energy but have an impact (directly or indirectly) on energy consumption and can therefore contribute to energy savings, such as: windows, thermal insulation materials, sanitary ware, taps, etc. Directive 2009/125 / EC – Ecodesign on ecological design does not provide mandatory product requirements, product requirements are set out in European Commission Regulations.

Figure 1 – Energy label of a home appliance

Thus, the implementation of Directive 2009/125 / EC – Ecodesign consists in establishing a framework for establishing the eco–design requirements applicable to energy–related products. In this way, the Directive aims to reduce the environmental impact of the product life cycle (from raw material procurement, production, assembly, distribution, retail, use, transport and recycling) by designing it better.

EcoDesign means better products, but better and more effective tools are needed to design better products. There are several types of tools, from guides and checklists to selection indicators and life cycle assessment, including methodologies, process simulation software and databases of materials and processes. The pressure exerted by the governments of the economically developed states in the post–1990 period through legislation to implement the requirements of sustainable development in industry, the attitude of citizens towards the purchase of environmentally friendly goods, and the prospect of depleting essential resources for production and consumption are the main factors that have accelerated the transition from non–organic industrial products to organic industrial products.

Based on an analysis of several guidelines found in some company guides and in various textbooks, the professor Luttropp et al., 2006, at KTH, Stockholm, formulated 10 golden rules, which are very generic and need to be transformed and customized to be really used in product development. The rules are not listed in any order of preference:

1. Do not use toxic substances and utilize closed loops for necessary but toxic ones;
2. Minimize energy and resource consumption in the production phase and transport through improved housekeeping;
3. Minimize energy and resource consumption in the usage phase, especially for products with the most significant aspects in the usage phase;
4. Promote repair and upgrading, especially for system–dependent products;
5. Promote long life, especially for products with significant environmental aspects outside of the usage phase;
6. Use structural features and high quality materials to minimize weight. Nevertheless, these shall not interfere

with necessary flexibility, impact strength or other functional priorities;
7. Invest in better materials, surface treatments or structural arrangements to protect products from dirt, corrosion and wear;
8. Prearrange upgrading, repair and recycling through access ability, labelling, modules;
9. Promote upgrading, repair and recycling by using few, simple, recycled, not blended materials and no alloys;
10. Use as few joining elements as possible and use screws, adhesives, welding, snap fits, geometric locking, etc. according to the life cycle scenario.

BASIC CONCEPTS OF ECOLOGICAL DESIGN

The number of consumers who show greater responsibility for sustainable consumption of products and resources is growing day by day. Consequently, this type of consumer aims to support environmental sustainability by requiring companies, especially manufacturing companies, to demonstrate respect and commitment to the environment and natural resources, consolidating the entire product life cycle with actions that demonstrate such a commitment. Regarding these types of activities, the most remarkable action is the ecological design, which has become the main methodology, which can be used by companies to make their products more sustainable and environmentally friendly. We can define eco–design as a "systematic incorporation of environmental aspects into product design in order to reduce its impact on the environment throughout its life cycle". For any manufacturing industry, eco–design supports the need to incorporate environmental and sustainability criteria into the basic requirements of product design, such as cost, function, utility, aesthetics, reliability, safety, and so on. These environmental criteria range from the fight to minimize all consumption and the reduction of emissions and pollutants throughout the life of the product, not only during the manufacturing process, but until the end of its useful life.

Environmental psychology, behavioural psychology, consumerism, business, environmental policy, and additional research in the social sciences were used to define cognitive concepts that led to the purchase and use of environmentally friendly products. The basic concepts and explanations of eco–design are *(MacDonald et al., 2015)*:

≡ responsibility, a sense of personal control over actions and results;
≡ complex decision–making skills, mental tools, which structure complex decisions;
≡ decision heuristics, mental shortcuts, which simplify decisions;
≡ the link between altruism and sacrifice, an assumption that doing good requires personal sacrifice;
≡ trust, the degree to which a person believes the information given to him / her;
≡ cognitive dissonance / guilt, mental processes, which can occur when a mismatch between intention and action is identified;
≡ motivation, intrinsic and extrinsic satisfaction, which determines the designer's behaviour.

Eco–design is focused on monitoring the product life cycle. All the stages that the product goes through, from the purchase of raw materials, which will be part of it or its generation from natural resources, to the moment of its final disposal. Consequently, this cycle covers the forms of raw materials until final disposal, through the intermediate stages of manufacturing, packaging *(Monteiro et al., 2019)*, logistics and distribution, sale, maintenance and even reuse. Companies that decide to include eco–design in their product development as part of their business strategy not only demonstrate environmental sensitivity, but increase their competitiveness by having better products, better projects, better manufacturing with a clear distinguishing factor. In other words, at the beginning of the third millennium, deeply affected by the global problems facing humanity, organic products are selling better. Companies that promote the ecological development within sustainable development must demonstrate that an appropriate balance has been achieved between economic, ecological and social growth, which contributes to sustainability *(QuellaDr., 2013)*:

≡ At the economic level: demonstrating the rational use of resources, in particular in the key stages of the value chain (supply, manufacturing, transportation and waste management).
≡ At the environmental level: demonstrating that the type and origin of the raw materials, the energy consumed for their manufacture, the pollution caused and all aspects that could affect the environment have been deeply considered.
≡ At the social level: demonstrating that the company maintains and consolidates its corporate social responsibility, being part of an elite of companies, which demonstrates that it ensures the well–being of the affected workers and work groups (partners, employees, etc.).

