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The **ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering, Tome XI [2018], Fascicule 1 [January – March]**, includes scientific papers presented in the sections of:

» **The 13th International Conference on Accomplishments in Mechanical and Industrial Engineering – DEMI 2017**, organized by University of Banja Luka, Faculty of Mechanical Engineering, in Banja Luka, BOSNIA & HERZEGOVINA, 26 - 27 May 2017. The current identification number of the papers are the **#1–4, #9–12, #21** and **#23**, according to the present contents list.

» **The 9th International Conference "Management of Technology – Step to Sustainable Production" – MOTSP 2017**, organized by Faculty of Mechanical Engineering and Naval Architecture of the University of Zagreb, CROATIA and University North, Varaždin, CROATIA, in Dubrovnik, CROATIA, 5 – 7 April 2017. The current identification number of the papers are the **#5–6 and #17–18**, according to the present contents list.

» **The 7th International Conference Industrial Engineering and Environmental Protection 2017 – IIZS 2017**, organized by University of Novi Sad, Technical Faculty "Mihajlo Pupin", in Zrenjanin, SERBIA, 12 – 13 October 2017. The current identification number of the papers are the **#7, #13–14, #16** and **#25**, according to the present contents list.

Also, the **ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering, Tome XI [2018], Fascicule 1 [January – March]** includes original papers submitted to the Editorial Board, directly by authors or by the regional collaborators of the Journal.

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EXPERIMENTAL AND NUMERICAL INVESTIGATION OF A SOLAR DISH COLLECTOR WITH SPIRAL ABSORBER

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Abstract: The objective of this work is to investigate experimentally and numerically a solar dish collector and to examine the impact of possible improvements in its performance. The examined solar dish collector has a spiral absorber and it is lightweight, fact that makes the system to have low cost and to be sustainable. The experimental results are compared with the results of a developed numerical model written in EES (Engineering Equation Solver) and validation between the results is observed. The validated numerical model is used for further investigation of the solar collector for operation with Therminol VP1. In the first part of the investigation, the impact of flow rate on the thermal and the exergetic performance is examined, and finally 200 l/h was found as the best solution. The next part is the optical investigation of the collector and greater optical efficiencies are tested. It is found that optical performance of 75% leads to maximum exergetic efficiency of 22.49%, three times greater than 7.49% which corresponds to the present situation of 35% optical efficiency. In the last part of this study, the selective absorber is compared to the non-selective of the real system and it is found that the use of the first is vital for achieving high operating temperature levels. The results of this study can be used as guidelines for the future improvement of the present facility.
Keywords: Solar dish collector, thermal analysis, exergy analysis, parametric analysis

INTRODUCTION

Solar energy utilization is vital for facing the present environmental problems and the fossil fuel depletion [1-3]. The use of concentrating collectors is one of the most promising ways for producing, heating, cooling, electricity and other useful products with a clean and cheap way [4-6]. Solar dish concentrators gain more and more attention the last years and a lot of research has been focused on them. Reddy et al. [7] investigated a modified cavity receiver of a solar dish collector with a numerical model for the natural convection heat losses of the receiver. This configuration includes a tube wound in a hemispherical geometry which is covered with insulation to reduce the thermal losses. Daabo et al. [8] examined three receiver geometries: cylindrical, conical and spherical.

In every case, a helical tube was used in order to utilize the solar energy. According to their results, the conical shape is the best choice among the examined cases. Przenzak et al. [9] examined a solar dish collector with a two optical elements and a curved radiation absorber. This system was designed for operation in high temperature levels and there was a special design for achieving this goal. More specifically, a parametric analysis has been applied in order the optimum receiver location and the most suitable mass flow rate to be determined.

In this study, the spiral absorber is examined in a lightweight receiver which is manufactured by 11 reflecting petals. The basic idea is to create a low cost solar collector which can operate in medium high temperature levels, ideal for polygeneration systems. In literature, there are also preliminary studies about the design of this system [10-12]. In this study, his system is examined experimentally and also a thermal model is developed in order to examine the collector parametrically. The objective of this paper is to show how this configuration can be improved in the future in order to be commercialized.

METHODS

The examined setup

In this section, the examined experimental set up is described. The solar dish collector is given in figure 1. The first innovation of this design is the spiral absorber which leads to a relative uniform heat flux distribution. The next innovations are the low cost and the lightweight structure of this collector. The main characteristics of the collector are given in the flow chart of figure 2 and in Refs [10-12].

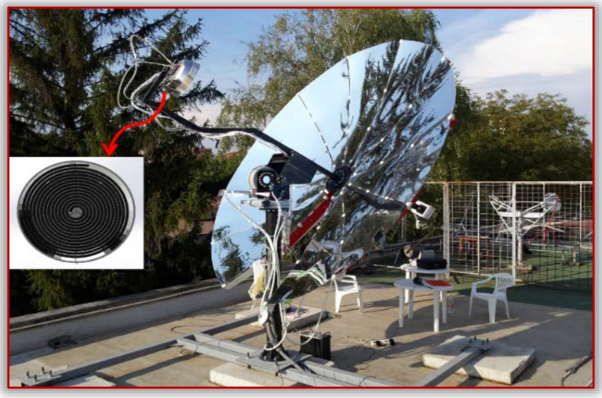

Figure 1. The examined solar dish collector

The numerical model

The developed numerical model is based on the energy balance on the spiral receiver and it is developed in EES (Engineering Equation Solver) by F-Chart [13]. This model has been also used and validated in other literature studies [14-15] and it is presented in figure 2 with the suitable modifications. Also it is essential to state that some useful references have been used for the utilized equations [15-19].

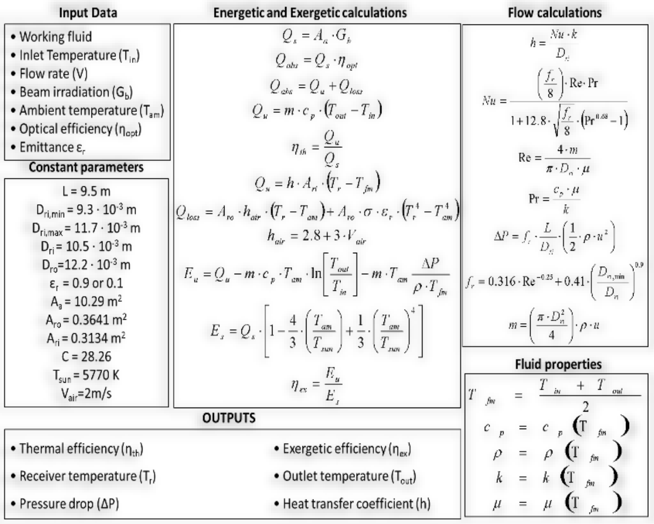

Figure 2. The flow chart of the developed numerical model

Followed methodology

The first part of this study (subsection 3.1) is the validation of the developed thermal model. Experimental results are used in order this model to be tested. For these tests, water has been used as working fluid with volumetric flow rate of 200 l/h. The experiments have performed the time period of August-September 2016, in the solar laboratory of the Faculty of Mechanical Engineering in the University of Nis (latitude 43°19' and longitude 21°54'). Moreover, it is essentially to state that for the real experimental setup, the optical efficiency has been estimated to 35%, after experimental tests. The reason for this low value is the low quality reflectance and manufacturing errors in the paraboloid shape of the concentrator. In the parametric studies, different parameters of the examined solar collector are investigated. In all these studies (subsections 3.2, 3.3 and 3.4) the working fluid is Therminol VP1 [20] because this is the best candidate for operation in higher temperature levels. In section 3.2, the flow rate is investigated, in section 3.3 the optical efficiency and in section 3.4 the receiver emittance. The emittance of the real collector is about 0.9 because the absorber is non-selective, while the case of selective absorber with emittance equal to 0.1 is examined numerically.

3. RESULTS

Model validation

In this subsection, the experimental results are used for validation of the developed model. Figure 1 illustrates the thermal efficiency and it is obvious that the experimental and the numerical results are close to each other, with mean deviation close to 5%. Thus, the developed numerical model is validated. Also it is essential to state that the thermal efficiency of the real collector operating with water (in low temperature levels) is close to 34%; low value which has to be increased for making this collector a competitive technology.

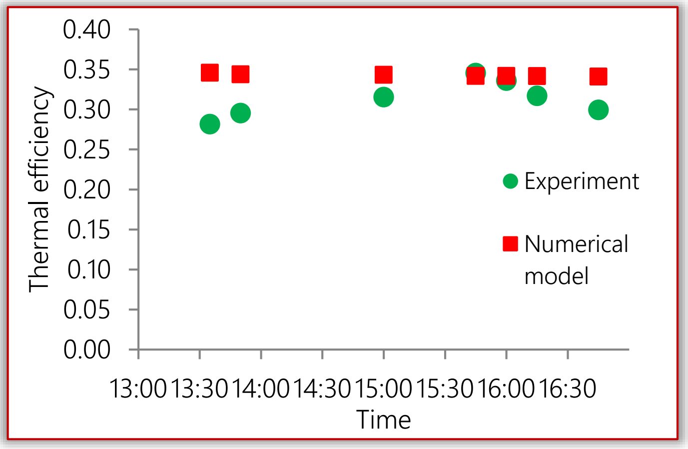

Figure 3. Thermal efficiency comparison between experimental and numerical results

Flow rate investigation

In this subsection, thermal oil is used and six different flow rates are examined. Figure 4 show that higher flow rate leads to higher thermal efficiency. After 200 l/h, all the curves tend to one, so this flow rate is selected as the optimum one. Figure 5 depicts the exergetic performance of the collector for the same examined cases. In low temperature levels, the lower mass flow rate is the best candidate, while in higher temperature levels, higher mass flow rates have to be used. Generally, the maximum exergetic efficiency is observed in the region between 145 °C to 165 °C and it is about 0.075; a low value which is explained by the low optical efficiency.

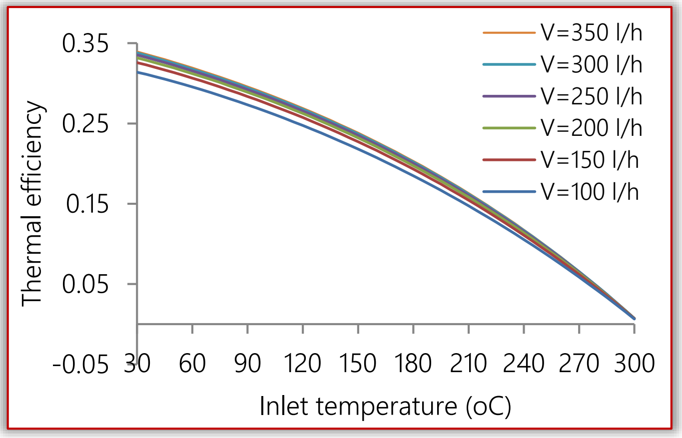

Figure 4. Thermal efficiency for various flow rates

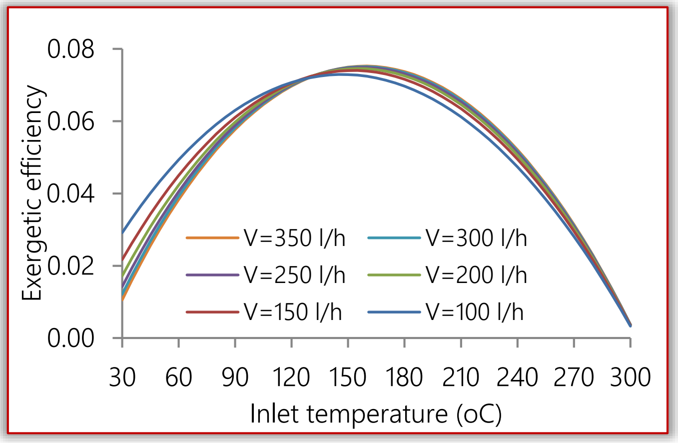

Figure 5. Exergetic efficiency for various flow rates

Optical efficiency investigation

The optical efficiency of the present collector is about 35%. This low value can be increased by using higher quality reflector and improving the shape of the reflector. In this section, the thermal and the exergetic efficiency are examined parametrically with the optical efficiency for thermal oil flow rate equal to 200 l/h. Figure 6 exhibits the thermal efficiency and it is obvious that all the curves seem to be parallel. The interesting result is that higher optical leads to higher thermal efficiency and to higher stagnation temperature. This temperature is the one which leads to zero thermal performance. This results is important for the determining the temperature operating range of the collector in every case.

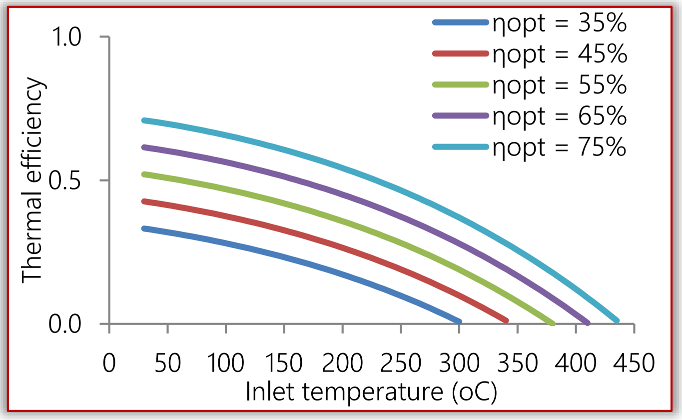

Figure 6. Thermal efficiency for various optical efficiencies

Figure 7 depicts the exergetic efficiency for the similar cases. Higher optical efficiency leads to higher exergetic performance. Moreover, higher optical efficiency leads to the exergetic efficiency to be maximized in greater temperature level. This is an interesting result which indicates that the exergetic performance of the collector is associated with the optical performance of it. For 75% optical efficiency, the maximum exergetic efficiency is 22.49% and it is observed at 210°C inlet temperature. For the optical efficiencies of 65%, 55%, 45% and 35%, the respective maximum exergetic performances are 18.41%, 14.52%, 10.85% and 7.46%, while the respective inlet temperature levels for exergetic maximization are 200°C, 190°C, 175°C and 155°C.

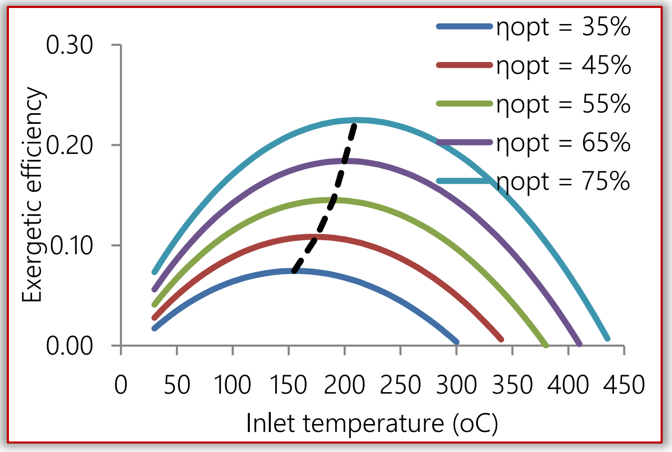

Figure 7. Exergetic efficiency for various optical efficiencies

Emittance investigation

In the last subsection, the impact of emittance on the collector performance is investigated by using 35% optical efficiency and 200 l/h thermal oil flow rate.

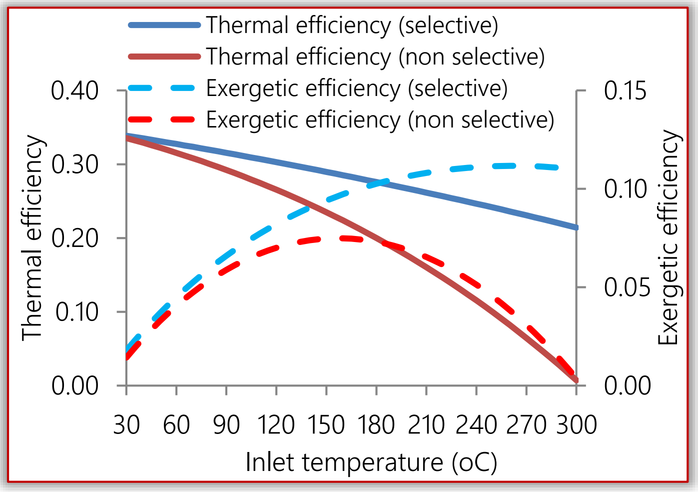

Figure 8. Thermal and exergetic efficiencies for the examined absorbers

Figure 8 show the thermal and the exergetic efficiencies for the non-selective absorber case (emittance equal to 0.9 – real case) and for selective absorber case (emittance 0.1). It is obvious that the performance with selective absorber is higher and the collector can operate in higher temperature levels. It is important to state that the non-selective case presents maximum exergetic efficiency for 155 °C and the selective for 265 °C with 7.49% and 11.17% respectively.

4. CONCLUSIONS

In this paper, a solar dish collector with spiral absorber is examined experimentally and numerically. The developed numerical model is validated with the experimental results for operating with water. Moreover, the developed numerical model with EES is utilized for examining the solar collector in various operating conditions, by changing the inlet temperature levels and the mass flow rates. Moreover, the impacts of the optical efficiency and of the absorber emittance are examined. The most important conclusions are summarized below:

» The present collector has low efficiency (about 34%) and it can operate up to 300 °C.
» The minimum suitable flow rate for thermal oil is 200 l/h for efficient operation.
» Higher optical efficiency makes the system to operate with higher thermal and exergetic efficiency, as well as to increase the maximum temperature close to 400°C.
» The maximum exergetic efficiency of the present system (optical efficiency equal to 35%) is about 7.49% and it is observed for 155°C, while for optical efficiency equal to 75%, the maximum exergetic efficiency is 22.49% for 210°C.
» The influence of the absorber emittance on the results is critical and it can make the collector to perform better and to operate in higher temperatures.

Nomenclature

A	Area, m2
C	Concentration ratio, -
c_p	Specific heat capacity, kJ/kg K
D	Diameter, mm
E	Exergy flow, W
f_r	Friction factor, -
G_b	Solar beam radiation, W/m^2
h	Convection coefficient, W/m^{2}K
k	Thermal conductivity, W/mK
L	Tube length, mm
m	Mass flow rate, kg/s
Nu	Mean Nusselt number, -
Pr	Prandtl number, -
Q	Heat flux, W
Re	Reynolds number, -
T	Temperature, K
u	Working fluid velocity, m/s
V	Volumetric flow rate, m^3/s
V_{air}	Ambient air velocity, m/s

Greek symbols

ε	Emittance, -
ΔP	Pressure drop, kPa
η	Efficiency, -
μ	Dynamic viscosity, Pa s
ρ	Density, kg/m^3
σ	Stefan–Boltzmann constant

Subscripts and superscripts

a	aperture
abs	absorbed
air	ambient air
am	ambient
ex	exergetic
fm	mean fluid
in	inlet
loss	losses
opt	optical
out	outlet
r	receiver
ri	inner receiver
ri,max	inner receiver max
ri,min	inner receiver min
ro	outer receiver
s	solar
sun	sun
th	thermal
u	useful

Note

This paper is based on the paper presented at 13th International Conference on Accomplishments in Mechanical and Industrial Engineering – DEMI 2017, organized by University of Banja Luka, Faculty of Mechanical Engineering, in Banja Luka, BOSNIA & HERZEGOVINA, 26 - 27 May 2017.

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PACK ALUMINIZATION PROCESS OF HEAT RESISTANT FeCrAl AND NiCr ALLOYS

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Abstract: Pack aluminization process is one of the possible production methods to improve oxidation resistance at high temperatures of various types of metallic materials. It is a chemo-thermal process where products are embedded in the powder mixture, consisting of Al powder, halide activator NH_4Cl, and inert diluent Al_2O_3 powder, and annealed at high temperature. This exposure to high temperature causes the Al diffusion into the base material and formation of the aluminide surface layer. During the component service at elevated temperatures, the oxidation resistance is obtained due to the constant formation of an aluminium oxide film that forms on the aluminide surface layer and acts as an oxygen impermeable barrier. In the present study, FeCrAl and the NiCr heat resistant alloys in the form of 1mm thick sheet were aluminized at various process parameters. The effect of time, temperature, concentration of aluminium and halide activator in the powder mixture as well as the influence of furnace atmosphere on coating formation mechanism, mass gain and the thickness of the aluminide diffusion layer was evaluated by scanning electron microscopy, X-ray photoelectron spectroscopy and micro hardness analytic techniques. Isothermal exposure tests at 1200 °C for 24h in air were conducted and compared with untreated samples for high temperature oxidation resistance estimation.
Keywords: Aluminizing, heat resistant alloys, FeCrAl, NiCr, high temperature oxidation

INTRODUCTION

Aluminizing is a widely used process to protect materials, particularly metals and alloys against high temperature oxidation and hot corrosion attack. In this process the metal to be coated is placed in a powder pack consisting essentially of the coating element source such as pure aluminium or aluminium alloy (Cr-Al), an activator such as halide salts AlF_3, NaCl, NH_4Cl and NH_4F and an inert filler material, usually alumina [1]. The process is carried out at atmospheric pressure in flowing hydrogen or in an inert atmosphere at a temperature between 700 °C and 1150 °C. The aluminizing process can be divided into three steps: (a) gaseous diffusion, (b) surface reaction and (c) solid diffusion. At the coating temperature halide activator reacts with the metal elements in the powder pack and form a series of metal halide vapour species with characteristic partial pressure distribution that is determined by their thermodynamic stability in a particular powder pack. The coating is formed via reduction reaction of metal halide vapours at the substrate surface and subsequent solid state diffusion between metal elements and substrate [2,3].

The thermodynamics and kinetics of the aluminizing process are defined by the pack components and operating conditions like temperature, time and atmosphere [4]. Two critical issues for the application of aluminide coating have been identified: (i) loss of Al from the coating into the substrate which limits coating lifetime, (ii) the difference in thermal expansion coefficient (CTE) between aluminide coating and the substrate, which can cause mechanical damage (cracks) to the coating [5].

EXPERIMENTAL PROCEDURE

The substrate alloys used in this study were a commercial ferritic alloy Fe-Cr-Al (Kanthal AF) and a commercial austenitic alloy Ni-Cr (Nicrothal 80); the composition is listed in Table 1.

Table 1. Chemical composition of the coated alloys in wt.%.

Alloy	Ni	Cr	Fe	Mn	Si	Al	Ti
Kanthal AF	0.4	21.0	Bal.	0.2	0.2	5.5	1.0
Nicrothal 80	Bal.	20.0	1.0	0.5	1.3	-	-

Flat coupons (20 x 10 x 0.7 mm) were ultrasonically cleaned in an alcohol, dried and immediately embedded in a powder pack, which consist of the deposition element (Al), an activator (NH_4Cl) and an inert filler (Al_2O_3), and semi-sealed in alumina crucible. The crucible is heat treated in a tube furnace under an Ar-5%H_2 atmosphere. Process parameters of the aluminizing process are process time, process temperature and the powder pack. The coating time was varied from 0.5 to 2.5 hours and the process temperature from 670°C to 750°C. The heating rate was 10°C/min and the cooling rate from the process temperature to 200 °C was 5 °C/min. The Al to NH_4Cl mass ratio in the powder mixture was 3 (21 wt.% Al, 7 wt.% NH_4Cl, 72 wt.% Al_2O_3) for all aluminizing experiments. Coated specimens were cleaned with a brush and then put into ultrasonic bath and cleaned in an alcohol.

Cross sections of samples for microstructure observations were prepared by standard metallographic preparation by grinding and polishing. Optical microscope AXIO CSM 700 and scanning electron microscope Jeol JSM 5610 with energy dispersive X-ray spectroscopy (EDS) were used for the microstructure observations.

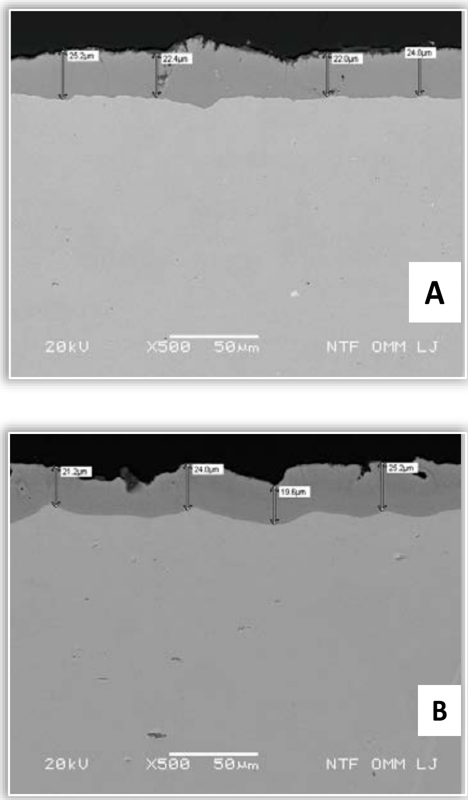
The phase constitution of the as deposited coatings was examined by X-ray diffraction (XRD), using Cu Kα radiation. The oxidation resistance of the samples was investigated under isothermal conditions by thermobalance Netzsch STA 429 at 1200 °C, 24 h in a laboratory air atmosphere. Samples were heated at a rate of 20 K/min, followed by cooling at the rate 20 K/min.

RESULTS AND DISCUSSION

Coating thickness as a function of time and temperature

Aluminium was successfully deposited onto Fe-Cr-Al an Ni-Cr alloy in the form of 0.7 mm sheet through the halide activated aluminizing process at different coating temperature and time. The coatings show some irregularities and a small pore size but are free of cracks. The number of irregularities in coatings increases with coating temperature. After aluminising, coating thickness measurements were performed at various sites.

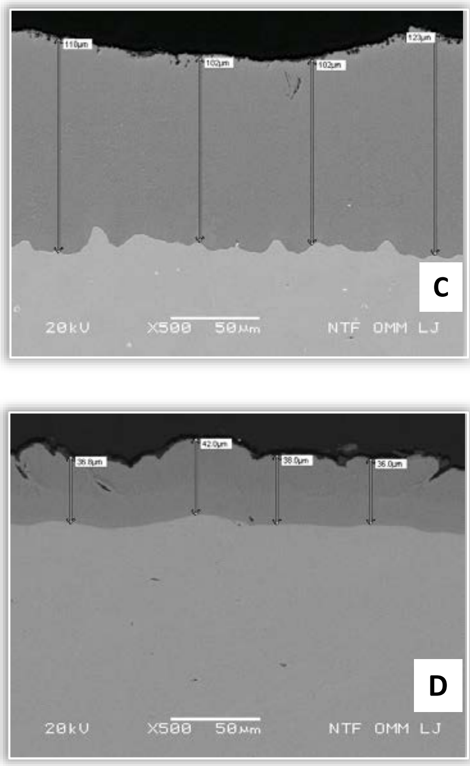
Figure 1 shows the SEM cross sections of aluminide coatings on Fe-Cr-Al and Ni-Cr alloy deposited at 670 °C for 1.5h and Figure 2 aluminide coatings on both alloys deposited at 730 °C for 1.5 h. The aluminide coating is thicker in the case of Fe-Cr-Al alloy because of a higher diffusion rate of Al in Fe-Cr-Al alloy, especially at higher temperature.



(A)

(B)

Figure 1. SEM image of FeCrAl (A) and NiCr alloy (B) aluminized at 670°C, 1.5 h



(C)

(D)

Figure 2. SEM image of FeCrAl (C) and NiCr alloy (D) aluminized at 730°C, 1.5 h

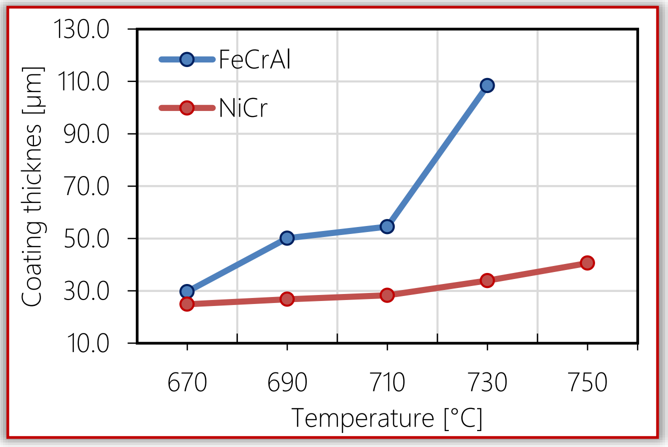


Figure 3. The average aluminide coating thickness as a function of aluminizing temperature at a constant annealing time 1.5 h

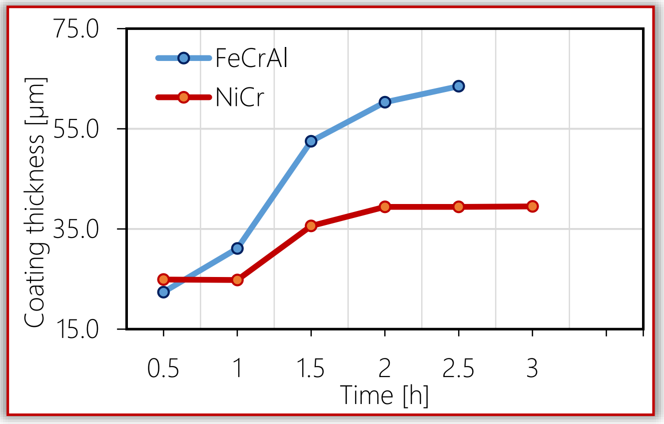
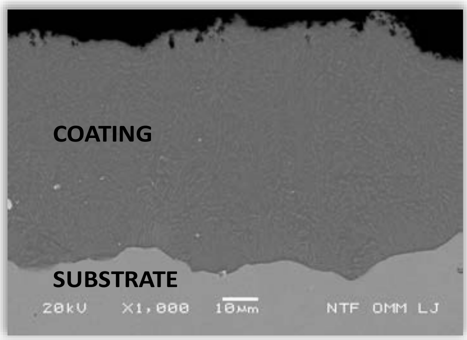


Figure 4 . The average aluminide coating thickness as a function of time at a constant temperature 690 °C

Figure 3 shows the average coating thickness as a function of coating temperature at constant time. The data points for each coating temperature demonstrate that as the coating temperature is increased, the coating thickness increased. With an increase in aluminizing temperature from 670 °C to 730 °C at constant coating time 1.5 h, the coating thickness is increased threefold for Fe-Cr-Al alloy and thirty percent for Ni-Cr alloy. Figure 4 shows the average coating thickness as a function of coating time at constant temperature 690 °C. The thickness of the coating increase with time from 0.5 to 3 h for both alloys. Increase in thickness was much higher for Fe-Cr-Al alloy.

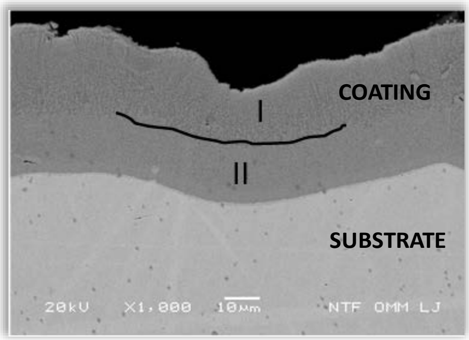
Scanning Electron Microscopy (SEM/EDS)

Chemical analysis of coating and substrate subsurface were performed by energy dispersive spectroscopy (SEM-EDS). Figure 5 shows the representative sample subjected to the coating temperature of 730 °C for 1.5h for the Fe-Cr-Al alloy and Figure 6 for the Ni-Cr alloy. Coating thickness ranged from 100 to 120 µm for Fe-Cr-Al alloy and 30 to 45 µm for Ni-Cr alloy.



Principal elements in EDS analysis (wt.%)					
hase	*O*	*Al*	*Cr*	*Fe*	*Co*
area		49.68	4.03	45.41	0.89
area	0.40	40.34	22.97	35.59	0.69
rate		3.82	21.22	73.84	

Figure 5. SEM-EDX analysis of Fe-Cr-Al coated at 730 °C for 1.5 h



Principal elements in EDS analysis (wt.%)						
Phase	Al	Si	Cr	Mn	Fe	Ni
Area I	48.97	0.26	10.76	0.13	0.34	39.54
Area II	37.55	0.50	11.50	0.10	0.37	49.98
Substrate	0.12	1.25	20.43	0.17	0.50	77.54

Figure 6. SEM-EDX analysis of NiCr coated at 730 °C for 1.5 h

The coating on Fe-Cr-Al alloy is a dual phase mixture with dark and light areas. EDS analysis show that the dark phase is rich in aluminium and contain iron and a small amount of chromium. The light phase contains a smaller percentage of aluminium and iron, and a larger percentage of chromium. It is evident that Fe-Cr-Al alloy forms a number of different phases. The formation of these phases depends on the diffusion of aluminium through the coating in direction to the substrate. The aluminium content increased in the direction to coating surface and the content of chromium and iron decreased.

On the other hand, aluminized layer on Ni-Cr alloy consists of two layers: the darker top layer (Area I), rich on aluminium, chromium and nickel and lighter subsurface layer (Area II), which contains smaller percentage of aluminium and a higher percentage of nickel and chromium. The average coating thickness is 35 µm, thickness of top layer is 15 µm followed by a sub layer of about 20 µm.

X-ray diffraction

X-ray diffraction (XRD) was used for phase identification of coatings. From these study it was established that for the coating time 1,5h at 730°C, the surface of the coated Fe-Cr-Al alloys consists mainly from α- Al_8Fe_5, β- Al_5Fe_2, γ- $AlFe_3$ (see Figure 7a). According to the phase diagram Fe-Cr the iron forms a number of different intermetallic compounds such as: $FeAl_3$, Fe_2Al_5, $FeAl_2$, FeAl, Fe_3Al, as well α-Al and α-Fe. Based on the intensity of the scattered X-rays the largest content has Al_5Fe_2 phase.

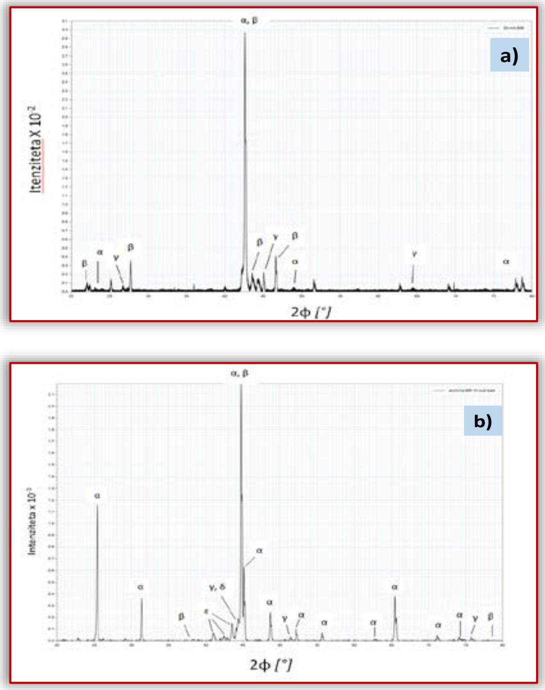


Figure 7. XRD patterns of the aluminizing coating on Fe-Cr-Al substrate a) and NiCr substrate b)

Aluminized coating of Ni-Cr alloy comprises the following phases: α- Al_3Ni_2, β- Al, γ- Ni, δ- Cr, ε- Al_3Ni (see Figure 7 b), with the largest proportion of the Al_3Ni_2 phase. From the results of XRD and SEM analysis, it can be concluded, that the upper layer (I) is comprised mainly of Al_3Ni phase, and the layer (II) of Al_3Ni_2 phase, with continuously increased proportion of other phases according to the Al-Ni phase diagram. This finding is in a good agreement with [6]. They found out that Al_3N_2 is the major phase because of a very high diffusivity of Al_3Ni_2.

Oxidation test

The effectiveness of the aluminizing process was evaluated by the oxidation testing of the commercial Fe-Cr-Al 0.7 mm thick sheet in comparison with aluminized Fe-Cr-Al samples under isothermal conditions (thermo-balance Netzsch STA 429) at constant temperature of 1200 °C/24 h in a laboratory air atmosphere. Samples were heated and cooled at the same rate of 20 K/min. The results are presented by the relative mass gain versus time (Figure 8). According to the measurements, the initial oxidation rate of as received commercial Fe-Cr-Al sheets is higher than for aluminized Fe-Cr-Al samples (first 24 h). Because of short time of isothermal temperature exposure, further longer tests would be needed to determine whether or not the increased Al alloy content prolong the life time of the Kanthal AF sheet at 1200 °C [7].

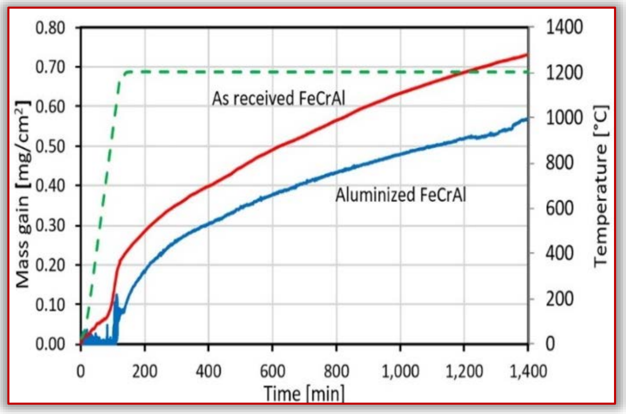


Figure 8. Relative mass gain as a function of oxidation time in air at 1200°C (heating rate 20 K/min)

CONCLUSIONS

Within the work it was successfully prepared homogeneous aluminized layer on ferritic Kanthal AF (Fe-Cr-Al) and on austenitic Nicrothal 80 (Ni-Cr) with sufficient aluminium reservoir, which should enable the formation of protective alumina scale in oxidizing conditions.

The effect of Al activity in powder pack on the coating kinetics and structure was studied at several coating temperatures in the range from 650 to 750 °C for 0.5 to 2.5 hours. Samples in the form of sheet were uniformly aluminized at various times and temperatures. The dependence of coating thickness from temperature and time at constant powder pack was evaluated.

The coating is free of cracks with some imperfections like pores or porous area. According to SEM/EDS analyses of Fe-Cr-Al alloy aluminium content decreased from the coating surface to the substrate material, the content of chromium and iron increases. Aluminized layer on Fe-Cr-Al alloy contains intermetallic phases Al_8Fe_5, Al_5Fe_2 and $AlFe_3$.

Analyses of the aluminized layer on Nicrothal 80 (Ni-Cr) alloy showed that aluminized layer consists of two layers. The upper layer, with higher percent of aluminium and the lower layer, with smaller percentage of aluminium and a higher percentage of nickel and chromium. The upper layer is comprised mainly of Al_3Ni phase, and the lower layer of Al_3Ni_2 phase, with continuously increased proportion of other phases in direction of the substrate alloy. The thickness of the layers increases with aluminizing time and temperature. Coating thickness is increased faster in Fe-Cr-Al alloy because of significantly higher diffusion rate of aluminium in KANTHAL AF alloy than in Nicrothal 80 alloy [8].

Note

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CRACK PROPAGATION ANALYSIS OF CYCLICALLY LOADED STRUCTURAL COMPONENTS

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Abstract: The present paper proposes a computational model for the failure analysis of finite plate with quarter-elliptical corner crack located at a hole. Such a theoretical investigation takes into account the stress intensity factor calculation and fatigue life estimation. Fracture mechanics based analytical approach is employed to analyze the stress-intensity behaviour, whereas the stress-ratio dependence crack growth model is applied for assessing fatigue life to failure. The crack growth estimations show a good correlation with experimental data.
Keywords: fatigue, quarter-elliptical crack, stress-intensity behaviour, residual life calculation

INTRODUCTION

The integrity of engineering structures may be often threatened by fatigue crack-like flaws, i.e. damages during service operations. Therefore, significantly important aspect is to estimate the failure strength of components by taking into account reliable fracture mechanics based computational models.

Under cyclic loading, the crack propagation behaviour can be theoretically examined either as through-the-thickness crack situations or surface problems (quarter-elliptical corner crack, semi-elliptical crack and embedded-elliptical crack) through the stress analysis and residual life assessment by means of analytical methods and numerical approaches. Thus, Elber [1] suggested the crack closure concept, whereas Walker [2] and later Kujawski [3] proposed the two-parameter driving force model for the fatigue life estimations. Glinka et al. [4] found that the damage accumulation ahead of the crack tip can be employed to describe the crack growth rate. Furthermore, different fracture mechanics based numerical models such as: the finite element alternating method [5], the boundery integral equation method [6], the finite element method with singularity elements [7, 8] can be applied to assess the stress-intensity behaviour under fatigue conditions.

In the present paper, a mathematical model is developed for fatigue failure analysis of quarter-elliptical corner crack emanating from a hole. The proposed model considers the stress-intensity analysis and fatigue life estimation for depth and surface crack length directions. Relevant experimental crack growth data are employed to verify the predictive capability of failure assessments.

RESIDUAL LIFE ESTIMATION UNDER CYCLIC LOADING

The complex interaction of applied load and environment can often endanger the service life of engineering structures due to appearance of fatigue failure. In order to ensure safe exploitation, the reliable computational models for the fatigue analysis have to be developed by taking into account appropriate fracture mechanics principles. Thus, the propagation of quarter-elliptical corner crack emanating from a hole is herein theoretically examined through the crack growth law proposed by Walker [2[in depth and surface crack directions, as follows:

$$\frac{da}{dN}=\frac{C_A\left(\Delta K_{IA}(a,b)\right)^{m_A}}{(1-R)^2}$$

and

$$\frac{db}{dN}=\frac{C_B\left(\Delta K_{IB}(a,b)\right)^{m_B}}{(1-R)^2} \qquad (1a\text{-}b)$$

where a, b and ΔK_{IA}, ΔK_{IB} are the crack length and the stress intensity factor in depth and surface crack directions, respectively, R is the stress ratio and C_A, C_B, m_A, m_B denote material constants experimentally obtained.

In the residual strength assessment, the final number of loading cycles is computed by integrating the relationship related to the crack growth rate for depth and surface crack direction, respectively i.e.

$$N=\int_{a_0}^{a_f}\frac{(1-R)^2\,da}{C_A\left(\Delta K_{IA}(a,b)\right)^{m_A}}$$

and

$$N=\int_{b_0}^{b_f}\frac{(1-R)^2\,db}{C_B\left(\Delta K_{IB}(a,b)\right)^{m_B}} \qquad (2a\text{-}b)$$

where a_0, b_0 and a_f, b_f are initial and final crack lengths in depth and surface direction, respectively.

Since the relationships for the crack growth rate and the stress intensity factor are the complex-valued functions, the numerical integration based on the Euler's algorithm is taken into account. Thus, according to the software program here examined, the fatigue life to failure is estimated by applying Eqs. (2a)-(2b) step-by-step for appropriate crack growth increments.

STRESS-INTENSITY ANALYSIS OF QUATER-ELLIPTICAL CORNER CRACK

From the fracture mechanics theoretical point of view, the crack propagation under cyclic loading may be examined if the geometry of structural component together with parameters related to material and external loading are involved through the stress intensity factor. In the present study, the stress-intensity behaviour of the quarter-elliptical corner crack emanating from a hole (Fig. 1) is analyzed by taking into account the following relationship [9]:

$$\Delta K_I = \Delta S \sqrt{\frac{\pi a}{Q}} M_e f_1 \sqrt{\frac{1}{\cos\left(\frac{\pi D}{2w}\right)}} g_\phi \qquad (3)$$

where ΔK_I is the stress intensity factor range, ΔS denotes applied stress/load, D and w are diameter and width of the plate, respectively. Further, Q, M_e, f_1 and g_ϕ represent fracture mechanics based functions related to crack configuration and loading, expressed in the following way [9]:

$$Q = 1 + 1.47\left(\frac{a}{b}\right)^{1.64}, \left(\frac{a}{b} \le 1.0\right) \qquad (4)$$

$$M_e = \left(M_1 + \left(\sqrt{Q\frac{b}{a}} - M_1\right)\left(\frac{a}{t}\right)^p\right) f_{w1} \qquad (5)$$

$$M_1 = 1.2 - 0.1\frac{a}{b}, \left(0.02 \le \frac{a}{b} \le 1.0\right) \qquad (6)$$

$$p = 2 + 8\left(\frac{a}{b}\right)^2 \qquad (7)$$

$$f_1 = 0.707 - 0.18\lambda + 6.55\lambda^2 - 10.54\lambda^3 + 6.85\lambda^4 \qquad (8)$$

$$\lambda = \frac{1}{1 + \frac{2b}{D}\cos(0.85\phi)} \qquad (9)$$

$$f_{w1} = \sqrt{\frac{1}{\cos\left(\frac{\pi}{2}\frac{D+b}{w-b}\right)}} \qquad (10)$$

$$g_\phi = 1 + \left(0.1 + 0.35\left(\frac{a}{t}\right)^2\right)(1 - \sin\phi) \qquad (11)$$

where t is the thickness of the plate and ϕ denotes parametric angle of ellipse.

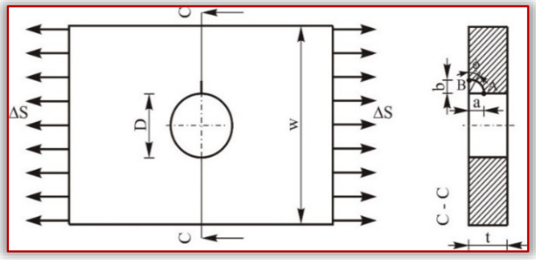


Figure 1. Geometry of the plate with quarter-elliptical corner crack emanating from a hole (a - depth direction, b – surface direction).

NUMERICAL APPLICATIONS

In the present Section, the failure behaviour of quarter-elliptical corner crack emanating from a hole is theoretically examined through the proposed computational model. Such fatigue crack growth investigation takes into account the stress intensity factor calculation and the residual life estimation.

The crack growth estimation under cyclic loading

The fatigue strength of the plate with quarter-elliptical crack emanating from a hole (Fig. 1) is tackled through the residual life calculation.

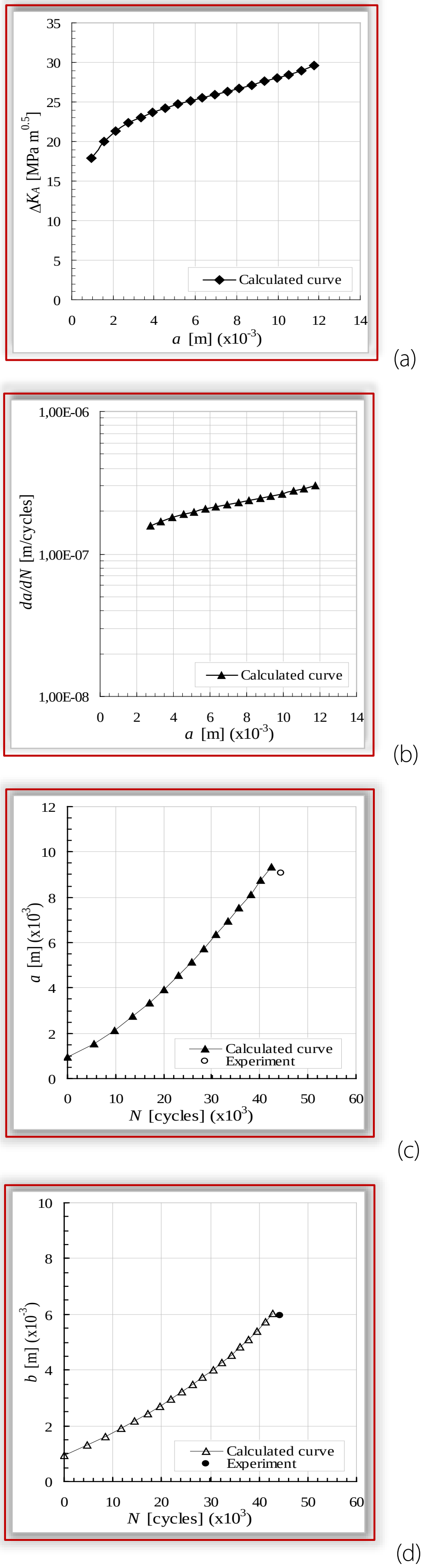


Figure 2. The fatigue failure analysis of the plate: (a) ΔK_A-a, (b) da/dN-a, (c) a-N, (d) b-N.

The crack growth process is here analyzed under cyclic axial loading wirh constant amplitude (S_{max} = 155.69 MPa, R = 0.05). The plate (w = 73.66 mm, t = 12.7 mm, D = 12.7 mm, a_0 = b_0 = 0.9398 mm) is made of Ti-6Al-4V Alloy and the following material parameters are assumed: C_A=1.12 10^{-10}, C_B= 1.03 10^{-10} and m_A=m_B= 2.3.

The fatigue behaviour of quarter-elliptical corner crack is examined by employing Eqs. (3)-(11) for the stress intensity factor evaluation, then the residual life is assessed through Eqs. (2a)-(2b). The calculations related to the stress intensity factor and the crack growth rate are presented in Figs. 2a and b, respectively. Further, the number of loading cycles to failure, as a function of crack length for depth and surface direction, are shown in Figs. 2c and d, respectively.

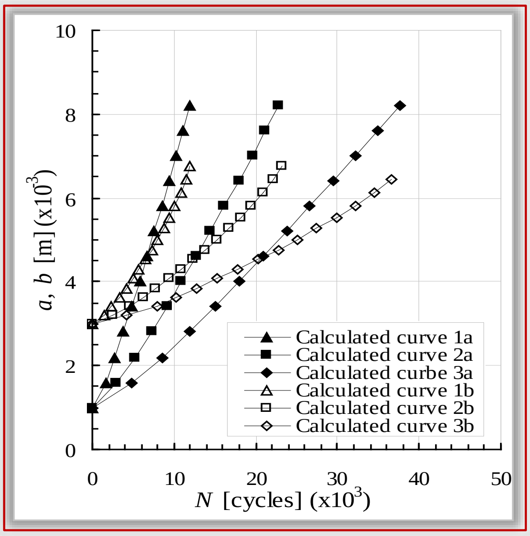
Then, to assess the predictive capability of developed computational model for the fatigue analysis of quarter-elliptical corner crack located at a hole, the residual life calculations are compared with experimental observations, as shown in Fig. 2. Hence, such comparisons indicate that proposed model here examined enables the reliable fatigue strength estimation for both depth and surface crack length directions.

The effect of thickness and width on the fatigue failure behaviour

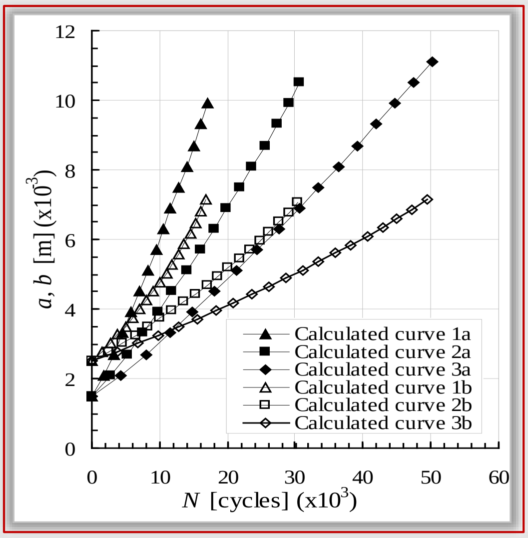
The crack growth analysis, presented in this Section, examines the effect of thickness and width of the plate on the fatigue life to failure. In such investigation, the plate with quarter-elliptical crack, made of Ti-6Al-4V Alloy, has the following geometry and loading parameters for two cases tackled here: (a) a_0=1.5 mm, b_0= 2.5 mm, *D* = 15 mm, *w* = 65 mm, P_{max}= 130000 N, R = 0.1, t = (12, 15, 18) mm and (b) a_0=1.0 mm, b_0=3.0 mm, D = 10 mm, t = 10 mm, P_{max}= 100000 N, R = 0.1, w = (50, 65, 80) mm. Under cyclic axial loading with constant amplitude the failure behaviour is theoretically considered by assuming the same material parameters as those mentioned above.

In the residual life assessment, the stress intensity factor is calculated through Eqs. (3)-(11), whereas the number of loading cycles is estimated by applying Eqs. (2a)-(2b) for both depth and surface crack directions. The effects of thickness and width are shown (as numbers of loading cycles to failure against crack length) in Figs. 4a and b, respectively. It should be noted that calculated curves 1a, 2a, 3a and corresponding 1b, 2b and 3b (see Fig. 3) represent the fatigue estimations for the depth and surface crack length direction, respectively.

The comparisons presented in Fig. 3 show that thickness and width have significant impact on the fatigue strength of the plate with quarter-elliptical corner crack. Thus, the developed computational model enables a quick identification of the most influent parameters, in order to reach an optimal design solution, as well as to timely predict fatigue failure caused by initial quarter-elliptical corner crack during mandatory inspections and controls.



(a)



(b)

Figure 3. Crack length against number of loadng cycles to failure: (a) the effect of thickness of the plate (w = 65 mm, 1 – t = 12 mm, 2 – t = 15 mm, 3 – t = 18 mm), (b) the effect of width (t =10 mm, 1 – w = 50 mm, 2 – w = 65 mm, 3 – w = 80 mm).

CONCLUSIONS

In the present paper, the fatigue failure behaviour of a quarter-elliptical corner crack emanatig from a hole is theoretically examined. Such a fracture mechanics based investigation takes into account the stress analysis and the residual life estimation. Under cyclic loading, in order to describe the stress-intensity behaviour analytical approach is employed. Further, the fatigue life to failure is assessed by means of the stress-dependance crack growth law. A good correlation between the crack growth calculations and available experimental data verifies that proposed computational model can be employed for reliable strength analysis of the quarter-elliptical corner crack located at a hole.

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Note

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ADVANTAGES OF DRYING OF VEGETABLES USING THE INTEGRATED HEAT PUMP TECHNOLOGY

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Abstract: The world is facing an increase in human population and consequently need to produce more fresh and dried products for this expanding population. New technologies should fulfill the objective of economical profitability, which is mostly dependable on energy efficiency due to the trend of increasing energy cost. Currently, as a drying process consumes up to 50% of the total amount of energy used in industrial purposes. One of the relatively new technologies for these requirements is heat pump drying (HPD). In this work a laboratory heat pump drying is applied for vegetables drying. The drying of vegetables was conducted in fluidized bed. Fluidized bed gives important advantages such as good solid mixing, high rates of heat and mass transfer and easy movement of materials. The air drying was adjusted on temperature regimes of 45°C and 15°C with three relative humidity levels. Some of the limitations in fluidized bed drying application are high pressure drop and high electrical power consumption. The results have shown that higher temperatures increase the rate of moisture removal from the vegetables (green peas). Difference in relative humidity of the air drying plays an important role in the process.
Keywords: drying, heat pump, vegetables, fluidized bed

1. INTRODUCTION

This work covers the experiments and modeling green peas drying on a pilot scale heat pump dryer. Focus will be given on the effect of heat pump operating conditions, drying temperature and relative humidity on kinetics and on the dried product's characteristics. Heat pump dryers have been known to be energy efficient when used in conjunction with drying operations. The principal advantage of heat pump dryers emerge from the ability of the heat pumps to recover energy from the exhaust gas as well as their ability to control the drying gas temperature and humidity. Many researchers have demonstrated the importance of producing a range of precise drying conditions to dry a wide range of products and improve their quality. The main components of the single stage heat pump system are the expansion valve, evaporator, internal and external condenser and compressor as illustrated in figure 1.

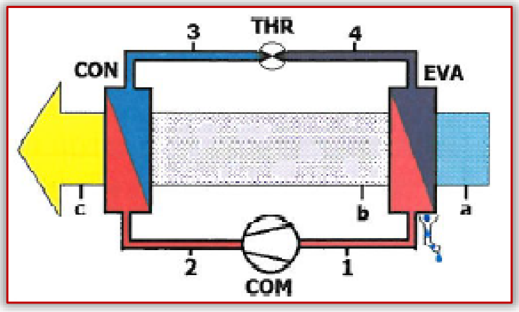

Figure 1. Principle of operation in a simplified heat pump dryer

After flowing through the evaporator and condenser of the heat pump the dry and warm air is ready to flow into the drying chamber in which the material, which is to be processed, is being placed. The simplified heat pump dryer has two separated loops with common heat exchangers. The drying air loop (*abcd*) contains the air cooler (*EVA*), heater (*CON*), blower and drying chamber. The refrigerant loop (*12341*) main components are the expansion valve (*THR*), evaporator (*EVA*), condenser (*CON*) and a compressor (*COM*). The fluid of the heat pump and drying air loops are coupled through the common evaporator and condenser to recover the exhaust energy.

2. PRINCIPLE OF HEAT PUMP DRYING

Figure 2 illustrates the isentropic and non-isentropic saturated vapor compression heat pumps with dry expansion evaporator and drying channels.

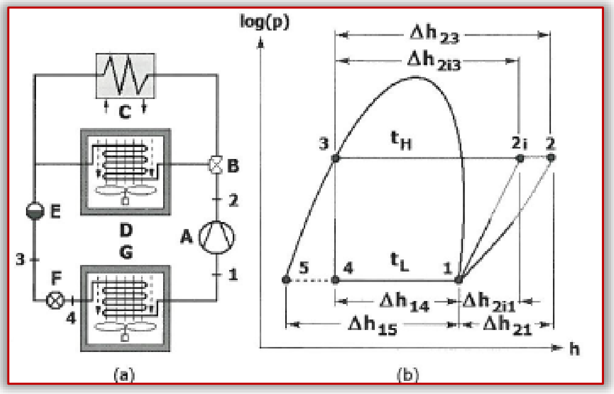

Figure 2. The isentropic and non-isentropic saturated vapour compression heat pumps indicating the corresponding specific enthalpy differences in each process

Figure 2a shows the main components: A – compressor, B – three way valve, C – external condenser, D – drying channel with air heater, E – liquid receiver, F – expansion valve, G – drying channel with air cooler. Also, Figures 2a and 2b show the layout and the state points in the cycles in a log pressure versus enthalpy diagram, respectively. From state point 1 the saturated vapor is isentropic and non-isentropic compressed to super-heated vapor to points 2_i and 2, respectively. Then, the vapor flows through the condensers changes phase to saturated liquid and is collected in the receiver. The saturated liquid leaves the receiver at point 3 and it is throttled to a liquid and vapor mixture at point 4. Then, the mixture flows through the evaporator and becomes saturated vapor at point 1 to be compressed again.

3. FLUIDIZED BED AND PRODUCT QUALITY

Fluidized bed dryers (FBD) are used extensively for the drying of wet particulate and granular materials that can be fluidized, and even slurries, pastes, and suspensions that can be fluidized in beds of inert solids. They are commonly used in processing many products such as chemicals, carbohydrates, foodstuff, biomaterials, beverage products, ceramics, pharmaceuticals in powder or agglomerated form, healthcare products, pesticides and agrochemicals, dyestuffs and pigments, detergents and surface-active agents, fertilizers, polymer and resins, tannins, products for calcination, combustion, incineration, waste management processes, and environmental protection processes. Fluidized bed operation gives important advantages such as good solid mixing, high rates of heat and mass transfer, and easy material transport.

Some advantages of fluidized bed drying are the high rate of moisture removal, high thermal efficiency, ease of control and low maintenance cost. The high rate of moisture removal is due to the large interfacial surface area which is in order of 3000 to 45000 m^2/m^3 in the fluidized bed. This is also the reason for very high rates of heat transfer achieved in fluidized beds.

Some of the limitations in drying application of the fluidization are high pressure drop and high electrical power consumption for the blower. Also the drying product may be damaged in intensive fluidization or particle to particle and particle to wall collisions.

Experimental design

The experiments were conducted in a heat pump drying system with a fluidized bed. Each batch of raw material placed inside the drying chamber had a mass of 1000 grams. The green peas samples were dried at three values of drying air temperature and three values for the relative humidity. The temperatures were 45°C and 15°C and each temperature was fixed tested at relative humidity of 60%, 40% and 20% with exception of 45°C as previously mentioned. This resulted in a design of eight drying tests. The details of experimental conditions and setup for all eight tests are presented in Table 1.

Table 1. Experimental conditions and setup for all heat pump drying tests

Test Number	Temperature, [°C]	Relative humidity, [%]
1.	45	40
2.	45	20
6.	15	60
7.	15	40
8.	15	20

The frozen green peas were mixed and homogenized to form a large batch that was partitioned into eight uniform batches of green peas to be dried according to the mentioned design. One drying test took 3 hours to complete. During the drying of all tests the drying chamber was taken out every 20 minutes period to measure the change in mass. Relatively small masses of dried product samples were also extracted at every 60 minute interval, which makes 3 extractions every test. The extracted material was put in small vessels whose mass was determined previously, and then the total mass of vessel with extracted sample was measured, after which they were put into preheated oven for 24 hour drying period. The drying oven was set at a temperature of 105°C and for 24 hours. The already known mass of the empty vessel and total mass of vessel with the product allows us to calculate the mass of extracted product. The product was dried in the fluidized bed with the air velocity kept at approximately 1 m/s.

The drying chamber and supporting cabinet

The drying chamber is placed inside the isolated wooden cabinet made of plywood with styro foam insulation. The cabinet's dimensions are 0.8x0.8m in cross section with height of 1.5m.The drying chamber is made of plexiglas and it is easily locked and unlocked in central base positioned within the cabinet using a three pin lock-rotation mechanisms. The chamber is inserted in the drying loop but separated from outdoors by a sampling access door located in the front of the cabinet. The door is opened and closed using two external locks. There are two inlet and outlet tubes connecting the cabinet and chamber to the drying loop. The inlet tube is connected to the central base of the cabinet and to the cylindrical chamber containing the green peas. The chamber exhaust flows through the outlet tube that is positioned at the upper part of the cabinet. During the process of moisture removal the green peas contained in the cylindrical chamber is in a fluidized by controlled air flow. The density was measured based on standard determination of both mass and volume.

4. ANALYSIS OF DATA AND MEASUREMENTS

Water content

The water content of the green peas sample is defined either on a wet or on dry basis.

The moisture content in wet basis is calculated using the equation:

$$w_{wb} = \frac{m_w}{m_t} = \frac{m_t - m_d}{m_t}$$

The moisture content on dry basis w_{db} is calculated by dividing the mass of water m_w in green peas sample with mass of dry-matter md as shown in equation:

$$w_{db} = \frac{m_w}{m_d}$$

The bulk density

We have used both the density of individual particles and the density of the bulk material, which also includes the air spaces between the particles. The latter measure is termed the bulk density and it is the mass of solids divided by the bulk volume as expressed through the equation:

$$\rho_b = \frac{m}{V}$$

The particle density

To obtain the particle density from each test samples of ten individual green peas were taken and the diameters were measured using a caliper with accuracy to 1/20mm.

Similarly the particle density is obtained using ratio of the average mass of ten particles and average volume of same particles and it is expressed by equation:

$$\rho_p = \frac{\overline{m}}{\overline{V}}$$

5. RESULTS AND DISCUSSIONS

Drying Kinetics

Table 2 shows the values of moisture content on dry basis calculated for tests 1 and 2 done with temperature of 45°C and relative humidity of 40% and 20%. The development of moisture content on dry basis follows the kinetic measurements at time intervals of 20 minutes over a period of three hours. It is obvious that test 2 with the lowest relative humidity is the one with the lowest moisture content after this drying time. The experimental data for these tests are plotted in Figure 3.

Table 2 Experimental conditions and setup
for all heat pump drying tests

Moisture content on dry basis [%]		
Elapsed time [min]	Test 1	Test 2
0	323.19	323.19
20	180.58	170.84
40	119.64	114.6
60	84.34	81.76
80	63.06	61.57
100	49.77	48.88
120	40.88	40.12
140	34.66	33.6
160	30.17	29.5
180	26.66	24.8

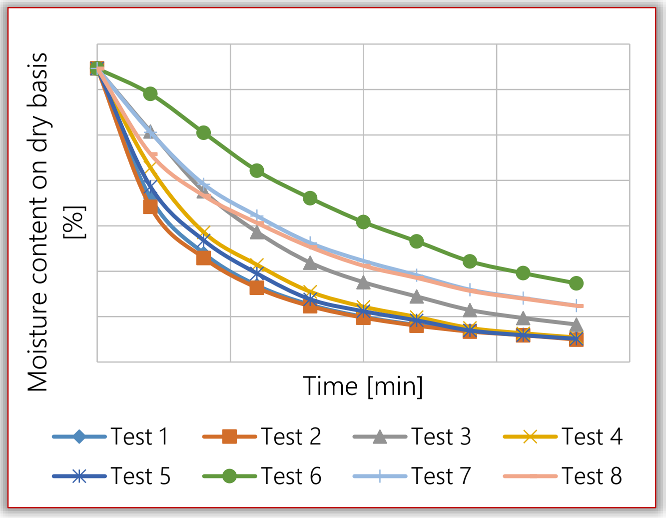

Figure 3. Development of moisture content
on dry basis for all tests

Table 3 shows the development of moisture content on dry basis for tests 6, 7 and 8 done with temperature of 15°C and relative humidity of 60%, 40% and 20%. Test number 8 is the one with lowest moisture content and it is the same test in which the drying air had the lowest relative humidity. The experimental data for these tests are plotted and presented in Figure 3.

Table 3. Development of moisture content
on dry basis for tests 6, 7 and 8

Moisture content on dry basis [%]			
Elapsed time [min]	Test 6	Test 7	Test 8
0	323.19	323.19	323.19
20	295.13	252.98	229.07
40	252.43	195.68	183.16
60	210.71	160.85	153.15
80	180.45	131.19	126.62
100	154.08	111.38	106.01
120	132.84	95.68	92.64
140	110.92	79.73	78.42
160	97.93	70.46	69.83
180	86.67	62.21	61.96

6. CONCLUSIONS

Advantages:

» Heat pump drying (HPD) offers one of the highest specific moisture extraction ratio (SMER), often in range of 1.0 to 4.0, since heat can be recovered from moisture-laden air.

» Heat pump dryers can significantly improve product quality by drying on low temperatures. At low temperatures, the drying potential of the air can be maintained by further reduction of the air humidity.

» A wide range of drying conditions typically -20°C to 100°C (with auxiliary heating) and relative humidity 15 to 80% (with humidification system) can be generated.

» Excellent control of the environment for high value products and reduced electrical energy consumption for low-value products.

This work focus on heat pump drying of green peas at varying conditions. The results have shown that the temperature of the drying air has the highest influence on products moisture content. There is also a significant influence of the relative humidity of the drying air on the final product's moisture content.

We can see that the tests with 45°C inlet air have faster moisture removal but also that Test 4 and Test 5 with 35°C inlet air 40% and 20% of relative humidity is approaching the value of the test 1. On the other hand the set of tests with 15°C have high values of moisture content and it is obvious that for that low temperature not even changes in relative humidity can increase moisture removal rate.

Overall, test 2 produced the dried green peas with lowest moisture content. In terms of color a higher temperature regime influenced the most drastic change in the color properties of the final product but still the values remained relatively close between tests. The biggest difference that can be noticed is the similarity of values for Test 1 to Test 4, and also the similarity in results of color for Test 5 to Test 8.

Note

This paper is based on the paper presented at 13th International Conference on Accomplishments in Mechanical and Industrial Engineering – DEMI 2017, organized by University of Banja Luka, Faculty of Mechanical Engineering, in Banja Luka, BOSNIA & HERZEGOVINA, 26 - 27 May 2017.

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ACCELERATING IDEA TO MARKET PROCESS IN MANUFACTURING INDUSTRIES

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Abstract: Traditional European manufacturing industries overdesign an engineer products before their commercialization. Product idea, concept, design and engineering are done in multiple stages, many times even without analyzing the real end-user needs and requirements. At the same time in ICT sector and software industries, especially in cases of start-ups, time to market process is really fast, or otherwise business opportunity might be lost. This study indicates four stages how to accelerate idea to market time in manufacturing industries, by combining lessons learned from startups and lean methodology.
Keywords: engineering, time to market, acceleration, manufacturing industries

INTRODUCTION

The product design and engineering in manufacturing industries has been the way to competitive edge, when looking for a next generation product innovations. Earlier, in the 70s-80s the manufacturing industries focus was on the streamlining and speeding up the production. Toyota's focus on quality, eliminating waste, and continuous improvement through Kanban, made the Toyota Production System benchmark for lean production globally [1]. Since then, lean has been several times a trend in manufacturing industries and surely some companies are continuously following lean principles. Womack and Jones (1996) have identified the lean principles, starting from specifying customer value, identifying value streams and then streamlining material flows, as seen in following table [2].

Table 1 – Five Lean Principles according Womack and Jones, 1996 [2]

Principle	Description
Value	Specify the value desired by the customer
Value Stream	Identify the value stream for each product providing that value and challenge all of the wasted steps currently necessary to provide it
Flow	Make the product flow continuously through the remaining, value-creating steps
Pull	Introduce pull between all steps where continuous flow is impossible
Perfection	Manage towards perfection so that the number of steps and the amount of time and information needed to serve the customer continually falls

By now, lean principles have become also important for general management, and other disciplines like IT development, which make use of lean concepts but transfer them also to nonmanufacturing contexts [3]. Not only the lean thinking but also agile project management methods has been widely taken in use to large-scale and distributed projects. Agile project management focused on four core values: customer collaboration, iterative development, self-organizing teams, and adaptability to change [4]. Together lean thinking and agile methods have been successfully applied to product development at startup companies, which is called the lean startup methodology [5]. However, many lean startup principles may also be of benefit to established firms.

Traditional manufacturing companies have successfully implemented lean and agile methods for production and supply chain management, but at the same time product innovations, design and engineering are done in multiple stages, without any lean and agile methods. Development of complex, industrial products and services requires several engineering, operative, marketing, etc. skills for making continuous trade-offs and successful design decisions, additionally each customer delivery might include tailored and specific parts [6]. Time to market takes typically even years, as manufacturing industry companies are executing their business plans and realizing fully functional prototypes [7]. Actually, European companies are over designing and engineering products before commercialization. This study indicates best practices and defines four stages how to accelerate idea to market time in manufacturing industries, by combining lessons learned from software industries and lean methodology.

RESEARCH DESIGN

The aim of the study is to discuss the challenges that manufacturing industries companies are facing in their product innovation processes and engineering. The study seeks the answer in the question: how to improve mature companies' product innovation lifecycle in traditional product-based businesses? The study is a part of the large-scale research project creating product innovation cycle for different industries. However, the results have been analyzed so that the method can be used in manufacturing industry. The study is based on the state-of-the-art of innovation processes in startups from the literature review and on the empirical case data evidence from the multiple case studies. The qualitative case study research approach was chosen in order to gain both theoretical and empirical insight into the mature companies' innovation culture, especially in product innovations [8]. The outcome is a four-stage innovation lifecycle model for mature companies improving their product innovation speed and strategic development as well the daily operations by utilizing lessons learned from startups.

INNOVATIONS AND TIME TO MARKET IN STARTUPS

The OECD (1991) definition for technology innovation: "an iterative process initiated by the perception of a new market and/or new service opportunity for a technology-based invention which leads to development, production, and marketing tasks striving for the commercial success of the invention" [9]. Later, OECD (2005) has broadened their definition "the implementation of new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations" [10]. Innovation is the core for the startup, as they have to provide something new for the market, or otherwise their existence is questioned. In the cases of startups, time to market innovation process is really fast, or otherwise the entire business opportunity might be lost. In product development, the Minimum Viable Product (MVP) is a product with just enough features to gather validated learning about the product and its continued development [5]. The concept of MVP is well known for startups, but hardly heard by mature companies' employees. Startups are focusing to solve some customer problems and create business model to solve that customer problem. Only then startups are developing real product, and firstly MVP. For existing companies, it's different. Companies that have a business plan how to operate, and product innovations are done in linear or step-by-step methods. Product should always fit or support existing offerings. That makes it more difficult for mature companies to improve competitiveness and create something unique.

Table 2 – Different types of innovations [11]

Innovation type	Important	Typical	Challenges	Questions
Technology	Invention, R&D, research cooperation	Newness, creativity, knowledge	How to embody into products, services and processes	What is possible?
Product (good & services)	Need identification, concepts, development process, network utilisation, user involvement	Newness to user, changing, improving, combining, user driven	Timing	What is needed?
Process	Way of doing things, network	Changing, improving	Readiness for change, inter-organisational processes	How?
Strategy/ business	Business models	Distribution of work in network	Changing mind set, ecosystem building	What business are we in? Who are our customers? What are we offering and with whom?

Product innovations are not the only type of innovations in startups or mature companies. Accelerate project has indicated different types of innovations, in table 2[11].

Actually, even startups should yield different types of innovation, but different innovations need different capabilities. Comparing SME and start-up companies to large, mature company's in their innovation capabilities Accelerate -project find differences but also many similarities. If caricaturise SMEs, they have are more innovative in new ideas stage of the process, as their success is also strongly dependent on innovations. They are flexible and employees are generally enthusiastic about future possibilities, entrepreneurship is natural for them. Same, if caricaturise large companies, they have resources, both monetary and knowledge. Large companies have large networks relationship and processes to co-operate with other companies, universities and other ecosystem partners, which makes them better opportunities to innovate if they will. [11].

When looking at the operations, startups are more customer oriented as mature companies. The idea behind the Lean startup method is that in addition to a process for "product development", a startup also needs a process for "customer development" to find and understand the customers [12]. This leads to developing solutions based on a user-centered approach and adapting to customer needs. Lean, agile and customer orientation is the way to success in startups, but these ideas are usually lost when company grows and get older.

NEW METHOD FOR ACCELERATION IDEA TO MARKET IN MANUFACTURING INDUSTRIES

This study indicates best practices and defines four stages how to accelerate the idea to market time in manufacturing industries, by combining lessons learned from software industries and lean methodology. Acceleration or acceleration of innovation is not a common term, and here the study understands acceleration as accelerating innovation go-to-market and commercialization [11]. Acceleration is a combination of means: processes, tools and methods, which help companies go faster to the right markets [11]. So many times can be heard from the practitioners that they have growing pressure to make product development and production more efficient to aiming for profitability. In addition, practitioners in manufacturing industries are saying their products are increasingly complex, often with high engineering content, and they need to improve product quality continuously. It is time for mature companies to change their innovation culture towards their origins, the way successful startups are innovating. According to Steve Blank (2005), most new product development ventures fail not because they lack a product, they fail because they lack customers and a profitable business model [13]. Companies in this situation should focus on searching for a product-market fit and a sustainable, scalable, profitable business model [13]. An essential product innovation activity at this phase is customer development: a systematic approach for identifying and validating assumptions about customers, their problems, product features as a solution to their problems. In cases of mature companies, the business model is not typically changed. Mature companies focus on the development of new product, which does not actually bring competitive advantage today. Actually, product innovation should be continuous and lean process, depending on the actual stage, which the Accelerate project has indicated: Idea stage, Problem/Solution Fit, Product/Market Fit, Scaling (see table 3) [11].

Table 3 – Different stages of acceleration [11]

Idea stage	The focus of the Idea stage is to find a problem worth solving and understand it in detail. The problem must be important enough to create a solid foundation for a new business. In this phase the initial concept and vision of the business opportunities are specified, and people needed to get the development work going are gathered. The main activities in this stage are research, ideation and exploration.
Problem/ Solution Fit	In the Problem/Solution Fit phase, a solution with real demand to the earlier identified problem will be specified. At least one real customer needs to be found before going further from this phase. The main activities of this phase are the development and validation of a Minimum Viable Product (MVP) and its value proposition.
Product/ Market Fit	The Product/Market Fit phase focuses on validating your solution, market strategy and business model. It was enough to find one real customer in the solution discovery phase, but now the aim is to acquire and retain more customers to prove that your business model works. The key activities in this phase are generating a business model and testing it.
Scaling	The Scaling phase focuses on growth and it is the final step. You will get ready to scale-up and to find ways to grow quickly. This is the phase where you will reap the results of the work and investments made in the earlier phases.

The study has indicated that acceleration should be a continuous cycle. Same company can have many cycles at the same time, as product innovations might be in different stage or part of the different product lifecycles (Figure 1) [14].

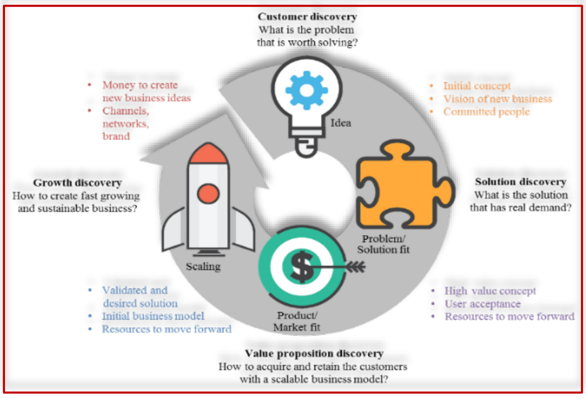

Figure 1 – Different stages of acceleration, according Acceleration stage-model [14]

To help companies identifying all required aspects in acceleration stages, the Acceleration - project have developed a self-test, which is available online [14]. Test helps companies to evaluate the status of product or service innovation development and gives ideas of how to proceed successfully from an idea to a scaled-up, profit generating product or service.

Starting from the Idea stage, companies should have a deep understanding of the customer need or problem, and data or evidence that proves its criticality and how the idea fulfils it in a new way. The idea should be documented and development activities so far to support further development. Practitioners should identify, based on data or evidence, why it is now a good time to solve the need or problem. In the Idea stage is also needed to have initial understanding how company will generate revenue from the solution to be developed. Innovators should have looked at the existing solutions and to know that competitors do not provide the value that our customers consider important. The core team of people with versatile skills (i.e. technical, teamwork, communication etc.) should be committed to take the idea further, and have the time to improve it. They have and we know where to acquire the missing skills.

In the Problem/Solution Fit stage, a company should have defined the initial functional, economic or emotional customer value of the solution, and have built or are currently building a prototype or demo to make the idea concrete. A product owner and team are committed to take the idea into further development and they have resources for it. End-users should be involved in testing the idea and know what input needed from them. The initial KPIs should be set to measure development progress and go-to-market of the solution. Necessary funding should be indicated to validate prototype or MVP. The company should have an understanding of the earning logic of the solution. It may be a direct price or an indirect revenue model.

In the Product/Market Fit, company should have extensively validated prototype or MVP value proposition, and have evidence and data, such as customer feedback to prove its success. They have defined focus markets and customer segments, and planned how to test and validated our solution in them. Different earning logics should be validated and have a cost structure that both funding partners and company accept. In this stage the marketing and distribution channels and strategies is defined, which allow future customers to know new solutions and to get them. Initial business model is defined in this stage and planned how to test it. Mature companies might need to change their existing business model.

In the scaling stage, companies should have ensured that have the needed personnel resources and competences for scaling, such as maintenance, after sales services, marketing, sales, and technology. As well channels, which allow customers to know about our solution and acquire it. At this point companies should have reliable way of controlling costs and avoiding cash flow problems.

CONCLUSIONS

A lean product development helps companies to launch products that customers actually want, and more quickly and cheaply than traditional methods [7]. To ensure survival and growth, mature and even large companies need to keep inventing new business models [Blank]. There are many differences in startups operating lean and traditional methods of operation. Traditional manufacturers have usually long technology development cycles, which actually has been one of the main reasons for startups to failure [7]. New ventures launch products that customers actually want, far more quickly and cheaply than traditional methods [7]. Actually traditional companies built the product iteratively, or fully specify the product before building it [7]. By that way cannot be sure that customers are getting product they want. Our model suggests improving design, engineering and product launch time in traditional companies. Blank (2003) have indicated the main differences between Lean and Traditional methods (Figure 2) [7].

Lean	Traditional
Strategy	
Business model Hypothesis-driven	Business model Hypothesis-driven
New-Product Process	
Customer development Get out of the office and test hypotheses	Product management Prepare offering for market following a linear, step-by-step plan
Engineering	
Agile development Built the product iteratively and incrementally	Agile or waterfall development Built the product iteratively, or fully specify the product before building it
Organization	
Customer and Agile development Teams Hire for learning, nimbleness, and speed	Departments by Function Hire for experience and ablity to execute
Financial Reporting	
Metrics that matter Customer acquisition cost, lifetime cusotomer value, churn, viralness	Accounting Income statement, balance sheet, cash flow statement
Failure	
Expected Fix by iterating on ideas and pivoting away from ones that don't work	Exception Fix by firing executives
Speed	
Rapid Operates on good-enough data	Measured Operates on complete data

Figure 2 – What lean start-ups do differently [7]

This paper may contribute to a better understanding of challenges that are related to accelerating time to market in manufacturing industries. Lean methodologies, agile and customer orientation may help entrepreneurs to run their business successfully and especially for improving their innovation projects. Traditional manufacturers should implement leaner and agile methods, improve their business model and decrease time to market continuously. Customer feedback should be collected in any earlier phase than traditionally. Minimum Viable Product concept might not fit in every high-tech product, but most of the product innovations can be presented for potential customers as early as the prototype phase. It is time to stop over-engineering in manufacturing industries. Listening to the customer is the key that startups do when validating a business model [7].

The presented process model of acceleration stages is intended as a step towards a better management of time to market processes. Future work will include the application of the suggested acceleration stages in manufacturing case studies, in order to validate its advantages compared to traditional product innovation and time-to-market processes.

Note

This paper is based on the paper presented at 9th International Conference "Management of Technology – Step to Sustainable Production" – MOTSP 2017, organized by Faculty of Mechanical Engineering and Naval Architecture of the University of Zagreb, CROATIA and University North, Varaždin, CROATIA, in Dubrovnik, CROATIA, 5 – 7 April 2017.

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DATA MATURITY FOR SMART FACTORY APPLICATIONS – AN ASSESSMENT MODEL

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Abstract: Due to the Industry 4.0 initiative, data analytics gained importance even in the industrial environment in the past years. New and affordable technologies like sensors, RFID and wireless connectivity enable companies to collect huge amounts of data. In combination with already existing data a wide range of data is available for finding improvement potential with data analytics applications. Nevertheless the experience gained through different projects in the past years shows a lack of maturity in data and data systems suitable for automated analytical approaches. Because of that a model to assess the fitness of systems for data analytics is in development. A key factor, the assessment categories, will be introduced in this paper.
Keywords: data quality, smart factory, big data, big data analytics, industry 4.0

INTRODUCTION

Data is considered to be one of the most important resources of the 21st century. It is a resource which is created through internal processes as well as the utilization of products and services by the customer. The Smart Factory is a focal point of Industry 4.0. It generates and collects data on a large scale. [1]

Figure 1 gives a visual representation which illustrates the importance of data, as universal data utilization is the foundation of the Smart Factory. This data can be further processed to knowledge which makes the Smart Factory smart at last. Sources for the data collection can be products, customers, services provided in addition to the products and the production process itself. The production process generates data via sensors and machines as well as administrative actions.

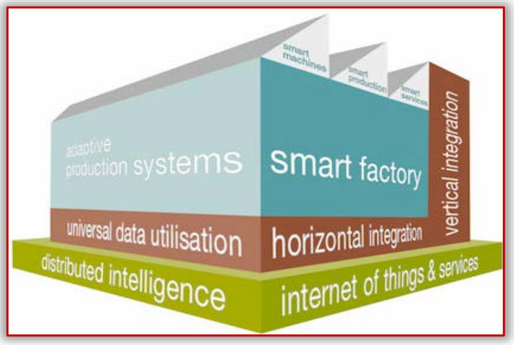

Figure 1 – Smart Factory [2]

As the end-products get ever more refined the resources used during the manufacturing process are subjected to a more and more rigorous quality process. Since data is a key resource in the Smart Factory and the knowledge generated is only as good as the data used, the same quality standards must apply there. Nevertheless, previous experiences show that most of the time data quality is not suitable for knowledge generation through new data analysis techniques. [1] This statement can be confirmed due to the work in at least twelve different projects. Quite often data, the data system and the processes concerning data generation were not mature enough.

This article introduces the first steps of an assessment model for data maturity explicitly aimed on Smart Factory applications like data analysis for the purpose of prognosis, suggestion systems or weak point analysis for sustainable process improvement.

BIG DATA AND DATA QUALITY

One of the most common used terms in combination with Smart Factory is Big Data. It was first mentioned in 1998 by John Mashey and the first scientific paper was published by Francis X. Diebolt in 2000. In these two publications, 'big' was only a lot of data - sheer volume. But volume was not the only key figure in Big Data, since it was always an issue. Gartner, former META Group, defined 2001 three dimensions which define Big Data. These 3 Vs, as the dimensions are known ever since, are still used to define the core essentials of Big Data. They stand for volume, velocity and variety. [3]

Volume

As mentioned above, this dimension represents the amount of data as a whole. Considering the fact that the information content in the world increases nearly in an exponential rate one can hardly try to grasp the full extent. A simple machine with a standard complimentary of sensors produces, depending on the sample rate, several gigabytes in a short period of time.

Velocity

Arguably the dimension that distinguishes the sheer volume from real Big Data. The speed by which data is produced is also a cause for the volume. It is a dimension imposed by the information age of the 21st century. Therefore, it is fitting, that the term Big Data was created at the beginning of the century. The sensors mentioned above might produce data every millisecond. Smartphones, GPS-trackers in vehicles and so forth send data in real time and nearly every second. Velocity is certainly a dimension that challenges every classical data management system.

Variety

As a dimension, which is mentioned above indirectly variety represents the fact that data is coming from a great range of different sources. This is also caused by the modern information age, which allows for the instantaneous connection of different data sources. These sources can be machines, ERP Systems, products or service platforms. The variety of the sources also contribute to the volume of the generated data.

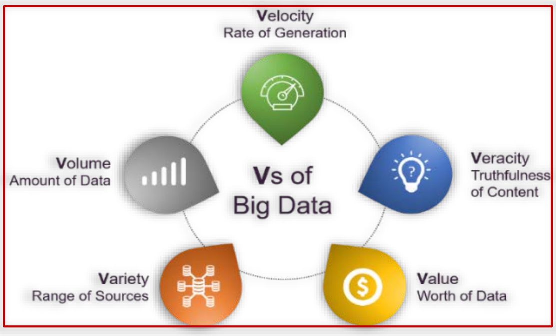

Figure 2 – Dimensions of Big Data

Although these three dimensions define Big Data and are sufficient for business intelligence applications, recent experiences made during projects in the manufacturing industry show that additional dimensions need to be considered when working with Big Data in a Smart Factory context. [4] This can be confirmed by on own experience gathered in various projects. Figure 2 gives an overview of the classical dimensions which define Big Data and the dimensions which need further consideration in combination with Smart Factory applications.

One of the most important dimensions concerns the quality of data, expressed in the dimension 'veracity'. And lately the contribution of data stated by the dimension 'value'.

Veracity

It describes the fact that data is in doubt. The fact might be triggered by inconsistencies, incompleteness or general ambiguity. The root cause might lie in the variety – one of the originally three Vs – of the data sources. If data can't be trusted, the value it contributes might be in doubt.

Value

Generally, the value is defined monetary for example what business models can be associated to the data. The different services or the internet of service (figure 1) come to mind, which are built on the compilation of knowledge out of data to provide a virtual product for which the customer is willing to pay. In the scope of this work, value is defined differently. It is considered, what value it might bring to classical data analytics applications. The better the quality and therefore the dimension veracity, the better is the result of a classification, a prognosis or a root cause analysis. That might bring a contribution to the continuous process improvement by eliminating weak points in the process.

ASSESSMENT MODEL

The new technologies developed in the past ten years contribute to a near exponential growth of the data stream and amount. This trend will intensify itself in the years to follow.

Yet a lot of companies, especially SMEs are overwhelmed by the possibilities and feel pressured to start Industry 4.0 initiatives on their own.[4] Data analytics projects are often the first step to gain experience with Smart Factory applications. Since data is produced in every company it is deemed to be the easiest way. Unfortunately, a lot of data found when starting with a data analytics project is not suitable for analytics projects right away. This problem will intensify in the future, because companies plan to invest in data recording. To get a quick overview of the data situation in a company prior starting the data analytics project, an assessment has been developed. In the following pages the categories of the assessment will be introduced.

Future Developments

The variety dimension and therefore the veracity dimension are getting more important in the future. A BARC study which was conducted in 2014, shows the intention of companies to further invest in data acquisition and gathering data from a growing number of sources. As can be seen in Figure 3, a significant increase will be in sources concerning Smart Factory applications, like machine data, sensor data or event streams from processes. [4]

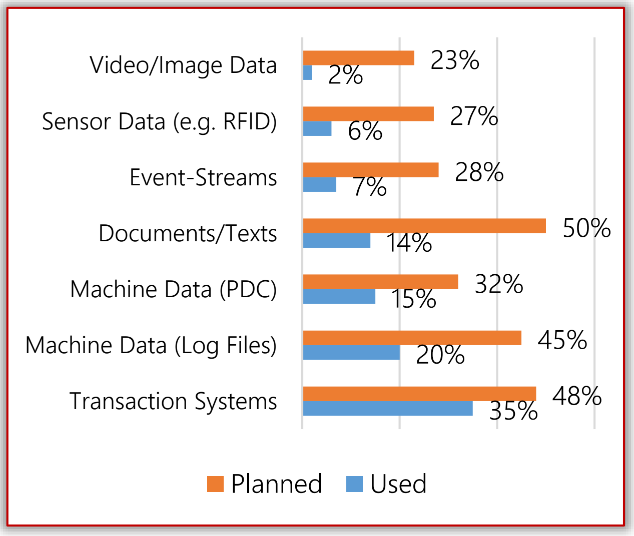

Figure 3 - Which data is used or is planned to be used to do big data analytics [4]

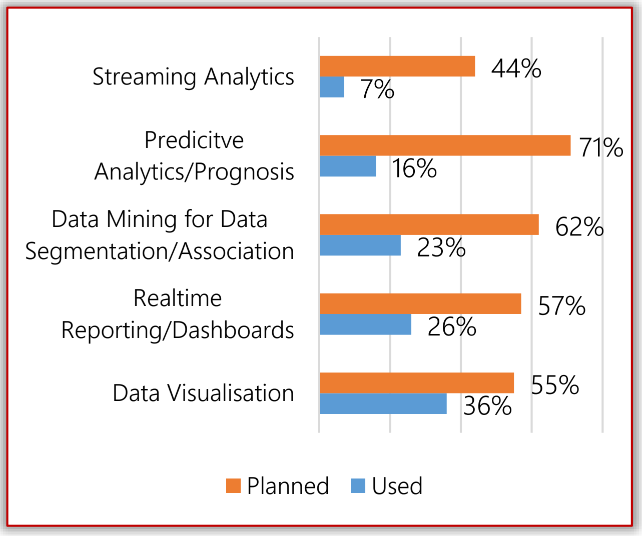

Figure 4 - Which big data analysis is currently performed and which is planned in the near future [4]

Figure 4 provides a summary of planned analytics applications. When looking at future applications of big data analytics, predictive analytics and prognosis, data segmentation and association or reporting and visualization of data are among the most mentioned applications. Especially the first two are prime applications of data analytics concerning Industry 4.0 and Smart Factory applications. The study also mentions the importance of data quality to harness the potential of the data and the possibilities of analysis applications. [4]

Assessment Model

Numerous projects offered the opportunity to verify the numbers above. The project portfolio includes, but is not limited to, production management. Here cluster algorithms where used to automatically form product families to use them in the improvement of planning robustness. Another project was conducted in the field of asset management with the goal to implement predictive maintenance in a steel mill. Upcoming projects, where the model will be further developed, will deal with an automated damage or root cause analysis to find problems concerning a welding robot.