Therefore, eco–design takes off as an essential tool for achieving the desired sustainable development (Figure 2). From a "key business factor" perspective, design is an increasingly important factor in the competitiveness of companies.

The current competition, globalization and high customer knowledge have transformed the association, which requires not only a well–balanced quality cost, but also a demonstrable respect for the environment. This is why companies need to consider the environment, operationally and especially strategically, as a key factor. Therefore, the first step of eco–design is to integrate the environmental factor into the design and manufacturing of the product, to clearly try to prevent any potential contamination associated with a product through all the stages it goes through (design, manufacture, use and disposal). However, it should be clear that eco–design not only aims to ensure that the product is environmentally friendly, but also to implement a global environmental concept, which determines the maximum involvement of the company by integrating an identification–based methodology, control and continuous improvement of all environmental aspects of manufactured products.

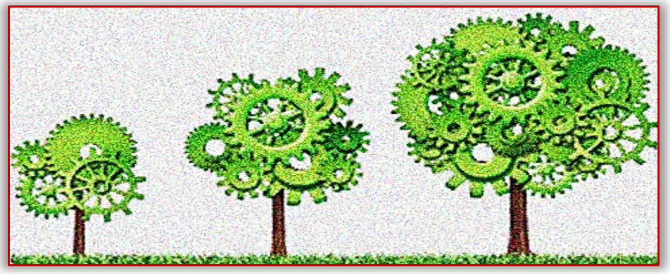


Figure 2 – Evolution of sustainable ecological design

ECOLOGICAL DESIGN STRATEGIES

Ecological design highlights a number of strategies, the main objective of which is to help prevent, reduce and / or minimize the impact of the product on the environment, associated with its life cycle. These strategies highlight a number of considerations that must be applied during the development of a new product.

The products are very different in terms of design, creation process and purpose of use. The nature of the product is assessed when the applicable strategies are to be selected. It is important to keep in mind that due to the close relationship between different strategies and life cycle stages, when implementing strategies, the impact of one stage must be taken into account and not transferred to another stage.

Figure 3 – Eco–design strategy wheel in the product life cycle

The development of new products will have a considerable impact on the environment. An eco–design strategy can be pursued to minimize this impact *(Fernández Fernández, 2018; Anghel et al., 2018)*. The eco–design strategy wheel (Figure 3) shows the strategies that can be followed. Thus, the implementation methodology can be structured on four different levels:

- conceptualization (includes strategies 0 – 2);
- manufacturing (includes strategies 3 – 4);
- application (includes strategies 5 – 6);
- end of life (includes strategy 7).

TRADITIONAL DESIGN VERSUS ECOLOGICAL DESIGN

Eco–design is like a design philosophy, which supports the need to include environmental criteria in the basic requirements of a product, such as cost, utility, aesthetics, reliability, safety, etc. Obviously, environmental requirements support the optimization of consumption, emissions and any possible contamination during the life cycle of the product. Eco–design does not refer to a substantial change in the traditional stages of the product design and development process, but to providing a new perspective, considering sustainability issues as part of the essential requirements. The difference between the traditional design process and the ecological design are presented in Figure 4. The environmental criteria indicated in the eco–design at each stage are added to the traditional design and development.

— The legal framework of ecological design

The European Union began to develop regulations and legislation in the field of green product design as early as the 1990s. Eco–design is of vital importance in European environmental policies, as demonstrated by the European 'Sustainable Development' Strategy of 2009, which established Sustainable Consumption and Production as one of the priority areas for action.

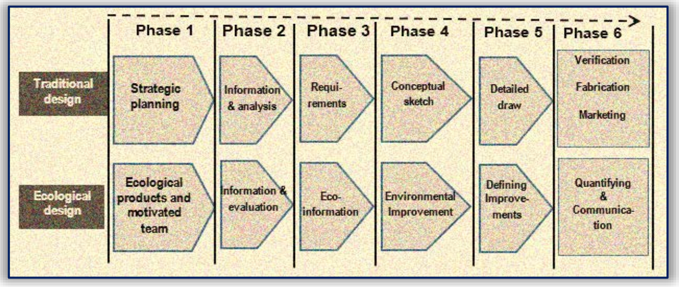


Figure 4 – The difference between the traditional design process and ecological design

For the quantitative assessment of the environmental impact levels, eco–indicators are defined and implemented by going through the following phases:

- inventory, which involves compiling a list of relevant inputs and outputs to identify factors that contribute to an ecological problem;
- characterization, which is the process of quantifying the description of the contributions;
- quantification, which involves the quantitative assessment of the characterizations relative to each other.

Eco–indicators are methods that are used to calculate the environmental impact, usually assessable in the form of an associated global score, of materials and processes. There is a possibility of errors on each phase. Studies and analyses are currently being carried out on eco–indicators based on life–

cycle methods in order to identify the sources of error as well as to assess the validity and scientific objectivity. An illustrative methodology is wheel graphics, which allow users (designers, manufacturers, managers) to identify priorities for green development. Figure 5 shows the cost diagram of the industrial product: total production costs (TPC), life cycle costs (LCC) and social cost accounting (SCA), highlighting the environmental costs of the product life cycle.

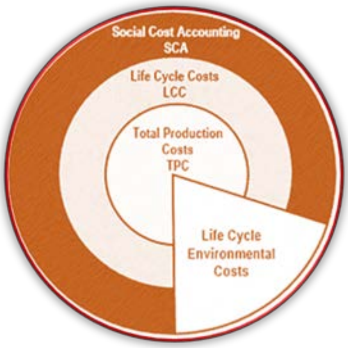


Figure 5 – Industrial product cost diagram

— Eco–design aspects in engineering: the stages of the ecological product design process

Product and process designers must ensure that they excel in all aspects, which lead to meeting customer demands by ensuring functional performance, cost–effectiveness, reliability and, equally, environmental impact.

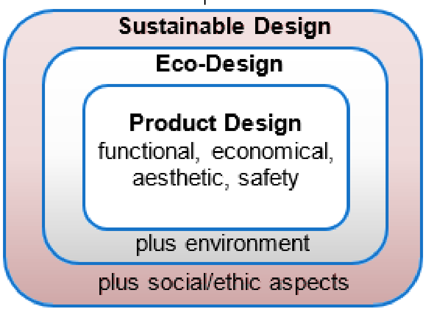


Figure 6 – Sustainable design of an industrial product

The purpose of ecological design in the context of sustainable design (Figure 6) is to minimize the impact (negative effects, harms) of products and processes on the environment throughout the life cycle, while maximizing the benefit, performance and quality. Sustainable design requires consideration of social and ethical implications in addition to functional economic and environmental issues.

With the growing importance of environmental issues, specific information systems, models, methodologies and tools have been developed to make products and processes better for reducing environmental impacts (increasing environmental performance), which can be varied levels of quantification. In the last period of time, intense efforts are being made to introduce in the study programs at all levels notions and even advanced elements of industrial ecology, ecological design, sustainable design, etc. On the other hand, the future development of integrated EcoCAD / CAE / CAM tools will lead to high performance in the long–term optimization of the planetary existential complex.

Acknowledgement

European funding has been granted, under Competitiveness Operational Programme POC 2014–2020, call POC–A1–A.1.1.3–H–2016, financial agreement no. 253/02.06.2020, signed between INOE 2000 and the Ministry of Education and Research for the project titled "Horizon 2020 Support Centre for European Project Management and European promotion PREPARE", MYSMIS2014 code 107874.

Note: This paper was presented at ISB–INMA TEH' 2021 – International Symposium, organized by University "POLITEHNICA" of Bucuresti, Faculty of Biotechnical Systems Engineering, National Institute for Research–Development of Machines and Installations designed for Agriculture and Food Industry (INMA Bucuresti), National Research & Development Institute for Food Bioresources (IBA Bucuresti), University of Agronomic Sciences and Veterinary Medicine of Bucuresti (UASVMB), Research–Development Institute for Plant Protection – (ICDPP Bucuresti), Research and Development Institute for Processing and Marketing of the Horticultural Products (HORTING), Hydraulics and Pneumatics Research Institute (INOE 2000 IHP) and Romanian Agricultural Mechanical Engineers Society (SIMAR), in Bucuresti, ROMANIA, in 29 October, 2021.