Companies want to use the potentials mentioned in Figure 4 and they are using more and more data from different sources. The great variety brought problems with the data quality which delayed a project or changed the focus and scope of a project. Since many assessment models and methodologies have a different scope than Smart Factory applications, the development of an own model has been started. It specifically aims to assess categories, relevant to applications mentioned in figure 4 and it takes the fact of different sources and formats from figure 3 in account. [4]

The proposed model is still in development and being evaluated but has been tested as well in projects. When applied, it should help to estimate the effort in data acquisition and selection phase of the data mining process. At the current state the models allows a user, who has already gained some experience in data science, to estimate if a data mining project will lead to success. If the success might be in question the assessment categories, which a depicted in figure 5, help in improving the data quality by showing the current state of the data at hand. The operationalization is another point to consider. Often data analytics projects prepare data with considerable effort for the prototype phase. But the model developed can't be applied, because the data at hand can't be used without the recurring preparation phase.

The maturity or the necessary data quality depends, like the quality of each productions factor, on the application. Data analytics methods can be divided in various ways. In the case at hand we will use clustering, classification, prognosis and association or root cause analysis. Clustering is used to find prior unknown similarities in data while classification is used to learn given structures in data. Prognostic methods try to predict future outcomes based on past data and association analysis aims to find common occurrences of data values. [5]

The assessment model itself is based on different consecutive categories. The first three evaluate the data management and have relevance for the company in general. [6] The latter three rate the measures more specifically for data analytics applications in the Smart Factory.

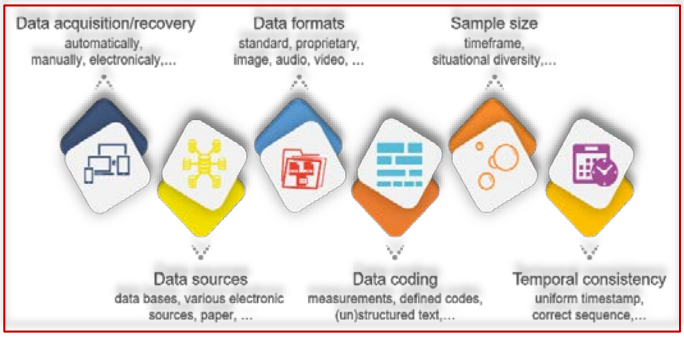

Figure 5 - Assessment categories [7]

Data acquisition/recovery

This category assesses the general organization of the data recovery process. Data can be recorded automatically or manually. An example for an automated recording of data would be sensors which send the measurements directly in a data management system or the automated recording of incidents or other process parameters.

The manual recovery of data needs a far more differentiated point of view. Generally speaking it means that data is recorded or entered by a user. A type of recording could be tablets, smartphones or other mobile solutions. The recording is done on site and the data is fed to the data warehouse in real time or at least on the first opportunity for synchronization. [7]

Data sources

Data sources can be differentiated in electronically and non-electronically sources like paper notes. Electronically sources are always preferred over paper sources. The most preferable source are databases. They allow for a systematic input and recovery of data. A lot of them apply routines to ensure redundancy free entries and therefore constitute a single point of truth. As mentioned in section 2 the variety of data sources is one defining aspect of Big Data. Data base systems increase the possibility to unambiguously merge data from different tables and sources by clear defined primary-foreign key relations. Closely related to the category data sources is the category data formats. [7]

Data formats

Data formats or more specific file formats are manifold. Well known standard formats are markup languages like HTML or XML. One big advantage is the meta information, that can be encoded and is machine readable as well. [8] Others are different spread sheet formats like Microsoft Excel or HDF (Hierarchical Data Format). HDF is very well suited to store huge data volumes in one- or multidimensional tables. The list could be continued with CSV files, an often used format to exchange structured text, or image, audio or video files.

A key fact about data formats is the compatibility. Different data formats should be convertible to a common one in order to form a consistent data base to work with. Therefore proprietary formats are the least favorable, because they often aren't compatible and convertible to others. [7]

These three categories are important not just for data analytics applications, but for all data based applications in a company. The following three categories are more specific for big data analytics applications. They should give a better understanding which analysis methods are possible and what the results may be. [6]

Data coding

This category takes the semantics into account. Major fields are unstructured text, defined measurements and KPIs or standardized codes and messages. Despite modern text mining routines, unstructured text the way it was found in different projects, is still a challenge. Problems occurred through spelling errors, colloquial language or dialectic entries or simple phony entries with no sense at all. So it is important to take the entries to the next level and establish a hierarchy of codes, which represent the most common occurrences and therefore entries. Defined and standardized parameters are the most preferable for automated analysis. In the end they only differ in the scale of measurement and application. Measurements and KPIs are mostly metric scaled and are used as attributes. Standardized codes and messages are often nominal scaled and are used as attributes as well or for supervised learning methods as labels.

If the data fulfills most of the positive criteria - like automated recording, standard formats like CSV or HDF or a structured coding scheme - of the categories so far, a successful application of some data analytics methods is very likely. That might be a clustering algorithm for the segmentation of the product portfolio into product families. In lots of cases a classification algorithm might also be suitable, for example to automatically define quality classes but to be sure the next category might be necessary to have a look at. [5,7]

Sample size

For supervised learning algorithms, this is one of the most important categories to be assessed. The success of a reliable accuracy depends of course on one hand to use the right context that should be learned and on the other hand on the sample size of things and occurrences that should be learned. It is imperative that the necessary data is recorded reliable, which should be ensured by a high maturity in the prior categories. To name a definite number of samples is difficult. But of course every combination that should be learned and of course each label value should occur several times at least. If there are more label values, each should represent at least 10% of the entire sample size. The time horizon should encompass at least 2-3 years to account for possible seasonal effects. [6, 10]

Temporal consistency

It is a category important for supervised learning with time critical dependencies as well as for prognosis purposes or association and root cause analysis. When comparing time series from different sources it is of the utmost importance to have a common timestamp. So it is possible to combine them in a common data structure and find correlations and causations. In many cases when making a subsequent measurement, for example in product quality assurance, the time of the measurement is recorded and not the time of the production. So it is not possible to make a connection between a quality feature of a product and for example a machine failure. The two features, machine failure and product quality feature, are temporally not consistent in a way it might be necessary for a data analytics application. [7]

Table 1 sums up the categories to be assessed and gives an overview about the two possible extremes which might be found in each category. The graduations between them a numerous and will be developed to a capability maturity model in future research. The common case is a based on an evaluation of the data provided in the different projects of the Chair of Economic- and Business Management.

Table 1 – Assessment categories and possible characteristics

Category	Worst Case	Best Case	Common Case
Data acquisition/ recovery	Manually on paper with time delay	Automated with sensors with real time transfer	Manually but in electronical form
Data sources	Paper	Cloud based data base	Spreadsheets and ERP systems
Data format	(Several) proprietary formats	(one) Standard e.g. markup languages	A mixture of basically everything
Data coding	Unstructured text	Standardized codes or metric scaled values	Use case and data source dependent
Sample size	(Fragmented) test month with incomplete labels	Several years and entries to each label	Features enough, labels too little
Temporal consistency	No timestamps at all	Common timestamp, aliened to the cause of the analysis	Timestamps are available but often unreliable

One essential project where the categories were applied is called Maintenance 4.0 (Instandhaltung 4.0). It is publicly funded by the Austria Research Promotion Agency (FFG). The results of the application of the assessment categories helped to identify potentials in the sample size of the maintenance data and the acquisition of machine related data.

The value of a data assessment is manifold. A quick assessment gives an overview of the situation of the data quality. It helps therefore to improve the time and cost estimations for analytics projects. Knowing the maturity in the six categories makes it easier to find potentials for future improvements. The same way it helps to lay down tasks to reach higher levels in the assessment categories toward a state where automated real time analytics is possible. That might very well be the most important benefit, because if one does not improve the maturity long-term it is never compatible with an automated analysis process. Every manual data preparation and cleansing step of a prototypical analytics project needs to be automated or better removed in order to operationalize the analytics process later on. This will also save a lot of time and therefore money. As can be seen in figure 6, up to 85% of the time in an analytics project is spend during the first two phases. The understanding encompasses the business or domain understanding, and the data understanding. The modelling, hence application of algorithms, and evaluation of the results take only 15%. The numbers are rounded averages of projects at the Chair of Economic- and Business Management. They are quite consistent to those found in different literature [11].

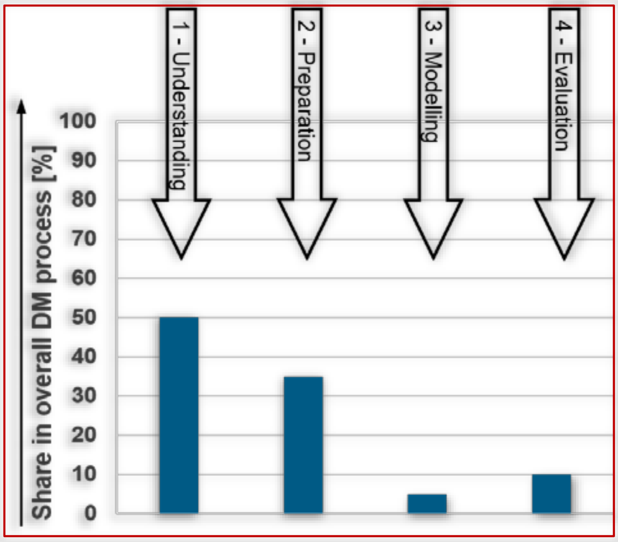

Figure 6 – Average time distribution in analytics projects

CONCLUSIONS

Data quality is an important perspective in every business situation and has been studied in BI applications during the last decade. Due to the chances initiated by new information technologies the factories change to Smart Factories where data becomes an ever more important resource. Therefore data quality is getting an integral part in the manufacturing industry as well. To fully embrace the possibilities given by Smart Factory and Big Data analytics it is important that data reaches a certain quality level or gain a certain maturity not just by the property of the data itself but also by the properties of the hard- and software systems.

This article discusses the nucleus of each assessment model, which are the assessment categories. They are not defined in general, but specific for Smart Factory and big data analytics applications in particular. The references and experiences were gathered in several projects with companies with the goal to use Big Data analytics on existing data to find valuable information for Smart Factory applications. In these projects the assessment categories where developed. They are the core of the further development of the model which should provide an easy and quick estimate about the situation of the data in a company concerning data analytics projects even before the projects gets fully started.

Note

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OIL PRODUCTS AND PUMPING STATIONS

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Abstract: From several wells on the oilfield field, crude oil is transported by pipelines to collecting stations, the number of which depends on the layout and the yield of the wells. Boreholes can be fountain gutters and pumps. Purification of crude oil is carried out in collection stations. Gas is a regular companion of crude oil, and therefore each collecting station has gas discharge devices. Purified crude oil is transported through several pipelines to pipeline to the dispatch station, and from here by the main pipeline to the refinery or to the loading station, if the transportation to the refinery is carried out by means of mobile means (wagon tanks, car tanks, tankers). From the gas obtained, butane and propane, as well as carbon dioxide and sulfur are separated in the collection stations, if present in the gas.
Keywords: collection pipelines, oil pipelines, collection stations

INTRODUCTION

Crude oil is a multiphase-multicomponent mixture of various hydrocarbons, water, gas and Solid particles. The properties of crude oil depend on the massive participation of certain phases and components in Mixture. The diameter of the main pipelines is usually over 500 mm, the length is over 50 km, and the pressure of the transported raw material at the beginning of the pipeline is 50-65 bar and more. The collection pipelines in the oilfield fields have a much smaller diameter and its size depends on the volume of the well. They are usually 100-150 mm, but they can be even larger. In order to ensure the continuous receipt of crude oil from the collection stations from oilfield fields and the optimum regime of the main oil pipeline, the dispatching pump station, often referred to as the main pump station, has a large reservoir space. At the main pumping station, the first introduction of the transported raw material into the pipeline is performed, as well as the control of physical properties, if this has not been done previously. Figure 1 shows the technological scheme of the main pipeline.

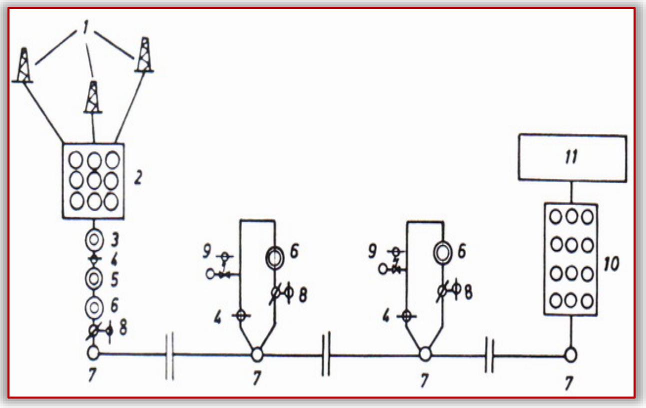

Figure 1. Technological scheme of the main pipeline

From several wells (1) from oil fields, crude oil is transported by pipelines to collecting stations (2). In collecting stations, purification of crude oil is carried out. The purified crude oil is transported from a number of collecting stations by a main pipeline to a delivery station consisting of: main pumping stations (3), filters (4), measuring devices (5) and auxiliary pumping station (6). Crude oil is further transported by a main pipeline along which there are devices for introducing and extracting a pipeline cleaner (7), as well as auxiliary stations in which the pressure increase and heating of the oil are made, consisting of: an auxiliary pump station (6), a filter (4), a pressure regulator (8) and a hydraulic shock absorber (9). Crude oil comes to receiving stations with tanks (10), and then pipelines are transported to the refinery (11).

OILFIELDS

Boreholes can be:
- » fontanske,
- » gas-lifts,
- » pumpne.

Fontane boreholes are those in which the oil pressure in the well is sufficient to expel oil to the surface of the earth and carry the oil transport to the reservoirs within the collection stations.

Gas-lift wells are those in which the oil pressure in the well is not sufficient to expel oil into the surface of the earth. Due to this, at a certain depth, a gas under pressure, which flows, is injected It vertically pushes up crude oil upward so that oil goes up to the surface of the earth.

Figure 2. The appearance of the pump well

Pump holes (Figure 2) are those in which, in addition to insufficient pressure of the well, the oil is discharged. On the surface of the earth, the borehole also has a slight abundance. Then use the piston-piston pumps with Weights. The fountain wells become gas-lifts and pumps over time, as time pressure decreases Wellness of the well.

COLLECTING PIPES AND SABIRNE STATIONS

The collection pipelines have the task of transporting crude oil from the wells to the collection station. The collection pipes are made of steel. The diameter of the collecting pipeline depends on the wellness of the well and it ranges from 100 to 150 mm, although it can be even larger. In the collecting stations (Figure 3), crude oil is purified. Gases are allocated, Water and solid particles.

Figure 3. The appearance of the oil collecting station

The process of extracting crude oil from gas can also begin in the collection pipelines itself specific pressure and temperature of the mixture. In the collection stations, the units are separated gas is extracted from crude oil. Then the butane and propane, carbon dioxide are separated from the gas obtained and sulfur.

After the extraction of the gas from crude oil in the tanks, water and solid particles are removed. Water and Solid particles are heavier than crude oil and after a few hours of resting water and solid particles fall to the bottom of the reservoir in the form of sludge. This sludge selection process can be intensified Heating crude oil and adding calcium chloride. Purified oil is pumped into pure Reservoirs, and then the water and solid particles are transported to the place where it is carried out by the drainage channels Water treatment. Sulfur is extracted prior to transport to the crude oil dispatch station.

OUTPUT PUMP STATIONS

The purpose of the delivery pump station is multiple. In the dispatch pump station (Figure 4) are:

- the reservoir space accepts crude oil from collecting stations;
- pressurizes crude oil;
- refining crude oil;
- regulates the pressure of crude oil in the main pipeline and,
- performs measurement of physical properties of crude crude oil.

Figure 4. Pump station

Due to the fall of the pressure during transport, they are installed along the pipeline of the auxiliary pump station in which the increase in the pressure of crude oil compensates for lost energy in the previous one shares and heats up if necessary. At that time, the auxiliary pumping stations were supplied larger tank space and crude oil heating devices. Auxiliary pumping stations are usually built along the main pipeline route near the inhabited Places, electricity connections, water supply and sewerage.

Distance between the main pump the stations and the first auxiliary pumping stations are 100 to 150 km, and the distance between the auxiliary ones pumping stations from 50 to 80 km. If the pipeline has to be laid far from the inhabited and if this would make it difficult to maintain pumping stations and generally exploitation. Then these distances are increased to 200 km between the main and the first auxiliary pump Stations, or up to 100 km between the following pumping stations.

MAGISTRAL OILS

Main pipelines are the pipelines through which they are transported (Figure 5):

- refined oil from shipping stations in oil fields to refineries or loading boats Stations for loading mobile means of transport;
- refined oil from unloading stations in river and seaports to refineries when crude oil is supplied to tankers and refer oil crude oil from refineries to large consumers or to loading stations when their transport is predicted by mobile means of transportation. The diameter of the main pipeline is above 500 mm, the length is over 50 km, and the pressure is transported oil at the beginning of the pipeline from 50 to 65 bar and more.

As part of the refinery, when crude oil is transported through the pipeline, or in the circle of consumers centers, if the products of crude oil are transported through an oil pipeline, there are reception stations with Sufficient tank space (Figure 6). When one pipeline predicts Supplying more refineries, or supplying more consumers with crude oil products, then Such an oil pipeline is equipped with drainage pipelines, devices for measuring delivered quantities and Remote control devices. The same is true when a pipeline is being moved to a place Oil for the loading station for filling a wagon tank, tank or tanker.

Figure 5. Appearance of the above-ground oil pipeline

Figure 6. It looks like a tank space

Magistral oil pipelines are usually buried in the ground at a depth of 0.8 to 1.1 m measured from surface of the earth to the upper edge of the pipeline. Depth of digging depends on the category of oil pipeline and the width of the protective belts of the populated areas, the facilities near the pipeline, etc. The depth of burial is Increases to 1 to 1.35 m when various obstacles have to be overcome when laying pipelines: Waterways, roads, railways, etc. The depth is then measured from the bottom of the water flow, respectively from the upper edge of the road, rail, etc. Sometimes the main pipelines are laid above the ground on concrete Columns of height from 0.5 to 0.75 m. There are other ways of laying off the main pipelines: Beneath the sea and lakes at various depths, above wetlands, etc.

Valves are installed every 10 to 15 km along the pipeline route in order to prevent major losses Oil if, for any reason, pipeline breakdowns occur. Damaged place is blocked by valves between which it is located. At the distance along the 15 to 20 km route, the house of the watchman is being built Oil pipeline, which includes a handy workshop with the most important tool for removing smaller ones Breakdowns on the pipeline. A pipeline cleaner (Figure 7) is used to clean the pipeline. The pipeline cleaner is through the cleaners Station enters the pipeline. Moving through the pipeline, he removes the deposits from the pipe wall.

Figure 7. The appearance of the pipeline cleaner

Crude oils that are very viscous (heavy crude oil) must warm up before being introduced into Pipeline. This is done in the main and auxiliary pump stations that are then equipped Boiler rooms. Boilers are usually fueled by the transported oil itself, and as a heating fluid Hot water or overheated steam is used. Oil pipelines as well as other pipelines through which energy fluids must be transported must be equipped with fire extinguishers. Propulsion motors must be protected against explosion and they are located in separate departments, especially when it comes to petrol and diesel engines, or bath tubs for use, engines that consume gas are used as propellants.

CONCLUSIONS

Due to the fall of the pressure during transport, auxiliary pumping stations are installed along the pipeline in which, by increasing the pressure of crude oil, the lost energy in the previous section is compensated and it is doing the heating of crude oil if necessary. At that time, the auxiliary pumping stations are equipped with a larger tank space and heating devices for crude oil. Auxiliary pumping stations are usually built along the main pipeline route near settlements, electricity connections, water supply and sewerage. The distance between the main pump station and the first auxiliary pump station is 100-150 km, and the distance between the auxiliary pumping stations is 50-80 km. Crude oil that is very viscous (heavy crude oil) must warm up before being introduced into the pipeline. This is done in the main and auxiliary pumping stations that are then equipped with boiler rooms.

Note

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EFFECTS OF INOCULATION ON VARYING WALL THICKNESSES IN GRAY CAST IRON RECYCLING

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Abstract: Cast irons are important engineering materials, which possess a wide range of attractive properties. Their properties are significantly dependent on the microstructure of the cast irons. A way of controlling the microstructure of cast iron is through the control of cooling rates during solidification. To control the cooling rate, inoculants are necessary mostly in the thin castings. This project presents the study of the effect of inoculants of fixed composition in the wall thickness ranges from 3.5–12.5mm of grey cast iron. The chemical compositions of both the inoculated and un-inoculated were determined. The eutectic cells, the graphite flakes in the microstructure and hardness of the varying wall thicknesses were also evaluated. From the results there were significant effects of inoculants on the section thickness unlike the un-inoculated sample. The eutectic cells were more in the 3.5, 4.5 and 5.0 mm thicknesses while the other thicknesses showed the reduction in the eutectic cells. There is evenly distribution of graphite flakes in the 11.5 and 12.5 mm thicknesses of type A, 7.0 and 8.0 mm sections contain graphite flakes of type B while 3.5 and 4.5 mm sections contain no graphite flakes due to rapid cooling of the samples.
Keywords: microstructure, inoculants, graphite flakes, wall thickness, grey cast iron

INTRODUCTION

Inoculation is a means of controlling the structure and properties of cast iron by minimizing undercooling and increasing the number of nucleation sites during solidification. An inoculant is a material added to the liquid iron just prior to casting that will provide a suitable phase for nucleation of graphite during the subsequent cooling. Traditionally, inoculants have been based on graphite, ferrosilicon or calcium silicide. Almost exclusively, inoculants today are ferrosilicon based containing small quantities of active elements such as Al, Ba, Ca, Sr, and Zr.

According to Woolley cast iron can be used to produce thin-wall iron castings if developed to its full potential'[1]. There are several reasons why chilled structures are normally undesirable. Chilled structures are hard and brittle and interfere with machining, necessitate additional heat treatment operations, resulting in nonconformance with specifications and, in general, increase the total cost of production [2]. Inoculation changes the structure of cast iron by altering the solidification process. Proper inoculation practice results in reduced shrinkage, improved fluidity, the reduction of residual stresses and better machinability [3].

However, automotive manufacturers have turned to new technologies to make cars lighter. There are several disadvantages to using Al over ferrous alloys. Aluminium alloys lose their strength at high temperatures, making them unsuitable for applications where higher engine temperatures are required to produce more efficient combustion. Aluminium also provides much less damping than ferrous alloys, resulting to increased levels of noise [4]. Finally, and perhaps most significantly, Al is much more expensive than ferrous alloys.

The biggest impediment to using cast iron instead of Al is that cast iron components are often thicker than necessary to carry an applied load, resulting in added weight and reduced energy efficiency [4]. There are two reasons responsible for this. First, cast iron has a minimum casting thickness necessary to maintain its structural integrity. Second, moulding technology is often inadequate to produce quality thin-wall castings.

The definition for thin-wall casting varies. Several authors refer to thin-wall castings are being anywhere from 3mm to 5mm, while Hornung defines thin-wall as anything less than 2.5mm [5]. This work majorly focuses on casting of grey iron of thickness ranges from 3.5mm to 12.5mm.

MATERIALS AND METHODS

Equipment and Materials

The equipment and tools are: Rotary furnace, sieve, moulding box, blower, strike-off bar, shovel, band saw, gating tools, grinding and polishing machine, mounting machine, bellow, and pyrometer. The major materials are: Engine-block scraps iron, graphite, fuel (diesel), green sand, 7 wooden pattern (block form) of dimensions 60mm x 40mm and varying thickness of 3.5-12.5mm, parting sand, facing sand, ferrosilicon (0.2 wt % inoculant).

Pattern Design

The patterns were made of wooden material in block form. The pattern comprises 7 sheets of plywood of different thickness of 3.5-12.5 mm. It is rectangular in shape with a very smooth surface. Good design was incorporated in the making of the pattern to ensure a perfect cast.

Making of Mould

The mould was prepared with green sand. The green sand have good permeability, good grain size, accurate moisture content and with a very good refractoriness. Bentonite was added to the green sand to increase its bonding strength. Suitable flask is first selected large enough to accommodate the pattern.

Facing sand was put into the drag and the content was well rammed. The drag was turned upside down on the mould board, the pattern as well as its accessories were placed on the board inside the flask in such a position that space is left for gate cutting. Parting sand was sprinkled over the top surface and the drag is turned upside down.

The cope was placed over the drag and top parts of the pattern assembled in position. Runners, risers were put in position and supported vertically by taking a small amount of moulding sand around them, therefore, the excess sand was cut off, runners, riser and pins removed, venting was done on the top surface of the mould. The pattern and its accessories were removed from both the drag and cope. The sprue well and in-gate was dressed to allow molten metal to flow freely into the mould cavity without turbulence.

Charged Materials

The materials charged in the furnace are 60kg of engine scraps iron, 40kg ferrosilicon, 2kg flux and 4kg graphite.

Melting and Casting Processes

The furnace is first preheated to about 1 hr. After melting of the scraps, the molten metal was tapped at a temperature of 1555ºC. The pouring temperature was 1520ºC, right from the pouring to the ladle; the inoculant (0.2% ferrosilicon of elemental compositions: Si-74.22%, Ca-2.44%, Al- 1.21% and Zr-1.21%) was added to the molten metal. The molten metal was quickly poured into the mould before the inoculants faded away.

Evaluation of the Parameters

After casting, the samples were cleared from unwanted particle that attached to the cast. Each of the samples was cut and various tests were performed on them. The operations performed on the samples were chemical analysis to determine the composition of various elements present in the sample, metallographic analysis to reveal the eutectic cells using Stead's reagent (8g of $MgCl_2$, 2g of $CuCl_2$, 4ml of HCl, 100ml of Grain Alcohol) and to reveal the types of flake graphites present using nicter etchant, Hardness test using Rockwell hardness tester.

Spectrographic Analysis

The chemical composition of each sample was analyzed to determine the variation of C, S, Si, Mn, P, in the samples.

Metallographic Examination

This was carried out to show how the flake graphite is distributed in the samples so as to know what effect the inoculant of fixed composition has on each sample due to their thickness. It was done by cutting parts of the cast products to represent each sample. The steps are shown below for each sample. After the micro-examination, the next stage was photomicrography. The observed microstructure was prepared for printing.

Hardness Measurement

Part of the cast product were cut, ground to ensure smooth surface and hardness test was performed on them using the Rockwell hardness of scale HRA.

RESULTS AND DISCUSSIONS

The following chemical compositions were obtained from the engine blocks (scraps).

Table 1: Elemental composition of scrap from auto parts

%C 3.97	%Si 1.94	%Mn 0.87	%P 0.088
%S 0.131	%Cr 0.163	%Ni 0.058	%Mo 0.0015
%Al 0.0058	%Cu 0.137	%Co 0.015	%Ti 0.0015
%Nb <0.0025	%V 0.0099	%W <0.010	%Pb 0.0083
%Mg 0.0033	%B <0.0005	%Sn 0.0083	%Zn 0.0081
%As 0.020	%Bi <0.0015	%Ce <0.0030	%Zr <0.0015
%La <0.0033	%Fe 92.5		

Chemical Equivalent Value

The carbon equivalent (CE) is a simplified method of evaluating the effect of composition on cast iron. One of the most common equations used is

$$CE = Tc + \frac{\%Si + \%P}{3} \quad (1)$$

where T_C is the total carbon, and %Si and %P are the silicon and phosphorus contents [6]

The value is important because it can be compared with the eutectic composition (4.3%) to indicate whether the cast iron will behave as a hypoeutectic iron or hypereutectic iron during solidification [6]

Effect of chemical composition on the eutectic cell in varying thickness

It can be shown from the table 2 and 3 that the chemical equivalent value is less than 4.3%, which is hypoeutectic cast iron in both the inoculated and un-inoculated grey cast iron. However, in the uninoculated, there is larger proportion of dendrites due to lower carbon equivalent value compare to the inoculated grey iron where the dendrites tend to reduce because of the increase in carbon equivalent value. With decrease of carbon equivalent, the length of primary austenite dendrite increases [7]. The reduction in the dendrites by the inoculants led to the increase in the eutectic cells. There is decrease in the eutectic cells as the thickness increases.

In figure 1 and 2 in which the wall thickness are 3.5 mm and 4.5 mm, the section sizes have higher eutectic cells. The sulphur content of 0.06%, Mn of 0.31% in the inoculated grey iron has effect on the eutectic cells and there is greater effect of inoculation. This is in accordance with what has been done by Zhou Jiyang, 2009 that "low sulphur content < 0.03%, the number of eutectic cells is significantly reduced and the inoculation effect is reduced".

The eutectic cells also increases in figure 3 with wall thickness 5.0 mm and figure 4 with wall thickness 7.0 mm but the grain boundaries begin to increase and eventually reduce the eutectic cells in figures. 5, 6, and 7 respectively with wall thickness 8.0 mm, 11.5 mm and 12.5 mm.

Table 2: Chemical Composition of Un-Inoculated Sample (control)

C	Si	Mn	P	S
2.354	2.450	0.234	0.088	0.135
Cr	Ni	Mo	CE	
0.090	0.059	0.007	3.200	

Table 3: Chemical composition of 0.2% inoculated sample

C	Si	Mn	P	S
2.78	3.25	0.31	0.16	0.06
Cr	Ni	Mo	CE	
0.11	0.05	0.01	3.92	

Microstructure of Eutectic cells

The following microstructures of the eutectic cells were obtained in different wall thicknesses using stead reagents.

Effect of microstructure in the varying thicknesses

With reference to the Figure 8, the results showed that in an uninoculated structure there is presence of globular graphite inclusions at low magnifications. The structure does not produce enough graphitization due to lack of inoculants and it will reduce the total amount of carbon formed. In this case, thin and fine graphite morphology of type D was noticed. In figure 9-14, the morphology of the inoculated iron shows the presence to some extent the evenly distribution of graphite flakes. There are more and longer bulky graphite inclusions than in the case of no addition of inoculant.

The microstructures revealed in the specimens show that there is presence of graphite flakes in a pearlitic matrix and very little ferrite was found. It shows that ferrite was more in 8.0 mm, 11.5 mm and 12.5 mm sections than in the 3.5 mm and 4.5 mm sections.

The 7.0 and 8.0 mm sections show that there is mixture of rosette graphite flakes of type B and type A while 11.5 and 12.5 mm sections have the graphite flakes of type A, that is, the graphite flakes are randomly distributed and oriented throughout the matrix.

The 5.0 and 7.0 mm specimens are dominated by type B due to the flake graphites that are not well distributed. The 3.5 and 4.5 mm have short graphite flakes and not as visible enough as compared to the 12.5 mm. Mostly, there is presence of cementite and small amount of graphite flakes in the 3.5 mm thickness due to greater undercooling.

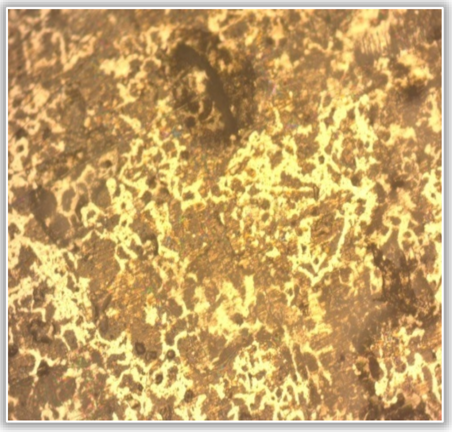

Figure 1: Eutectic cell 3.5 mm: x100

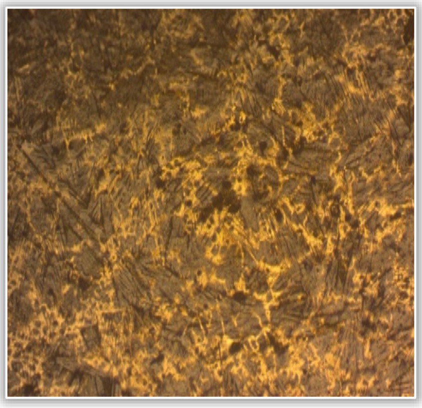

Figure 2: Eutectic cell 4.5 mm: x50

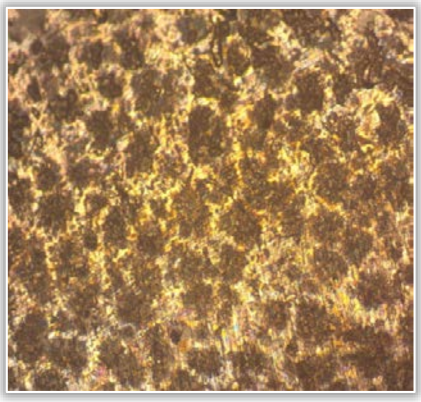

Figure 3: Eutectic cell 5.0 mm: x50

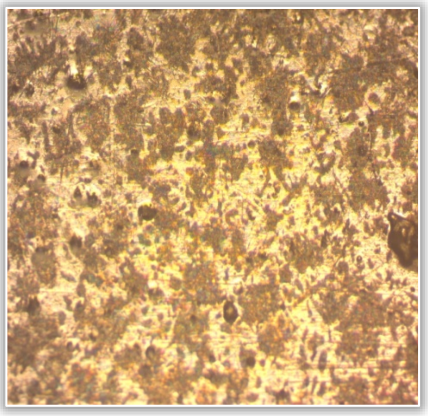

Figure 4: Eutectic cell 7.0 mm: x50

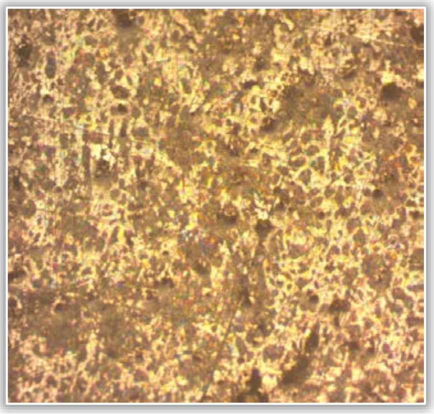

Figure 5: Eutectic cell 8.0mm thickness x100

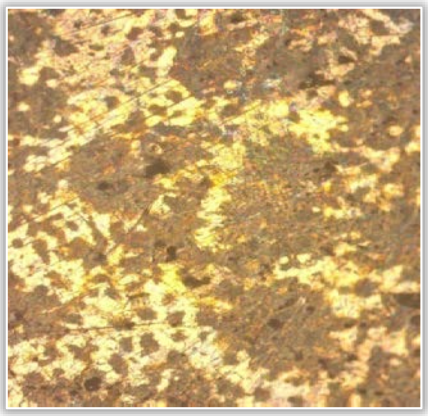

Figure 6: Eutectic cell 11.5 mm thickness x100

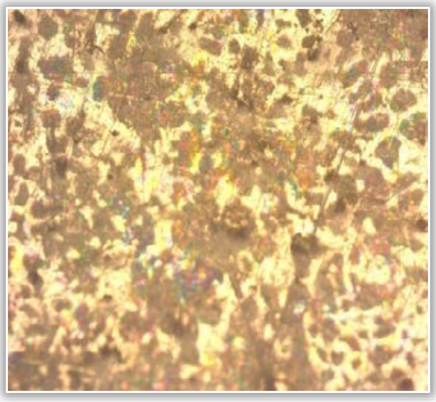

Figure 7: Eutectic cell of 12.5mm thickness x50

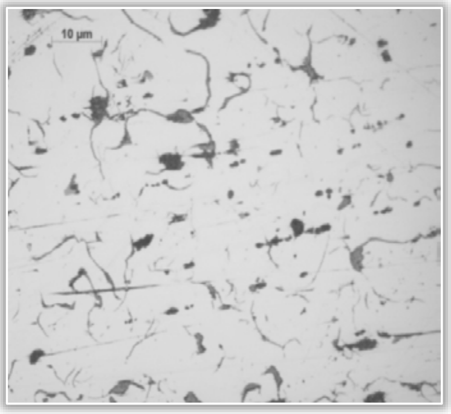

Figure 8: Microstructure of un-inoculated sample x50

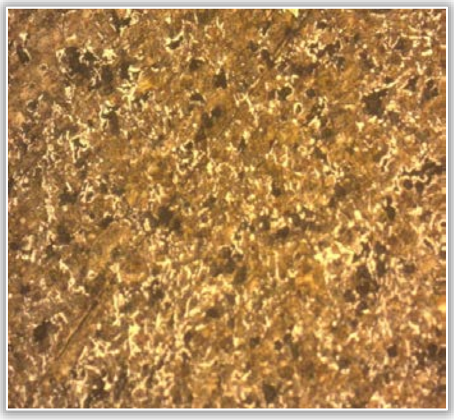

Figure 9: Microstructure of 3.5 mm thickness x100

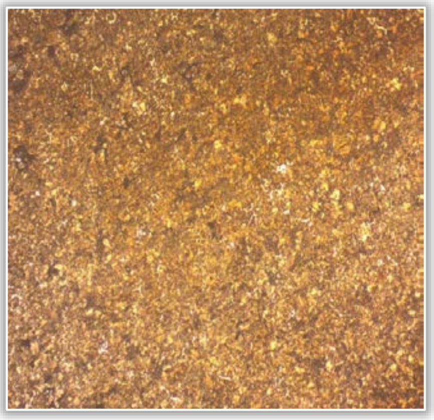

Figure 10: Microstructure of 4.5mm thickness x50

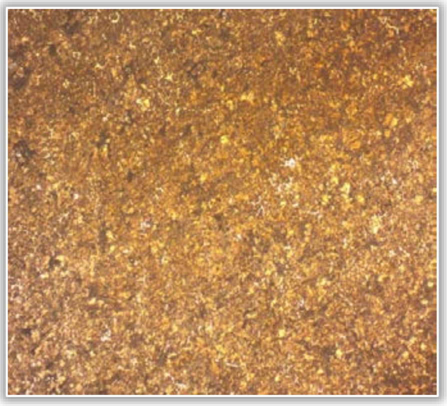

Figure 11: Microstructure of 5.0 mm thickness x100

Figure 12: Microstructure of 7.0 mm thickness x50

Figure 13: Microstructure of 8.0 mm x100

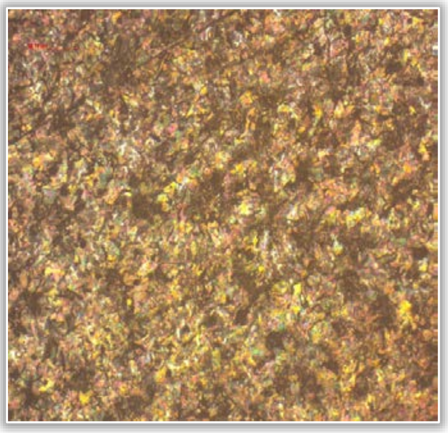

Figure 14: Microstructure of 11.50 mm thickness x100

Figure 15: Microstructure of 12.50 mm thickness x50

Table 4: The hardness values in different wall thicknesses

Thickness values (mm)	3.50	4.50	5.00	7.00	8.00	11.50	12.50
HRA	66.4	55.8	55.4	53.2	52.5	50.5	49.1

▫ The effect of hardness values on the wall thicknesses

It was observed from the figure 16, when the thickness of the wall was 3.50 mm, the hardness value was 66.4 HRA, when the thickness of the wall was increased to 4.50 mm in figure 10, there was decrease in the hardness value to 55.8 HRA.

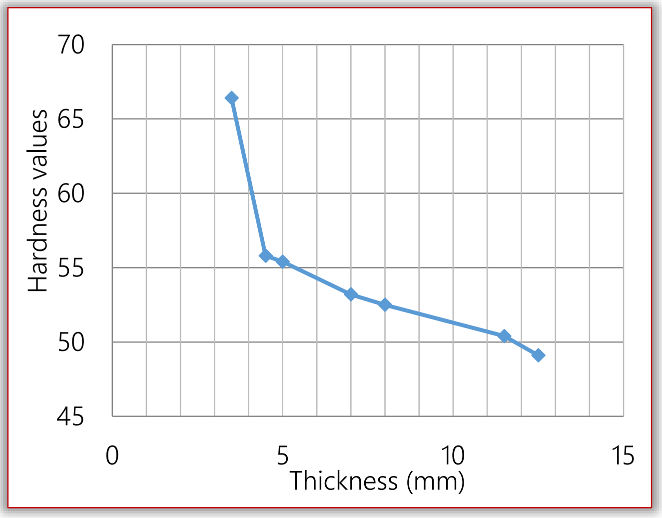

Figure 16: Graph of hardness values against wall-thickness

As the wall thickness increases, it was discovered that the hardness value decreases [8]. The cooling has to do with thickness, the lower the thickness, the faster the cooling rate. In wall thickness 3.50 mm as compared with thickness 4.5 mm, 5.0 mm, 7.0 mm, 8.0 mm, 11.5 mm and 12.5 mm, the cooling rate was faster and it follows that order, as a result carbon in it was found in the form of carbides which is responsible for the increase in hardness, as the wall thickness increases there is decrease in carbide formation and reduction in hardness.

CONCLUSIONS

The results discussed above showed that inoculant has greater influence on the different wall thicknesses. This was clearly shown in the eutectic cells and the graphite flakes exhibited in each microstructure. Based on this work the following main conclusions can be drawn:

- It was revealed that the eutectic cells in the 3.5 -5.0 mm section sizes were greater than the 7.0, 11.5 and 12.5mm section sizes. Therefore, the eutectic cells decreases as the wall thickness increases.
- The graphite flakes exhibited in 3.5 mm and 4.5 mm thickness were not revealed as much, due to greater undercooling and presence of cementite. The inoculant has a greater influence on the wall thickness. There is evidence of graphite flakes in 5.0 mm thickness and uniform distribution of graphite flakes are showed in 11.5 and 12.5 mm sections.
- The composition of 0.06%S and 3.25%Si are beneficial for graphite nucleation in inoculated grey irons with a lower incidence of carbides and undercooled graphite, compared to the 1.94%Si obtained from the scraps.
- Hardness increases with decreasing casting wall thicknesses due to structure refinement effect.

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AIR POLLUTION REMOVAL AND CONTROL BY GREEN LIVING ROOF SYSTEMS

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Abstract: Cities are open and dynamic urban ecosystems, which consume, transform and release matter and energy. By erecting buildings change in the flow of energy and matter through the urban ecosystems occurs creating multiple environmental problems. Those problems are amplified by transportation and production systems, which influence the elements of the ecosystem negatively. Air pollution in the urban environment, as one of the problem, is a major threat to human health. Conventional air pollution management programs focus on controlling the source of air pollutants but do not address the pollutants already in the air. Green roof implementation strategy is an innovative approach that can be adopted to remove existing air pollutants thereby reducing air pollution concentrations to an acceptable level, as vegetation plays important roles on remediating air pollution after the emission occurs. The green roof can be used to supplement the use of urban trees in air pollution control, especially in situations where land is not available and public funds are insufficient. This review paper presents collected data comparing the findings from different research conditions and approach, to explore the important role that the green living roofs can play in the dense urban areas, mainly considering the impact on air quality. Pollution level, type of green roof involved in researches, and different material selection, for both plants and soil, have considering the influence on the performance of the green roof as a passive natural air filtration system.
Keywords: green roof, air pollution, environment, building

INTRODUCTION

Change in the flow of energy and matter through the urban ecosystems occurs by altering the surface cover of an area. Urban areas invade natural landscapes creating a deficiency of green spaces and multiplying environmental problems impacting the entire planet. Those problems are amplified by modern anthropogenic sources such as transportation (vehicular traffic fuel combustion, particularly diesel, and vehicular component wear) and production systems, which influence the elements of the ecosystem negatively. A focus on decreasing energy consumption should progressively reduce air pollution from power generation and industry. Transitional nations, with increasing traffic amounts, need to focus on preserving the health of their citizens. Concerns about black smoke and air acidification (sulfur dioxide, SO_2) from coal burning have been replaced by new concerns about particle pollution and nitrogen dioxide (NO_2) from transport, and the air pollution that forms through chemical reactions between other pollutants in the atmosphere. City residents are at most risk from being exposed to urban particulate pollution. Particles smaller than 10 μm diameter (PM_{10}) can penetrate deep into the pulmonary passages where any transition metals present can release free radicals in lung fluid and cause cellular inflammation [1]. Conventional air pollution management strategy effectively reduces the emission of new air pollutants focusing on controlling the source but does not address the issue of pollutants already spreading.

By combining nature and built areas in their designs urban planners can respond to these serious human health and welfare issues and restore the environmental quality of dense urban areas. Greening the building envelope is innovating technology in architecture that can regain losses of natural environment produced by erecting buildings. As vegetation plays important roles on remediating air pollution after the emission occurs adapting the existing building envelope into a green living system would be an efficient and sustainable solution for improving the environmental balance of cities. Greening horizontal surfaces with intensive and extensive green roofs could remove existing air pollutants thereby reduce air pollution concentrations to an acceptable level.

GREEN LIVING ROOF SYSTEMS

Living architecture is the integration of the living, organic systems characterized by green walls and green roofs, with the inorganic and lifeless structures that have come to dominate modern architecture.

The model of the green roof consists of three main components: structural support, the soil layer, and foliage layer. The structural support includes all the layers between the inner plaster and the drainage layer or filter layer. The soil layer is complex with the solid phase (organic and mineral material), the liquid phase (water) and the gaseous phase (water vapor and air). The foliage layer (canopy) is composed of the leafs and the air within the leafs and depends on the plant selection. Depending on its complexity several more layers could be present. The drainage layer provides water for upper layers in relatively small space and with lightweight; excess water overflows and easily passes underneath it away and down the roof drain. The growing medium, filter and protection layer act to support plants and protect lower levels.

There are two main classifications of green roofs: Extensive Green Roofs (EGR) and Intensive Green Roofs (IGR).

The extensive green roofs (EGR)

Extensive Green Roofs are lightweight in structure with a thinner substrate and feature succulent plants like sedums that can survive in harsh conditions (Figure 1). Extensive green roofs are used mainly for environmental benefit, require little maintenance once they are established and are generally cost effective, particularly in commercial and public buildings with long life spans.

Figure 1. EGR, Headquarter Honda, Clermont, FL, USA (left) IGR, Delft University of Technology Library, Delft, The Netherlands (right)

The intensive green roofs (IGR)

Intensive Green Roofs may require irrigation during dry periods having a thicker soil layer than extensive ones. Because of their thicker soil, these roofs require greater structural support (Fig. 1). IGR allow a greater variety and size of plants such as shrubs and small trees but have higher initial costs and maintenance.

THE ROLE OF GREEN LIVING ROOF SYSTEMS IN THE REMOVAL OF AIR POLLUTION

In the reduction of air pollutants, an important role is played not only by trees but also by the structure, texture, and localization of green infrastructure components. Vegetation has been found to be significant sinks for gaseous, aerosol, particulate and rain-borne pollutants. Four processes are responsible for deposition onto the large surface area provided by leaves [2]:

- sedimentation under gravity,
- diffusion,
- turbulent transfer giving rise to impaction and
- interception

The ability to remove air pollutants can be affected by tree crown morphology and city design [3]. The large leaf area and turbulent air movement caused by their structure make trees particularly effective for particle removal. Adapting flat roof surfaces into green living systems is an efficient and sustainable solution as there are limited opportunities to implement urban greenery in ground areas. Roof area fraction may vary from 20% to 25% for less or more dense cities. A study in Toronto found that 58 metric tones of air pollutants could be removed if all the roofs in the city were converted to green roofs, with intensive green roofs having a higher impact than extensive green roofs [4].

Vegetation removes pollutants directly and indirectly. Plants take up gaseous pollutants through their stomata, intercept particulate matter with their leaves, and are capable of breaking down certain organic compounds such as poly-aromatic hydrocarbons in their plant tissues or in the soil. The city of Los Angeles conducted the report and it was estimated that 2000m^2 of uncut grass on the green roof can remove up to 4000kg of particulate matter showing that one square meter of the green roof could offset the annual particulate matter emissions of one car.

Over 889 tons per year of NO_2, 0.5% of that area's emissions, would be removed in Detroit, MI if 20% of all industrial and commercial roof surfaces convert to EGR [5]. Assuming the NO_2 uptake rates by green roof plants were constant Corrie et al. [6] estimated the annual reduction of NO_2 by green roofs in Chicago and Detroit. Their study showed by covering 20% of the roof surface in Chicago the reduction of NO_2 was between 806.48 and 2769.89 metric tons depending on the type of plants used.

Measuring the concentrations of acidic gaseous pollutants and particulate matters on a 4000m^2 roof in Singapore before and after the installation of a green roof Tan and Sia [7] found that after installation of the green roof the levels of particles and SO_2 in air above the roof were reduced by 6% and 37%, respectively. This field measurement proved that green roofs can reduce certain air pollutants but it is difficult to extrapolate their results to other places or to a larger scale.

Using the Urban Forest Effects (UFORE) dry deposition model developed by the USDA Forest Service Currie and Bass [8] studied the effects of green roofs on air pollution in Toronto. The model quantified levels and hourly reduction rates of NO_2, SO_2, CO_2, PM_{10} and ozone as well as their economic value. UFORE calculations were based on vegetation cover, hourly weather data, and data on the concentration of pollutants. Trees and shrubs were more effective in removing contaminants than herbaceous perennials largely due to greater leaf surface area. Although intensive green roofs with trees and shrubs are more favorable in terms of reducing pollution, extensive green roofs can play a supplementary role in regards to air quality.

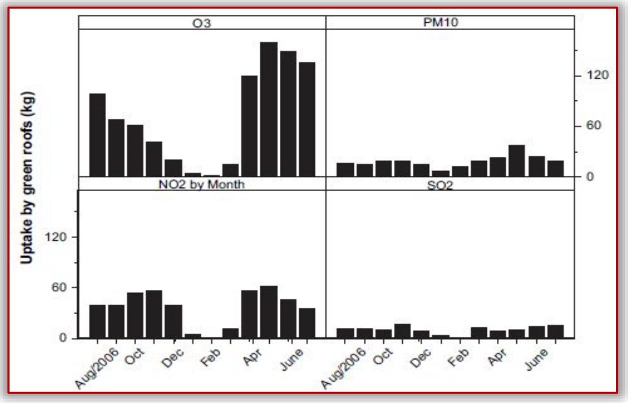

Figure 2. Monthly uptake of air pollutants by green roofs in Chicago between August 2006 and July 2007.

Using also the UFORE dry deposition model the research in Chicago was conducted [8]. The total air pollution removal by 19.8ha of green roofs was 1675kg between August 2006 and July 2007 (Fig. 2). If the reported 2787ha of green roofs were all completed and had the same ratio of extensive vs. intensive green roofs, the air pollutants removed could reach 2388kg. The 19.8ha of green roof consisted of 63% short grass and other low-growing plants, 14% large herbaceous plants, 11% trees and shrubs, and about 12% various structures and hard surfaces. Among the four air pollutants, the uptake of O_3 was the largest, 52% of the total uptake followed by NO_2 (27%), PM10 (14%), and SO_2 (7%). If all remaining roofs in Chicago were planted with intensive green roofs, the direct removal of air pollutants could reach as high as 2046.89 metric tons.

Indirectly lowering surface temperatures by providing shade use of energy for air conditioning is less, due to reduced energy the emission of pollutants from power plants decreases. Calculations showed [9] that emissions from coal-fired power plants could be reduced by 350 tons of NOx per day in Los Angeles by reducing the need for air conditioning. Vegetation also lowers the ambient air temperature by changing the albedos of urban surfaces and through transpiration cooling, which in turn decreases photochemical reactions that form pollutants such as ozone in the atmosphere. A green roof program covering 50% or more of roof space in a city, when implemented in coordination with other large-scale greening efforts like street tree planting, could result in city-wide cooling throughout the day and during peak summertime energy demand periods.

Carbon sequestration

When green coverage is less than 10%, the concentration of CO_2 in the air would be 40% higher than the one with 40% coverage rate, and when the coverage rate reached 50%, the concentration of CO_2 in the air can maintain a normal rate of 320 ppm. Carbon is a major component of plant structures and is naturally sequestered in plant tissues through photosynthesis and into the soil substrate via plant litter and root exudates. The carbon fixation and oxygen release capabilities of the green roof depend on the plant selection. Trees, bushes, and shrubs are better in controlling the CO_2 concentration at certain level improving the environment and maintaining oxygen balance than the grass.

Getter et al. [10] quantified the carbon sequestered by four species of Sedum in a 6.0cm substrate depth extensive green roof in Michigan over a period of two years. At the end of the study, above-ground plant material and root biomass stored an average of 168g C /m^2 and 107g C /m^2, respectively, with differences among species from 64g C /m^2 to 239 g C /m^2 for *S. acre* and *S. album*, respectively. Increasing substrate depth would not only provide a larger volume for carbon storage, it would also enable a wider plant palette that could include larger perennials and even trees.

In Hong Kong, [11] in summer, on a typical sunny day, the CO_2 absorption rate of a plant in the daytime is much higher compared with the CO_2 emission rate at night. The research showed that the extent of the green roof effectiveness depends on factors such as the ambient airflow condition, the green roof position, and the plant's condition and that the green roof can reduce the CO_2 concentration in the nearby region by nearly 2%.

Table 1. Peer-reviewed journal articles written in English on the effects of green roofs on air pollution [12].

Reference	Location	Topic
Clark et al., 2008a	Michigan, USA	Estimates that NOx reduction would provide an annual benefit of $895-3392 for a 2000 ft^2 green roof and would lead to a mean NPV (net present value) for the green roof that is 24.5-40.2% less than the mean conventional roof NPV.
Currie and Bass, 2008	Toronto, Canada	Effect of various vegetation scenarios (trees, shrubs, green roofs, and green walls) on air pollution estimated using the UFORE model. Results indicate that intensive green roofs would have the greatest impact, but extensive roofs could augment the effect of trees and shrubs.
Getter et al., 2009	Michigan, USA	Measured carbon sequestration of sedum-based extensive green roofs over time, included carbon cost embedded in green roof materials, and calculated the reduction in CO_2 given off from power plants due to energy savings.
Yang et al., 2008	Illinois, USA	Estimated level of air pollution removal in Chicago using a dry deposition model. Annual removal of pollutants per hectare of green roof was 85 kg ha^{-1} yr^{-1} with the highest and lowest removal during May and February, respectively. Would remove 2046.89 metric tons if all rooftops in Chicago were covered with intensive green roofs.

Sterilization

Garden plants as the major species in urban greening have the important role in reducing the amount of environmental harmful pathogenic microorganisms and improving the urban environment's ecological value and adding social benefits. Plants can sterilize and inhibit the bacteria and other pathogenic microorganisms in their living environment to varying degrees. High green coverage rate helps to reduce the bacterial content in the air. Some tree species produce essential oils called phytoncides, which when inhaled, improve mental well-being.

PLANTS SELECTION

The process of pollution removal is depended on distinguishing features of various plant species, their habit, habitat, leaf physical parameters and weather conditions present in the areas. The tolerant species can be used for reducing the level of pollution and sensitive species as bio-indicators for monitoring ambient air quality. The mix of both types can be used for developing green belt in polluted areas. Because plant species possess varying abilities to remove air pollutants and reduce emissions they can be selected to maximize improvements in air quality. Using a better adapted and tolerant floral species in green living roof systems would help to enhance the ecosystem services and reduce the detrimental effects of pollution on the environment.

Reductions in particulate matter, ozone, NOx, and SOx occur while plants are actively growing and in-leaf so evergreen conifers may provide a greater benefit than deciduous species because they retain their leaves year-round.

Table 2. Annual removal rate of air pollutants per canopy cover by different vegetation types in Chicago between August 2006 and July 2007 [8].

Type of vegetation	SO_2 [g/m²yr]	NO_2 [g/m²yr]	PM_{10} [g/m²yr]	O_3 [g/m²yr]	Total [g/m²yr]
Short grass	0.65	2.33	1.12	4.49	8.59
Tall herb. plants	0.83	2.94	1.52	5.81	11.10
Deciduous trees	1.01	3.57	2.16	7.17	13.91

CONCLUSIONS

Air pollution in the urban environment is a major threat to human health. The green living roof systems can be used to supplement the use of urban trees in air pollution control, especially in situations where land is not available and public funds are insufficient. As a strategy to remove air pollutants, intensive green roofs IGR with trees and shrubs are comparable to urban forests and play a much larger role in improving air quality than grasses or succulents that are often found on extensive green roofs EGR.

Beside carbon sequestration by plants and the substrate in the green living roof systems, there is also a reduction in CO_2 given off from power plants due to the green roof's ability to insulate individual buildings and reduce the urban heat island. Reductions in particulate matter, ozone, NOx, and SOx occur while plants are actively growing and in-leaf. Green roofs perform better when designed as ecosystems to promote biodiversity instead of monocultures. Plants need to be evaluated in various locations and climatic regions, as well as for management and maintenance practices.

In addition, viewing green vegetation and nature has beneficial health effects as well as improved health and work productivity. Green roofs improve urban air quality and by extension public health and quality of life.

Note

This paper is based on the paper presented at 13th International Conference on Accomplishments in Mechanical and Industrial Engineering – DEMI 2017, organized by University of Banja Luka, Faculty of Mechanical Engineering, in Banja Luka, BOSNIA & HERZEGOVINA, 26 - 27 May 2017.

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APPLICATION OF POLYURETHANE WASTE IN VIRGIN RUBBER BLENDS

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Abstract: With the wide application of polyurethane foam, large amounts of polyurethane wastes are generated. Polyurethane waste from vehicles, waste of electrical and electronic equipment and many other sources attracted great attention worldwide as a result of rapidly rising amounts and increasingly tight legislation on its treatment and disposal. Polyurethane waste is recycled in two primary ways. Mechanical recycling, called powdering or recycling of regrind, involves grinding of waste containing polyurethane, and one of the fractions obtained is polyurethane powder. Thus obtained powder is mixed with virgin polymer materials and it can be used for new products. Chemical recycling takes the material back to its various chemical constituents. In this article polyurethane waste from electrical and electronic equipment is used as filers in virgin rubber. Different amount of polyurethane powder was added to rubber blend and their influence on mechanical properties and structure of rubber blends were examined. This study determined the optimal share of powder, in which there is no significant decrease in the properties of rubber compounds.
Keywords: polyurethane waste, recycling, rubber blends

INTRODUCTION

Waste electrical and electronic equipment (WEEE) is one of the fastest growing types of waste in the world. In the US, it amounts from 1% to 3% of the total waste generated in the municipalities. In the EU, the WEEE is growing for 16-28% every 5 years, which is 3 times faster than the average waste generated in a year [1].

WEEE contains more than 1000 different substances among them are considerable quantities of valuable materials such as precious metals. Early generation PCs used to contain up to 4 g of gold each; however, this has decreased to about 1 g today. The value of metals contained is also very high (for example 1 ton of WEEE contains up to 0.2 tons of copper). Therefore, recycling WEEE has the potential of becoming an attractive business for companies [2].

According to the European Topic Centre on Resource and Waste Management, iron and steel are the most common materials found in electrical and electronic equipment and they account for almost half of the total weight of WEEE. Plastics are the second largest component by weight representing approximately 15% of WEEE. The percentage share of material and mass balance of a refrigerator with the average weight of 54 kg is given in Table 1.

The table shows that the highest content of material in the refrigerator is iron (63.33%) and plastics (12.65%), which are successfully returned to the production process. In addition, there is a huge amount of polyurethane foam, almost 16%, for which there is currently no acceptable way of reusing it.

During WEEE recycling that contains polyurethane foam (refrigerators, freezers, cooling equipment, etc.), the waste polyurethane powder (WPU powder) has been generated as one of recycling product. Such WPU powder cannot be re-processed, expanded and used as an insulator. So far, WPU powder is used in two primary ways. Mechanical recycling, called powdering or recycling of regrind. Thus obtained powder is mixed with virgin polymer materials and it can be used for new products. Chemical recycling takes the material back to its various chemical constituents. Also, WPU powder has a high heating value (27 MJ/kg), and it can be used in incineration process as a fuel.

Table 1. Mass Balance of a Refrigerator

Material	Share (%)	Weight (kg)
Iron	63.33	34.20
Aluminum	4.17	2.25
Copper	0.58	0.31
Stainless steel	0.02	0.01
Plastic	12.65	6.83
Rubber	0.77	0.41
Freon	0.54	0.29
Wood	0.76	0.41
Polyurethane foam	15.71	8.48
Mineral wool	0.51	0.27
Oil	0.01	0.01
Other	0.95	0.51
Total	100	54.00

In this article WPU powder obtained from WEEE recycling is used as filers in virgin rubber. Different amount of polyurethane powder was added to rubber blend and their influence on mechanical properties and structure of rubber blends were examined.

EXPERIMENTAL RESEARCH

Rubber blends

WPU powder was produced only from waste refrigerated and waste freezer, where the present impurities were less than 0.05% and the particle size was less than 250μm. The characteristics of rubber blend with 0% of WPU powder (virgin rubber blend) was compared with the characteristics of two blends in witch were added 5% and 20% of WPU powder, respectively. Composition of NR/SBR blend is shown in Table 2.

Table 2. Composition of rubber blends

Ingredients	Virgin rubber blend (g)	Rubber blend with 5% of WPU powder (g)	Rubber blend with 20% of WPU powder (g)
SMR-10	225	225	225
SKS-30	870	870	870
ZnO	48	48	48
Stearin	15	15	15
4010 Na	11	11	11
TMQ	11	11	11
SOLAR-3	70	70	70
N-220	580	550	350
CBS	14.6	14.6	14.6
MS	1.0	1	1.0
S	24.2	24.2	24.2
PVi	1.8	1.8	1.8
WPU powder	0	54.75	219

The blends were mixed in a 2kg laboratory size two-roll mill at temperature of 80°C and the mixing time of 15 min. The time and length of the curing process was determined by the Monsanto Rheometer 100S according to ASTM D 2240-93, with the vulcanization time of 15 min, and the vulcanization temperature of 155 °C.

Mechanical testing

All measurements were performed before and after aging. The aging process was conducted in the aging oven for the period of 7 days at a temperature of 100 °C.
Hardness measurements were performed in accordance with ISO 7619-1 [3], using a manual durometer type Shore A. The measurements were carried out 5 times for each sample.
The testing of wear resistance was performed in accordance with ISO 4649 [4] using a Shopper cylindrical device with 5 measurements per sample.
The determination of tensile strength was carried out in accordance with ISO 37 [5] at the Instron testing machines, on dumbbell specimen type "2" of 2 mm in thickness, strained to break. The clamp separation speed was 100 mm/min.
Tear resistance was analyzed in accordance with ISO 34 [6]. Three angular type "A" tubes of 3 mm in thickness were strained to break in the measuring point, where the speed of clamp separation was constant at 500 mm/min.
Scanning electronic microscope was performed at JFC-1100E (JEOL, Japan).

RESULTS AND DISCUSSION

Hardness of all samples is illustrated in Figure 1. Hardness increases with the increase in the amount of WPU powder. Hardness increases more significantly when the amount of WPU powder reaches 20%, resulting in around 9% of the initial hardness. This appears to happen due to the decrease in cross-link density when WPU powder filler is used. Large deviations in hardness occur after aging, where hardness increases significantly with the increasing percentage of WPU powder.

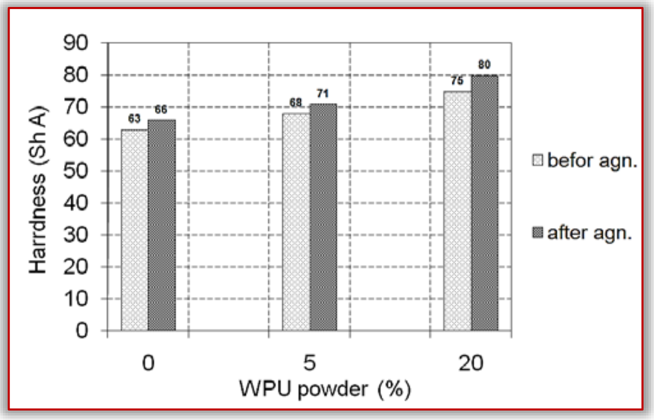

Figure 1. Results of hardness testing

Tensile properties fall into one of the most important properties of rubber compounds (tensile strength and modulus of elasticity). Tensile strength is shown in Figure 2.

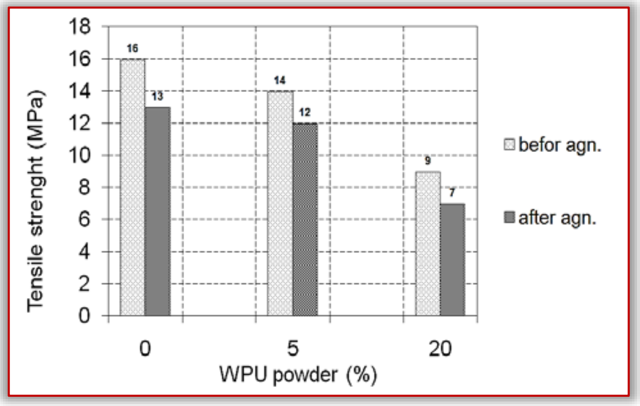

Figure 2. Results of tensile strength of rubber blends

It decreases slightly with the increase in the amount of WPU powder, where the small difference in tensile strength for 5% of WPU powder. Tensile strength decreases significantly when the amount of filler reaches 20%. This can be explained by weak bonds between particles and polymer chains, as well as irregular networking, which lead to a decrease in tensile strength. With the increase in the amount of WPU powder, the possibility of improper particle dispersion also increases, causing the more frequent occurrence of errors in the material. On the basis of the aforementioned, it can be concluded that the WPU powder behaves like a rigid filler since it has a higher modulus of elasticity than the natural rubber matrix.
Test results for wear resistance are shown in Figure 3. It can be concluded, from the diagram, that WPU powder particles have small effect on this property either before or after aging. Residual elongation after unloading increases with the increase in WPU powder percentage, as well as breaking

elongation. This is explained by the poor cross-linking between WPU powder particles and NR / SBR compounds which leads to weakened bonds, as well as the decrease in the ability to of rubber compounds to absorb the stresses.

Test results of tear resistance are shown in Figure 4. A significant decrease in tearing force was recorded after adding 5% of WPU powder, which is followed by a slight decrease with the increasing percentage of WPU powder, which can be explained by poor distribution of particles in the cross-linked chains of WPU powder, particles being grouped by themselves, and the varying particle size, which negatively affects the resistance to fragmentation.

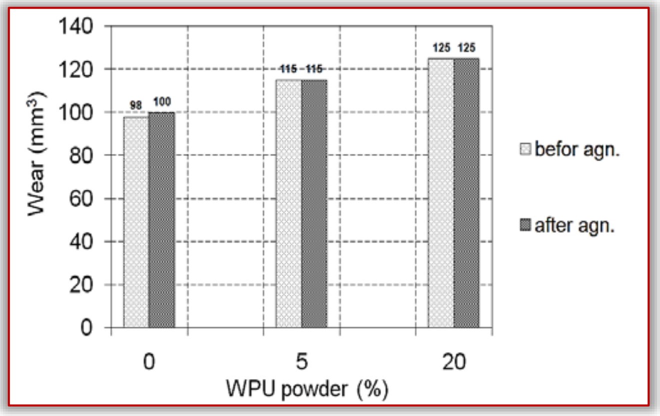

Figure 3. Results of wear resistance test.

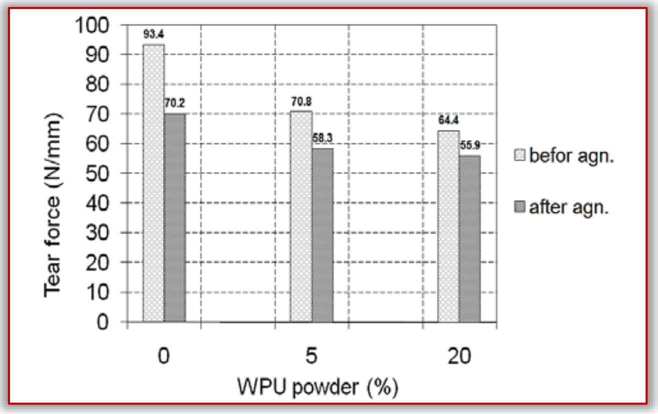

Figure 4. Results of tear resistance testing

The recycling process of PU foams considerably affects on its microstructure. As can be seen in the SEM pictures before and after recycling, shown in Figure 5 where the honeycomb structure of the PU completely is destroyed.

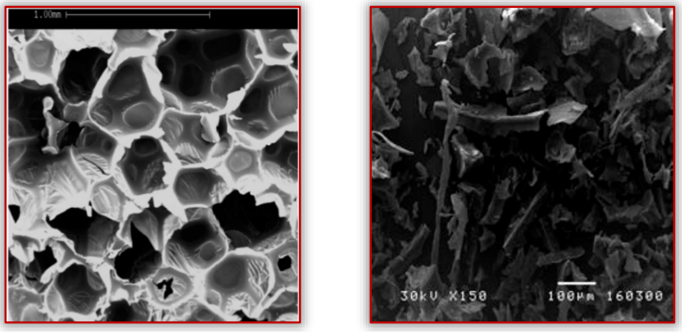

Figure 5. Appearance of PU before and after recycling

Because of its sharp edges (glassy structure) particles of WPU powder threads to bind to the rubber polymer chains and behave like inclusions in the chains. These damaging the structure of the rubber and adversely affect the elastic properties. A set of rubber structure with or without WPU powder, done on SEM, is shown in Figure 6.

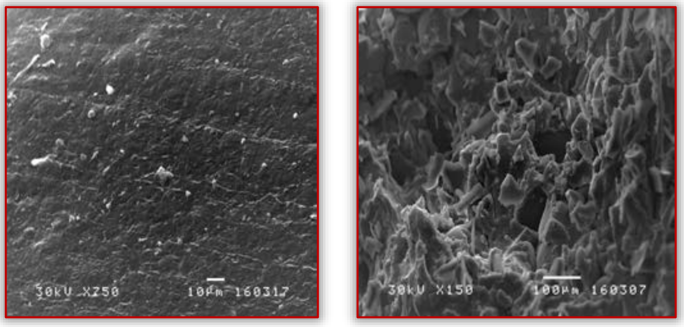

Figure 6. Structure of rubber with 0% and 20% of WPU powder

CONCLUSIONS

The results presented analyses suggest that the possible use of WPU powder in NR/SBR compound depends on the required characteristics of rubber products. Hardness, which is one of the most important properties, can be achieved by maximal amount of 5% of WPU powder. As far as tensile properties (tensile strength and permanent elongation) are concerned even a small amounts of WPU powder lead to a significant drop of properties. Wear resistance shows small sensitivity to application of WPU powder.

In the aforementioned properties, the best properties are achieved by applying less than 5% of WPU powder, yet the optimal ratio from the standpoint of economic and technical analysis is 5 %.

However, for products where a prominent feature are tensile properties and tear resistance, the use of WPU powder is not recommended since it leads to significant reduction of thease properties.

Note: This paper is based on the paper presented at 13th International Conference on Accomplishments in Mechanical and Industrial Engineering – DEMI 2017, organized by University of Banja Luka, Faculty of Mechanical Engineering, in Banja Luka, BOSNIA & HERZEGOVINA, 26 - 27 May 2017.

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THE ANALYSIS OF TECHNOLOGICAL PROCESS IN MANUFACTURING FACILITY "SANI GLOBAL" AND PROPOSED MEASURES TO IMPROVE THE PROCESS

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Abstract: Technological process is not constant, it is subjected to constant improvement and continuous innovation. Dynamics of the technological process is necessarily not only because of technological level of production and production time, but also for the competitiveness of product on the market and for the existence of given production system. In this paper, for the given production system which produces beech plywoods, massive beech panels, stair treads etc., technological process of the massive panels production has been analyzed and appropriate measures of its improvement along with the measures to increase the production competitiveness has been proposed.
Keywords: Analysis, technological process, production, product, CNC machine, production system

INTRODUCTION

The term technological process means the prescriptive sequence of processing operations that are needed to be performed in order to obtain a geometrical shape of given dimensions, accuracy, processing quality and other properties. The most significant objective of production are final products that give new value called added value that is obtained by transformation of the lower-cost raw materials into a higher-cost finished product, and performing of manufacturing services which is becoming increasingly important.

Each manufacturing facility uses experience, knowledge and skills of workers, where human resources of knowledge together with technology, technological processes and processing systems are the basis for the successful production. If modern methods of production preparation, organization and management are used, then we can say that it is a production that has all the prerequisites to be profitable.

THE METHODOLOGY OF ANALYSIS OF THE EXISTING SITUATION IN PRODUCTION SYSTEM

The analysis of technological process as well as the complete reengineering includes, if that is necessarily, all the resources, for example new and modern technologies, modern production systems, knowledge management, innovations etc. The analysis of process is carried out in several main stages, as shown in Figure 1.

Production program contains the following:

» Production of beech plywood,
» Special beech panels and massive beech panels,
» Planed elements and stair treads.

Defining the type of production system depends on the assortment or the program structure. If it is assumed production system of production assortment (structure) with *n* types of products: p_1, p_2, p_3, ..., p_i... p_n and quantity of *n* products: q_1, q_2, q_3, ..., q_i... q_n, along with assumption that is: $q_1 > q_2 > q_3 ... > q_i ... q_n$, then by increasing the width of assortment the number of specific products will be reduced and vice versa, as shown in Figure 2.

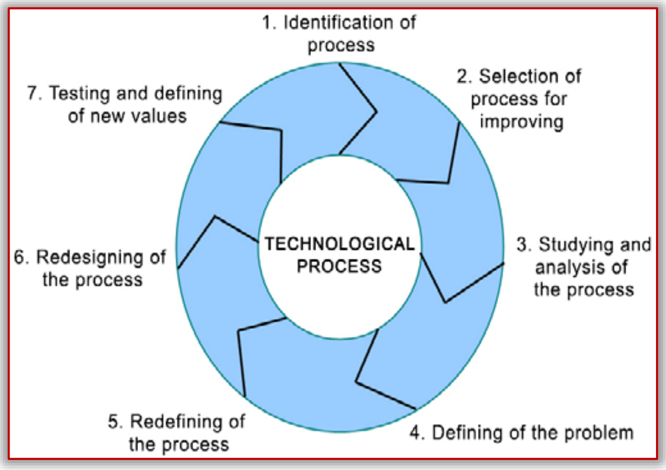

Figure 1. Stages in analysis of the technological process

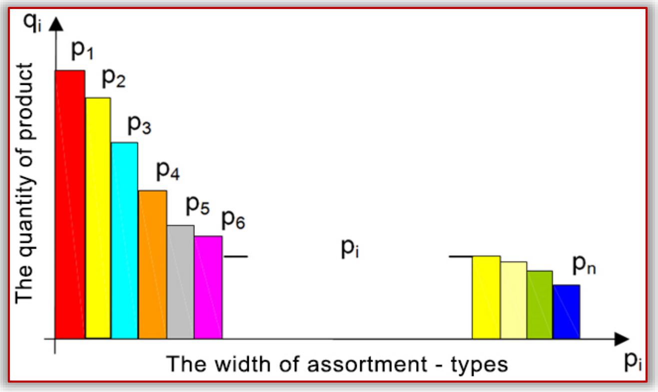

Figure 2. The correlation between quantity of product and assortment

According to type, massive panels are divided into width-connected panels and length-width connected panels. Material for making of the width connected panels is beech (gently steamed). The panels are made in thickness of 40 to 45 mm while the standard width is 650 mm. The lengths are in range of 800 to 2000 mm (sometimes even more than 2000 mm). Width connected panels are intended primarily for the making of treads. The length-width connected panels are made primarily of beech (gently steamed). According to the requirements of purchasers, for making of the length-width connected panels, black and European walnut, oak, ash tree and cherry are used.

The thickness of panels is from 18 to 50 mm while the widths can be in the range of 1200 mm. Maximal length is 5000 mm. The use of length-width connected panels is various, primarily they are used for production of furniture, stair treads and so on. According to quality (category), massive panels are divided into the following: A/B, B/B, B/C, KERN and RUSTIK. The Figure 3 shows the massive panels.

Figure 3. Massive panels

THE EXISTING TECHNOLOGICAL PROCESS FOR PRODUCTION OF MASSIVE PANELS

The existing production process in "Sani Global" company consists of the following operations which are performed to obtain final product.

Fine shortening

After an operation on planning machine has been performed the next operation is fine shortening, by which the workpiece gets its final length. This operation is performed using a circular saw for fine shortening. By circular saw it is determined the final length of workpiece, it is obtained clean measures and it is created the conditions for further processing of workpiece (gluing).

The gluing

As binders, in production of massive wooden panels the glues are used. The glues are substances that have ability of transformation from the liquid into the solid state by what the monolithization of connected elements is achieved. Monolithization is done by adhesiveness of glue to contacting wood surfaces and during that, cohesion of materials that are participating in the process of bonding remains unchanged. In "Sani Global" company, for production of massive panels glue DIN EN 204 | D3 is used, and it satisfies the following requirements:

- strength through the time,
- resistance to chemical influences,
- strength of connected part that is at least the same as the shear strength of wood parallel to the fibers and perpendicular to the fibers,
- resistance to organic and inorganic materials (agents),
- water resistance,
- it dries at temperature within 25 °C.

Width-gluing of wood (extension) - Equipments for width joining of the wood elements are various tools and machines. It is necessarily that glue has hardened while press machine performs one complete revolution.

Length-gluing of wood (elongation) - Equipments for length joining of the wood panels are apparatuses for applying the glue and apparatuses for achieving the frontal and vertical pressure that are perpendicular to the connecting panel dowel.

Surface treatment of wood

Surface treatment of wood is processing of wood surface with objective to improve the quality, appearance or to protect wood surface from being affected by different agents.

The grinding - Grinding is the technological operation in final processing by which wood surface is grinded with objective to achieve the adequate quality of smoothness of grinded surface. Grinding of workpieces is performed through three phases: rough, medium and fine grinding. Technological operation is performed on grinding machine.

The varnishing - By varnishing the properties of wood are to be highlighted, hidden or changed. As an agent for surface treatment of wood, different types of lacquers, paints, and other chemical agents are used, which also have some specific physical-mechanical properties. There are several ways to apply these agents: manual by the brush, gun spraying, pulling the element through the curtain of liquid material, immersing the element in the paint, roller varnishing in which the elements pulls through the rollers.

Quality control

Quality is a feature that defines and classifies the product or other articles. It is a basic specification od product. Quality is defined by standards, by which are also defined all characteristics and properties of products, processes or services which should have possibility to satisfy specific or indirect needs.

The term quality in not only used to express the perfection in comparative sense for technical evaluation but also it is used in quantitative sense for technical evaluation. System elements of quality are defined by Recommendations of international institutions for standardization ISO 9000 and EN 29000.

THE OVERVIEW OF TECHNICAL-TECHNOLOGICAL MEASURES FOR IMPROVING PRODUCTION PROCESS

Improvement in "Sani Global" company can be achieved if some of the following requirements are satisfied:

- The introduction of new technologies – increase of productivity, increase of production time and decrease of working time on machine per product unit,

» Replacement of technologically old machines – by exploitation of machine, technological and total imperfectness of machine increase with time,
» Replacement of old parts of machines – it is always good to have spare parts of machine especially when we have possibility to change old parts right after they stop working,
» Expanding the capacities of existing production facility – manufacturing facility "Sani Global" builds one more hall with area of 1000 m^2. This new hall is of great importance for improving the production process. The hall will also be supplied with new machines and new workers will work in it so more jobs will be opened.

Without CNC processing centers, modern production in wood industry is hard to imagine. They are far more effective than grinding and milling machines. CNC machines can be combined in flexible processing group that can work and produce more than one individual machine.

The comparison between conventional and CNC technology is given in Table 1.

Table 1. Comparison between some characteristics of conventional and CNC technology

Characteristics	Conventional technology in the factory (d.o.o. Sani Global)	Proposed improvements (CNC technology)
Performing more than one operation with one machine	Each operation is performed one by one but preparation of machine is multiplex	Combining of more operations of one machine or combining the operations using more machines with one preparation of CNC machine
Preparation for work	During the preparation, machine can't perform production	The preparation is done in the office so that machine can simultaneously produce other products
The first processing	Making of templates and adjusting the machine	Program simulation trial
Repeated processing	Complete adjusting	Self-connecting of program
Required drawings	It is required to have dimensioned drawings or sketches	For CNC machine, paper drawing is not often required
Required working space	It is required working space for each machine with belonging manipulative space for every machine	It is only required space for one machine with belonging manipulative space

Table 1. Comparison between some characteristics of conventional and CNC technology (continuing)

Characteristics	Conventional technology in the factory (d.o.o. Sani Global)	Proposed improvements (CNC technology)
Number of workers /duration of processing	Higher number of workers or longer duration of processing with lower number of workers	Most often it only one worker with low duration of processing is required
Worker competence	Knowledge in carpentry	Carpentry knowledge, general and technical knowledge
Required support from machine producer	Support is sufficient mainly when specific spare parts are ordered	Support is permanent and depends on service of machine producer
Investments	Cheaper machines, cheap maintenance and spare parts, more expensive working space	Expensive machine requires office computer. Technical software's (programs), worker training, maintenance are also expensive.

CONCLUSIONS

For high quality product it is required quality raw material – wood (trunk of beech or oak which are among the most significant raw materials for producing the massive panels). For successful production none of the process may be considered as less important than other, but all parts of process must be integrated and performed by technological standards.

The best solution to increase the production is the introduction of CNC machines which would allow flexible production. Although the mentioned machine is very expensive, by flexible production costs that was spended for machine would quickly be refunded. In addition, with using CNC machine it is possible to achieve automatization of work with reduced number of workers and so that the cost have less values. At the end, it can be concluded that the best measures to improve the production process in "Sani Global" company are installing one CNC machine and building new production hall.

Note

This paper is based on the paper presented at 13th International Conference on Accomplishments in Mechanical and Industrial Engineering – DEMI 2017, organized by University of Banja Luka, Faculty of Mechanical Engineering, in Banja Luka, BOSNIA & HERZEGOVINA, 26 - 27 May 2017.

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COMPARATIVE ANALYSIS OF GEOTHERMAL HEAT PUMPS

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Abstract: Geothermal Heat Pumps (GHP) belong to a class of modern sustainable technologies that use energy (heat) available underground for heating or cooling households and residential buildings, as well as commercial and industrial spaces. They are widely deployed across Europe and enable savings in primary energy sources, simultaneously cutting down the costs of heating/cooling. This paper discusses advantages of GHPs, especially the pumps of the type earth-water, and provides a comparative analysis of different types of those pumps currently available on the market according to their coefficient of performance (COP), CO_2 emission footprint, and power. Based on the collected data from 309 different GHP models coming from 32 different manufacturers, we derive expressions for characterizing GHPs of the type earth-water, which can be useful in performing initial feasibility studies and system designs.
Keywords: geothermal energy, heat pump, COP, heating, cooling

INTRODUCTION

Energy consumption poses a major environmental and energy problem, in terms of global warming and limitted availability of fossil fuels. The main advantage of using geothermal energy lies in the fact that this renewable source of energy is freely available as the earth heat or heat from groundwater (whit temperatures between 5°C and 30°C). Estimated installed capacity at world level amounts to nearly 12,000 MWt (thermal energy), so the annual energy need is about 72,000 TJ (20,000 GWh) [1,2].

Heat pumps are widely used because of their high efficiency compared to conventional heating and cooling systems. There are two basic types of heat pumps: those that use air as the heat source and those that use ground, known as geothermal heat pumps (GHP) and ground source heat pumps (GSHP), respectivly [3,4].

An estimated power of all existing geothermal wells in Serbia is about 160 MW, out of which about 100 MW is currently used. Wiht the heat pumps, we can use as much (completely clean) energy from the ground as we need. For example, with installation of 20,000 heat pumps of 20 kW power each for heating residential facilities, the necessary amount of energy for a power plant that produces 300 MW can be taken from the ground.

Europe sets very high goals in terms of renewable energy and reducing greenhouse gas emissions. Geothermal energy is the most appropriate to achieve these objectives and the only one of available renewable energy sources that has entered the legal obligation to be used in heating new buildings in several European countries. By joining the European Union, Serbia would need to follow those obligations regarding the use of renewable energy and reducing greenhouse gas emissions.

Serbian Energy Law [5] regulates the issuance of authorizations for the construction and reconstruction of facilities that produce electricity and thermal energy. Currently licensing is defined by the Rulebook on Criteria for the Issuing of Energy permits, Contents of the Application and the Manner of Issuing the Energy Permit and the conditions for approval of energy facilities for which no energy permits are needed [6,7].

Total installed power in geothermal power plants in the world is presented in Table 1. This Table also shows the short-term forecast for 2020.

During the period of five years, between 2010 and 2015, an increase of 1.7 GW (16%) is achieved, which in the judgment of the linear trend is about 350 MW/year with an obvious increase in the average value of 200 MW/year in the period from 2000 to 2005.

Table 1. The total installed capacity of geothermal energy at the global level from 1995 until the end of 2015 and short-term forecast for 2020 [8]

Year	Installed capacity [MWe]	Produced energy [GWh]
1995	6.832	38.035
2000	7.972	49.261
2005	8.933	55.709
2010	10.897	67.246
2015	12.635	73.549
2020	21.443	

Ruggero Bertani in his research showed that the total amount of electric energy generated by geothermal power station in 2015, in several countries on five continents, is about 12.6 GWh [8].

TECHNOLOGY OF GEOTHERMAL HEATING

The geothermal energy potential is huge. It is estimated that there is multiple times more geothermal energy than the total amount of energy sources based on fossil fuels (coal, oil and gas) around the world. Serbia, ranks among the richer countries on the geothermal potential although this is still an under-utilized resource. The use and exploitation of geothermal energy must become more intense because of a number of factors: a steady growth in the price of fossil fuel, worsening environmental situation, the increase in the cost of protecting the environment.

Heat pumps are devices that work on the thermodynamic principle of the heat exchange, i.e. the heat from the lower temperature place shifted to higher temperature place while consuming mechanical work, which is several times smaller than the energy transferred by left-turn circular process of an appropriate working fluid. The share of electrical energy consumption ranges from one-third to one-fifth of the resulting thermal energy, which means that the expenditure of 1 kWh of electricity can be transformed into 3 - 5 kWh of thermal energy.

Geothermal heat pumps use the ground or ground water as a heat source, whose temperature is mostly constant throughout the year. There are three different sources of heat - outside air, earth and groundwater. On this basis, there are three different systems of heat pumps: air - air, water - water and ground - water. The earth is a very good accumulator of solar heat because the temperature at a depth of 1.2 - 1.5 meters throughout the year is constant, ranging between 5 - 15°C.

COP coefficient describes the efficiency of the heat pump, i.e. the ratio indicates how many times more thermal energy is obtained in relation to the electricity consumed by the compressor. The efficiency depends on the type of heat source (ground, water, air), thermal building insulation and heating systems. The most economical use of heat pump is in well insulated buildings with heat losses less than 50 W/m^2 and a low-temperature heating system (floor/wall heating) with a primary flow temperature of 35°C.

Selection of the working fluid used in the heat pump is carried out by considering a number of different aspects. Some of the working fluids which are intensively used in heat pumps have a serious impact on the environment. The working fluid must meet the appropriate set of conditions such as:

» chemical stability (stability of working fluid within the system);
» impact on the environment, health and safety;
» thermodynamic properties.

The CO_2 emissions shall be determined by multiplying the annual primary energy for the operation of the facility, by source of energy, and the appropriate data for specific emissions of CO_2.

Reduction of greenhouse gases emissions (GHG) in the geothermal heat pump is around 44% compared to air-cooled heat pump and even 72% compared to heating systems that use electricity [9].

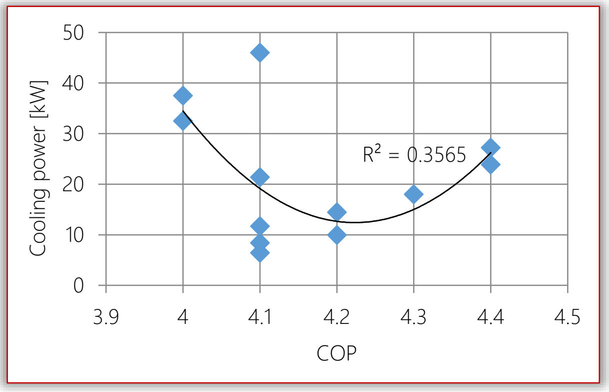
COMPARISON OF TYPES, COP AND POWER OF HEAT PUMP EARTH - WATER BEETWEEN DIFFERENT MANUFACTURERS

In the manufacturers brochures of heat pumps of the type earth – water, the following data is readily available: the coefficient of performance (COP) of heat pumps, the heating and cooling power as well as which medium is used for cooling. The price of heat pumps depends on several factors and it is not available from all the manufacturers.