References

[1] Anghel, D.C., Rizea A.D., & Sicoe G.M. (2018). Proiectarea funcțională a produselor (Functional product design). Pitesti University Publishing House
[2] Dulgheru, V. (2020). The basics of creative product design (Bazele elaborării creative a produselor) (2nd ed.). BonsOffices Publishing House
[3] Fernández Fernández, C. (2018). Basic Concepts on Ecodesign/ ECOSIGN Project. http://www.ecosign–project.eu/
[4] Lasliu, E., & Lasliu, G.M. (2019). Ecodesign, Ecological design – generator of ecological economy (Ecodesign, Proiectarea ecologică – generatoare de economie ecologică). https://csfpm.ro/
[5] Luttropp, C., & Lagerstedt, J. (2006). EcoDesign and The Ten Golden Rules: generic advice for merging environmental aspects into product development. Journal of Cleaner Production, 14(15–16), 1396–1408
[6] MacDonald, E.F., & She, J. (2015). Seven cognitive concepts for successful eco–design. Journal of Cleaner Production, 92, 23–36
[7] Monteiro, J., Silva, F.J.G., Ramos, S.F., Campilho, R.D.S.G., & Fonseca, A.M. (2019). Eco–Design and Sustainability in Packaging: A Survey. Procedia Manufacturing, 38, 1741–1749
[8] QuellaDr., F. (2013). Ecodesign Strategies: A Missing Link in Ecodesign. In: Kauffman, J., & Lee, K. M. (eds) Handbook of Sustainable Engineering. Springer, Dordrecht, 269–284
[9] Sapuan, S.M. (2017). Concurrent engineering, product design, and development. Composite Materials, 29–56
[10] *** Ecodesign Aspects / Project (Aspecte privind Ecodesignul / Proiect). https://biblioteca.regielive.ro/proiecte/
[11] *** The European Union is introducing new eco–design rules (Uniunea Europeană introduce noi reguli de eco–design). https://www.green–report.ro/

ISSN: 2067–3809

[1.]Larisa C. CRISTEA, [1.]Marinela MATEESCU, [2.]Dragos PREDA, [2.]Bogdan DURAN, [1.]Oana–Diana CRISTEA

MOBILE SYSTEM FOR THE PRODUCTION OF ELECTRICITY FROM ALTERNATIVE SOURCES (SOLAR + WIND)

[1.]National Institute of Research – Development for Machines and Installations Designed for Agriculture and Food Industry – INMA Bucharest, ROMANIA
[2.]S.C. Rolix Impex Series SRL, ROMANIA

Abstract: The paper presents a mobile system for the production of electricity from alternative sources (solar + wind) which is intended for use in any isolated place, where there is no possibility to connect to an electricity grid, to ensure the electricity needed by various consumers in agricultural applications and agricultural crop monitoring, remote transmission and management services. At the same time, this mobile system, which is an ecological and economical electricity generator, can be used in the following locations without electricity: holiday homes, cottages, sheep farms, farms, greenhouses, caravans, bee trailers, boarding houses, monasteries, etc. The results of the research allow useful recommendations for farmers who want to use alternative energy sources in isolated farms, to reduce dependence on volatile and uncertain fossil fuel markets, especially oil and gas ones.
Keywords: mobile system, renewable energy, agricultural crop management

INTRODUCTION

A number of studies have been made so far on the development and promotion of energy obtained from renewable energy sources because they contribute to environmental protection, security of energy supply and independence from rising energy prices, thus solving current global problems: energy crisis and environmental impact (Comşa, M. L. 2015; Duhaneanu, M. et. al, 2015; Ilie, A. B. 2012).

The use of hybrid systems (solar + wind) contributes to reducing energy dependence, reducing losses through transmission and transformation, the lack of gaseous and liquid pollutants and to the low price of primary energy (Gheorghe, M. et. al, 2018).

Romania has temperate continental climate, with a high energy potential of energy resources for alternative energy supply (solar + wind) of isolated areas where there is no possibility to connect to a grid (Marcu, C. et. al, 2015). At the same time, it is in the 3rd group being characterized by relatively high intensities of solar radiation, with fluctuations in a wide range, but not extreme (annual maximum of 1600 kWh/m^2 in Dobrogea to 1250 kWh/m^2 in the north of the country) (Purece C., 2020).

The European Commission's Research Centre has developed software called the "Photovoltaic Geographical Information System (PVGIS)" which is used as a tool to assess the performance of photovoltaic technology in geographical regions and to provide interactive access to data, maps and tools for other research and education institutes, decision makers, PV professionals and system owners, as well as the general public (Baghdadi, A. et. al, 2010).

In this paper, the PVGIS application (http://re.jrc.ec.europa.eu/pvgis/apps4/) was used to estimate solar energy from an agricultural farm located in Fundeni, Călăraşi County, which does not have access to classical electricity.

Wind energy is one of the safest methods of producing electricity from renewable sources, the resources involved in air movements being considerable.

According to the National Institute of Statistics (INS), the production from wind power plants was 4125.7 million kWh in the first eight months of 2021 (http://www.insse.ro/cms).

The electricity produced by the turbine over a period of time depends on its constructive characteristics and the wind potential of the area where the turbine is installed, and the latest generation wind turbines have an efficiency of up to 98% (https://www.buletinulagir.agir.ro/).

A wind turbine with a vertical axis of 2kW (https://www.rolix.ro/proiecte_cercetare/inma–1.htm) was used to estimate the wind energy production by collecting the low intensity wind existing at low altitude in the Fundeni location.