Based on the available data, in this paper we present the values of COP, cooling and heating power obtained for 309 different models of geothermal heat pumps of the type earth - water (from 32 different manufacturers, [10,11,12,13]).

Figure 1 presents the dependence between the COP and heating and cooling power for several manufacturers. Temperature of the heat source and the heat sink are 5/55°C [10,11].

Efficiency coefficients (COP) of processed heat pumps differ a little bit but, for the purposes of initial studies, the effectiveness of specific model for a given heating or cooling power can be determined based on the diagrams given in Figure 1.



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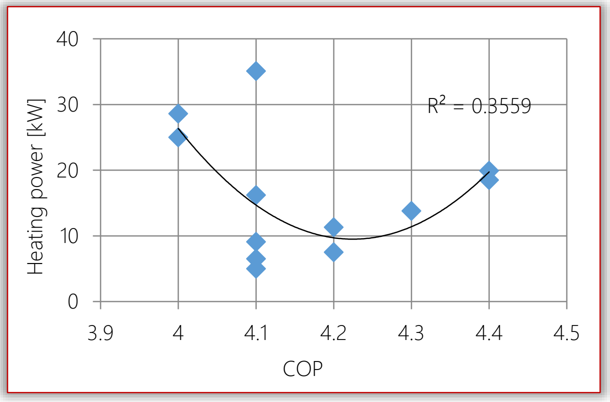

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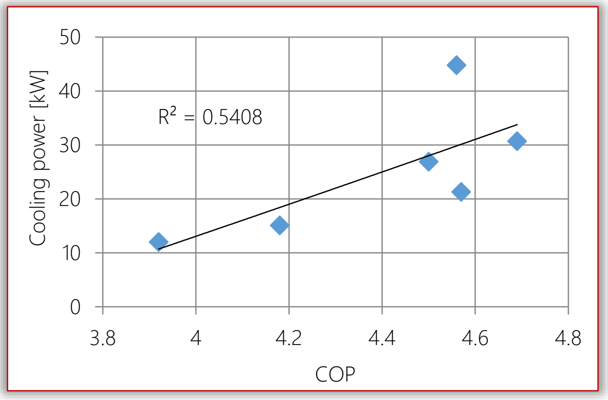
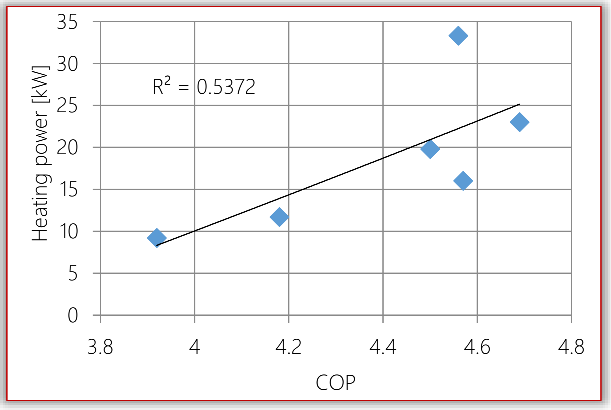


c)

Figure 1. The dependence of the COP of the geothermal heat pump type earth – water on the heat (left) and cooling power (right) (figures formed based on data from [10,11,12,13]).
a) Rehau heat pump - the COP dependence on the cooling power; b) Rehau heat pump - the COP dependence on the heating power; c) Bosch Logatherm WPS heat pump - the COP dependence on the cooling power;



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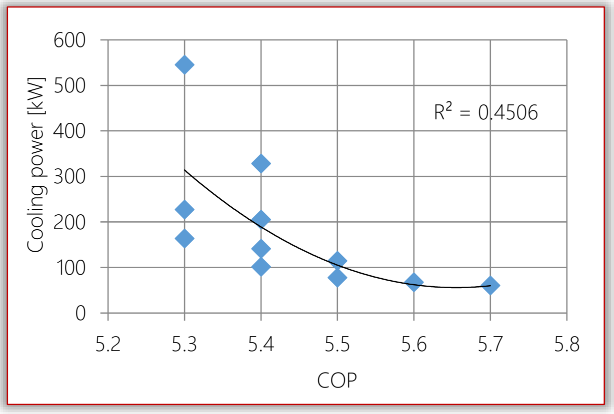

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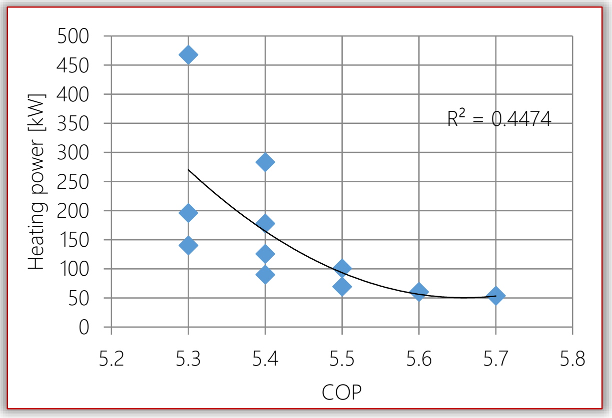
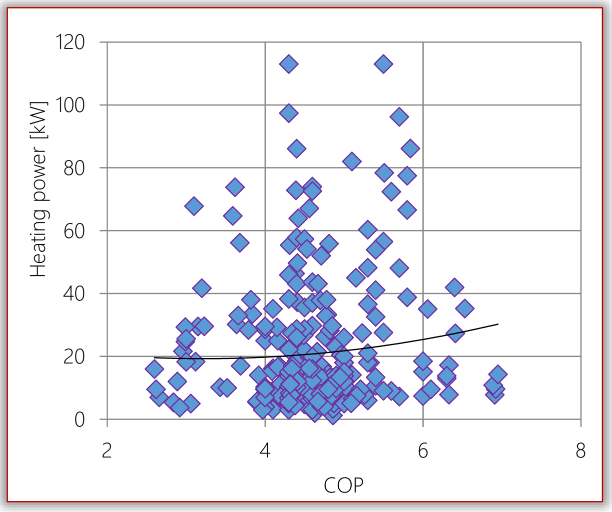


f)

Figure 1 (continuing). The dependence of the COP of the geothermal heat pump type earth – water on the heat (left) and cooling power (right) (figures formed based on data from [10,11,12,13]). d) Bosch Logatherm WPS heat pump - the COP dependence on the heating power; e) Hidros heat pump - the COP dependence on the cooling power; f) Hidros heat pump - the COP dependence on the heating power

Figure 2 presents the total dependence of the COP of heat pumps and heating and cooling power for collected data from available manufacturers.

The market offers a relatively large number of geothermal heat pumps of the type earth - water of different heating/cooling powers and the efficiency of heating/cooling, so that an appropriate model for almost any requirement of potential users can be found from above Figures.



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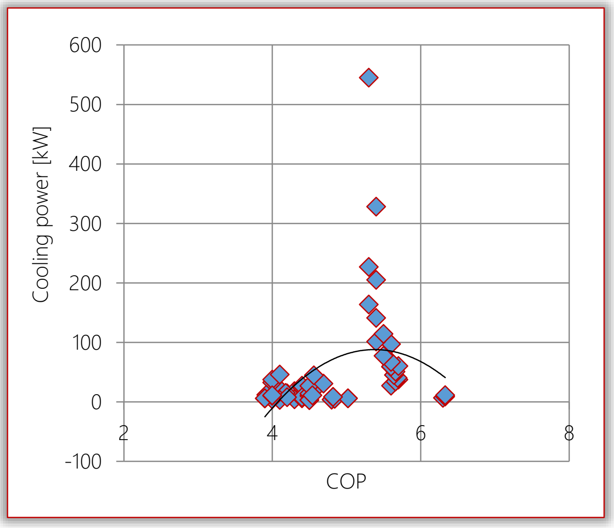

b)

Figure 2. Dependence of the COP of the geothermal heat pump type earth - water on the heating and cooling power for all manufacturers (figures formed based on data from [10,11,12,13]). a) The COP dependence on the heating power for the collected data from 32 manufacturers of geothermal heat pumps; b) The COP dependence on the cooling power for the collected data from 32 manufacturers of geothermal heat pumps

CONCLUSIONS

This paper presents a total installed capacity [MW] and the total electricity production [GWh] in geothermal power plants worldwide, as well as the short-term forecast for 2020. The paper also shows 32 manufacturers (309 models) of geothermal heat pumps of the type earth - water. The prices of geothermal heat pumps are not presented because the relevant data was not available for all the heat pumps. Models of geothermal heat pumps that are discussed in this paper are available on the market and are suitable for use in family homes, apartment buildings, public buildings, hotels and small industrial plants.

Based on the analysis of the characteristics of geothermal heat pumps, the conclusion is that the use of geothermal energy reduces the need for primary energy sources by half, compared to traditional heating systems, and reduce emissions of greenhouse gases. In other words, heat pumps contribute to reducing the demand for energy from fossil fuels.

Acknowledgements

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Note

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HYDROKINETIC TECHNOLOGIES AND APPLICATION

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Abstract: Known by all parties, the use and prevalence of renewable energy is essential because of the global warming and environmental pollution effects of fossil fuels. Hydrokinetic is a renewable energy source. Marine currents and river currents at high-altitude internal regions create significant hydrokinetic potential. Hydrokinetic energy conversion systems are in development and new application stages. Researchers and organizations are working intensively on this topic. During some systems are in the phase of research and prototype development, others are at commercialization phase. This study presents some informations to understanding the existing systems, the implementation possibilities, the application difficulties and some solution suggestions.
Keywords: renewable energy, hydrokinetic potential, hydrokinetic energy conversion systems

INTRODUCTION

Depleting fossil fuels, increasing environmental pollution due to the widespread use of fossil fuels, changing and developing consumption habits, and rising energy consumption per person require the introduction and better evaluation of new and alternative energy sources Hydrokinetic energy has a significant place among these sources. The power of the water current creates hydrokinetic energy. Renewable hydrokinetic energy can be harnessed from water currents via hydrokinetic technology [1].

Hydrokinetic technologies are similar in many aspects to wind energy conversion systems. With another explanation, we can think of them as being immersed in water of wind turbines by taking necessary precautions. Hydrokinetic sources can be divided into two groups as ocean /sea and river currents. In some cases, tidal energy and wave energy are considered hydrokinetic sources. However, they vary in terms of their structure, conversion systems, and Technologies. Since water is 832 times denser than air, hydrokinetic energy conversion systems are able to obtain the same power from much smaller rotor swept area comparing with wind energy.

Process losses are occurring in all of the conversion systems. Therefore process efficiency emerges during such conversions. All of these losses are substituted by the system performance coefficients. The performance coefficient of the hydrokinetic and wind energy conversion systems are limited to the Betz limit of 59.3%, which is the maximum theoretically possible conversion efficiency.

Special incentive schemes are being implemented in some developed countries to promote the development and deployment of hydrokinetic Technologies [2]. Interest in the progress and development of hydrokinetic energy conversion technology has grown significantly in recent years. The hydrokinetic industry has advanced by taking necessary steps beyond the testing and prototype phase and will soon install demonstration projects with arrays of full-scale devices [3].

Despite all this, hydrokinetic energy conversion systems and technologies are in the developmental stage in some aspects. In addition, there are many prototypes or new project implementation stages. It is important that these studies are gathered together and discussed. In this context, it is essential to raise awareness what is the application frame of the hydrokinetic energy, how it is applied, and the challenges and differences in applications. In this work, hydrokinetic energy, the power to be obtained from it, performance coefficient, classification of turbines, application and information about turbines have been tried to be given.

MATERIAL AND METHODS

Hydrokinetic power

Hydrokinetic turbines generate power only from the kinetic energy of moving water (current). This power is a function of the density of the water and the speed of the current cubed. The available hydrokinetic power depends on the speed of the river, ocean, or marine current [3]. Most of the principals of this type of turbine are based upon wind turbines, as they work in a similar way. During the quiet flow state, a column of wind upstream of the turbine with cross-sectional area A of the turbine disc has kinetic energy passing unit time as follows [4-6].

$$P=1/2\ \rho.A.U^3 \qquad (1)$$

The power that can be obtained from the hydrokinetic turbine or wind turbine when using the performance coefficient instead of process and conversion losses is as follows [6].

$$P_T=1/2\ \rho.C_P.A.U^3 \qquad (2)$$

where:

» ρ the density of the fluid passing through the turbine (kg/m^3)
» C_P performance coefficient of the system
» A rotor swept diameter (m)
» U free water flow velocity (m/s)

The system performance coefficient indicated by Cp is limited by the Betz limit as mentioned earlier and can be maximum

59.3%. However, in practical applications it seems to vary between 0.1 and 0.4, Figure 1 [7].

As water is involved in hydrokinetic conversion systems, the density may vary depending on the salt content of the water. In addition, the system performance coefficients vary depending on the flow rate (velocity). Creating power is raising in proportion the rotor diameter. The power to be obtained from the system varies with the cube of the free flow velocity.

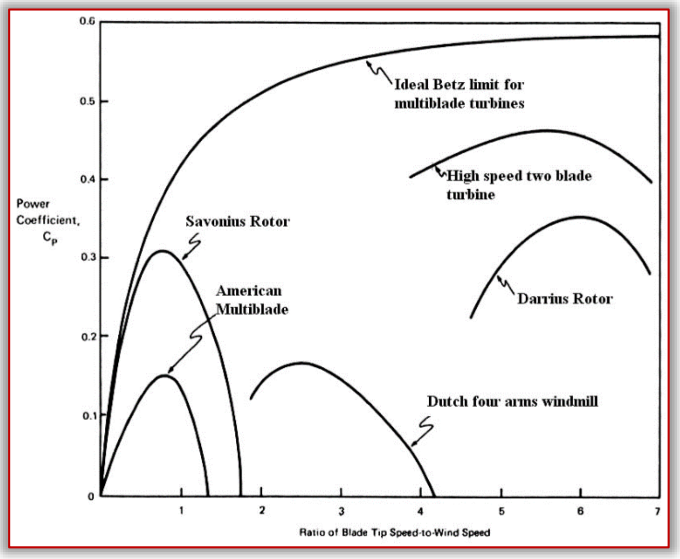

Figure 1. The power coefficient C_p as a function of the tip speed ratio for different wind machines designs. [7]

The total hydrokinetic energy resource in a region can be estimated using two alternative methodologies. The first approach involves calculating energy expenditures in rivers, and second involves tracing potential hydrokinetic energy back to its source. In the second approach, total potential hydrokinetic energy for a region equals the sum of the potential energy of the water that drains towards the outlet [8].

Hydrokinetic turbines

The classification of hydrokinetic turbines can be made basically as horizontal axis and vertical axis. The horizontal axis turbines can be separated into two groups. The rotational axis of the first one is parallel to the water stream direction. The rotational axis of the other is perpendicular to the water stream direction. Water wheels or cross-flow turbines can be classified as perpendicular horizontal axis turbines, axial flow turbine can be usually constructed as two-, three- or multi-blade. The structure can be opened or ducted [9]. Horizontal axis turbines have passed the development phase and are now starting to commercialize.

If the rotational axis of turbine rotor is perpendicular to the water surface, such turbines are named vertical; typical examples of vertical axis are Savonius, H- Type, Darrieus, Helical turbine [9]. H-Type (cross-flow), Tropostien/Darrieus and Gorlov helical turbines are encountered in practice and work extensively on various organizations and researchers. They can be reached partly by commercializing among vertical axis turbines. In addition, the combination of Darrieus and Savonius turbines in a single body has been tested.

RESULTS AND DISCUSSION

Hydrokinetic turbines can be arranged directly to the regions where the ocean or marine water correct occurs. This application can be done to sea bottom as well as close to sea level. Horizontal axis turbines are often seen in this type of marine application. In practice of this type, it is possible to take measures to increase the water flow rate by using ducted structure. Vertical axis helical turbine is used in surface applications. In this case floating platforms and mounted turbines are involved. The hydrokinetic turbines can be utilized in principle at the main turbine outlets in the hydroelectric power plants based on the water accumulation and drop because the water velocities are very high. Axial turbines seem to be more suitable here, but it is important to consider how and where the turbine base mechanism is to be mounted. Axial turbines can be directly applied in river application if there is adequate water depth available. Necessary precautions should be taken in these applications by taking into account special conditions such as river sediment structure, movements and flood cases. Moreover, hydrokinetic turbines can be conveniently and optimally used in manmade water flow channels, such as water mill channels formed at the edge of the river. In that application, measures to prevent fish and other aquatic entrances from entering the channel can also be easily taken. Turbines can be serially connected in succession into these hydrokinetic channels. Both horizontal and vertical axis turbines can be used in these channels. The system may be simpler by vertical axis turbines since components such as generators and speed increasers can be mounted on the water level. Furthermore, It is also possible to increase the water flow velocities 2 to 3 times by using smooth surface channel materials as the sediment structure decreases water flow in the river [6, 9].

CONCLUSIONS

Hydrokinetic turbines are immersed in water from wind turbines. Significant increases in hydrokinetic turbine applications should be expected over the next decade although not as much as the prevalence of wind turbines. The main bodies of the turbines will not be as noticeable as the wind turbines because they are usually underwater in the sea and ocean applications. In such applications, it should be possible to establish well the regions where there are sufficient water currents and to establish and construct the transmission lines which will be produced with electricity so as not to obstruct the sea traffic and marine life. In such applications it is necessary to determine well the regions where there are sufficient water flows. it is important to safely transport the electricity to be produced. Transmission lines should not obstruct and harm marine traffic and marine life. Wind turbines are capable of delivering 1 MW power at wind speeds of 13-14 m / s with rotor diameter of 50 meters. Hydrokinetic turbines can reach the same power values at water speeds of about 3 m / s with 11 meter rotor diameter units. Utilizing the water currents in the rivers will gain prevalence even easier via hydrokinetic channels. The hydrokinetic channels that will be formed here will offer advantages both in terms of increasing of water speed and ease of taking precautions to prevent any live habitat entry. Also, changes in water velocities in the canal will be very slight, so they will not be too complicated in frequency regulating mechanism. Consequently, It is possible to convert both the ocean and the river water current into electricity by well-designed, with scrutiny measuring systems for potential negative effects on the environment.

Note

This paper is based on the paper presented at 7th International Conference Industrial Engineering and Environmental Protection 2017 – IIZS 2017, organized by University of Novi Sad, Technical Faculty "Mihajlo Pupin", in Zrenjanin, SERBIA, 12 – 13 October 2017.

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HYDROMETEOROLOGICAL MONITORING IN WEST MORAVA RIVER BASIN (SERBIA)

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Abstract: Due to the unfavorable environment conditions that Serbia, and mainly Čačak, have been experiencing in the last few years (such as frequent floods, droughts and fires), as well to the particularly underdeveloped monitoring system that can't properly envisage and prevent such situations, it is essential for Serbia to get familiar with the application of new and up-to-date technologies in this field. This paper has the aim to analyze the situation in the area of Čačak, in particular in the West Morava river basin, to collect data about the hydrometeorological monitoring standards in Serbia and the methodology of monitoring the main hydrometeorological parameters. The paper shows some climatic trend with the data available for precipitation and runoff in the area of West Morava river basin. The results of the research can contribute to the prevention of floods in the West Morava river basin.
Keywords: hydrometeorological monitoring, West Morava river, rainfall and runoff regime

INTRODUCTION

Streamflow serves man in many ways. It supplies water for domestic, commercial and industrial use; irrigation water for crops; dilution and transport of wastes; energy for hydroelectric power; transport channels for commerce; and a medium for recreation. Records of streamflow are the basic data used in developing reliable surface water supplies because the records provide information on the availability of streamflow and its variability in time and space. The records are therefore used in the planning and design of surface water related projects, and they are also used in the management or operation of such projects after the projects have been completed.

Streamflow records are also used for calibrating hydrological models, which are used for forecasting, such as flood forecasting. Streamflow, when it occurs in excess, can create a hazard and floods caused extensive damage and hardship. Records of flood events obtained at gauging stations serve as the basis for the design of bridges, culverts, dams and flood control reservoirs, and for flood plain delineation and flood warning systems. Likewise, extreme low flow and drought conditions occur in natural streams, and should be documented with reliable streamflow records to provide data for design of water supply systems. It is therefore essential to have valid records of all variations in streamflow. In May 2014 Serbia was hit with floods and as a consequence, the importance of an efficient hydro meteorological and environmental monitoring system in strategic areas, as that close to Čačak, became vital [1-2].

West Morava river basin includes a significant part of the western and southwestern Serbia, and covers an area of 15,805 km2. From a morphological point of view, in the basin stand mountains, plateaus and valleys. The highest point on the mountain basin is Hajle (2400 meters above sea level), while the lowest part of the West Morava river is 127 meters above sea level. Measured from the source West Morava is 208 km long. The average width of the river is about 35 m, with maximum depths of up to 4 meters. The bottom frame is changed depending on the surface of the terrain through which it flows, and can be rocky, gravelly, and sandy to muddy the downstream part of the course. The highest mountains in the basin are Kopaonik (2017 m) and Mokra Gora (2155 m). High mountain formations occupy the western, northern and central parts of the basin, while the lower formations are in the south. A regards valleys and ravines, in the West Morava river basin we found the greatest depression Polje, in Kosovo. In the river basin take place different valleys: Part of the basin around the lower courses of the West Morava has the characteristics of plain hilly terrain. This paper shows the results of hydrometeorological monitoring in West Morava river basin on the basis of available hydrological data as well as forecasts that can be expected in the future [3].

MATERIAL AND METHODS

The rating curve, also known as stage-discharge relation, is the empirical or theoretical relationship existing between the water-surface stage and the simultaneous flow discharge in an open channel. The rating curve is a very important tool in surface hydrology because the reliability of discharge data values is highly dependent on a satisfactory stage-discharge relationship at the gauging station. As regards the determinations of rating curves in different section of West Morava river, it is used the method with flow equations of hydraulics. The stage-discharge relation for open-channel flow at a gauging station is governed by channel conditions downstream from the gauge, referred to as a control. Generally, the flow in this area is controlled by a section control that is a specific cross-section of a stream channel, located downstream from a water level gauge that controls the relation between gauge height and discharge at the gauge [4].

The table 1 shows the Manning's coefficient used to estimate the value of the discharge for each station on West Morava river and rating curve's equations defined by the Ordinary Least Squares method.

Table 1. Manning's coefficient and rating curve's equations in different section of West Morava river

Station name	Manning's coefficient n ($m^{-1/3}s$)	Equation
Jasika	0.036	$Q=63.67(h-136.93)^{1.76}$
Trstenik	0.038	$Q=74.42(h-159.81)^{1.94}$
Miločaj	0.050	$Q=59.53(h-194.89)^{1.58}$
Kratovska Stena	0.038	$Q=20.57(h-292.22)^{1.81}$

For the station in Čačak we have a detailed rating curve and the profile of the control section used to calculate the dependence of the discharge from the stage values. This control section is situated in correspondence of a bridge, not too far from the bridge where the stage instruments are set. Figure 1 shows the rating curve for the station in Čačak.

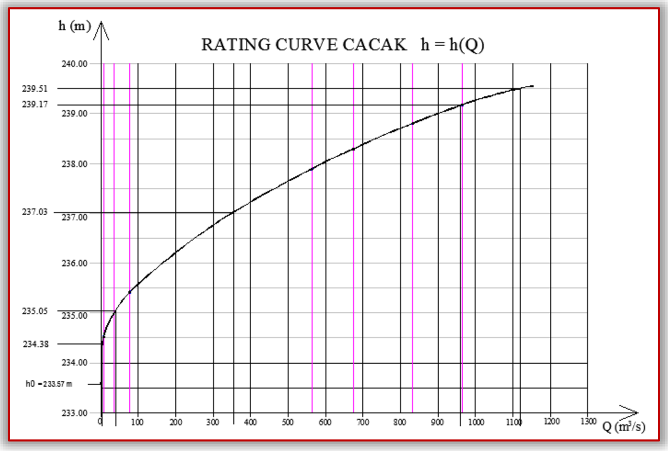

Figure 1. Rating curve for the station in Čačak

The flow duration curve is a plot that shows the percentage of time that flow in a stream is likely to equal or exceed some specified value of interest. Although the flow duration curve does not show the chronological sequence of flows, it is useful for many studies. It can be used to show the percentage of time river flow can be expected to exceed a design flow of some specified value, or to show the discharge of the stream that occurs or is exceeded some percent of the time. A flow duration curve characterizes the ability of the basin to provide flows of various magnitudes. Information concerning the relative amount of time that flows past a site are likely to equal or exceed a specified value of interest is extremely useful for the design of structures on a stream [5].

The shape of a flow-duration curve in its upper and lower regions is particularly significant in evaluating the stream and basin characteristics. The shape of the curve in the high-flow region indicates the type of flood regime the basin is likely to have, whereas, the shape of the low-flow region characterizes the ability of the basin to sustain low flows during dry seasons. A very steep curve (high flows for short periods) would be expected for rain-caused floods on small watersheds. Snowmelt floods, which last for several days, or regulation of floods with reservoir storage, will generally result in a much flatter curve near the upper limit. In the low-flow region, an intermittent stream would exhibit periods of no flow, whereas, a very flat curve indicates that moderate flows are sustained throughout the year due to natural or artificial streamflow regulation, or due to a large groundwater capacity which sustains the base flow to the stream [6].

For the station in Čačak, are available the daily value of discharge for the years 1991, 1992, 1993, 1999, 2002, 2003 and 2005. Figure 2 shows the average duration curves for all the period and the characteristic values for the monitoring stations in Čačak.

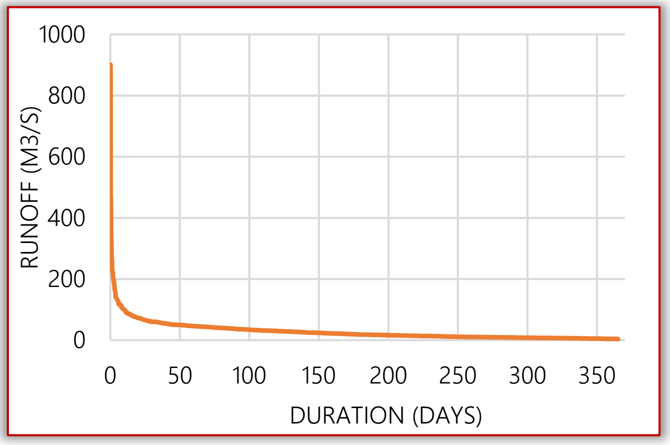

Figure 2. Flow duration curve and characteristic Q values for the station in Čačak

Table 1. The characteristic Q values for the station in Čačak

Discharge	Value (m^3/s)
Q_{max}	901
Q_{min}	3.8
Q_{91}	36.5
Q_{182}	18.4
Q_{247}	9.4

RESULTS AND DISCUSSION

The probability distribution of annual maxima it's a procedure to estimate the maximum water flow for a fixed time return period, starting from hydrometric observations. A series of maximum observed flow forms, on a statistical point of view, a sample of all the possible values that flow can have, so it is the so called population. The probability distribution functions most used in the hydrological practice for fitting the values of extremes, as annual rainfall and runoff maxima, are the lognormal distribution and the Gumbel distribution.

For that purpose we will use the Gumbel distribution, also known as distribution of extreme values type 1 (EV1). For the station in Čačak, the analysis on the annual maxima, is made with a series of 21 data. In some cases there is just the value for river level, so we calculate the discharge with the rating curve. The Figure 3 shows the probability distribution for this station. We calculated also the maximum flow for fixed return period of 5, 10, 20, 50, 100, 200, 250, 300 and 500 years.

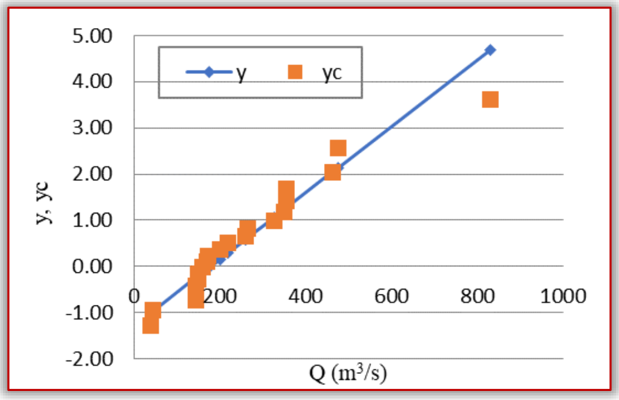

Figure 3. EV1 Gumbel for Čačak station

Table 2. The maximum flow Qc values for Čačak for fixed return periods

T in years	Qc in (m^3/s)
5	386.7
10	491.1
20	591.3
50	720.9
100	818.1
200	914.9
250	946.0
300	971.4
500	1042.6

Figure 4 reports the variability of the flood peaks as a function of the basin area. We can see that the experimental points can be approximated as a linear function.

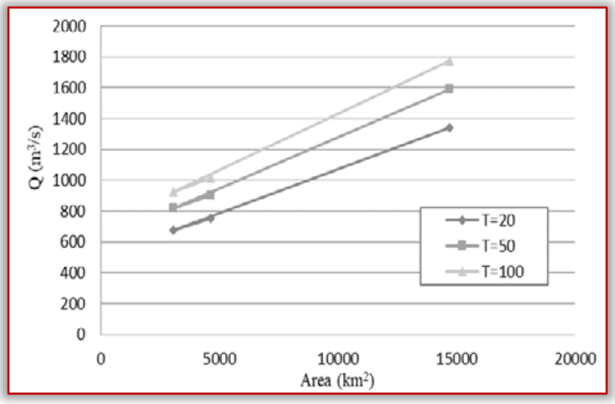

Figure 4. Variability of the T-quantiles of flood peaks as a function of the West Morava river basin

About the characterization of the climatology in this area, we have to discuss some results from specific statistical tests. In order to assess a possible trend in the historical series considered in the analysis, several statistical tests are available in the literature: among them, Mann Kendall (MK) and Spearman's rho tests are widely used. These tests are nonparametric test, one of their primary merits being that they do not assume that the data under analysis were drawn from a given distribution.

MK test was selected in our analysis since it has been extensively used in hydrology; on the other hand the performances of MK and Spearman's rho tests are almost identical in terms of power. To compute a trend slope of the runoff series, we used the Sen Theil test for the estimation of the regression line [7].

From the obtained results for the stations Miločaj and Jasika, the values for both the tests Man Kendall and Spearman are out of the confidence interval. In fact, the values are both less than 1.76 (for Miločaj is -2.153 the Man Kendall and -2.121 the Spearman and for Jasika is -2.296 the Man Kendall and -2.289 the Spearman), so it means that there is a significant decreasing in the runoff regime. For the other station Kratovska Stena, the nearest station to Čačak city, the results of tests and the linear trend show a constant trend with small scraps.

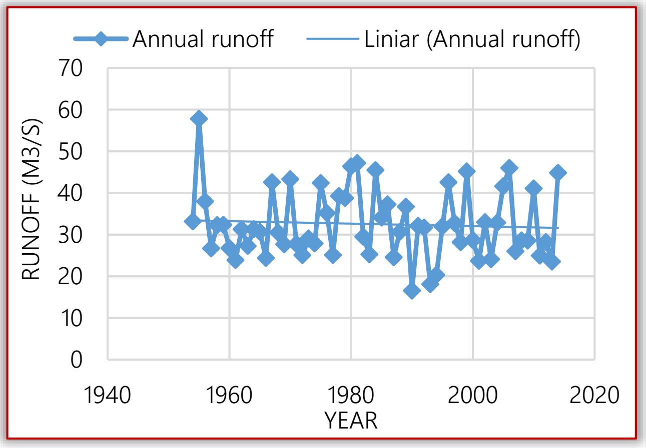

Figure 5. Linear runoff trend for Kratovska Stena station

CONCLUSIONS

Rainfall and runoff regimes in the West Morava basin were investigated to understand the hydrology of this catchment in view of the improvement of its hydrometeorological monitoring system. Monthly rainfall and runoff data were analyzed to detect regimes and trends. It was observed that for two out of five rainfall stations a significant increasing trend results from the application of Mann-Kendall and Spearman statistical tests. Runoff data exhibit that for two of the three runoff station with an enough big range of data, there is a significant decreasing trend results from the application of Mann-Kendall and Spearman statistical tests. To make some conclusions about this work, it is necessary also to underline that the monitoring in the city of Čačak is not exhaustive. This entails that it's very difficult to prevent some dangerous situations. The installation of a meteorological and hydrological station in the city of Čačak will help, in the years, having a more complete perspective of the meteorological and hydrological situation in the area, in particular in the West Morava river basin.

Acknowledgements

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Note

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EFFECTS OF ZINC POWDER ADDITION TO VILLA GLOSS AND SILKA LUX MARINE ENAMEL PAINTS ON CORROSION RESISTANCE OF MILD STEEL

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Abstract: The most common method of protecting steels and other similar engineering materials from corrosion is by painting or coating. Development in the paint industries suggests that the modern paints exhibit improved corrosion resistance over their predecessors. However, anti-corrosion properties of the paints can further be optimized when adequate proportions of the paint constituents are used. Effect of zinc powder addition to Villa Gloss and Silka Lux Marine Enamel paints on corrosion resistance of mild steel was studied. The results indicate that zinc powder addition between 15 and 25 % significantly reduced the corrosion rate and thus increased the inhibition efficiency of mild steel immersed in seawater. The corrosion rate stabilizes at approximately 0.10 mmpy when zinc powder added was above 15 %, independent of the exposure time. Potentiodynamic anodic polarization curves of the samples immersed in seawater show that sample with 25 % zinc powder addition exhibited highest corrosion potential and the least corrosion current. Microstructural analysis of the samples also revealed the presence of pit corrosion at the surfaces of the samples and their geometry, volume fraction and distribution vary with the zinc powder addition.
Keywords: Zinc powder, inhibition efficiency, potentiodynamic anodic polarization, seawater, corrosion rate

INTRODUCTION

Painting or coatings of all kinds are often used to provide interior and exterior decoration, which makes the environment appealing. Painting is a major method of protecting metal surfaces from different types of corrosion and it application is comparatively easy with no limitation on the size of the steelwork or materials that can be treated. Hence, painting of all kinds is very attractive and convenient means of corrosion control. Besides decoration and corrosion prevention purposes, painting or coating of surfaces can also serve purposes such as light reflectivity, camouflaging surfaces and heat absorber [1], [2].

Paintings of steelwork and other surfaces are very useful. However, deterioration and degradation of paints set-in over time and thus corrosion of surfaces is inevitable. Commonest among the causes of earlier corrosion are deficient surface preparation [3], insufficient coating thickness [4], [5], incorrect formulation of paint by the manufacturer[6], [7], inadequate skill of the painter, wrong choice of paints, drastically change in environmental conditions, mechanical or human physical damage.

Incorrect formulation of paint by manufacturer seems to be a major challenge in corrosion prevention [7]. This is because all other causes of corrosion can be corrected prior to paint application but wrong formulation required new production. The principal ingredients of paints are pigments, fillers, co-reactant and surfactant [1]. Each of these ingredients is required in a certain proportion for the formulation and performance properties. The atoms of the ingredients join together to form molecules, which crosslinks with one another, the reactive sites of each of the reacting molecules must align and come within very close proximity to each other for coating. Basically, the main function of the metallic pigments is to form sacrificial metallic oxides with the environment or seawater [8]. However, paints with inadequate metallic pigments corrode earlier and the steel underneath is exposed for chemical attack. For example, when a scratch or a break occurs in a zinc-rich paint film, water and oxygen combine with the metallic zinc. Over time, the zinc particles will corrode away and the paint's protective ability will be lost.

Investigations have been conducted to examine the effect of metallic pigments on corrosion control of steels immersed in corrosive media. In the study of Fayomi and Popoola, the electrochemical behaviour and the corrosion properties of Zn coating on steel substrates by means of Vickers micro hardness and polarization measurements was investigated [9]. Effect of graphite addition on the corrosion resistance and mechanical properties of zinc chromate epoxy paint was evaluated by Mirhabibi et al. [10]. They declared that addition of graphite decreases the corrosion rate and impact resistance while the resistance against the abrasion increases due to hydrophobic properties of the graphite. In a similar study by Durodola et al. In their work, steel substrate was coated with zinc and immersed in seawater and compared with uncoated steel. They concluded that coated steel performed better than uncoated steel substrate [11]. Abdou and Yaser studied the effect of recent three types coatings used in marine ship surfaces for prevention against corrosion. They revealed that coating significantly enhance the corrosion protection of coated sample by 70 % when compared to the uncoated sample [8]. In this current study, the effect of zinc powder addition on corrosion properties of Villa Gloss and Silka Lux Marine Enamel paints was examined. The objective of this article is to investigate the benefit that zinc powder addition as on the paints for corrosion control.

MATERIALS AND METHODS

Materials

The materials used for this study are mild steel, paints (red and white colours), zinc powder, seawater, distilled water, emery papers, ethanol, digital weighing balance, hack saw, laboratory beaker, flask and plastic brush.

The mild steel used in this work was obtained from Niger Dock Nigeria PLC, Lagos, Nigeria. The red and white paints were procured from local vendors in Lagos State, Nigeria. The nominal chemical composition of mild steel and paints are given in Table 1 and Table 2 respectively.

Table 1: Chemical Composition of the Mild Steel used (Wt %)

C	Si	Mn	P	S
0.129	0.242	1.35	0.0148	0.0031
Cr	Mo	Ni	Al	Co
0.0187	0.0011	0.0015	0.027	0.0040
Cu	Nb	Ti	V	W
0.008	0.004	0.001	0.0057	0.007
Pb	Sn	Mg	As	Zr
0.002	0.0035	0.001	0.003	0.0015
Bi	Ca	Ce	Sb	Se
0.002	0.001	0.0015	0.0025	0.0037
Te	Ta	B	Zn	Fe
0.0027	0.0430	0.0014	0.003	98.1

Table 2: Atomic Absorption Spectrophotometric Results of Analysed Red and White Paints

Paint types	Zinc (mg/L)	Calcium (mg/L)
Villa Gloss (white paint)	0.2817	2.009
Silka Lux Marine Enamel (red paint)	1.6618	24.57
Blank	0.001	0.001

Table 3: The Nominal Chemical Composition of the Zinc Powder

Elements	Cd	Ca	Fe	Cu	Sn	Zn
(%)	0.200	4.200	0.010	0.005	0.010	95.570

Table 3 is the chemical composition of zinc powder used. The chemical composition of the corrosive medium (seawater) used is also presented in Table 4. Metal analyzer was used to obtain the chemical composition of the mild steel and zinc powder while atomic absorption spectrophotometer shown in Figure 1 (a) was used for the paints.

Preparation of samples and its immersion procedure

The as-received mild steel was machined into test samples of dimensions of 2.20 cm by 1.50 cm by 1.16 cm. The samples were smoothened on emery papers of 80, 150 and 320 grits. The samples were washed in distilled water with a plastic brush and then soaked in an ethanol for 5 minutes. Subsequently, the samples were allowed to sun dried for 10 minutes.

The test samples were individually designated for easy identification (see Nomenclature). The test samples were then coated sacrificially with two different commercial paints that have varying percentages by weight of zinc powder addition (see Nomenclature) and Figure 1c. The coating thickness ranged between 10 and 20 μm, which classify the coating process adopted as thin films [14]. The initial weight (W_1) of the sample was taken using a digital weighing scale.

Table 4: Chemical Composition of Seawater

Parameters	Unit	Results	Maximum Permitted [12], [13]	Health Effect
	Seawater			
pH	-	6.47	6.5-8.5	None
Conductivity	μS/cm^3	4940.000	1000	None
Total hardness	mg/L	150.00	150	None
Total alkalinity	mg/L	50.00	50	-
Total acidity	mg/L	50.00	50	-
Calcium	mg/L	60.12	50	-
Magnesium	mg/L	21.84	0.20	Consumer Acceptability
Chloride	mg/L	15083.98	250	None
Salinity	mg/L	27250.00		
Copper	mg/L	0.072	1	Gastrointestinal disorder
Iron	mg/L	0.69	0.3	None
Zinc	mg/L	0.169	3	None
Lead	mg/L	0.09	0.01	Cancer
Cadmium	mg/L	0.002	0.003	Toxic to kidney
Nickel	mg/L	0.16	0.02	Possibly carcinogenic
Chromium	mg/L	0.051	0.05	Cancer

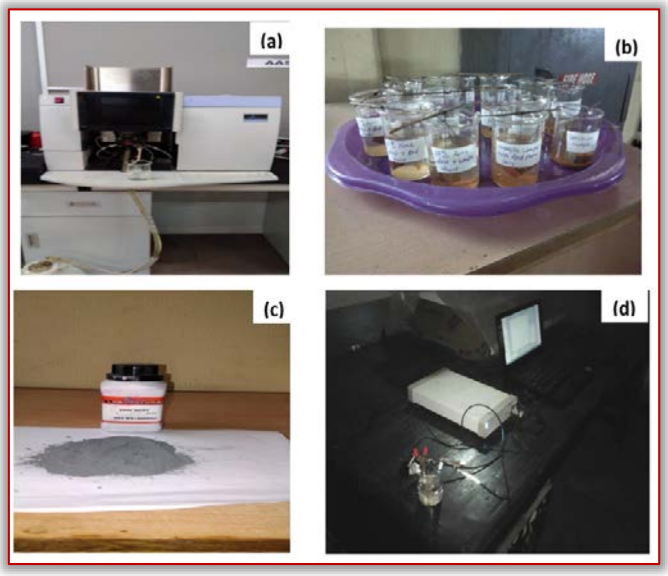

Figure 1: The laboratory set-up and material used a) Atomic Absorption Spectrophotometer, (b) Experimental Set-up, (c) Commercial Zinc Powder and (d) Potentiodynamic polarization test set-up

Thereafter, equal proportion of analyzed corrosive medium was measured out with laboratory beaker and poured in a transparent flasks. The samples were then completely immersed in the corrosive medium (see Figure 1b). After every 3-day (72-hour) of immersion, individual sample was brought out of the corrosive medium and then gently and thoroughly cleaned with distilled water and ethanol and then weighted for final weight (W_2). The weight loss (W_t) obtained was then used to calculate the corrosion rate. In all cases, the processes of samples cleaning, washing, drying, weighing were thoroughly and gently carried out – since the data collection largely depend on these processes [15].

Quantitative Analysis Method

This work employed a quantitative analysis techniques for the determination of the corrosion rate based on the weight loss method. It involved taken the weight loss (W_t) of uncoated and coated samples before and after immersion in the corrosive medium. The corrosion rate was calculated according to the formulae (1) and (2) [8].

$$\text{Corrosion rate (mmpy)} = \frac{87.6 * \text{weight loss } (W_t)}{\text{Area (A)} * \text{time(T)} * \text{Density}(\rho)} \quad (1)$$

where

$$\text{Surface area (A)} = 2[L * B) + (L * H) + (B * H)] \quad (2)$$

The weight loss was also used to calculate the surface coverage and Inhibition Efficiency according to formulae (3) and (4) respectively after 1800 hours.

$$\text{Surface Coverage, SC} = \frac{CR_a - CR_p}{CR_a} \quad (3)$$

$$\text{Inhibition Efficiency, IE (\%)} = 100SC \quad (4)$$

where CR_a and CR_p are corrosion rates in the absence and presence of the inhibitor, respectively.

Potentiodynamic Polarization Technique

Potentiodynamic polarization test was performed with cylindrical steel electrodes mounted in acrylic resin. The steel electrode was prepared according to ASTM G59-97 [16]. The studies were performed at 25°C ambient temperature with Digi-Ivy 2300 potentiostat and electrode cell containing 200 ml of the acid media (see Figure 1d). Platinum was used as the counter electrode and silver chloride electrode (Ag/AgCl) was employed as the reference electrode. Potentiodynamic measurement was performed from -1.5V to +1.5V at a scan rate of 0.0015 V/s according to ASTM G102-89 [16]. The corrosion current density (j_{corr}) and corrosion potential (E_{corr}) were derived from the Tafel plots of potential versus log current.

Preparation of Samples for Microstructural Analysis

The corroded samples were examined with an optical microscope for surface defects. Prior to the microstructural examination, each of the samples was dried in an oven at 30° C for 5 minutes.

RESULTS AND DISCUSSION

Corrosion Rate and Inhibition Efficiency

In this study, two types of industrial paints were used: Villa Gloss (white paint) and Silka Lux Marine Enamel (red paint). The atomic absorption spectrophotometric analysis of the two paints indicates that the red paint is of higher zinc and calcium constituents than the white paint (see Table 2). The chemical analysis of the corrosive medium used was shown in Table 4. The calcium, salinity and chloride (mm/L) that are present in corrosive medium are well above the required limit for a normal water [12], [13]. Thus, the sea water used is suitable for this study.

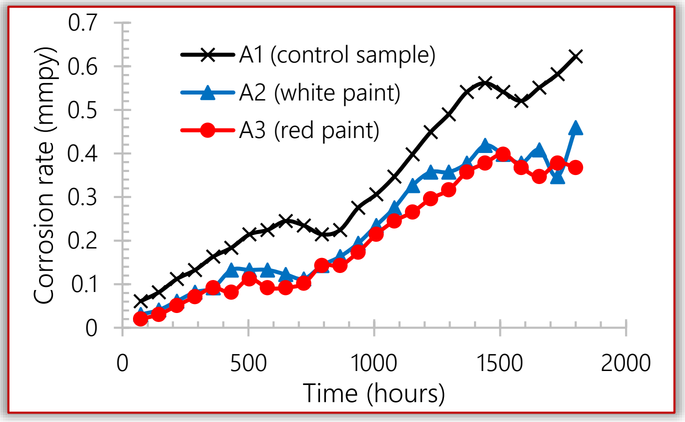

Figure 2: Variation of Corrosion Rate with Exposure Time for Mild Steel without Zn Powder Addition

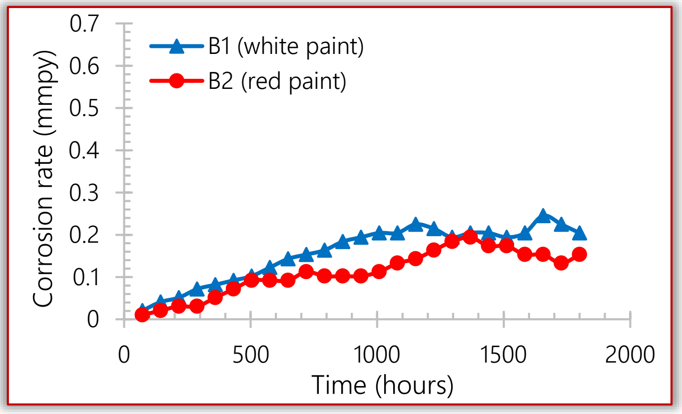

Figure 3: Variation of Corrosion Rate with Exposure Time for Mild Steel with 5 % Zn Powder Addition

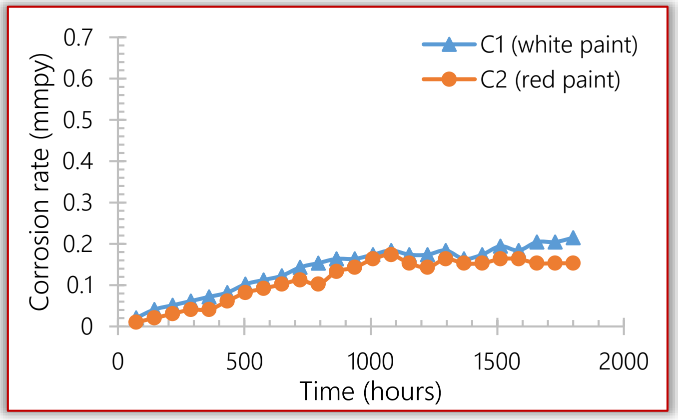

Figure 4: Variation of Corrosion Rate with Exposure Time for Mild Steel with 10 % Zn Powder Addition

Figures 2-4 show the variation of the corrosion rate with the time of exposure for the mild steel coated with varied zinc powder addition. Figure 2 indicates that for the control sample and as-procured paints, corrosion rate increased with exposure time. However, it decreased as the percent of zinc powder addition is increased as shown in Figures 3 and 4. The decreasing in the corrosion rate with 5 to 25 % addition of zinc powder is shown in Figures 5 and 6. In general, coating of the mild steel significantly reduces the corrosion rate as compared to the uncoated sample. The initial slow rate of the corrosion at exposure time less 700 hours is due to the formation of a barrier between the substrate and the sea water. Thus, the mild steel is isolated from the aggressive corrosion of the seawater due to the passivation of zinc. Above 1100 hours, passivation can also be noticed with stability in the corrosion rate (Figures 3 & 4). In this condition, corrosion products, which provides a protective layer has been formed. It can also be deduced from Figures 3 and 4 that for the same exposure time, the red paint performed credibly well than the white paint, evidence in it lower corrosion rate. The effect of zinc powder addition to the paints on the corrosion rate is less significant when the exposure time exceeded 1500 hours.

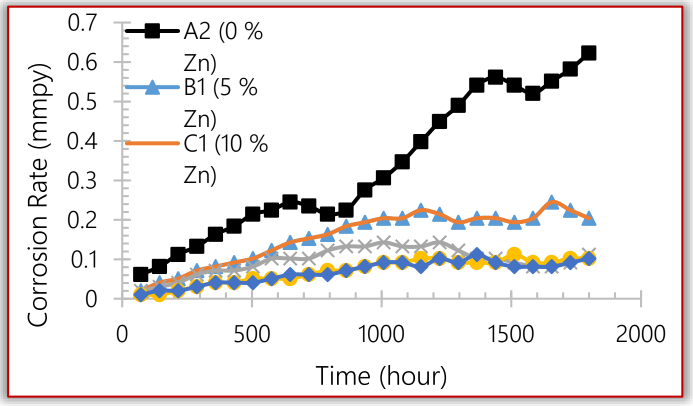

Figure 5: Variation of Corrosion Rate with Exposure Time for Mild Steel Coated in Red with 0-25% Zn Powder Addition

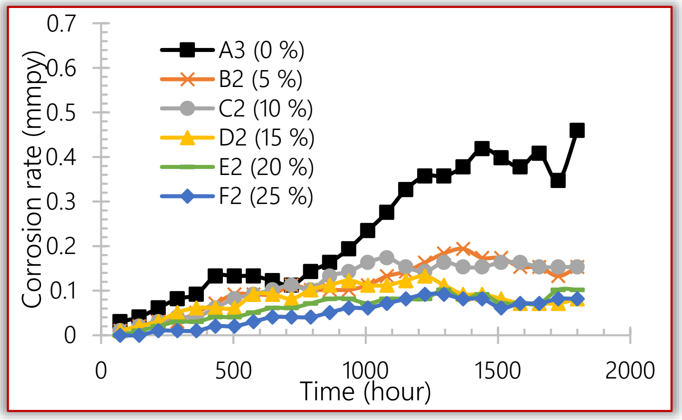

Figure 6: Variation of Corrosion Rate with Exposure Time for Mild Steel Coated in White with 0-25% Zn Powder Addition

The colour change in the corrosive medium over the exposure time play a major role in determining the extent of corrosion rate. In this study, the main constituents of the paints are calcium and zinc elements. The colour of the corrosive medium that contain control sample turned completely dark while the coated samples were observed to be colourless and later lightly dark due to the formation iron oxide of the former and $CaCl_2$ and $ZnCl_2$ in the later. Zinc is sacrificial coatings that lessen the corrosion on the mild steel underneath. As it can be noticed in Figures 5 and 6 that the corrosion rate of the samples with 15 to 25 % zinc powder addition stabilises at 0.10 mmpy. At optimum zinc powder addition, corrosion rate stabilises due to the conversion of the zinc to zinc trioxocarbonate IV ($ZnCO_3$) during the natural corrosion cycle. The zinc constituent is converted to zinc oxide (ZnO) and later to zinc hydroxide depends on the water and air presence in the sea water. Further reaction of ZnO (white rust) with CO_2 (carbon IV oxide) formed $ZnCO_3$, which is corrosion product that is impermeable to the seawater and very dense layer [17]. Thus, with 15 to 25 % zinc powder addition, a barrier is formed that prevent further corrosion of mild steel underneath.

The experimental results indicate that the adhesion of corrosion product of $ZnCO_3$ layer is effective. The protection demonstrated by the layer, however, depends on the pH of the environment [18]. The corrosion rate changes in an acidic or basic, which ultimately dissolve the $ZnCO_3$ layer with time. The reaction is more aggressive in acidic medium than basic. In this study, the pH of the seawater used is 6.47, as shown in Table 4. Thus, it is expected that within 15 to 25 % zinc powder addition and seawater under investigation, the effect of pH is minimal and erosion of $ZnCO_3$ is low or absent.

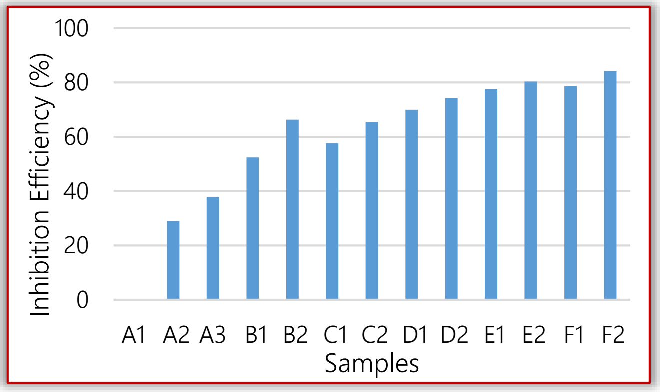

Figure 7: Dependence of Inhibition Efficiency on Sample Processing Condition for Mild Steel Painted in Red and White with 0-25% Zn Powder Addition

Figure 7 shows the dependence of inhibition efficiency on the types of paints and zinc powder addition. The inhibition efficiency was obtained from surface coverage (SC). The inhibition efficiency increases with zinc powder addition. Red paint exhibits higher inhibition efficiency over white paint for the same zinc powder addition due to higher proportion of the zinc present in the as-procured red paint. Above 15 %, the effect of zinc powder addition for the two paints on the inhibition efficiency is less significant. This suggests that there is an optimum zinc and calcium mixing composition that is required in a paint to achieve effective and protective layer, which ultimately reduces and stabilise the corrosion rate. On one hand, zinc and calcium present in the paint formed a barrier between mild steel and the sea water, which increases the inhibition efficiency. On the other hand, the formation of $CaCl_2$ and $ZnCl_2$ tends to reduce the inhibition efficiency. However, saturation of the $CaCl_2$ and $ZnCl_2$ within the seawater stabilise the inhibition efficiency. Figure 8 is the result of total corrosion rate as function of types of paints and zinc powder addition. Stability in the corrosion rate corresponds to zinc powder 15 to 25 % addition.

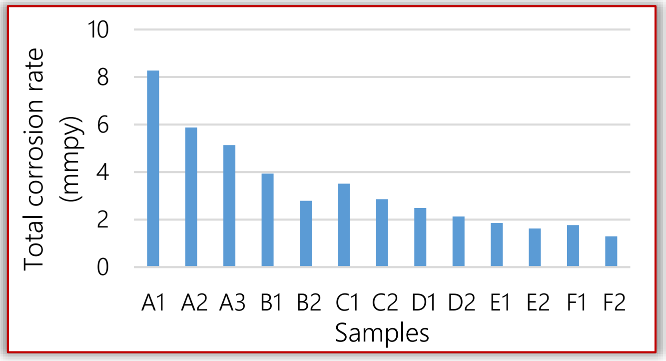

Figure 8: Dependence of Total Corrosion Rate on Sample Processing Condition for Mild Steel Painted in Red and White with 0-25% Zn Powder Addition

Potentiodynamic Polarization Technique

Figure 9 shows the potentiodynamic anodic polarization curves of the mild steel immersed in seawater with and without zinc powder addition. The corrosion potential from the figure tends towards the positive direction for all samples except for the control sample. This shows the inhibiting effect of the paints and zinc powder added. The samples with zinc powder addition display active-passive polarization behaviour. Table 5 shows the electrochemical corrosion parameters derived from the potentiodynamic polarisation curves shown in Figure 9. By single out the corrosion potential and corrosion current for the analysis, the addition of zinc powder causes an increase in corrosion potential and a decrease in corrosion density. Apparently, the ratio of calcium to the zinc in the paints changed with addition of zinc powder, which enhances the inhibition ability of the paint. For the red paint which 25 % zinc addition has the highest corrosion potential and the lowest corrosion current, thus, better corrosion resistance. The possible reasons for such behaviour may be addressed as follows. Firstly, zinc powder addition increase the formation of amorphous phase within the matrix of the paints thereby enhance the corrosion resistance property of the mild steel compared to samples with little or no zinc powder addition. This implies that samples coated with 25 % zinc addition have the highest corrosion resistance. Secondly, increasing in the volume fraction of the austenite phase within the matrix of the paint contribute to the improving inhibition ability, because austenite phase has better corrosion resistance than the ferrite phase [19], [20].

Certain condition needs to be met prior to self-passivation, as suggested by Yang, et al. [20] in formula (5).

$$E_{e,c} \geq I_{max} \qquad (5)$$

where $E_{e,c}$ is the equilibrium potential of depolarizer in the cathodic reducing reaction and I_{max} is the current density of the depolarizer. From Table 5, it can be observed that Equation 5 has been satisfied. The corrosion potential and corrosion current of the samples are stable for the mild steel coated with 25% Zinc powder addition at $\cong -0.6505$ V and $5.40 * 10^{-8}$ A respectively.

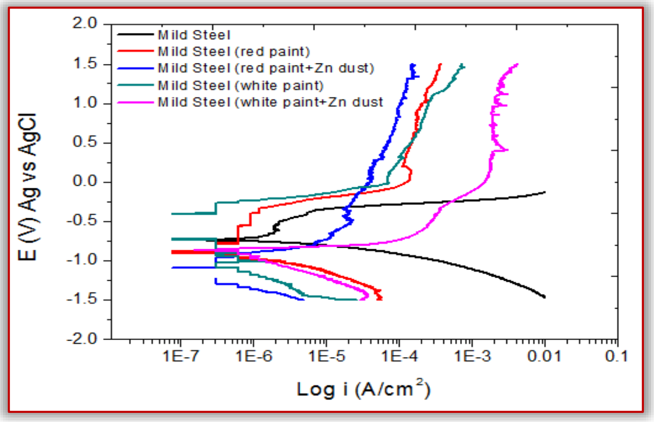

Figure 9: Potentiodynamic Anodic Polarization Plots of Mild Steel Immersed in Sea Water with and Without Zn Powder Addition

Table 5: Electrochemical corrosion parameters of mild steel immersed in sea water with and without Zn powder addition

Sample	Corrosion Current (I_{cor}) (10^{-8} A)	Corrosion Current Density	Corrosion Potential (E_{cor}) (10^{-8} V)
Mild steel	1.371E-06	2.17E-06	-0.738
Mild steel (white paint)	5.681E-07	9.47E-07	-0.406
Mild steel (red paint)	4.921E-07	7.81E-07	-0.501
Mild steel (red paint + 25 % zinc powder)	5.40E-08	9.00E-08	-0.6505
Mild steel (white paint + 25 % zinc powder)	5.40	1.60E-07	-0.6001

Surface Morphology

Figure 10 (a)-(d) show the surface morphology of some corroded samples. Presence of pit corrosion can be seen. The sizes of pits are more pronounced in Figure 10(b) compared to Figure 10(a) due to high inhibition efficiency of red paint. When zinc powder was added, there is a reduction in the amount of the pits visible in Figure 10 (c) and (d). The addition of zinc powder enhances the inhibition efficiency and significantly reduces the corrosion of the samples. It can be observed that samples without zinc addition are more badly corroded. The attack may be due to presence of salinity and chloride in the sea water. The reactions of these substance causes variation in layer thickness of the coating, which lead to localized corrosion characterized by depression or pit formation. Thus, there is a rapid inward penetration of oxygen at the exposed region for the formation iron oxide [14]. Pit formation may also be attributed to ionic migrations, which are influenced by the applied voltage [5]. With the addition of the zinc powder, the process is retarded due to better adhesion of the paints on the surface of the mild steel. Addition of zinc powder does not completely stop the corrosion process. Nerveless, there is an improvement in reduction of corrosion rate when compared with other samples.

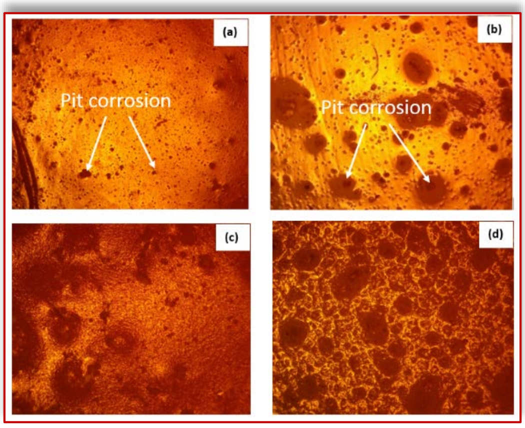

Figure 10: Surface morphology of the corroded samples (a) coated with red paint, (b) coated with white paint, (c) coated with white paint and 10 % zinc powder addition and (d) coated with white paint and 10 % zinc powder addition

CONCLUSIONS

This study has shown that:

a) Addition of zinc powder to the locally procured Villa Gloss and Silka Lux Marine Enamel paints improved the corrosion resistance of the mild steel.
b) The corrosion rate stabilised at approximately 0.10 mmpy when zinc powder added was above 15 %. This result was achieved independent of the exposure time.
c) Zinc powder addition to both paints was beneficiary to the corrosion potential and corrosion current.
d) Surface morphology of the samples revealed pit corrosion characteristics due to the inward penetration of oxygen at the exposed region.

Nomenclature

A_1 uncoated sample.
A_2 sample coated with 10 ml white paint + 0% zinc powder.
A_3 sample coated with 10 ml red paint + 0% zinc powder.
B_1 sample coated with 10 ml white paint + 5% zinc powder additive.
B_2 sample coated with 10 ml red paint + 5% zinc powder additive.
C_1 sample coated with 10 ml white paint + 10% zinc powder additive.
C_2 sample coated with 10 ml red paint + 10% zinc powder additive.
D_1 sample coated with 10 ml white paint + 15% zinc powder.
D_2 sample coated with 10 ml red paint + 15% zinc powder additive.
E_1 sample coated with 10 ml white paint + 20% zinc powder additive.
E_2 sample coated with 10 ml red paint + 20% zinc powder additive.
F_1 sample coated with 10 ml white paint + 25% zinc powder additive.
F_2 sample coated with 10 ml red paint + 25% zinc powder additive
C_r corrosion rate (mmpy)
W weight loss (milligrams)
A surface area of the sample (cm^2)
T time of exposure of the samples in hour(s)
ρ metal density (g/cm^3)
L length of the sample (cm)
B breadth of the sample (cm)
T thickness of the sample (cm)

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CHIP SHAPE AS MACHINABILITY PARAMETER IN THERMOPLASTIC TURNING

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Abstract: Chip shape, as a parameter of machinability, can be one of the most important parameters during certain machining processes. Different shapes of chip in steel machining can be obtain by removing chip to outside of machining zone, different geometry of cutting tool, defining chip breaker on tool face and similar. Problem appears with materials that have much lower mechanical properties comparing to steel. This includes almost all non-metals, and the most prominent among them are thermoplastic materials. The paper discusses the possibility of obtaining the chip shape that would be the most acceptable for easy removal from the cutting zone when processing thermoplastic materials. It is considered that with adequate choice of cutting regime parameters, it could be obtained the ideal chip shape, with small length and low percentage of twisting, which is confirmed by experiment.
Keywords: thermoplastic materials, regime of cutting, chip, machining

INTRODUCTION

Chip shape, as a parameter of machinability, can be one of the most important parameters during certain machining processes. Different shapes of chip in steel machining can be obtain by removing chip to outside of machining zone, different geometry of cutting tool, defining chip breaker on tool face and similar [1 - 3]. Problem appears with materials that have much lower mechanical properties comparing to steel. This includes almost all non-metals, and the most prominent among them are thermoplastic materials.

A special problem is to get acceptable chip shape for easy removal from cutting zone when machining thermoplastic materials. Thermoplastic materials have high toughness but low hardness and strength, and with that kind of material the most common is striped and long chip shape that wound around the cutting zone on coupled elements, i.e. tool and workpiece. That kind of chip is hard to remove from cutting zone, and piling it around the cutting edge of tool increase the temperature on face of tool and increase surface pressure on contact surface between tool and workpiece. The question arises as to whether the adequate choice of cutting regime parameters can lead to most acceptable chip shape, with small length and low percentage of twisting. In this paper the researches on subject and results of measurement are presented.

The wide application of thermoplastic materials is conditioned by the possibility to recycle, low cost, machining with small resistance force and low machining temperature, resistance to external influences and many other acceptable properties [4].

Many contemporary researchers of today are dealing with the problem of testing the characteristic values of the machining process, such as cutting force, the shape of chip, the temperature in the cutting zone [5 - 8], and many have made a full contribution with similar research in their time.

MATERIAL AND METHODS

In the experiment, a CNC machine with the following technical characteristics was used (Table 1).

Table 1. Technical characteristics of the EMCO F5 CNC

Name	Unit of measure	Value
The power of the EM	W	440
Travel over X axis	mm	150
Travel over Z axis	mm	300
Machine accuracy	mm	0.01
Feed rate	(mm / min)	5 - 400
Main spindle speed	rpm	50 - 3000
Connector	RS 232	

The values of the input parameters of the turning cutting regime are given in Table 2, and the measurement method used in the experiment is based on eight measurements by variation of the given variable parameters of the turning cutting regime in Table 3.

Table 2. Value of input parameters

	min	max
a_p (mm)	1.5	2
v_f (mm/min)	80	300
n (rpm)	600	1200

where: a_p (mm) – cutting depth, v_f (mm / min) – federate, n (rpm) - main spindle speed

Table 3. Experiment plan

		Measurements			
		1	2	3	4
a_p	(mm)	2	2	2	2
v_f	(mm/min)	80	80	300	300
n	(rpm)	600	1200	600	1200
		Measurements			
		5	6	7	8
a_p	(mm)	1,5	1,5	1,5	1,5
v_f	(mm/min)	80	80	300	300
n	(rpm)	600	1200	600	1200

Tool used in the experiment is made of HM (hard metal) with a handle of HSS (high speed steel). The HM turning insert is hard solder connected to the handle of the tool. The workpiece material is PTFE (polytetrafluoroethylene). Other technical characteristics of the tool are given in Table 4.

Table 4. Characteristic sizes of rotary knife

Characteristic value	mark	Dimension
Tool handle	DIN 4976	1010 P10
Turning insert	SPGN	12 07 08
Side cutting edge angle	κ	45^0
Auxiliary side cutting edge angle	κ_1	45^0
Back rake angle	γ	10^0
End relief angle	α	11^0
Angle of the patch surface	λ	4^0
Nose radius	r (mm)	0,8

RESULTS AND DISCUSSION

In the experimental measurement 1, an unfavorable chip shape was obtained, which was striped and twisted in a narrow space (figure 1).

Figure 1. Measurement 1:
(a_p=2 mm; v_f=80 mm/min; n=600 rpm)

Such chip is twisting directly to the cutting edge of the tool and burdens the tool with additional surface pressures, causes the appearance of vibration during machining and prevents the cooling and lubricating agent from entering the immediate cutting zone. In order to successfully remove the chip from the cutting zone, it is necessary to construct special forms of chip breaker, which would increase the production costs.

By changing one of the parameters of the cutting regime (experimental measurement 2), in this case main spindle speed n, a more favorable chip shape is obtained compared to the previous one (figure 2). The chip in this case is straight shape, partially ragged and with a much smaller length. This shape is highly desirable in machining because it is easily removed from cutting zone and does not affect on the appearance of vibrations that impair the quality of the machined surface.

In experimental measurements under 3, a continuous chip shape was obtained that has mostly twisted around the workpiece rather than tools (figure 3). In comparison with the experimental measurement 1, this kind of chip less burdens the coupled elements of machining and does not lead to additional vibration of the tools. This kind of chip can be shortened by the previous application of a series of transversal machining, ie by more precise design of the technological machining process.

Figure 2. Measurement 2:
(a_p=2 mm; v_f=80 mm/min; n=1200 rpm)

Figure 3. Measurement 3:
(a_p=2 mm; v_f=300 mm/min; n=600 rpm)

The chip shape in the experimental measurement 4 is a long and continuous chip without visible deformations and ragged edges (figure 4). This shape is very unfavorable and it was obtained using the maximum values of all three parameters of the cutting regime. In this case, the circle is twisted around the tool and around the workpiece, further burdening the entire tribological system with visible distortion of the quality of the machined surface.

Figure 4. Measurement 4:
(a_p=2 mm; v_f=300 mm/min; n=1200 rpm)

The circle in the experimental measurement 5 has similar characteristics as in the measurement 4, but in this case the obtained chip shape is achieved using the minimum values of all three parameters of the machining cutting regime (figure 5). The conclusion is that a linear reduction in the value of the parameters of the machining cutting regime can also result in an unfavorable chip shape, and that the parameters of the machining regime according to the nonlinear principle should be varied in order to achieve a more favorable shape.

Figure 5. Measurement 5:
(a_p=1,5 mm; v_f=80 mm/min; n=600 rpm)

The experimental results of the measurement in the sixth test confirm this thesis (figure 6). In this experimental measurement, a short chip is obtained that can easily be removed from the cutting zone, with very small vibrations of the coupled system (tool-processing-clamping accessories) and similar characteristics as in experimental measurement 2.

Figure 6. Measurement 6:
(a_p=1,5 mm; v_f=80 mm/min; n=1200 rpm)

In the experimental measurement 7, the chip shape was similar to that in experimental measurement 1 with all the negative characteristics (figure 7). The chip shape in the experimental measurement 8 (figure 8) is somewhat more favorable in relation to measurements 4 and 5, which can be concluded that the most unfavorable shapes are obtained in the given measurements. The chip in experimental measurement 8 is striped, but not continuous. At a certain length, the chip breaks and thus more easily go out of the cutting zone. A partial conclusion is that by reducing the machining depth, while retaining the maximum values, the remaining two parameters of the cutting regimen can be obtained more favorable chip shape.

Figure 7. Measurement 7:
(a_p=1,5 mm; v_f=300 mm/min; n=600 rpm)

Figure 8. Measurement 8:
(a_p=1,5 mm; v_f=300 mm/min; n=1200 rpm)

CONCLUSIONS

Chip is a good indication of the machinability of certain materials, especially materials with higher toughness and less hardness and strength. The expected chip shape in the machining of thermoplastic materials is almost always spiral with a large length and without visible broken segments in the operation of the chips breaking. The chip brakers almost have no effect on the shape and length of the chips in these materials.

Experimental data in this paper show that the production of small and shredded chips can be achieved by adequate selection of parameters of the cutting regime, primarily by the main spindle speed (n [rpm]) and step size (f [mm / 0]), i.e. feedrate (v_f [mm / min]). By increasing the speed and at the same time by reducing the step size (experimental measurements 2 and 6), the required chip shape is obtained which is most easily removed from the cutting zone.

The cutting depth for these two experimental measurements is different and it is not a decisive factor for the given material. This assumption complies with experiments of world famous tool manufacturer Sandvik-Koromant, which confirmed assumption that with variation of step size and spindle speed, independently from machining depth, can be influenced on shortening overall length of chip.

Note

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TEACHING-LEARNING BASED ALGORITHM COMBINED WITH CUTTING FORCE MODELLING FOR END MILLING OPTIMIZATION

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Abstract: This paper presents a multi-objective optimization of milling process by using ANFIS modelling and TBLO optimization algorithm. The ANFIS model is used to predict objective function and TLBO algorithm is used to obtain optimum spindle speed and feed rate for a typical case of milling found in industry. A set of 5 constraints were used during optimization. The paper presents mathematical fundamentals of TBLO optimization. The optimal cutting conditions obtained by TLBO have been verified through experiments. They have been conducted with optimal cutting parameters to verify the optimization results and effectiveness of the optimization approach.
Keywords: end-milling, cutting parameters, optimization, TLBO, cutting force

INTRODUCTION

The proper selection of machining parameters is an important step towards increasing productivity, decreasing costs, and maintaining high product quality. Many researchers have studied the effects of optimal selection of machining parameters of end milling [1]. This problem can be formulated and solved as a multiple objective optimization problem [2]. In practice, efficient selection of milling parameters requires the simultaneous consideration of multiple objectives, including maximum tool-life, desired roughness of the machined surface, target operation productivity, metal removal rate, etc. [1]. In some instances, parameter settings that are optimal for one defined objective function may not be particularly suited for another objective function. Solving multi-objective problems with traditional optimization methods is difficult and the only way is to reduce the set of objectives into a single objective and handle it accordingly.

Therefore population based heuristic algorithms such as evolutionary algorithms (EA) and swarm intelligence (SI) are more convenient and usually utilized in multi-objective optimization problems. These methods are summarized by [3]. Some of the recognized evolutionary algorithms are: Genetic Algorithm (GA) [4], Evolution Strategy (ES), Evolution Programming (EP), Differential Evolution (DE), Bacteria Foraging Optimization (BFO), etc. Some of the well-known swarm intelligence based algorithms are: Particle Swarm Optimization (PSO) [5, 6], Ant Colony Optimization (ACO), Fire Fly (FF) algorithm, etc. All of these algorithms are probabilistic algorithms and require controlling algorithm-specific control parameters [7]. The proper tuning of the algorithm-specific parameters is a very crucial factor which affects the performance of the algorithms [8].

Rao et al. [3] introduced the teaching – learning - based optimization (TLBO) algorithm which does not require algorithm - specific parameters. The TBLO is an efficient alternative over other population-based search algorithms, especially when dealing with multi-objective optimization problems. It is relatively easy to implement and has only two parameters to adjust [3]. The working of TLBO algorithm is explained in the next section. In our research ANFIS is used to model the objective function of the process, and an TBLO is utilized for solving multi-objective optimization problems observed in milling operations.

DETAIL OF TEACHING-LEARNING BASED OPTIMIZATION

TLBO is population based method and uses a population of solutions to obtain a global optimum. In TLBO a group of learners (students) is considered as population. TLBO is a teaching-learning process inspired algorithm based on the effect of influence of a teacher on the output of learners in a class. Teacher and learners are the two vital components of the algorithm and describes two basic modes of the learning, through teacher (known as teacher phase) and interacting with the other learners (known as learner phase). Moreover, learners also learn from the interaction among themselves which also helps in improving their results. The learners' result is analogous to the fitness value of the optimization problem. In the entire population the best solution is considered as the teacher. The output in TLBO algorithm is considered in terms of results or grades of the learners which depend on the quality of teacher.

The working of TLBO is divided into two phases, Teacher phase and Learner phase. Both phases are explained below.

Teacher phase

In this phase the learners learn through the teacher. A teacher conveys knowledge among the n students (population size, k=1,2,…,n) and tries to increase the mean result of the class M. At any teaching-learning iteration i, Mj,i is the mean result of the learners in a particular design variable j (j=1,2,…,m). m is the number of subjects (i.e. design variables) offered to n number of learners. X_{total}-$k_{best,i}$ is the result of the best student considering all the subjects, who is identified as a teacher for that iteration. The best identified student is considered as the teacher in the algorithm. The students will acquire knowledge according to the quality of teaching delivered and the quality of students in the class. Figure 1 shows the flowchart of the TLBO algorithm [3].

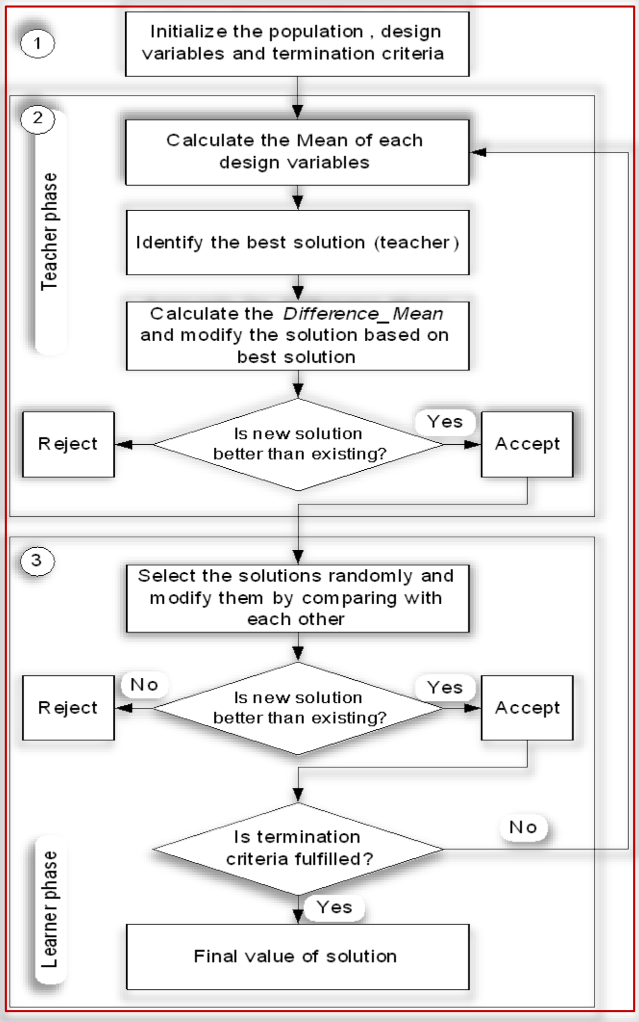

Figure 1 – The diagram of the TBLO algorithm

The difference between the result of the teacher and mean result of the students in each subject is expressed as:

$$Difference\_Mean_{j,i} = r_i\,(X_{j,kbest,i} - T_F M_{j,i}) \qquad (1)$$

where, $X_{j,kbest,i}$ is the result of the teacher (i.e. best learner) in subject j. T_F is the teaching factor which decides the value of mean to be changed, and r_i is the random number in the range [0, 1]. Value of T_F can be either 1 or 2. The value of T_F is decided randomly using Eq. 2

$$T_F = \text{round}\,[1+\text{rand}\,(0,1)\,\{2-1\}] \qquad (2)$$

Based on the $Difference\_Mean_{j,k,i}$, the existing solution is updated in the teacher phase according to the following expression.

$$X'_{j,k,i} = X_{j,k,i} + Difference\_Mean_{j,k,i} \qquad (3)$$

where $X'_{j,k,i}$ is the updated value of $X_{j,k,i}$. $X'_{j,k,i}$ is accepted if it gives better function value. All the accepted function values at the end of the teacher phase are maintained and these values become the input to the learner phase.

Learner phase

In this phase the learners increase their knowledge with the help of mutual interactions. The students can gain knowledge by discussing and interacting with the other students. The learning phenomenon of this phase is expressed below.

Every student has to interact with any other student. Randomly two learners P and Q are selected such that $X'_{total-P,i} \neq X'_{total-Q,i}$. $X'_{total-P,i}$ and $X'_{total-Q,i}$ are the updated values at the end of teacher phase.

$$X''_{j,P,i} = X'_{j,P,i} + r_i\,(X'_{j,P,i} - X'_{j,Q,i}),\ \text{If } X'_{total-P,i} > X'_{total-Q,I} \qquad (4)$$

$$X''_{j,P,i} = X'_{j,P,i} + r_i\,(X'_{j,Q,i} - X'_{j,P,i}),\ \text{If } X'_{total-Q,i} > X'_{total-P,i} \qquad (5)$$

Above equations are for maximization problem, reverse is for minimization problem. $X''_{j,P,i}$ is accepted if it gives a better function value.

CUTTING FORCE PREDICTION MODEL

In this section an accurate and reliable model for predicting cutting forces during end milling process is outlined. The cutting force prediction model is built according to the ANFIS method. The ANFIS method seeks to provide a linguistic model for the prediction of cutting forces from the knowledge embedded in the trained neural network. By given input/output data set, the ANFIS method constructs a fuzzy inference system (FIS) whose membership function parameters are tuned (adjusted) using a backpropagation algorithm. This allows fuzzy systems to learn from the data they are modeling. FIS Structure is a network-type structure similar to that of a neural network, which maps inputs through input membership functions and associated parameters, and then through output membership functions and associated parameters to outputs.

Four steps are required to develop an ANFIS system.

- In step 1, the training and testing data are loaded to the system.

The process variables are force sensor readings (F), spindle speed (n), feed rate (f) and depth of cutting (A_D/R_D).All the data were scaled. The whole data set is divided into the training and the testing set. 500 data points were used in this study. The training data set is used to find the initial premise parameters for the membership functions by equally spacing each of the membership functions.

A threshold value for the error between the actual and desired output is determined.

- The FIS architecture and training parameters were defined in step 2.

The optimization method, the tolerance error, the maximal number of epoch, the number of membership functions and the membership functions types are defined.

The fuzzy inference system under consideration has 4 inputs and one output. The inputs are the cutting conditions. The output is cutting force sensor signal.

- In step 3, the training phase is accomplished. With the input–output data, the neuro-fuzzy algorithm is trained, and the unknown parameters are identified.

Figure 2 shows the inputs, membership functions, and the fuzzy inference system for cutting force prediction.

During the training stage, the ANFIS adjusts its internal structure to give correct output results according to the input features. The process is terminated when the error becomes less than the threshold value. During training in ANFIS, 50 sets of experimental data are used to conduct 500 cycles of learning.

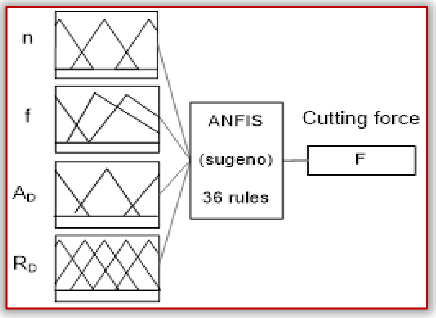

Figure 2 – Structure of ANFIS cutting force model

» Finally, in the fourth step the trained ANFIS is used to predict cutting forces.

IMPLEMENTATION OF TBLO APPROACH TO MILLING OPTIMIZATION

In order to find optimal cutting parameters, ANFIS model of cutting forces was integrated with TBLO algorithm. The optimization strategy is shown in Figure 3.

ANFIS model is developed, and its output is fed into the TBLO algorithm where constraints are defined.

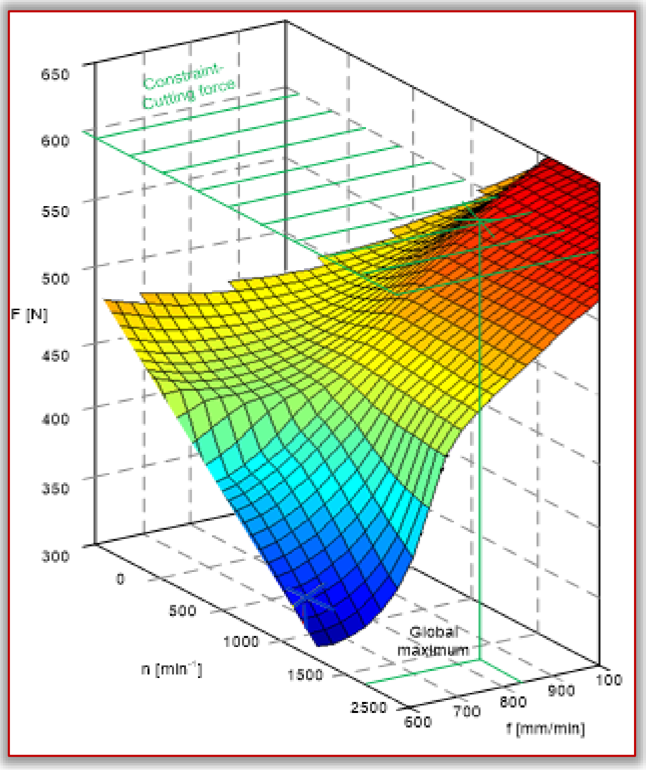

Figure 3 – Optimal cutting conditions searching procedure

TBLO algorithm is initiated with randomly generated answers in predefined population of students. The student`s answers are optimum solution candidates. ANFIS model predicts cutting forces for each of the student. Predicted maximal forces are used as an objective function which TBLO tries to maximize.

The objective function serves as the only link between the optimization problem and the TBLO algorithm.

The optimization process executes in two phases. In first phase, the ANFIS model on the basis of recommended cutting conditions generates 3D surface of cutting forces, which represent the feasible solution space for the TBLO algorithm. The cutting force surface is limited with planes which represent the constraints of cutting process. Seven constraints, which arise from technological specifications, can be considered during the optimization process. Those constraints are listed in Table 1.

Table 1 – Constraints and their expressions

Constraints	Expression	Variables
Feedrate	$f_{min} \le \frac{1000 \cdot z}{\pi \cdot D} v_c \cdot f_z \le f_{max}$	z –number of teeth, f_z –feeding per tooth, D –diameter of cutter
Spindle speed	$n_{min} \le \frac{1000}{\pi \cdot D} v_c \le n_{max}$	v_c –cutting speed
Radial depth of cut	$R_D \le ae_{max}$	ae_{max} –max. radial depth of cutting
Axial depth of cut	$A_D \le ap_{max}$	ap_{max} –max. axial depth of cutting
Power of cutting	$\frac{MRR \cdot Kc}{60} \le P_{dov}$	MRR –metal removal rate, Kc –specific cutting force
Cutting force	$F(f,n) \le F_{ref}$	F_{ref} –desired cutting force
Surface roughness	$R_a \le R_{a\ ref}$	$R_{a\ ref}$ - desired surface roughness

TBLO algorithm generates a population of students-learners during the second phase. The learners learn through the teacher and at the end phase increase their knowledge by interaction among themselves to find the maximal cutting force. The best answer of a student which has found the maximal but still allowable cutting force represents the optimal cutting conditions.

The optimization process is depicted by the following steps:

1. Define the optimization problem (maximization of cutting force surface) and initialize the optimization parameters: Population size (k=8 students), number of generations (i=20), number of design variables (j=2 for f and n) and limits of design variables (f_{min}, f_{max}, n_{min}, n_{max}).
2. Generate a random population according to the population size and number of design variables (j=2).
3. Teacher phase; Calculate the mean of each design variable (f, n), evaluate of objective (cutting force surface) function for each student, identify the best solution (teacher), modify solution based on best solution.
4. Student phase; increase the knowledge of students with the help of their mutual interactions.
5. Termination criteria; Steps 3 and 4 are repeated until the generation number reaches a maximum generation number.

Figure 3 shows simplified principle of optimization of cutting parameters by the use of TBLO. In this case, the group of students searches for optimal feeding and spindle speed.

Optimal feed rate is located at the cross-section of the following two planes: cutting force surface and the limit cutting force plane. The student's answer which is the nearest to mentioned cross-section represent the optimal feed rate and spindle speed.

A group of Matlab's m-files forms TLBO software for optimization. This software can be used for optimization of arbitrary non-linear system. The required input parameters required for executing TBLO algorithm are inserted in a software window.

The result of optimization (optimal cutting parameters) is presented to user in a tabular form. The progress of optimization process can be monitored on graph.

TBLO OPTIMIZATION OF CUTTING PARAMETERS WITH EXPERIMENTAL SETUP-TEST CASE

The repeatability of the TBLO optimization strategy is outlined with presented test case. The accuracy and repeatability of the proposed optimization strategy is first analyzed by simulations, and then it is verified by experiments on a CNC machine tool HELLER BEA02 for 16MnCrSi5 XM steel workpieces [2]. The solid ball-end milling cutter with two cutting edges, of 16 mm diameter and 8° helix angle was selected for experiments.

The following cutting parameters and constraints were used: milling width R_D=2 mm, milling depth A_D=3 mm, $500 \le n \le 2500$ min^{-1}, $10 \le f \le 950$ mm/min, $F(f, n) \le Fref = 600$ N.

The objective function is generated by ANFIS cutting force model.

The goal of this case is to maximize the objective function under given constraints. In TBLO, a population of 10 learners was used and learned continuously until global maximum is found within specified constraints.

The results are outlined in Table 2.

Table 2 – Repeatability of results

Test/Run	n [min^{-1}]	f [mm/min]	F [N]	Nr. of generations
1	1999	828.3	597	15
2	1994	830.5	600	17
3	1998	831.2	601	19
4	1997	839.6	597	23
5	2000	839.1	598	11
6	1999	839.3	599	20
7	2000	828	596	18
8	1996	828.9	597	12
9	1996	828.7	599	23
10	1999	828.4	596	21

Each run corresponds to each time the program is run to find the optimum machining parameters.

Table 2 shows optimal cutting conditions along with the number of generations it took to reach that optimum.

This optimization strategy has higher convergence, unlike traditional methods and is always successful in finding the global optimum. The machining time is reduced by 27% as a result of optimizing the feed and speed.