MATERIALS AND METHODS

The experimental researches regarding the location, efficiency and behavior in operation of a mobile system for the production of electricity from alternative sources (solar + wind), which was developed by INMA Bucharest and ROLIX IMPEX SERIES SRL, were carried out in an agricultural farm in Fundeni locality, Călăraşi county.

Figure 1. Mobile system for the production of electricity from alternative sources (solar + wind) for agricultural applications and monitoring, tele–transmission and crop management services

The mobile electricity generation system (Figure 1) is intended for use in any isolated place, where there is no possibility to connect to an electricity grid, to ensure the electricity needed by various consumers in agricultural applications (Marin E. et. al, 2019).

The mobile system for producing electricity from alternative sources (solar + wind) consists of a photovoltaic trailer (Figure 2) equipped with a system for folding/unfolding photovoltaic panels and a wind turbine with a vertical axis (Figure 3) to ensure electricity in the field where there is no possibility to connect to an electricity grid for agricultural crops monitoring and management in order to transmit accurate information, in real time, to farmers to improve agricultural management.

Figure 2. Trailer for transporting mobile electricity production system + photovoltaic installation

Figure 3. Vertical axis wind turbine

RESULTS

The efficiency of the LG Neon R LG360Q1C–A5 photovoltaic panels used depends on the temperature, the level of solar radiation – received from the Sun converted by the panel into electricity with an efficiency of max. 20%, the rest being transformed into heat.

The operating temperature is due to the radiation to which the ambient temperature is added; when the module receives solar radiation, it heats to a temperature above ambient level.

At high temperatures, the efficiency of the panel decreases and production decreases; the support installation of the modules will ensure a good ventilation, obviously – retaining as little heat as possible.

The manufacturer of the photovoltaic panel specifies the NOCT (Nominal Operating Cell Temperature) parameter: Irradiance kW/m^2, ambient temperature 20°C, wind speed 1 m/s, and the temperature from which the efficiency starts to decrease is 45°C.

The main characteristics of the LG Neon R LG360Q1C–A5 photovoltaic panel are the following:

≡ Maximum Power(Pmax), W: 271
≡ MPP Voltage (Vmpp), V: 36.4
≡ MPP Current (Impp), A: 7.45
≡ Open Circuit Voltage (Voc), V: 40.2
≡ Short Circuit Current (Isc), A: 8.69

The warranty of the manufacturers of crystalline modules does not allow a degradation of the output power performance by more than 10% for a period of 10 years and by 20% for a period of 25 years.

Table 1 presents estimates of solar energy production obtained by means of the mobile system for electricity production from alternative sources (solar).

Table 1. Estimates of solar energy production

	Average monthly electricity production from the given system [kWh]	Average monthly sum of global irradiation per square meter received by the modules of the given system [kWh/m^2]	Standard deviation of the monthly electricity production due to year–to–year variation [kWh]
June	316.4	189.2	18.8
July	343.04	207.6	22.5
August	333.75	201.3	17.3

The estimates were made taking into account the following data:

≡ estimated temperature losses: 8.8% (using local ambient temperature);
≡ estimated loss caused by angular reflection effects: 2.8%;
≡ other losses (cables, inverter etc.): 14.0%;
≡ combined system losses: 23.8%

Starting from the average speeds measured in Fundeni location, Călăraşi County, a series of approximate calculations of the powers and quantities of electricity produced by the wind turbine with a vertical axis of 2kW were performed, depending on the electrical load available to the user.

The maximum power simultaneously absorbed is the sum of the powers of the electrical receivers (a surface solar pump with controller and two LED projectors) that can operate simultaneously at a given time: 1100 W.

The daily energy requirement W_z was calculated by relation (1):

$$W_z = \sum_{i=1}^{n} P_n \times t_n, \left[{}^{Wh}/_{day}\right] = 1000 + 200 = 1200 \left[{}^{Wh}/_{day}\right] \quad (1)$$

where:
– P_n represents the installed power of an electrical receiver;
– t_n represents the operating time of that receiver in a day.

The average required electric power will be given by relation (2):

$$P = \frac{W_z}{24} = \frac{1200}{24} = 50[W] \quad (2)$$

The amount of daily electricity that the wind generator has to produce, taking into account the efficiency of the inverter (η_i=80% ÷ 90%) was calculated by relation (3)

$$W_G = \frac{W_z}{\eta_i} = \frac{1200}{0,85} = 1411,76\left[{}^{Wh}/_{zi}\right] = 1,412\left[{}^{kWh}/_{zi}\right] \quad (3)$$

Taking into account the average wind speed v=9.14 m/s, the electric power that the wind turbine can generate can be determined by relation (4):

$$P_e = 0,5 \times \rho \times v^3 \times S_{ref} \times C_p [kW] \quad (4)$$

where:

– ρ represents the density of the air $\rho = 1.2255$ kg/m^3

– S_{ref} represents the area described by the turbine rotor calculated by relation (5):

$$S_{ref} = \pi \times R^2 = 3,14 \times 1^2 = 3,14\ [m^2] \quad (5)$$

where:

– R represents the radius of the wind turbine rotor;

– C_p represents the power coefficient calculated by relation (6):

$$C_p = \eta_m \times \eta_e \times \eta_a = 0,95 \times 0,97 \times 0,593 = 0,546 \quad (6)$$

where:

– η_m represents the efficiency of the mechanical transmission; it has a value of 0.95;

– η_e represents the efficiency of the electrical components; it has a value of 0.97;

– η_a represents the aerodynamic efficiency and has the maximum theoretical value established by Betz; it has the value 0.593.