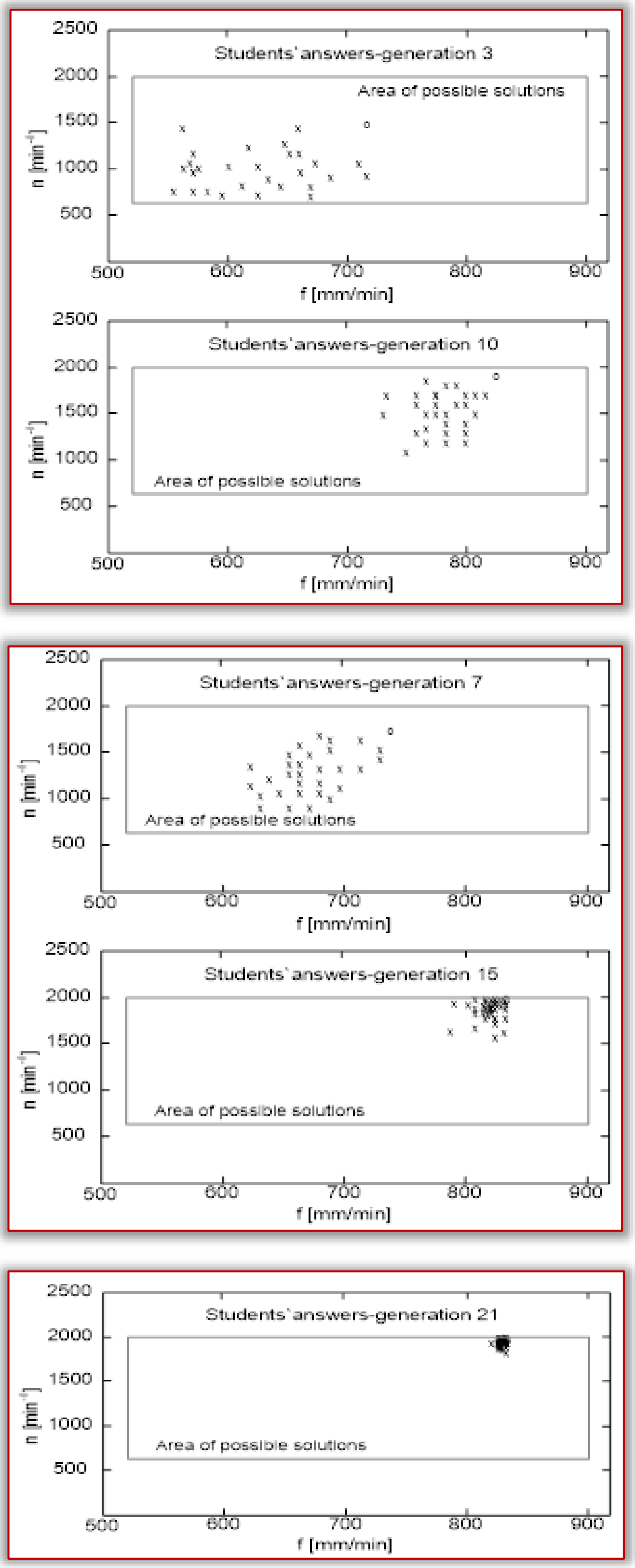

Figure 4 – TBLO simulation results

Figure 4 shows a typical student answers pattern toward the optimum solution. Generation 0 represents the random initialization of the student's answers coordinates in the solution space. In subsequent generations, the student`s answers are tracked with "x".

The optimal cutting condition are obtained in generation 21, where the optimization process is stopped.

The best student in population is presented with "O". The solution space is marked by the rectangle. An acceptable solution has to be found within this two-dimensional space.

The third constraint on force is also active and as such is not part of these illustrations.

By simulations the efficiency of the optimization approach is demonstrated.

CONCLUSIONS

This study has presented multi-objective optimization of milling process by using ANFIS modelling and TBLO optimization algorithm. First, dynamic cutting force components have been modeled using an adaptive neuro-fuzzy inference system (ANFIS) based on design of experiments.

The ANFIS model was used to predict objective function and TLBO algorithm was used to obtain optimum spindle speed and feed rate for a typical case of milling found in industry. A set of 5 constraints were used during optimization.

Ball-end milling experiments have been performed according to the experimental plan. Analysis of the developed approach has been performed to test its validity. The experimental results show that the metal removal rate (MRR) is improved by 19%. This optimization strategy has higher convergence, unlike traditional methods and is always successful in finding the global optimum. The machining time is reduced by 15% as a result of optimizing the feed and speed.

The optimal cutting conditions obtained by TLBO have been verified through experiments. They have been conducted with optimal cutting parameters to verify the optimization results and effectiveness of the optimization approach. It was found out that the experimental values at optimized cutting parameters are very close to the results obtained by TBLO.

Note

This paper is based on the paper presented at 9th International Conference "Management of Technology – Step to Sustainable Production" – MOTSP 2017, organized by Faculty of Mechanical Engineering and Naval Architecture of the University of Zagreb, CROATIA and University North, Varaždin, CROATIA, in Dubrovnik, CROATIA, 5 – 7 April 2017.

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MAINTAINABILITY, RELIABILITY AND SERVICEABILITY – INDUSTRIAL EXAMPLES AUTOMOTIVE INDUSTRY

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Abstract: Maintainability, reliability and serviceability are engineering and management functions spanning the product or service life cycle. It is a characteristic of equipment design, installation and operation, which is expressed in terms of ease and economy of maintenance, reliability of the equipment and safety and accuracy in the performance of maintenance actions. This paper shows industrial examples of a US automotive manufacturer. An overview is given of the plant maintenance and development, with which a sharp increase in the reliability and overall equipment effectiveness (OEE) could be achieved through the implementation of numerous activities and initiatives e.g. Total Productive Maintenance, long-term planning, design for maintainability, standardization and partnering, root cause focus, condition monitoring and constant adaption to new equipment.
Keywords: maintainability, reliability, standardization, design for maintainability, condition monitoring, total productive maintenance, OEE, industrial examples

INTRODUCTION

In this study, the automotive plant can be characterised as follows [1]: there has been no downtime since years and the equipment does not pose a stumbling block. Targets for overall equipment effectiveness exceed 90 percent (world class is considered 85 percent) [2,3,4,5]. This has proved achievable and, in some cases, has already been surpassed. Uptime nears 100 percent in some mission-critical areas. Maintenance attention is equally focused on the past, present and future (up to seven years down the line) and reactive work comprises less than five percent of the overall task load in a number of areas. Top management is a big advocate of effective plant maintenance, which is the reason for current state of reliability at the US plant.

Figure 1 – US automotive plant [1]

The plant located in North America (Figure 1) was constructed in 1993 and opened for full manufacturing in 1994. More than 1,400 of the company's high-end, technologically advanced, customization-heavy vehicles are built here on a daily basis. Inside the plant, the focus is on performance and taking a more stringent approach to reliability. Regardless of what is being operated and what is being tracked, the aim is to achieve
100 percent in terms of performance and reliability. Customers are paying for engineering and quality and do not expect breakdowns on the plant floor. To achieve maintenance and reliability excellence, the drivers are:

- Macro level: Seeking ways that can ensure the equipment is going to be able to do what it should do.
- Micro level: All maintenance is planned and scheduled.

Plant reliability has a strategic significance and there is a strong emphasis on planning, which is definitely one of the keys to ensuring reliability.

The former president of the US plant was a maintenance planner and later the director of maintenance planning at a German plant. He was passionate about maintenance when he was at the US plant and believes in its importance. This shows that there is support at top-level management for reliability matters. There have always been people at board level, who were very in tune with the floor and everyone in the higher management levels understands that the profit centre of a company doesn't reside in an office, but is at the line and dependent on how it is performing. Managers and technicians (known around the site as Equipment Service Associates, or ESAs) are empowered to structurally and functionally shape maintenance to fit the plant's needs.

PLANT SETUP AND PRODUCTION UNITS

Since the start of production in 1994, the plant has produced more than 3.7 million vehicles – a total of around 1,400 automobiles per workday. It provides jobs for 8,800 employees and is supplied by 270 North American suppliers. The setup of the plant (the site comprises 4.7 km^2, of which over 5-million-square-feet is under roof) is very unique. It is divided into four units: the Body Shop (Figure 2), Assembly (Figure 3), the Paint Shop and Facilities/Energy [6,7]. Each unit takes a slightly different approach to maintenance [1].

For instance, the Body Shop takes an integrated approach and has no "maintenance department", per se. While there are associates, whose focus is strictly on maintenance, they work together as a team with production and quality associates and report to the shop supervisor.

Figure 2 – Body shop - Best fit process [1]

Figure 3 – Assembly process [1]

The over 100 Body Shop ESAs work 10-hour base shifts with an additional two hours of mandatory overtime. If the line is running in top form after Hour 10, they punch out early. ESAs are not specialists, but are multi-craft technicians, who perform a range of preventive, predictive and corrective tasks. Since the vast majority of the line consists of automation equipment with around 1400 robots, a large proportion of the base shift is taken up with predictive maintenance, which mainly involves the use of infrared thermography and motor current monitoring, as well as scheduled corrective work and project planning. Preventive maintenance (PM) on the robots takes place after the shift or at any other scheduled point in time when the equipment isn't running, which is why planning is so important here.

Assembly operates in a more traditional manner. Its approximately 70 multi-craft ESAs report to the assembly/ installations engineering manager, who serves as the manager of maintenance. Shifts are similar to the Body Shop, but PM activities comprise the main share of the in-shift work. There are very few robots (nine) here, which is why 75 percent of the PM work can be done while the line is running. Corrective work is mostly scheduled for flexible time and off shifts.

Outsourcing plays a key staffing role in the maintenance of all four plant units. It provides flexibility and allows the groups to focus on their core competencies. A certain percentage of the maintenance tasks are contracted out. A core group of maintenance personnel is always kept on site to cover any possible volume fluctuation that may arise. Outsourcing provides the plant with the flexibility to expand and contract as necessary. This means that if a reduction of the workload becomes necessary, this can be achieved by cancelling outsourced contracts rather than eliminating the plant's own associates. The Facilities/Energy Unit [6, 7], with its staff of just over 20 employees, is reliant on contractors, who perform 30 percent of the unit's workload.

The automotive plant is operated on a very lean basis. It concentrates on its core competencies and on what needs to be done. The direction is to move towards equipment management, i.e. making the equipment run as efficiently as possible. There are commodity skills that can be easily purchased from external partners, e.g. changing air filters, a technical skill on which the staff's time should not be spent.

While the individual units are independent of one another, there are also collective issues involving all units. For example, there is no overall plant maintenance manager position, instead, managerial representatives from each unit form the Plant Maintenance Steering Committee, which is responsible for guiding the site's Maintenance &Repairs efforts.

MAINTENANCE AS DRIVER FOR RELIABILITY

The above non-traditional approach has played a major role in the plant's ascent into a world-class-and-beyond performance [1]. Maintenance and reliability doesn't reside in one department or with one individual. Everybody plays their part in achieving maintenance, reliability, uptime and overall equipment effectiveness. It's a team game and it is evident that this team mentality is the decisive factor in winning this game [1].

Overall equipment effectiveness OEE [2,3,4,5], uptime and the other factors are represented on the team-boards. OEE and uptime are the most substantial metrics at both the plant and departmental level, i.e. these Key Process Indicators are considered at all levels. OEE and uptime are directly related to the number of cars that can be produced for the customers.

The OEE is calculated as:

OEE = Equipment Availability x Equipment Efficiency x Quality Rate (EA x EE x QR)

EA refers to technical uptime. It is planned runtime minus equipment downtime divided by planned runtime. EE refers to process performance in units. It is 'units produced' multiplied by 'cycle time' divided by 'planned runtime'. QR is the quality rate in terms of equipment. If a piece of equipment causes a vehicle to require reworking, then this counts against OEE. It is 'total units' minus 'defect units' divided by 'total units'. Although it is standard procedure to use the maximum speed as a basis for this calculation, it is not applied in this particular case. Instead the speed is based on a unit goal and the plant is then staffed for this particular workload. The equipment is installed with a speed range and adjusted to market conditions. Two layers of OEE exist: Department-level OEE measures the whole line against a target, while Equipment-level OEE measures each piece against a target.

Assembly has a departmental OEE goal of around 93 percent, which includes the EA and EE sub-goals of 98.5 and 98 %, respectively. For the productivity and quality components of OEE, the target represents 100 percent. Facilities/Energy [6, 7] had an OEE target of 90 percent, but averaged a higher percentage. Charting uptime, the shops surpass 90 percent, both as a department as a whole and for critical pieces of equipment. Assembly's overall mark regularly exceeds 95 % and has been as high as 99.4 percent. In the warehouses, uptime scores of 99.99 and 99.8 percent have been achieved on critical equipment such as cranes, transfer cars and systems.

Only a small percentage of maintenance (less than five percent) is reactive, unplanned work, with 88 percent of the work performed according to the planned schedule. All maintenance work is planned, scheduled and tracked with regard to how well the plan is actually adhered to. The target for maintenance is set at 90 percent. It should be noted that, generally, there are only few equipment problems and the equipment cannot be considered a stumbling block for the plant.

ACHIEVEMENT OF RELIABILITY BY MAINTENANCE ACTIVITIES AND TOOLS

To achieve optimal reliability, there are many maintenance activities and tools that can be employed, which are briefly described in the following paragraphs [1].

Total Productive Maintenance TPM

Total Productive Maintenance (TPM) has helped raise uptime and OEE [2,3,4,5] by creating a team approach to maintenance work and improving reliability and serviceability. TPM activities vary by unit and production area. In the Body Shop, equipment is shut down in some areas for 15 minutes in each shift, so production workers can perform cleaning and adjustment activities. In other Body Shop areas, the shutdown can occur more often (15 minutes every two hours) or less frequently (a one-hour block once a week), while in Assembly, some production workers are assigned full-time TPM duties. The glazing cell and fluid fill cell each has two people per shift devoted to these tasks.

Production workers do have TPM limits. For instance, lubrication is strictly a maintenance task. It must be ensured that the associates responsible for maintaining the equipment cannot have a negative impact on it. This differs from Facilities/Energy, where basic and advanced TPM activities are outsourced to the plants contractors. TPM has worked to raise reliability through increased communication, ownership and responsiveness.

Long-term planning

The plant has drawn up documents that examine the maintenance needs of critical systems over a timeframe spanning several years. Major and minor activities are identified, which need to be performed to ensure the long-term sustainability of the assets. This has played an instrumental role in highlighting maintenance issues for which resources are needed. For example, the plant must regularly overhaul its gas turbines, because of the workhorse manner, in which they are used. It helps to look at the useful life of equipment and when it needs to be brought back to like-new condition.

Design for maintainability

The plant has been substantially extended and has changed its assembly layout from a two-line system to a one-line system. All vehicles are assembled on the same line. After the extension and conversion, the plant was able to take a fresh start approach to many things, including maintenance. New equipment was set up and installed in a manner that increased accessibility and maintainability.

Standardization and partnering for maintainability

The plant is a big supporter of equipment standardisation. For example, the site embarked on a project to convert its programmable logic controllers to Siemens products. The plant and the company are now on one

PLC platform. For a spread-out organisation such as this, standardisation makes corporate and cross-plant partnering possible.

Most of the equipment is the same at all company sites. This makes is possible to receive solutions to problems from plants around the worldwide corporate production network. This increases OEE and uptime. Equipment and maintenance standards (and maintenance best practices) are collected on a global basis at the company's Centre of Competencies in Munich, Germany.

All information gathered and lessons learned goes to the centre, where it can be accessed and used by other sites. Sharing these insights from the experiences of the different plants on a company-wide platform help others to get things right the first time and build reliability into equipment and processes. Considerable partnering/idea-sharing also takes place between the plant and its many capital and MRO (maintenance, repair and operations) suppliers.

Condition monitoring

The extension and conversion of the plant also provided an opportunity to install sensors on many highly critical equipment components. The initial system used monitored the entire factory and broke it down into zones, but now it is possible to precisely locate the problem down to the individual equipment. When a degradation or a potential issue is discovered, action is taken immediately and the issue addressed before any incident can occur (Figure 4).

The sensors and the PLCs interface with the plant's computerised maintenance software and SAP system to submit current status information. On the basis of this data and the subsequent comparisons to standard deviations, SAP can determine the need for a countermeasure. Depending on various factors, it may produce a work order or notification in the Computerised Maintenance Management System (CMMS) or send out a page, phone call and/or e-mail. Condition monitoring equipment is implemented on a cost-efficiency basis.

Root cause focus

The plant and its maintenance organisations are dedicated to identifying the source of problems and preventing their reoccurrence [8]. In the Body Shop, if a line breakdown takes 15 or more minutes to resolve (in Assembly, the standard is 10 minutes), maintenance leaders and ESAs perform a complete "five-whys" root cause analysis (RCA) to determine and correct the true root of the problem.

All possibilities are used for problem-solving and the associates stay tuned until the problem is solved. RCA is not a quick action. It requires manpower to implement it, whether it be people on the floor or the planning group. An appropriate course of action must be drawn up for simple tasks, i.e. 'in cases for which it is unreasonable to carry out the "five-whys" RCA with the effort and expenditure it entails.' In such cases, a full RCA is not necessary. Furthermore, if the equipment is very new and a malfunction occurs, it will take maintainers longer to solve the problem and rectify it, because they are still learning about its special features.

The recognition of problems and their solutions are transferrable to all similar pieces of equipment in the plant and the groups concerned ensure that the information they have gained is shared with senior departmental managers. This way, the managers are continually kept up to date with what maintenance is doing as well as why it is important and what is being undertaken to ensure that the production processes remain up and running. In other words, it is ensured that a constant spotlight is kept on equipment performance and maintenance.

Figure 4 –High-tech maintenance: Passion for perfect production processes

The plant, as a whole, also investigates and eliminates the root cause of problems through Lean Six Sigma projects. Currently, master black belts, black belts and green belts play key roles on five- to seven-person attack teams. Lean Six Sigma is data driven. That's the difference between it and the other problem-solving measures. Looking at the data and analysing it will lead to the correct solution to a particular problem.

Constant change

The plant functions on intervals. New car lines are introduced. With each new car line comes new equipment to produce the vehicle. This provides some OEE benefits. The equipment is often cutting-edge technology. This means the maintenance staff is constantly on the learning and training curve for that particular piece of equipment.

The changes and staff turnover means that maintenance must consistently re-evaluate its PM processes and activities. For example, if a machine undergoes PM events eight times per year and exhibits no problems, the annual PM frequency could possibly be cut in half. The aim is to find the right balance, i.e. not to perform too much, not to perform too little and to perform the right thing. PM frequencies are quickly changing from time-based to condition- or cycle-based. Preventive maintenance is based on how hard the equipment is running.

The trend to digitalisation [9] and demographical change [10] will lead to new challenges and adaption to new technology for maintenance.

CONCLUSIONS

The plant holds premier-level status because of its performance, style and reliability and because of its progress in these three areas. Years ago, there was not nearly the same level of utilization of the CMMS system. With SAP, preventive maintenance can be tracked and its effectiveness monitored. The mean time between repair and the response to calls and the level of predictive maintenance has been significantly improved.

However, the journey towards maintainability, reliability and serviceability is not yet finished and if plants aren't undergoing changes, they are either doing something wrong or they are falling way behind. Everything, including an inability to change, has a negative impact on customer satisfaction and customer demand.

The trend to digitalisation [9] and demographical change [10] sets the bar higher and maintenance must now adapt to new challenges and perform at a higher level.

Note: This paper is based on the paper presented at 9th International Conference "Management of Technology – Step to Sustainable Production" – MOTSP 2017, organized by Faculty of Mechanical Engineering and Naval Architecture of the University of Zagreb, CROATIA and University North, Varaždin, CROATIA, in Dubrovnik, CROATIA, 5 – 7 April 2017.

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DEVELOPMENT AND PERFORMANCE EVALUATION OF A SOLAR WATER STILL

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Abstract: The availability of potable water is a necessity for human existence. A simple laboratory scale solar water still capable of holding 75 litres of water has been developed and evaluated. The highest temperature in the solar still occurred at the vapour region and reached up to 66°C. The productivity of the solar still varies with the depth of water in the still. The results of the productivity were 67.4 ml/m^{2}h, 54.2 ml/m^{2}h and 43.4 ml/m^{2}h for depths of 20 mm, 40 mm and 60 mm respectively. The efficiency of the solar still was found to vary with the depth of water in the basin. The highest efficiency obtained for the solar still was 29.1% at a depth of 20 mm. Characterization of water quality before and after distillation in the solar still showed a reduction in chemical and microbiological constituents after distillation which was comparable to standard drinking water. The solar still could be developed at a small-scale workshop at reasonably cheap costs. Further work to improve the productivity of the solar water still is proposed.
Keywords: Solar energy; water still; distillation; water quality; temperature

INTRODUCTION

Supply of potable water is a major problem particularly in developing countries. The problem often faced is that protected or improved sources, such as boreholes and treated urban supplies, can still be contaminated such that microbiologically unsafe water is delivered [1]. Of major concern is the populace dwelling in rural regions of developing countries who do not have access to these improved sources and are at higher health risks as they depend on the natural sources like rivers, streams and springs which are often contaminated. The ability to be able to treat water on a domestic scale will therefore be of immense benefit.

Nigeria lies within a high sunshine belt and solar radiation is fairly well distributed within the country. The annual average total solar radiation varies from 12.6 MJ/m^2-day in the coastal latitudes to 25.2MJ/m^2-day in the far north [2]. This vast amount of solar energy could be utilized in purifying water domestically.

Solar distillation has been largely used in desalination. It involves utilizing solar energy for heating of water to cause evaporation. The vapour produced, then, condenses to produce distilled water. Gomkali and Datta [3] designed a simple solar still with a double-sloped glass cover plate which had an annual average productivity of 2.5 l/m^2-day and at an efficiency of 28%. Naim [4] also devised a single-stage solar desalination spirally-wound module which had maximum distillation efficiency of 34% and with a productivity of 575 ml/m^2-h. Medugu and Malgwi [5] designed and tested a solar still and claimed that the instantaneous efficiency increases with the increase of solar radiation and with increase of feed water temperature. Tarawneh [6] studied the effect of water depth on the performance evaluation of a solar still and stated that decreased water depth has a significant effect on increased water productivity, noting that the productivity of the solar still is strongly dependent on the climatic, design and operational conditions. Ighodalo and Ebhodaghe [7] also carried out a performance evaluation of a solar still for salty water desalination which produced 0.51 litres/day.

Furthermore, Eze et al. [8] distilled Lagos Bar-beach water using a rectangular still with a single slope inclined to 22° and showed that there was an improvement in water quality of the beach water after distillation. Patel et al. [9] reviewed the methods which can be utilized in improving the performance of solar still to improve productivity. Sathyamurthy et al. [10] investigated the performance of a semi-circular absorber solar still with baffles and reported that the daily yield was higher than conventional still. Ugwuoke et al. [11] evaluated a portable water distillation system and observed that the quantity of distillate water is higher with a higher ambient temperature.

In addition, mathematical modelling and simulation of the solar still have been presented by Adhikari et al. [12], Bemporad [13] and Mowla and Karimi [14]. Medugu and Ndatuwong [15] also carried out a theoretical analysis of heat and mass transfer of water distillation using solar still and concluded that the instantaneous efficiency increased with an increase of both solar radiation and feed water temperature.

There is a need to develop and improve the efficiency and productivity of solar water stills with low cost of production, maintenance and ease of operation. Hence, this study presents the development and evaluation of a simple laboratory scale solar water still with the characterisation of water quality before and after distillation in the still.

DESIGN CONSIDERATIONS

The solar water still consists of a black metallic basin to improve the absorptivity of incident solar energy. The basin holds the water to be purified and is covered with a transparent glass through which solar radiation passes to increase the temperature within the still. The heat transferred to the water still results in an increase in temperature of the water still. The increase in temperature causes steam, or water vapour, to be produced. The steam generated then condenses on the surface of the glass cover on the water still. The condensed water runs along the inclination of the glass cover and is collected in a distillate trough which passes the water into the collecting bottle via a flexible pipe connected to the trough. The metallic basin is lagged using wood. The details of the design of the solar water still and the specifications for the components of the water still designed are described in this section.

Basin

The basin has a square base with a volume of about 75 litres. The dimension of the basin was 600 mm × 500 mm × 250 mm. The black metallic basin was lagged in a wooden frame, 5 mm thick, to prevent heat loss.

Glass Cover

The glass cover is a 3 mm thick transparent glass which is tilted at an angle equal to the latitude of Lagos, Nigeria, to ensure optimum transmission of solar radiation into the still. The angle of inclination of the glass is 6.6° to the horizontal. The elevation will also allow the flow of condensed vapour along the surface of the glass to the distillate trough.

Distillate Trough

The distillate trough is made from a U-shaped polyvinylchloride material which is attached to one end of the basin and at the depressed portion of the glass cover. The distillate trough is connected to the collecting bottle via a flexible pipe attached to the free end of the trough.

Feed Water Inlet

The feed water inlet is located at a height of 140 mm from the base of the basin. The flow of feed water is regulated by a float valve which receives water from a stationary reservoir. The valve is adjustable so as to regulate the level of water in the basin. The experimental set-up of the solar water still is shown in Figure 1.

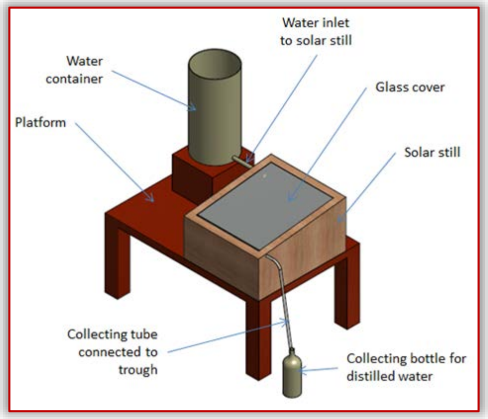


Figure 1. Experimental set-up of the solar water still.

Energy Received by the Solar Still

The energy received daily by the solar still is estimated from the solar radiation intensity, I_s, and the area of the basin, A. ECN and UNDP [2] have noted that the solar radiation intensity around the coastal region in Nigeria is about 12.6 MJ/m^2-day. The energy received by the solar still is therefore, estimated as:

$$E = I_s \times A = 12.6 \times 0.6 \times 0.5 = 3.78\text{MJ/day} \qquad (1)$$

Distillate Trough

The distillate trough is made from a U-shaped polyvinylchloride material which is attached to one end of the basin and at the depressed portion of the glass cover. The distillate trough is connected to the collecting bottle via a flexible pipe attached to the free end of the trough.

EVALUATION OF THE SOLAR WATER STILL

The solar still was set up and was positioned such that the inclined surface faced the south direction to ensure unhindered reception of solar radiation. The performance evaluation of the solar still lasted 10 hours per day from 0800 to 1800 hours local time. During evaluation, which was carried out between July and September, the height of water in the still was varied and the corresponding results observed were recorded. The heights used were 20 mm, 40 mm and 60 mm, which amounted to 6, 12 and 18 litres respectively. Water from the Lagos lagoon, Nigeria, was utilized in the evaluation of the solar still.

Temperature in the solar still

The temperatures of the water in the still, T_w, and the vapour region between the glass and water, T_g, were measured along with the ambient temperature, T_a, at 30-minute intervals. The temperatures were measured using K-type thermocouples. The positions of the temperature sensors of the thermocouples are indicated in Figure 2.

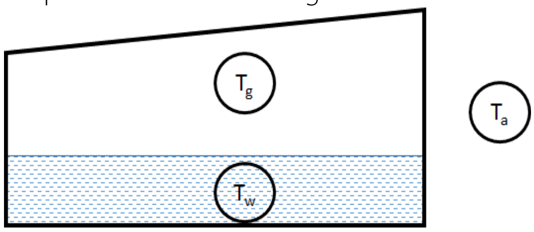


Figure 2. Schematic diagram showing the placement of thermocouples

Productivity of the solar still

The distilled water produced from the solar still collected was measured using a measuring cylinder. This was carried out hourly to determine the hourly production and the cumulative production of distilled water. The productivity of the solar still is the volume of distillate produced per unit area per unit time of operation. Taking V_T as the total volume of distillate and A as the base area of the solar still and t as the time of operation in hours, then the productivity, P, is estimated using Equation (2):

$$P = {V_T}/{A}\ \text{(per day)} = {V_T}/{At}\ \text{(per hour)} \qquad (2)$$

The term $\mathbf{t}$ is the total number of hours of production of distilled water.

Efficiency of the solar still

The heat utilized to evaporate a mass, m_e, of water with volume, V_d, and density, ρ, from the basin can be estimated from the latent heat of vaporization of water, L_v, using Equation (3):

$$Q_e = m_e \times L_v = \rho V_d \times L_v \qquad (3)$$

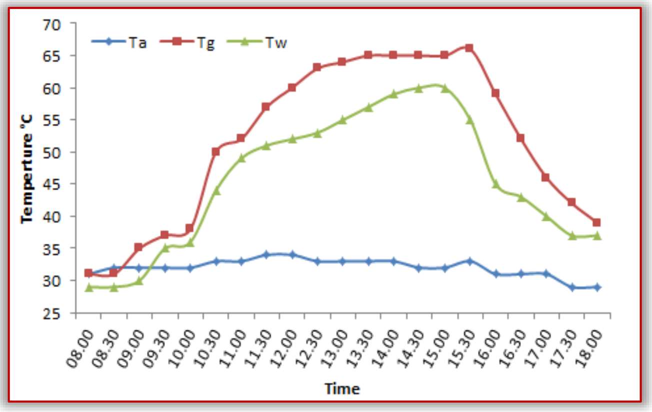
The efficiency of the solar still is a measure of its performance which is calculated from the ratio of energy utilized by the solar still to the energy received by the solar still. The efficiency of the solar still is estimated using [16,17]:

$$\eta_e = {Q_e}/{E} \qquad (4)$$

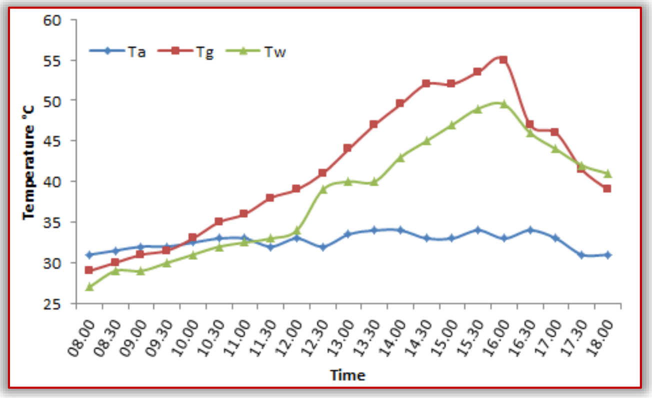
E is the energy received by the solar collector during the period of operation.

Laboratory Analysis

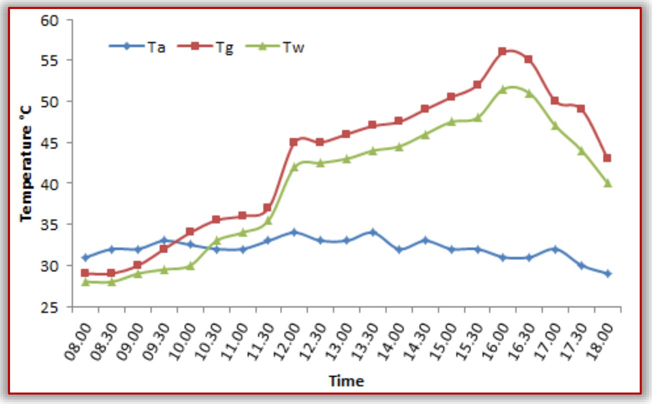
Laboratory tests were conducted to determine the physical, chemical and microbiological properties of water before and after distillation. Laboratory tests conducted determined the pH, conductivity, total dissolved solids, total suspended solids, turbidity, total organic matter, total hardness, nitrate, phosphate, sulphate, copper, iron, manganese, lead and zinc contents of both distilled and untreated water.



(a)



(b)

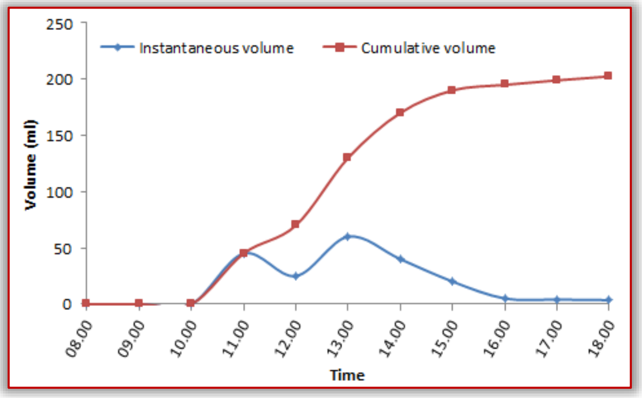


(c)

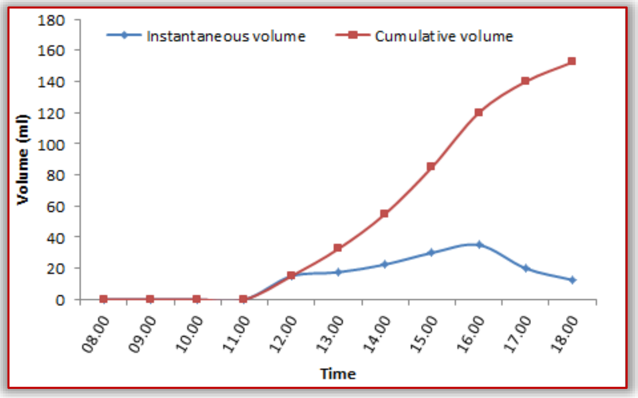
Figure 3. Variation of average temperature with time in the solar still for different days. a) Day 1; b) Day 2; c) Day 3

RESULTS AND DISCUSSION

Typical daily variation of temperature over time is presented in Figure 3(a)-(c). As was evidently observed, the temperatures within the still were higher than the ambient temperature. The maximum temperature of the vapour region just beneath the glass surface, T_g, ranged from 55°C to 66°C depending on the solar radiation intensity and weather conditions. Lower temperatures, and fluctuations in measurements, were recorded for periods with cloudy weather condition.



(a)



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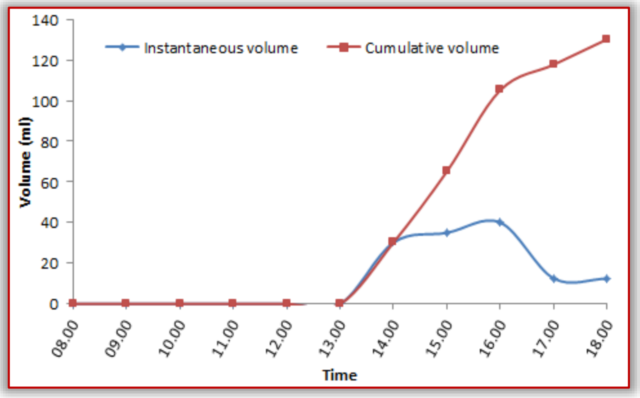
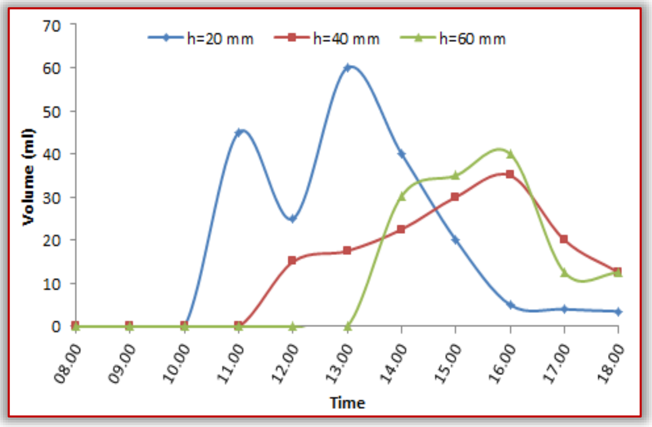


(c)

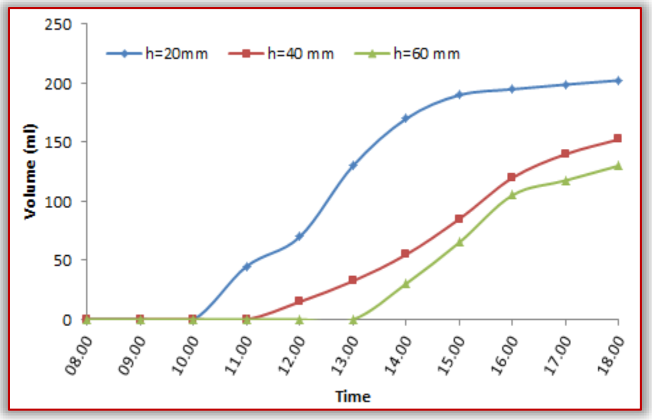
Figure 4. Volume of distilled water collected with time from the solar still at height (a) h=20 mm (b) h=40 mm and (c) h=60 mm

The maximum temperature of water in the basin ranged between 50°C and 60°C. The ambient temperature was between 29°C and 34°C, with the highest temperatures observed between 1200hrs and 1600hrs local time. The temperatures measured are comparable to those obtained by Singh et al. [18] who obtained glass temperatures between 32°C and 49°C and water level temperature ranging from 48°C to 53°C. Badran [19] also observed that the vapour temperature was the highest temperature followed by the water that has been heated in the basin. The range of temperatures obtained from the measurements also correspond to those obtained from studies carried out by Ahsan et al. [20] and Sathyamurthy et al. [10].

The average volume of distillate produced with variation in the height of the water level in the basin is shown in Figure 4(a), (b) and (c) for water level heights, h, of 20 mm, 40 mm and 60 mm respectively. The maximum volume was collected between 1300 and 1600 hours for the different tests and the maximum volume of distillate collected per hour ranged between 35 and 60 ml, depending on the depth of water in the water still.



(a)



(b)

Figure 5. Comparison of (a) instantaneous volume of distilled water collected from the solar still with time (b) cumulative volume of distilled water collected from the solar still with time.

Figure 5 compares the instantaneous and cumulative volumes of water collected over time for the different water depths. It was observed that production of distilled water began earlier between 1000 and 1100 hours when the water level height was 20 mm. Production of distillate started later (between 1100 and 1200 hours) when the height was 40 mm and latest (between 1300 and 1400 hours) when height was 60 mm.

Figure 5(a) also shows that the highest instantaneous distillate production occurred when the height was 20 mm. With higher water levels in the basin, the distillate produced was less than 40 ml.

Figure 5(b) shows that the rate of distillation increases with decreasing volume of water in the still. The total volume of distillate of 202 ml, 163 ml and 130 ml were recorded at different levels of 20 mm, 40 mm and 60 mm respectively. The productivity of the solar still at h=20 mm was 674 ml/m^2-day (67.4 ml/m^{2}h). At h=40 mm, the solar still productivity was 542 ml/m^2-day (54.2 ml/m^{2}h) while it was 434 ml/m^2-day (43.4 ml/m^{2}h) at h=60 mm. The productivity is less than that reported by Ahsan et al. [20], Gomkali and Datta [3], Ighodalo and Ebhodaghe [7] and Naim [4]. However, it was observed that the volume of distilled water produced by the solar still varied inversely with the volume of water in the still basin. The likely reason for this is that the energy required to raise the temperature of the liquid, and hence the kinetic energy of the molecules, increased with the volume. Therefore, the solar still will perform better at a minimal water level which is sufficient to cover the entire basin surface area. This requires that an efficient feed water control valve is installed for proper regulation of the feed water.

Reed [21] estimated the minimum daily drinking water required for a person to be 3 to 4 litres per day. The productivity of the solar still is less than the minimum required quantity of water for survival. The use of sun tracking has been proposed by Taiwo [22] to increase the temperature and consequently improve the productivity of the solar still. Other methods proposed include preheating the feed water, reducing the temperature of the glass surface by using cooling water on the glass cover, using dye in the basing and using energy storing materials [9].

The efficiency of the solar still has been estimated for the different depths of water in the solar still. For a water depth of 20 mm, the efficiency was 29.1% while efficiencies of 23.3% and 18.7% respectively were obtained for water depths of 40 mm and 60 mm in the basin. It appears the level of water affects the thermal efficiency of the solar still. This is probably so because more energy was consumed in heating a larger quantity of water to increase its temperature. This implies that, apart from improving productivity of the solar still, the efficiency can also be improved by maintaining a minimal water level within the solar still by the use of an efficient water regulator.

The results from the tests from the laboratory which characterized the physical, chemical and microbiological properties of water before and after distillation in the still are presented in Tables 1 and 2. It was observed that conductivity reduced from 75 µS/cm to 47 µS/cm; total dissolved solids reduced from 50 mg/l to 32 mg/l; and the total hardness reduced significantly.

It was also observed that there was a reduction in the chemical and elemental constituents in the water after distillation in the water still. The total bacteria count also reduced. The values obtained during the analysis were within acceptable ranges for drinking water when compared to standards from NIS [23] shown in Table 3.

Table 1. Physical and chemical characteristics of water before and after distillation in the solar still

Parameter	Before distillation	After distillation
pH	7.01	7.00
Conductivity (μS/cm)	74.7	47.7
Total dissolved solids (mg/l)	50.2	31.6
Total suspended solids (mg/l)	Not detected	Not detected
Turbidity (FTU)	0.0	0.0
Total hardness (mg/l)	28.0	18.0
Total organic matter (mg/l)	Not detected	Not detected
Nitrate NO_3^- (mg/l)	0.41	0.22
Phosphate PO_4^{3-} (mg/l)	0.006	0.002
Sulphate SO_4^{2-} (mg/l)	3.0	2.0
Copper Cu (mg/l)	0.04	0.02
Iron Fe (mg/l)	0.07	0.03
Manganese Mn (mg/l)	0.02	Not detected
Lead Pb (mg/l)	Not detected	Not detected
Zinc Zn (mg/l)	0.47	0.25

Table 2. Microbiological characteristics of water before and after distillation in the solar still

Parameter	Before distillation	After distillation
Total coliforms	Nil	Nil
E. Coli	Nil	Nil
Virus	Nil	Nil
Total bacterial count	1.3×10^1	1.0×10^1

Table 3. Parameters and maximum allowable limits for drinking water [23]

Parameter	Maximum permitted value	Health Impact
pH	6.5-8.5	None
Conductivity (μS/cm)	1000	None
Total dissolved solids (mg/l)	500	None
Total suspended solids (mg/l)	N/A	N/A
Turbidity (FTU)	5	None
Total hardness (mg/l)	150	None
Total organic matter (mg/l)	5	Cancer
Nitrate NO_3^- (mg/l)	`0.2	Cyanosis and asphyxia (blue baby syndrome) in infants under 3 months
Phosphate PO_4^{3-} (mg/l)	N/A	N/A
Sulphate SO_4^{2-} (mg/l)	100	None
Copper Cu (mg/l)	1	Gastrointestinal disorder
Iron Fe (mg/l)	0.3	None
Manganese Mn (mg/l)	0.2	Consumer acceptability

Table 3 (continuing). Parameters and maximum allowable limits for drinking water [23]

Parameter	Maximum permitted value	Health Impact
Lead Pb (mg/l)	0.01	Cancer, interference with Vitamin D metabolism, affects mental development in infants, toxic to the central and peripheral nervous systems.
Zinc Zn (mg/l)	3	None
Total coliforms	10	Indication of faecal contamination
E. coli	0	Urinary tract infections, bacteraemia, meningitis, diarrhoea, acute renal failure and haemolytic anaemia
Virus	N/A	N/A
Total bacterial count	N/A	N/A

CONCLUSIONS

A simple laboratory scale solar water still with dimension 600 mm × 500 mm × 250 mm, capable of holding 75 litres of water, was developed and evaluated. The maximum temperature in the still occurred in the vapour region of the space between the water and the glass cover reaching up to 66°C, with the temperature of water in the still reaching up to 60°C. The productivity of the still varied with the level of water in the still. The productivity of the solar still with a water depth of 20 mm was 67.4 ml/m2h while productivities of 54.2 ml/m^{2}h and 43.4 ml/m^{2}h were obtained for water depths of 40 mm and 60 mm respectively. The efficiency of the solar still reached up to 29.1%.

Characterization of water before and after distillation in the solar still showed a reduction in chemical and microbiological constituents after distillation. It is recommended that the height of water in the solar still should be kept to a minimum but enough to cover the water still for best results. Further work will require concentrating on improving the productivity and efficiency of the solar water still. However, the solar still can be produced at a cheap cost and in small scale workshops for developing countries.

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DETERMINING THE MAXIMUM CUTTING FORCE IN BAND SAW MACHINES WITH REGARD TO THE INFLUENCE OF THE RUN–OUT OF THE BAND SAW BLADE

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Abstract: Maximum cutting forces in band saw machines have been determined, taking into account the total axial run–out in their cutting mechanism according to known normative documents. The run–out in this mechanism is seen as a periodic approach and offset of the band saw blade to the workpiece under a harmonious law. As a result, the velocity of this shift is summed with the feed rate. It has been found that its velocity in certain sections of the band saw blade is comparable to the feed rate and can reach 44% of its magnitude. The cutting forces are equally larger than the traditionally calculated and, within one complete rotation of the band saw blade, change asymmetrically. This extra load on the traditionally calculated cutting forces corresponds to the real operating conditions of the band saw blade.
Keywords: Band saw machines, band saw blades, cutting forces, run–out

INTRODUCTION

The cutting forces in band saw and other woodworking machines are the basis for the strength dimensioning of the elements of their cutting mechanisms, as well as of other mechanisms and elements. These forces also need to be known in view of the proper operation of the machines.