The results for the electric power that the vertical axis wind turbine can generate are presented in table 2.

Table 2. The electric power that the vertical axis wind turbine can generate

Test no.	Average wind speed, m/s	Electric power, kW
1	14.0	2.851
2	12.0	1.795
3	8.0	0.532
4	9.0	0.757
5	7.0	0.356
Average	10.0	1.258

This calculation demonstrates that the wind speed in this area is sufficient to provide the necessary electrical power produced by the vertical axis wind turbine.

CONCLUSIONS

The research results allow useful recommendations for farmers who want to produce electricity from alternative sources in isolated places, where there is no possibility to connect to an electricity grid, to ensure the electricity needed by various consumers in agricultural applications and agricultural crops monitoring, tele–transmission and management services.

Acknowledgement

The work is carried out within the co–financed project of the European Regional Development Fund through the Operational Program Competitiveness 2014–2020 in the financing contract no. 80 / 08.09.2016, Axis 1, Action 1.2.3./ SMIS code 105551 / Subsidiary type contract D no. 913 / 21.08.2017.

Note: This paper was presented at ISB–INMA TEH' 2021 – International Symposium, organized by University "POLITEHNICA" of Bucuresti, Faculty of Biotechnical Systems Engineering, National Institute for Research–Development of Machines and Installations designed for Agriculture and Food Industry (INMA Bucuresti), National Research & Development Institute for Food Bioresources (IBA Bucuresti), University of Agronomic Sciences and Veterinary Medicine of Bucuresti (UASVMB), Research–Development Institute for Plant Protection – (ICDPP Bucuresti), Research and Development Institute for Processing and Marketing of the Horticultural Products (HORTING), Hydraulics and Pneumatics Research Institute (INOE 2000 IHP) and Romanian Agricultural Mechanical Engineers Society (SIMAR), in Bucuresti, ROMANIA, in 29 October, 2021.

References

[1] Baghdadi, A., & Zakey, A. S. (2010). Performances assessment of the first grid–connected photovoltaic micro power in Africa: The PVGIS approach. Moroccan Journal of Condensed Matter, 12(1)

[2] Comşa, M. L. (2015). Integration of Electric Plants that Use Renewable Energy into National Power System. The impact of socio–economic and technological transformations at national, European and global level, (4).

[3] Duhaneanu, M., & Marin, F. V. (2012). Romania is turning green – wind power plants, the new strategy for the future of renewable energy. Quality, 13(4), 45.

[4] Ilie, A. B. (2012). General Considerations Regarding the Status of Renewable Energies in the European Union and Romania. Pandectele Romane, 74.

[5] Marcu, C., & Crenganiş, L. (2017). A geospatial approach for analysing the main energy resources for isolated areas in Romania. Eastern European Journal of Geographic Information Systems and Remote Sensing, (1), 13–23.

[6] Marin E., Păun A., Manea D., Mateescu M., Preda D., Duran B., (2019), Alternative sources of electricity used in applications for agriculture, International Symposium, ISB–INMA–TEH, Agricultural and Mechanical Engineering, Bucharest, Romania, 31 October–1 November 2019. 2019 pp.894–900 ref.10

[7] Gheorghe, M., Ciobanu, D., Saulescu, R., & Jaliu, C. (2018). Economic analysis algorithm of a PV–wind hybrid system. ACTA TECHNICA NAPOCENSIS–Series: APPLIED MATHEMATICS, MECHANICS, and ENGINEERING, 61(3_Spe).

[8] Purece C., (2020), Analysis on the use of renewable energy sources in Romania, Energetica, Volume 68, ISSN: 1453–2360

[9] *** https://www.buletinulagir.agir.ro/articol.php?id=277

[10] *** http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php?lang=en&map=europe

[11] *** http://www.insse.ro/cms/ro/comunicate–de–presa–view

[12] *** https://www.rolix.ro/proiecte_cercetare/inma–1.htm

ISSN: 2067–3809

Fascicule 4
[October – December]
tome XV [2022]

ACTA Technica CORVINIENSIS
BULLETIN OF ENGINEERING

ISSN: 2067-3809

MANUSCRIPT PREPARATION – GENERAL GUIDELINES

Manuscripts submitted for consideration to ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering must conform to the following requirements that will facilitate preparation of the article for publication. These instructions are written in a form that satisfies all of the formatting requirements for the author manuscript. Please use them as a template in preparing your manuscript. Authors must take special care to follow these instructions concerning margins.

INVITATION

We are looking forward to a fruitful collaboration and we welcome you to publish in our ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering. You are invited to contribute review or research papers as well as opinion in the fields of science and technology including engineering. We accept contributions (full papers) in the fields of applied sciences and technology including all branches of engineering and management.

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering publishes invited review papers covering the full spectrum of engineering and management. The reviews, both experimental and theoretical, provide general background information as well as a critical assessment on topics in a state of flux. We are primarily interested in those contributions which bring new insights, and papers will be selected on the basis of the importance of the new knowledge they provide.

Submission of a paper implies that the work described has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis) that it is not under consideration for publication elsewhere. It is not accepted to submit materials which in any way violate copyrights of third persons or law rights. An author is fully responsible ethically and legally for breaking given conditions or misleading the Editor or the Publisher.

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering is an international and interdisciplinary journal which reports on scientific and technical contributions. Every year, in four online issues (fascicules 1–4), ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering [e-ISSN: 2067-3809] publishes a series of reviews covering the most exciting and developing areas of engineering. Each issue contains papers reviewed by international researchers who are experts in their fields. The result is a journal that gives the scientists and engineers the opportunity to keep informed of all the current developments in their own, and related, areas of research, ensuring the new ideas across an increasingly the interdisciplinary field. Topical reviews in materials science and engineering, each including:

- surveys of work accomplished to date
- current trends in research and applications
- future prospects.

As an open-access journal ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering will serve the whole engineering research community, offering a stimulating combination of the following:

- Research Papers – concise, high impact original research articles,
- Scientific Papers – concise, high impact original theoretical articles,
- Perspectives – commissioned commentaries highlighting the impact and wider implications of research appearing in the journal.

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering encourages the submission of comments on papers published particularly in our journal. The journal publishes articles focused on topics of current interest within the scope of the journal and coordinated by invited guest editors. Interested authors are invited to contact one of the Editors for further details.

BASIC MANUSCRIPT REQUIREMENTS

The basic instructions and manuscript requirements are simple:

- Manuscript shall be formatted for an A4 size page.
- The all margins of page (top, bottom, left, and right) shall be 20 mm.
- The text shall have both the left and right margins justified.
- Single-spaced text, tables, and references, written with 11 or 12-point Georgia or Times New Roman typeface.
- No Line numbering on any pages and no page numbers.
- Manuscript length must not exceed 15 pages (including text and references).
- Number of the figures and tables combined must not exceed 20.
- Manuscripts that exceed these guidelines will be subject to reductions in length.

The original of the technical paper will be sent through e-mail as attached document (*.doc, Windows 95 or higher). Manuscripts should be submitted to e-mail: redactie@fih.upt.ro, with mention "for ACTA TECHNICA CORVINIENSIS".

STRUCTURE

The manuscript should be organized in the following order: Title of the paper, Authors' names and affiliation, Abstract, Key Words, Introduction, Body of the paper (in sequential headings), Discussion & Results, Conclusion or Concluding Remarks, Acknowledgements (where applicable), References, and Appendices (where applicable).

THE TITLE

The title is centered on the page and is CAPITALIZED AND SET IN BOLDFACE (font size 14 pt). It should adequately describe the content of the paper. An abbreviated title of less than 60 characters (including spaces) should also be suggested. Maximum length of title: 20 words.

AUTHOR'S NAME AND AFFILIATION

The author's name(s) follows the title and is also centered on the page (font size 11 pt). A blank line is required between the title and the author's name(s). Last names should be spelled out in full and succeeded by author's initials. The author's affiliation (in font size 11 pt) is provided below. Phone and fax numbers do not appear.

ABSTRACT

State the paper's purpose, methods or procedures presentation, new results, and conclusions are presented. A nonmathematical abstract, not exceeding 200 words, is required for all papers. It should be an abbreviated, accurate presentation of the contents of the paper. It should contain sufficient information to enable readers to decide whether they should obtain and read the entire paper. Do not cite references in the abstract.

KEY WORDS

The author should provide a list of three to five key words that clearly describe the subject matter of the paper.

TEXT LAYOUT

The manuscript must be typed single spacing. Use extra line spacing between equations, illustrations, figures and tables. The body of the text should be prepared using Georgia or Times New Roman. The font size used for preparation of the manuscript must be 11 or 12 points. The first paragraph following a heading should not be indented. The following paragraphs must be indented 10 mm. Note that there is no line spacing between paragraphs unless a subheading is used. Symbols for physical quantities in the text should be written in italics. Conclude the text with a summary or conclusion section. Spell out all initials, acronyms, or abbreviations (not units of measure) at first use. Put the initials or abbreviation in parentheses after the spelled-out version. The manuscript must be writing in the third person ("the author concludes... ").

FIGURES AND TABLES

Figures (diagrams and photographs) should be numbered consecutively using Arabic numbers. They should be placed in the text soon after the point where they are referenced. Figures should be centered in a column and should have a figure caption placed underneath. Captions should be centered in the column, in the format "Figure 1" and are in upper and lower case letters.

When referring to a figure in the body of the text, the abbreviation "Figure" is used Illustrations must be submitted in digital format, with a good resolution. Table captions appear centered above the table in upper and lower case letters. When referring to a table in the text, "Table" with the proper number is used. Captions should be centered in the column, in the format "Table 1" and are in upper and lower case letters. Tables are numbered consecutively and independently of any figures. All figures and tables must be incorporated into the text.

EQUATIONS & MATHEMATICAL EXPRESSIONS

Place equations on separate lines, centered, and numbered in parentheses at the right margin. Equation numbers should appear in parentheses and be numbered consecutively. All equation numbers must appear on the right-hand side of the equation and should be referred to within the text.

CONCLUSIONS

A conclusion section must be included and should indicate clearly the advantages, limitations and possible applications of the paper. Discuss about future work.

Acknowledgements

An acknowledgement section may be presented after the conclusion, if desired. Individuals or units other than authors who were of direct help in the work could be acknowledged by a brief statement following the text. The acknowledgment should give essential credits, but its length should be kept to a minimum; word count should be <100 words.

References

References should be listed together at the end of the paper in alphabetical order by author's surname. List of references indent 10 mm from the second line of each references. Personal communications and unpublished data are not acceptable references.

- *Journal Papers:* Surname 1, Initials; Surname 2, Initials and Surname 3, Initials: Title, Journal Name, volume (number), pages, year.
- *Books:* Surname 1, Initials and Surname 2, Initials: Title, Edition (if existent), Place of publication, Publisher, year.

Proceedings Papers: Surname 1, Initials; Surname 2, Initials and Surname 3, Initials: Paper title, Proceedings title, pages, year.

ISSN: 2067-3809

INDEXES & DATABASES

We are very pleased to inform that our international scientific journal ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering completed its 14 years of publication successfully [2008–2021, Tome I–XIV].

In a very short period the ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering has acquired global presence and scholars from all over the world have taken it with great enthusiasm.

We are extremely grateful and heartily acknowledge the kind of support and encouragement from all contributors and all collaborators!

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering is accredited and ranked in the "B+" CATEGORY Journal by CNCSIS – The National University Research Council's Classification of Romanian Journals, position no. 940 (http://cncsis.gov.ro/).

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering is a part of the ROAD, the Directory of Open Access scholarly Resources (http://road.issn.org/).

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering is also indexed in the digital libraries of the following world's universities and research centers:

WorldCat – the world's largest library catalog
https://www.worldcat.org/
National Lybrary of Australia
http://trove.nla.gov.au/
University Library of Regensburg – GIGA German Institute of Global and Area Studies
http://opac.giga-hamburg.de/ezb/
Simon Fraser University – Electronic Journals Library
http://cufts2.lib.sfu.ca/
University of Wisconsin – Madison Libraries
http://library.wisc.edu/
University of Toronto Libraries
http://search.library.utoronto.ca/
The University of Queensland
https://www.library.uq.edu.au/
The New York Public Library
http://nypl.bibliocommons.com/
State Library of New South Wales
http://library.sl.nsw.gov.au/
University of Alberta Libraries – University of Alberta
http://www.library.ualberta.ca/
The University of Hong Kong Libraries
http://sunzi.lib.hku.hk/
The University Library – The University of California
http://harvest.lib.ucdavis.edu/

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering is indexed, abstracted and covered in the world–known bibliographical databases and directories including:

INDEX COPERNICUS – JOURNAL MASTER LIST
http://journals.indexcopernicus.com/
GENAMICSJOURNALSEEK Database
http://journalseek.net/
DOAJ – Directory of Open Access Journals
http://www.doaj.org/
EVISA Database
http://www.speciation.net/
CHEMICAL ABSTRACTS SERVICE (CAS)
http://www.cas.org/
EBSCO Publishing
http://www.ebscohost.com/
GOOGLE SCHOLAR
http://scholar.google.com
SCIRUS – Elsevier
http://www.scirus.com/
ULRICHSweb – Global serials directory
http://ulrichsweb.serialssolutions.com
getCITED
http://www.getcited.org
BASE – Bielefeld Academic Search Engine
http://www.base-search.net
Electronic Journals Library
http://rzblx1.uni-regensburg.de
Open J–Gate
http://www.openj-gate.com
ProQUEST Research Library
http://www.proquest.com
Directory of Research Journals Indexing
http://www.drji.org/
Directory Indexing of International Research Journals
http://www.citefactor.org/

ISSN: 2067-3809