The cutting forces in band saw machines are tangential and radial [4], [5], [9]. According to the famous theory of A. Bershadskiy [4], the tangential force of cutting is determined by the formula

$$P=\frac{KbhU}{V},\ N, \qquad (1)$$

where: P – the tangential cutting force, N; b – width of the slot, m; h – height of the slot, m; U – feed rate, $m.s^{-1}$; V – cutting speed, $m.s^{-1}$.

As it can be seen in formula (1), the tangential cutting force is directly proportional to the feed rate, which according to the known literature sources [4], [5], [9] is assumed to be uniform within one complete rotation of the band saw blade.

In these machines, as well as in many others, the geometric accuracy of some of the cutting mechanism elements is essential to their operation. One of the geometrical inaccuracies of this mechanism is the frontal run–out of the guide wheels' crown, which is regulated by standards for universal band saws [2] and band resaws [3]. A second geometric inaccuracy in this mechanism is the linearity deviation of the band saw blade, which during operation is expressed with its run–out on the back side. These two geometrical inaccuracies – the frontal run–out of the guide wheels' crown, as well as the run–out on the back side of the band saw blade, can cause a total axial run–out of the band saw blade. Here it is necessary to introduce some clarification regarding the terms used in the current work. It has been accepted that the frontal run–out of the guide wheels' crown shifts the band saw blade along with its linearity deviations, which are perceived as "its own axial run–out of the band saw blade". The latter, combined with the axial run–out of the guide wheels, is perceived as a "total axial run–out of the band saw blade".

In order to provide clarification of the second geometrical inaccuracy, the reasons why it is obtained can be indicated. They are various – the non–linearity of the back of the band saw blade, inaccurately joining both ends (soldering or welding), rolling, as well as cracking of the blade. The inaccuracies caused because of the first three reasons can be determined during a control check before placing the band saw blade on the machine, the latter, on the other hand, may appear during operation of the machine and thus not be detected. There are recommendations [10], [11] regarding the non–linearity of the back of the band saw blade, however, for the three following reasons mentioned above no such recommendations exist or at least are not known to the author.

There are known methods for straightening band saw blades, as well as ways to measure their offset from linearity [11], but there are no prescriptions regarding their size. In practice, axial run–out of the band saw blades is often seen in a rather wide range. The author has measured values above 1 mm for band resaws and log band saws where there is no back support roller in the guide wheel. This is the first reason for this article, and the second one being that the measured axial run–out of the band saw blades within 6 consecutive complete rotations is very rarely repeatable, both with respect to the first measurement as well as to any previous or next. This gives reason to assume that the total axial run–out of the band saw blade is the sum of its own axial run–out and the frontal run–out of the guide wheels'croun. As a result of this cumulative axial run–out, a part of the teeth of the band saw blade is periodically approaching the workpiece, and another part periodically withdraws from it, thus, the velocity of this approach is summed with the feed rate, and the velocity of offset is subtracted from it. The latter means that the feed rate by which the cutting force of formula (1) is to be calculated needs to be increased or decreased by the velocity of the periodic approach or offset of the tooth line of the band saw blade to the workpiece.

In view of this, the cutting forces of the band saw machines would be different in magnitude compared to the one in formula (1), taking into account the axial run–out. Research in this regard has not been found in any literature known to the author. Therefore, the purpose of the present work is to calculate the maximum velocity of offset of sections of the band saw blade to the workpiece as a result of the axial run–out in the cutting mechanism within the recommendations of the known standards and literature and to compare it with the feed rate. As a consequence, to determine how this affects the cutting forces.

THEORETICAL FORMULATION

In order to achieve the stated objective, it is necessary to calculate two velocities – the velocity of offset of the band saw blade to the workpiece and the feed rate of the workpiece. To calculate the first velocity, it is necessary to: 1 – analyze the geometrical inaccuracies in the cutting mechanism and to determine what impact on the total axial run–out of the band saw blade they would have; 2 – to determine the maximum values of these inaccuracies; 3 – From these maximum values, determine the velocity of offset of the band saw blade to the workpiece.

The feed rate of the workpiece is calculated by means of a known methodology [4].

As mentioned above, the cumulative velocity of offset of the band saw blade to the workpiece can be due to two geometrical inaccuracies – the frontal run–out of the guide wheels'croun and the axial run–out of the band saw blade itself. These two inaccuracies would in a different way cause the band saw blade to move towards the workpiece.

The first geometrical inaccuracy – the frontal run–out of the guide wheels' croun can cause a periodic shift of a part of the saw blade to the workpiece and its return back. This would be the case for each guide wheel, each of which would displace part of the band saw blade independently. At this run–out, a maximum value would be obtained when both guide wheels move the band saw blade in one direction. This is the case when their most protruding parts are at the same angle, e.g., vertically. Such a coincidence is likely to occur when placing the band saw blade on the guide wheels, as well as while the machine is in operation, since it is possible the blade to slip on them. The extent of the offset of the band saw blade to the workpiece due to the frontal run–out of the guide wheels' crown, according to the accepted formulation, is equal to the magnitude of their frontal run–out and its frequency is equal to their rotation speed.

The second geometrical inaccuracy – the axial run–out of the band saw blade, as mentioned above, can be obtained because of four reasons. Therefore analytical determination of its magnitude is practically impossible. Therefore, in order to determine its magnitude, it is necessary to hypothetically accept a case that is possible to happen in practice. This is the case when there is an accumulation of error on the back of the saw due to its deviation from linearity which has not been eliminated. This deviation, according to the German companies producing such saws, is 0,13 / 1000 mm, with only this protuberance being allowed on this part of the saw [10]. This means that the accumulation of error and deviation from linearity can occur on the back of the band saw blade. The latter would be copied onto the tooth line, as in sharpening machines the back is used to base the band saw blade. Its magnitude can be obtained, for example, when the accumulation of error is about half the length of the saw, since the latter is a closed contour. For the above mentioned deviation from linearity and band saw blade length of 7,4 m, which is the length of the band saw blade SB 111, the deviation from linearity is 0,48 mm, which would correspond to the maximum axial run–out of the band saw blade without any other geometrical inaccuracies included in this value. In case of cracking of the band saw blade during operation and in the case of incorrect joining of both ends, this deviation from linearity may be even greater.

In order to calculate the velocities of offset, it is necessary to know the laws under which these movements are accomplished. Since geometrical inaccuracies are of a random nature, [8] such laws are difficult to determine theoretically. In this case, it is expedient to use the results of the above measurements of the inaccuracies, to identify the predominant forms of curves that they describe and to establish the laws according to which the velocities of offset are to be calculated. From these measurements, it has been found that the frontal run–out of the guide wheels' croun, as well as the axial run–out of the band saw blades, describe predominantly sinusoidal shapes in an unfolded form / the solid curve between points A and B in Figure 1). The observed sinusoids are not entirely correct, and the most common inaccuracy is that the two half periods differ. Other shapes have also been established, e.g., linear sections / the dashed line in Figure 1 /, a circle arc, and others with an undefined shape, however, their relation to the sinusoid is approximately two times less. This justifies both calculations in the current work being carried out by a harmonious law [7], [12]. The reasons for the calculations to be carried out by this law are cyclicality and that in this form an intermediate velocity occurs – between a linear and an arcuate with a steep section of the curve.

The influence of the geometrical inaccuracies of the machine regarding the precision of processing is depicted analytically [8]. From the accepted thesis, of the two velocities of offset to be determined by a sinusoidal law, it is necessary to calculate them according to the maximum permissible geometrical inaccuracies and to calculate their maximum values by the formula

$$u_{max} = y_{max} + \vartheta_{max}, \ m.s^{-1}, \qquad (2)$$

where: u_{max} – the maximum total velocity of offset of the band saw blade to the workpiece, $m.s^{-1}$; y_{max} – the maximum velocity of offset of the band saw blade caused by the axial run–out of the guide wheels, $m.s^{-1}$; ϑ_{max} – the maximum velocity of offset of a section of the band saw blade caused by its own axial run–out, $m.s^{-1}$.

The offset velocity of the band saw blade caused by the axial run–out of the guide wheels for a sinusoidal law is determined by the formula [12]

$$\mathbf{y} = A_1\omega_1\cos(\omega_1 t_1+\boldsymbol{\varphi}_1), m.s^{-1}, \quad (3)$$

where: **y** is the velocity of offset of the band saw blade caused by the frontal run–out of the guide wheels'croun, $m.s^{-1}$; A_1 – the amplitude of oscillation of the axial run–out of the guide wheels, m; ω_1 – angular velocity of the guide wheels, $rad.s^{-1}$; t_1 – time, s; $\boldsymbol{\varphi}_1$ – the initial phase of the movement, $rad.s^{-1}$.

As it can be seen from the formula above, the velocity of offset of the band saw blade caused by the frontal run–out of the guide wheels' croun is variable and is determined by the angle of rotation. For force calculations, it is necessary to know the maximum velocity that is defined by the formula [1], [12]

$$\mathbf{y}_{max} = A_1\ \omega_1, m.s^{-1} \quad (4)$$

In order to calculate this velocity, it is necessary to know the magnitude of the amplitude and angular velocity of the guide wheels. The magnitude of the amplitude is determined by the magnitude of their frontal run–out and is equal to half of it, and the angular velocity is determined by the formula

$$\omega_1 = 2\pi n, rad.s^{-1} \quad (5)$$

where: n is the frequency of rotation of the guide wheels, s^{-1}.

The frequency of rotation of the guide wheels is determined by the formula

$$n = \frac{V}{\pi D}, s^{-1} \quad (6)$$

By replacing formulas (5) and (6) in (4) and expressing the magnitude of the amplitude with the permissible frontal run–out of the guide wheels' croun, for this velocity it is obtained

$$\mathbf{y}_{max} = \delta\frac{V}{D}, m.s^{-1} \quad (7)$$

where: δ is the permissible frontal run–out of the guide wheels' croun, m.

The way of determining the velocity of offset of a section of the band saw blade to the workpiece caused by its own axial run–out is illustrated in Figure 1, the indications being as follows: in position 1, the tooth line of the band saw blade is unfolded; position 2 – the workpiece; The cutting speed is indicated by V; The feed rate of the workpiece with U. The offset of a section of the band saw blade to the workpiece is indicated by $\boldsymbol{\vartheta}$, in which case is in opposite direction to the feed rate. The tooth line of the band saw blade is restricted by lines c–c and a–a, with the distance between them being Δ, which is the maximum axial run–out of the band saw blade, calculated above (Δ = 0.48 mm). Between points A and B is shown a half period of one sinusoid corresponding to the unfolded curvature of the band saw blade. When moving half the length of the band saw blade L / 2 in the direction of the cutting speed V, point B moves to point B', thus moving the tooth line to the workpiece at distance AB' = Δ. It can be seen from the figure that moving along the vertical line, the tooth line approaches and withdraws from the workpiece by a sinusoidal law as well.

The calculations that need to be made regarding the velocity of offset of the band saw blade to the workpiece caused by its own axial run–out are analogous to the previous ones. The difference is that the calculations are related to the cyclicality of motion of the band saw blade and not to the guide wheels.

The velocity of offset of a section of the band saw blade from its own axial run–out is calculated by formula (3) and its maximum value $\boldsymbol{\vartheta}_{max}$ by the formula

$$\boldsymbol{\vartheta}_{max} = A_2\ \omega_2, m.s^{-1} \quad (8)$$

where: A_2 is the amplitude of oscillation of the sinusoid, as described by its own axial run–out of the band saw blade, m; ω_2 – a circular frequency of the sinusoid described by its own axial run–out of the saw blade / matches the rotation speed of the band saw blade /, $rad.s^{-1}$.

The amplitude of oscillation of the axial run–out of the band saw blade is determined by the formula

$$A_2 = \frac{\Delta}{2}, m. \quad (9)$$

The circular frequency of the sinusoid described by the axial run–out of the band saw blade is determined by the formula

$$\omega_2 = 2\pi f, rad.s^{-1}, \quad (10)$$

where: f the frequency of oscillation of the sinusoidal line, s^{-1}.

The frequency of oscillation of the sinusoidal line is determined by the formula

$$f = \frac{V}{L}, s^{-1}. \quad (11)$$

By replacing formula (11) in (10), (9) and (10) in (8), the maximum velocity of offset of a section of the band saw blade caused by its own axial run–out is obtained

$$\boldsymbol{\vartheta}_{max} = \pi\Delta\frac{V}{L}, m.s^{-1} \quad (12)$$

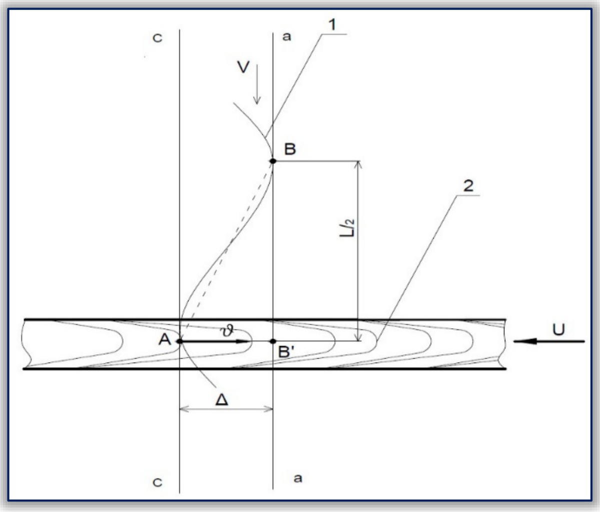

Figure 1: Scheme for determining the velocity of offset of a section of the band saw blade caused by its own axial run–out against the feed rate

RESULTS AND DISCUSSION

In order to determine whether the total velocity of offset of the band saw blade u_{max} is comparable to the feed rate U, it is necessary to make specific calculations for both velocities. The calculations to be made are for the case where the band saw blade is most loaded at a low feed rate (to be comparable to the velocity of offset of the tooth line) and a large slot height. This is one of the possibilities which can be encountered in practice and for which a maximum load on the saw is obtained.

The cutting mode selected to determine the feed rate is with the following parameters for a band resaw: BDK 111: diameter of the guide wheels –D = 1120 mm; Engine cutting power – 22000 W; Blade length – L = 7.4 m; Blade width – 100 mm; Blade thickness – 1 mm; Tooth pitch – 40 mm; Tooth height – 12 mm; Tooth type – flattened; Slot height – 0.7 m; Wood species – beech; Cutting speed – V = 40 m.s–1. The calculations are made according to the methodology exhibited in [4], [5], [9]. As the feed rate is also dependent on the dulling of the cutting tool it has been found that feed rates of less than 0.05 m.s–1 are obtained when the teeth are dulled over 30 µm.

The maximum total velocity of offset of the band saw blade to the workpiece according to formula (2) is calculated for the parameters of the above said machine under the following conditions; Frontal run–out of the guide wheels'croun – δ = 0.0002 and 0.0004 m; / A1 = 0.0001 and 0.0002 m /; The maximum axial run–out of the band saw blade, calculated above, is Δ = 0.00048 m / A2 = 0.00024 m /. It has been found that at these values, the maximum total velocity of offset of the band saw blade to the workpiece according to formula (2) is 0.0152 and 0.0221 m.s–1 for the different prescriptions of the standard.

From the calculations made, it can be seen that the maximum velocity of offset of the band saw blade to the workpiece is a quantity that may be comparable to the feed rate. It can have values of 30.4 and 44.2% of it for a complete rotation of the band saw blade. Considering the above and formula (1) it follows that the cutting force changes in the same way. Considering formula (3), it follows that this force is not a constant quantity and changes with an amplitude ± 0.3P and ± 0.44P, i. by an asymmetric cycle [6]. The analysis made shows that a band saw machine which is within its geometric precision can be loaded with cutting forces over the traditionally calculated and at that by an asymmetric cycle.

Similarly, calculations can be made with other laws regarding the movement of the axial run–out in the cutting mechanism, and higher loads on the band saw be calculated as well.

CONCLUSIONS

- The cutting force in band saw machines, taking into account the axial run–out in the cutting mechanism by a harmonious law, in certain areas of the saw blade may be 44% greater in comparison to the traditional calculation method where it is considered to be a permanent quantity within a complete rotation of the band saw blade;
- For the dimensioning of band saw blades operating at high loads, the asymmetric dynamic load cycle must be considered.
- The obtained results make it possible to make new, different calculations for the load of the shaft and axis of the guide wheels considering the calculated cutting force and its asymmetric load cycle.
- The analysis made shows that the axial run–out of the geometrical inaccuracy of the band saw blade is the greatest. To reduce these maximum cutting forces it is necessary to join the ends of the band saw blade with high precision, which means that the welding machines must be highly accurate as well.

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INFLUENCE OF OPERATING AND AMBIENT TEMPERATURE ON LOAD CAPACITY OF UNIVERSAL WORM GEAR REDUCER

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Abstract: The problem of worm gear heating is analysed in this paper. In most of cases, this heating has great impact on load capacity of worm gears, but in a great measure defines efficiency of worm gear transmission. Heating of worm gear is restricted by thermal power capacity of the gearbox. Thermal power capacity of the gearbox is defined as the biggest input power of the gearbox which could be transmitted by the gear unit, with the condition that power losses can be given to the surrounding without overheating of the gearbox, in the case of normal air temperature. Determination of the operating temperature represents the main problem for defining thermal power capacity of the gearbox. The highest operating temperature represents a limit until the gearbox (the oil in the gearbox) can be heated, but also in dependence of surrounding temperature (the ambient temperature where the gearbox operates). Influence of these temperatures is analysed in this paper.
Keywords: operating temperature, ambient temperature, thermal power capacity, worm gear

INTRODUCTION

Efficiency (η) is one of the most important characteristics of modern mechanical drives. Efficiency indicates the drive's effectiveness; so it is necessary to specify its values in catalogues and on the label plates which are mounted on the drive casing. It should have in mind that the value of mechanical drives is variable during a time.

Energy losses occurred during operating of mechanical drive are mostly transformed to the thermal energy, but smaller part is converted to energy of vibration and noise [1, 2]. This paper will consider only the losses transformed to the thermal energy to surrounding air by convection, while the small energy losses transformed by radiation and conduction are neglected. Since load capacity of worm gears depends on losses, i.e. its efficiency, during its calculation thermal flux of worm drive have to be defined. This thermal flux is necessary condition for convecting the energy to surrounding air without overheating the gearbox [1, 3]. This data is usually defined by thermal capacity of mechanical drive. Thermal capacity of universal gear reducer (P_Q) represents the greatest input power that can be transmitted through the gear unit, under a continuous duty and an ambient temperature of 20°C, without resulting in the damage of the inner parts or the degradation of the lubricant properties [2, 4]. Here the main problem represents determination of maximal operating temperature of mechanical drive, i.e. maximal permitted temperature of the oil in gear unit and the temperature of the ambient.

THE PROBLEM INTERPRETATIONS

During operating of mechanical drives, the loss of energy is converted into thermal energy which is given to the surrounding air mostly by convection.

Thermal capacity is calculated from the following equation [2, 4]:

$$P_L = P_1(1-\eta) \approx q \le q_o \quad (1)$$

where: P_L – loss of energy, P_1 – input power, η – efficiency of gear drive, q – thermal flux obtained due to losses in the gear unit, q_o – thermal flux that can be transferred to the environment, calculated from

$$q_o = k\,A\left(\vartheta_{1\max} - \vartheta_o\right) \quad (2)$$

where: k – coefficient of the heat transmission from the gear reducer oil to the environment, A – surface area of the housing of the gear reducer that can exchange heat, $\vartheta_{1\,max}$ – temperature of oil in the gear reducer (usually $\vartheta_{1\,max}$ = 80 - 100 °C), ϑ_o – temperature of the ambient where the gearbox operates (usually ϑ_o = 20 °C).

From the equations (1) and (2), it follows that the value of the thermal power capacity (P_q) is:

$$P_Q \le \frac{q_o}{1-\eta} = \frac{k\,A\left(\vartheta_{1\max} - \vartheta_o\right)}{1-\eta} \quad (3)$$

It is necessary to emphasize that the value of thermal power capacity changes with the changing of ambient temperature where the drive operates.

If a gear unit transmits larger power than thermal power capacity (P_Q), it starts to overheat and lubricant properties are changing. There is unwanted increase of components dimensions, incorrect operating of bearings and thus incorrect operation of whole mechanical drive, and also changing properties of materials which are a part of gear unit. If that problem ($q > q_o$) is noticed during design, it is tried to be eliminated by increasing the surface of the gear box in order to speed up heat convection from the housing (usually making the ribs on the housing).

If it is not enough, additional cooling is installed (installation of the fan on the high-speed shaft for forced air circulation around the gearbox, and/or installation the heat exchanger and the oil pump and cooling the oil of the gear drive).

If it is noticed that input power is larger than thermal power capacity during the selection of gear reducer, then the problem is usually eliminated by selecting larger size of mechanical drive (with higher thermal power capacity), or by cooling the oil which is always more expensive solution. This case usually occurs when transmitting high powers, or if mechanical drive operates in ambient with high temperature, or when power losses are significant (which is the usual case for worm gear drive).

The greatest influence in defining thermal power capacity has adopted operating temperature of the gearbox and adopted temperature of the ambient, so these two factors will be given special attention in the paper.

OPERATING TEMPERATURE

Permitted operating temperature of mechanical drive in large amount depends on applied type of lubricants, but also depends on permitted dilatation of mashed gear elements, material sensitivity on temperature dilatation, permitted heating of bearings, etc. Mineral lubricant was used for lubrication of gear units, but in recent time synthetic lubricant based on polyglycols is more often used. Lubricants are used for lubrication of gearing elements in order to reduce friction and teeth wearing, for lubrication of bearings, for heat dissipation and for corrosion protection.

Selection of lubricant depends on expected operating temperature, loads and number of revolutions of geared elements. Operating temperatures until 60°C are considered as normal operating condition, temperatures until 90°C are considered as higher and temperatures until 100°C or higher are considered as very high thermal conditions.

Operating temperatures of universal gear units usually covers normal and higher temperature conditions, so their lubricants can be heated until 80°C, or even 90°C. For specific thermal condition, driving units use lubricants intended for high temperatures [6].

AMBIENT TEMPERATURE

In calculation of thermal capacity of gearbox temperature of 20°C is assumed as normal ambient temperature, but some manufacturers adopt 40°C as a normal temperature of ambient [7]. According to instructions of most manufacturers, ambient temperature can be found in the range between 10 and 50°C.

Ambient temperatures depends on the conditions where the gearbox operates (outdoors subject to direct weathering, outdoors under roof, indoors with no room heating, indoors with room heating, indoors with room air conditioning), but it also depends on operating mode, specific operating conditions and year season. Also, the operating mode (continuous duty, intermittent duty with incomplete or complete cooling the gearbox) can affect the heat capacity since in the case of short time duty or intermittent duty with complete cooling, the gearbox can be higher loaded if it depends on load capacity.

Since these modes are specific and the load capacity of gear drives depends on other factors, but not only of thermal capacity, most of manufacturers of universal worm gear drives do not pay attention on these specific factors during defining thermal power capacity [6].

SELECTION OF GEAR DRIVE

Manufacturers of universal worm gearboxes propose the selection of gear unit size in three ways.

— The first way: Gear drives manufacturers who always take into account the ambient temperature have the simplest procedure of gearbox selection, no matter whether the load capacity is limited by thermal capacity or not. In this way, gearbox selection is significantly simplified, but certain mistake is consciously made since all possibilities of gear drives, whose load capacity is not limited by thermal factor, are not exploited. For example, company SEW recommends selection [7] of its worm drives by checking permitted load capacity of free output and input shafts, but in addition also by checking condition

$$T_{2N} \geq T_2 \; f_B \qquad (4)$$

where: T_{2N} – nominal output torque, i.e. the highest torque that can be transmitted continuously through the output shaft with the gear unit operating under a service factor $f_s = 1$ and with the economically acceptable maintenance costs; T_2 – output torque for defined power and rotations number:

$$T_2 = 9550\frac{P_2}{n_2} = 9550\frac{P_1\eta}{n_2} \qquad (5)$$

Service factor (f_B) takes into account all imbalances that occur during exploitation and it's calculated according equation:

$$f_B = f_1 \; f_2 \; f_3 \qquad (6)$$

≡ f_1 – factor which takes into account the type of driving machine (in this case electric motor), the type of operating machine, i.e. load classification (light, moderate, hard, very hard loads [6]), daily operating duration and number of starts per hour;

≡ f_2 – factor which takes into account the actual loading of the gear drive during the hour;

≡ f_3 – factor which takes into account the ambient temperature of surroundings where the gear drive operates (Table 1).

Table 1: Values of factor f_3 (SEW) [7]

ϑ, °C	light loads	moderate loads	hard loads
20	1	1	1
30	1.11	1.14	1.18
40	1.28	1.37	1.5
50	1.5	1.7	1.9

For proper selection of gear drives within the given power and rotations number it must be satisfied following condition:

$$f_B \leq f_{BD} = \frac{T_{2N}}{T_2} \qquad (7)$$

where: f_{BD} – permissible value of the service factor calculated according to Eq.(7) and it defines how heavy the gear drive can be loaded, given in catalogues of gearboxes.

— The second way: The company Rossi gives a more complex procedure of selection since heat capacity is observed

$$P_1 \leq P_q \; f_t \qquad (8)$$

where: P_1 – input power, P_q – thermal capacity of gearbox, given in catalogues of gear units limited by thermal capacity, f_t – factor which takes into account the ambient temperature and effective loads of gearbox, i.e. operating mode (Table 2).

Table 2: Values of factor f_t [6]

ϑ, °C	Continuous operation S1	Operating mode: Continuous operations S3 … S6 with ED factor			
		60	40	25	15
40	1	1.18	1.32	1.5	1.7
30	1.18	1.4	1.6	1.8	2
20	1.32	1.6	1.8	2	2.24
10	1.5	1.8	2	2.24	2.5

Additionally, company Rossi considerate permitted load capacity from the point of strength, wear and stiffness:

$$T_{2N} \geq T_2 f_B \quad (9)$$

Service factor (f_B) takes into account all imbalances that occur during exploitation and it's calculated according equation:

$$f_B = f_1 f_2 \quad (10)$$

- f_1 – factor which takes into account the type of driving machine (in this case electric motor), the type of operating machine, i.e. load classification (light, moderate, heavy) and daily operating duration;
- f_2 – factor which takes into account number of starts of the gear drive during the hour.

Condition given in Eq.(7) must be satisfied for proper selection of gear drives within the given power and rotations number. Operation and all imbalances are certainly defined in more detail by this way of calculation. This means the temperature is not considered if load capability is not limited by thermal capacity.

— The third way: The company Flender Cavex has the most complex procedure of selection since it requires more conditions to be satisfied:

1. From the point of strength, it must be satisfied following condition:

$$T_{2N} \geq T_2 f_1 f_2 f_3 \quad (11)$$

2. From the point of heating, it must be satisfied following condition:

$$T_{2N} \geq T_2 f_3 f_4 f_5 f_7 \quad (12)$$

3. From the point of the highest load capability, it must be satisfied following condition:

$$T_{2N\max} \geq T_{2A} f_2 f_3 \quad (13)$$

The minimum torque value of starting or breaking is at least $T_{2A} \geq 1.2\, T_2$, while $T_{2N\max}$ is the highest permitted value of short-time duty and it is given in catalogues.

4. From the point of the highest permitted load capability, it must be satisfied following condition:

$$T_{2N\max^*} \geq T_{2A} f_2 f_6 \quad (14)$$

where the highest permitted value of short-time duty $T_{2N\max^*}$ is given in tables in producer's catalogue for the smallest rotation number n_1.

- f_1 – factor which takes into account the type of driving machine (in this case electric motor), the type of operating machine, i.e. load classification (light, moderate, heavy) and daily operating duration;
- f_2 – factor which takes into account number of starts of the gear drive during the hour;
- f_3 – factor which takes into account the lubricant type and the size of gearbox (for synthetic lubricant $f_3 = 1$);
- f_4 – factor which takes into account the operating cycle per hour (ED factor);
- f_5 – factor which takes into account the ambient temperature of surroundings where the gear drive operates and input revolutions number (fan speed);
- f_6 – factor which takes into account direction of load (for alternating direction of load $f_6 = 1.2$);
- f_7 – factor which takes into account the type of gearing and thermal capacity and it is specially defined for each gear drive and gear ratio value.

PROBLEM SOLUTION

It is evident that thermal capacity of gear drive decreases with increasing of ambient temperature (Figure 1). So, if load capability is limited by thermal capacity that means the gear drive has lower load capability. If load capability is limited by strength of particular components, thermal capacity is not important factor for loadability until the moment it becomes limiting.

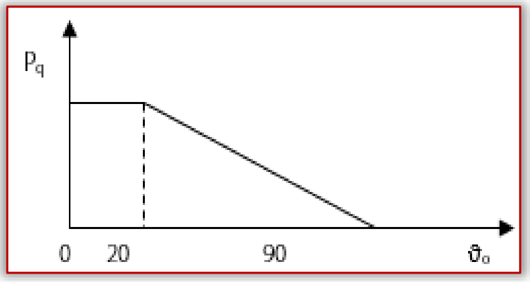

Figure 1. Diagram of thermal capacity decreasing with increasing ambient temperature

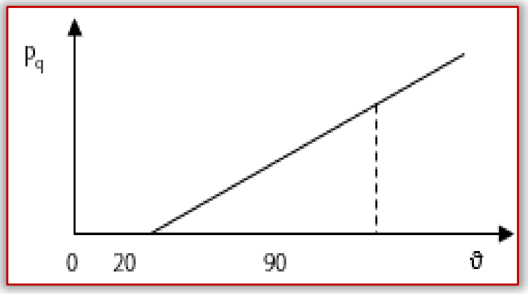

Figure 2. Diagram of changing thermal capacity with increasing permitted ambient temperature

If the changing of operating temperature of lubricant is permitted, it comes to similar change of thermal capacity (Figure 2). But, if load capability is limited by thermal capacity, the loadability will be also changed.

CONCLUSION

Analysing the influence of operating temperature, it can be concluded that it is very important feature since it is often limited factor for the thermal power capacity and thus for the load capability of gear drive. Some manufacturers do not show its value in their catalogues, since it is not important for the gearbox user.

The ambient temperature depends on the place of gearbox installation and it is taken into consideration by all manufacturers, but not with the same significance. If thermal power capacity, i.e. load capability, is limited by thermal capacity of gearbox, its value can be changed for 10-25 % with the changing of ambient temperature for only 10°C.

Heat capacity of gear drive cannot be crucially changed by changing limiting temperature, but only by increasing the efficiency of system (primarily the efficiency factor), by increasing the active surface of the housing, as well as by the method of lubricant cooling. Only in that way load capability of gear drive can be increased, and thus the gear drive will be competitive on the market.

Note

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HOUSING POLICIES AND STRATEGIES IN LIBYA: BRIEF AN OVERVIEW

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Abstract: Housing is a major concern for all people in every corner of the world as the wellbeing of a country is reflected in its people enjoying a certain standard of living. The Libyan government has made every effort to provide quality dwellings for its citizens as part of the overall welfare strategy. Different schemes were built over the last ten years in an attempt to satisfy the ever-growing social and economical needs of the society in addition to the huge population growth. Therefore, this paper aims to provide a short overview of the housing policies and strategies in Libya. A review of the housing policies and strategies were provided throughout secondary data obtained from various academic and published sources. This review was focused on issues such housing delivery, policies, funding systems, ways to improving the delivery system, etc. In the end, the paper has provided a brief conclusion to improve the shortcoming and suggestion for the way forward.
Keywords: housing, policies, strategies, development, Libya

HOUSING CONDITIONS IN LIBYA

Almost no city in Libya, or in other Arab countries, has remained intact in the face of the tremendous expansion of the urban population and the adaptation, on a large-scale, of foreign urban forms and modern technology. The urban environment has changed rapidly, both physically and socio-culturally. The original Arabic-Islamic urban forms of Tripoli, now found in what is left of the Medina, have been largely demolished or encircled by the expanding urban areas, with housing and streets laid out according to Western design patterns and a host of new transplanted from Europe and other foreign countries on the grounds of modernism (Hassan, 1982). At present, the old city houses have been left without any maintenance as a temporary shelter for the poor, most of whom are recent rural migrants. The people here live at higher densities and are characterized by low levels of income and literacy, and higher fertility rates than the average city inhabitant (Abdulmagid and Ruddock, 2001).

THE PUBLIC HOUSING APPROACH: AN OVERVIEW

After independence, the housing situation remained inadequate in quality and quantity. Bukamur (1985) argued that most Libyan cities witness a large number of shantytowns surrounding the planned areas. The first attempt to improve housing conditions was carried out when Libya was awarded of the UN from 1948 to 1951. The first major attempt at an urban plan in Libya since independence in February 1963 was the town of (El-Marj), which had been devastated by an earthquake. A comprehensive plan was drawn up for the construction of a new town. The main features of the new town were fundamentally Western in origin; detached houses with front gardens wherever possible, neighborhood centre with a range of facilities and a network of wide roads introduced by the government on a national level. The sum of 400 million Libyan pounds was allocated to build 100,000 dwellings over a period of five years, at a rate of 20,000 units per year. Western ideas appear to have been introduced wholesale and indigenous forms abandoned uncritically (Abdulmagid and Ruddock, 2001). Other features of the new public housing schemes ignored the socio-cultural values of the Libyan family or community. According to Bukamur, (1985) at the time of the Revolution about 220,000 Libyan families were in urgent need of housing. For this reason, from its early days, the Revolutionary Government (RG) has played the main role in solving the housing problem especially for low-income groups, by establishing family and housing allowances and subsidies and by reducing the selling price of government houses and land. The RG planned that each family should have the opportunity to own an adequate home.

HOUSING DELIVERY SYSTEM

The challenges

Although the Government has tried to address the problem of the adequate and affordable housing to the nations over the past 25 years, the progress is slow, and the problem of "informal settlements" is still growing. It is the dream of every Libyan to have a house of his own. However, the problem of access to affordable housing for the poor is too much for any one group to solve alone. The challenges today is to fill the missing link between the delivery system of affordable housing and the low-income communities, together with the long term commitments of the Government and private sectors who involved in the housing industry to resolve massive housing problem at the same time, seeking a balance between shareholder value and social responsibility. Our Government should be aware of this; it is an open market economy. This means that the economic growth depends on the market driven industry. There will be competition among industry players, and there is no exception in the housing industry. With globalization, foreign players will eventually penetrate the industry. Indirectly, the foreign contents in housing will increase. Although cheaper building materials and foreign input will be imported from the country, it will not be able to lower the price of the house. Local inputs such as building material, labor, and the whole delivery system that continue to rise the price houses. Moreover, with all above challenges, Libyan housing developers also need to accommodate new demands – both by regulations and market demand. As such, it is necessary to study the delivery system especially for the affordable housing and at the same time, to enhance the delivery system.

The Delivery System

» The Conceptual Process

This is process when the developer decides to develop a piece of land, and it all depends on the location of the land, the market demand, the budget, the price and its physical forms. All these elements will have an impact on what type of houses (flats or landed properties) to be built. Moreover, from there, the size and price of the houses will be determined. However, there are more and more challenges faced by developers during this process. The availability of land is one of the biggest challenges, as the developers need to ensure the location is suitable. However, land is a non-renewable resource, and the land prices have continued to escalate. Besides that, good land is more difficult to come by and houses are forced to build further and further away from economic centers indirectly, the traveling time and cost will increase. All these will be obstacles for the private sector to develop affordable housing in prime areas where demand for such housing is high. For no doubt, the Government should play a more proactive role in allocating suitable land for development of affordable housing. The other challenge is the costs of labor, material, and infrastructure which usually cost more than 60% of the cost of a house. The house pricing is all depending on the fluctuation of those costs. Especially when the housing industry is heavily relying on foreign workers – both the skilled and semi-skilled labors. The new restriction on hiring foreign labors strict has decreased the number of them. Due to the labor shortage, the builders faced disruptions, and the labor costs have increased significantly over the last few years. Investment in the housing sector constituted a high percentage of the country's five-year plans compared to the total amount of capital investment allocated for the development which was 10% in the fifth five-year plan (1990-1995). The three previous development plans in Libya (Second: 1975-1980; third: 1980-1985; and fourth: 1985-1990) increased the number of new houses and improved the existing ones (Hudana, 1995; Abdulmagid and Ruddock, 2001). The development process in the housing sector during these earlier periods depended on the Government's efforts in the field of building and construction. During the fourth development plan, housing activity greatly declined including the activity of governmental departments, which used to provide their staff with houses. The development of the housing sector is a field, which will depend greatly upon the activity of the private sector and its financial resources (Garnett, 2000). A basic need of the population is an adequate shelter. This is a major indicator of the living standards as it contributes directly to prosperity and indirectly to health and productivity. These two elements are vital to national economic growth.

» The Approval Process

We cannot deny that the Libya housing industry is really highly regulated. There are more than 50 pieces of legislations, guidelines, rules, and regulations on land, building, environment and workers' safety. All these laws, policies and regulations are different from state to state, local councils, and governmental agencies. Generally, the process state with the planning permission and ends with the Certificate of Fitness for Occupation (CFO). Throughout the whole process, there are so many regulatory requirements to be fulfilled before obtaining approval for each of the steps to get CFO. Sometimes, the guidelines are not clear enough and have caused unnecessary discretion for interpretation. This has delayed not only the process but also gave change for both the approving person and developers to abuse the system. Sometimes, the culture of facilitation can have the hidden costs up to 15% of the cost of a house. For sure, this is not what the nation desires in the long run as the cost of such practices will still go back to the house buyers at the end of the story. This means that the cost to develop a housing scheme will increase and cause the house prices becoming too much to be afforded by the low-income groups. In short, the trend of increasing regulatory and compliance costs, if not urgently arrested, will soon threaten to slow down the growth in the industry. Moreover, if the situation remained unchanged, the cost will continue to rise, and it will be impossible for all Libya to own a home. However, these regulatory costs are not the only hindrance to access to affordable housing in this country, but the weakness in distribution system has also caused the lower-income group not able to gain access to affordable housing. In fact, the distribution of LCHs which developed by the private sector is handled by the State Government through a computerized open registration system. In another word, developers will need to get the list of applicants from the respective State Government. However, we always hear that most of the time, the list fail to be delivered to developers and even the lists have been obtained, they are often outdated. At the end, only 10 present of the potential purchasers listed will take up the low-cost units offered. This is because these potential purchasers are not allowed to choose their preferred location, and when they are offered LCHs at the unsuitable location, they prefer not to accept them. This is definitely the mismatch between the supply and the demand. However, the developers are still required to build required quota of LCHs.

» The construction process

This process involves constructing houses, which have been purchased by the house buyers. We all know that it will take at least twelve to eighteen months to build for a housing scheme, simple process. However, complaints received from house buyers are often related to poor workmanship and quality of houses. Especially for the low-cost units, the poor conditions of the units are even worst. There are two major reasons for all these. The first reason is unskilled labors, mostly the foreign workers. Moreover, there is no skills training for them, and they can only improve their skills through time and work experience. Unfortunately, most of them do not. Besides that, lack of supervision during the construction period has also caused the poor workmanship and quality. The normal practice in this country is a site supervisor, a consultant or even a supplier will need to handle many projects at same time. This means that they do not have sufficient time to monitor each of the sites that they are handling with. Of course, loose supervision leads to the poor condition of the houses, especially the LCHs. Although Industrialized Building System (IBS) may solve part of these problems as it will manage to reduce construction time, labor input and ensure the quality of works, it will also increase the construction cost of the project. So, only 15% of buildings in Libya use IBS. From this section, a general conclusion can be drawn that it is clear there are many challenges facing the industry in delivering affordable house. As we can see, every player has an important role in each of the stage of the delivery process, and it is obvious that the access to the affordable housing should not only be the responsibility of the private sector alone. To ensure the delivery system to be successful and effective, everyone in the system, including the Government and its agencies, developer, contractors, consultants, etc must contribute to solving the above-mentioned problems.

HOUSING POLICY

The housing policy was aimed not just at low-income groups but also middle- income groups, living in either unsuitable houses or in huts. The main goal of this policy was to house all Libyan people by giving them the opportunity of owning an adequate home, and so raise the standard of living of the whole Libyan population. The government recognized not only the need for adequate housing for all citizens but also the need for public facilities such as water, electricity, sewage, parks, and security. The housing programmer consisted of 386,000 units in the period of 1970-1985. According to the study performed by the Ministry of Housing in1989 on future housing needs, 50000 dwelling units had to be built each year. During the period of the Transformation Plan 1976-80, with a total of 80,319 units completed by both private and public sectors, the overall average annual completion rate was 16,000 units. The housing situation deteriorated, the shortage in 1980 is 42% greater than that in 1975, although it cannot be denied that the quality of the housing stock in the country has improved considerably. Low-income type accommodation having been abandoned and middle-income type dwellings having been allocated to shack dwellers and low-income groups. In consequence of the shortcomings of the previous plan, of 1975-80, a new phase of development had started requiring the reorientation and further adjustment of housing policy (Essayed, 1981b). These adjustments were expressed in the comprehensive programmer of socioeconomic development as well as in a prospective plan for the housing sector for 1980-1985. The principal object of this plan was to shift the major burden in housing construction from the public to the private sector. The plan proposed a considerable increase in house construction. The target was 206,152 units to be completed, that is to say, 165% of the previous plan fulfillment target (Essayed, 1981a).

Government Efforts In Public Housing

During the development and changing process, the main challenge to Libyan cities was the problem of squatter settlements especially in the capital (Tripoli). These squatter settlements appeared around the industrial areas, military compounds, and commercial complexes. The Libyan government sought solutions for this problem considering its humanitarian aspect. It bought lands owned by individuals or other legal owners and then started constructing roads, schools and other services (Ministry of Housing and Works in Libya, 1997). It also provided people with plan and designs. Regarding low-income citizens, the government set forth a programme outfitting parcels of land, provided with all services and facilities, then distributed them among citizens free of charge. The government also gave easy long-term loans through the Real Estate Development Fund to enable the citizen's build their own adequate houses. These hundred of thousands of land parcels throughout the country solved the problems of hundreds of thousands of families in Tripoli, where more than fifty thousand parcels within ten years were distributed. The houses in Libya had local characteristics. They were generally built of the available simple local building materials such as stone, mud, date palm, trunks, branches or leaves, wood, and plaster. However, after the great expansion in the municipalities of the country, the conditions of residents and the houses changed (Hudana, 1995). The old buildings of most Libyan cities began to change rapidly and be upgraded. Buildings construction required permission from the municipality. Permits were issued upon fulfilment of certified plans and designs. Housing in Libya passed through several stages and phases of development and programmers until it reached its present position. Both major sectors participated in the housing development process - the public sector, and the private sector. The aim was to provide adequate, hygienic houses with facilities and services suited to modern life and at the same time conforming to the financial capabilities of individuals and families.

The funding of housing

According to the type of housing policies and programmers followed, funding is carried out through the following channels:

i. Public sector:

1. The Central Housing Corporation;
2. Ministries having Housing responsibilities;
3. The Real Estate Investment Company - The General Institute of Social Security;
4. The Real Estate Bank; and

5. The National Investment Company.

ii. The private sector:

1. Commercial Banks; and
2. Co-operative Housing Activity.

Modern housing built

Housing was one of the major concerns of the Revolutionary Government from the beginning, and the provision of adequate housing for all Libyans by the 1980s remained a top priority (Essayed, 1982a). By 1969, a survey at the time of the Revolution found that 150,000 families lacked decent shelter, the actual housing shortfall being placed at upward of 180,000 dwellings. Both the public and private sectors were involved in housing construction during the 1970s, private investment and contracting accounted for a large portion of all construction until new property ownership laws went into effect in 1978, that limited each family to only one dwelling. Despite the decline of privately financed, undertakings, the housing sector constituted one of the most notable of the government's achievements. By the late 1970, the hovels and tenements surrounding Benghazi and Tripoli had begun to give way to modern apartment blocks with electricity and running water that stretched ever further into what had once been groves and fields. These high-rise apartments became characteristic of the skylines of contemporary Benghazi, Tripoli, and other urban areas.

Building and construction sector

The national construction industry in Libya has been very weak and unable to meet the demands of development. The lack of manpower in general (and skilled manpower in particular), and a shortage of building materials as well as the low degree of industrialization in the building field, are the main reasons for the inadequate construction capacities that have caused long delays in the implementation of housing programmers (Essayed, 1981). The Government, having in mind the importance of this sector in the economic and social development of the country, has been concerned and involved in activities intended to overcome the construction problems. Between 1975-1986, the government invested some LD25.9 million in housing, which made possible the construction of 227,500 housing units, according to the official sources (Minister of Housing, 1989). To reach these targets, the regime drew not only upon Libyan resources but also enlisted firms from France, the Federal Republic of Germany, Spain, Italy, Turkey, the Republic of Korea, and Cuba.

Suggested ways to ensure quality housing

Libya suffers from a severe housing shortage, particularly in urban areas, where housing programmer are mostly dominated by public social rental housing. The housing sector does not perform well when measured against either economic growth or social shelter objectives. This situation is due to a combination of a malfunctioning housing market and policy constraints impacting housing supply and demand. On the demand side, effective demand for housing is suppressed by lack of access to finance mortgage market and the absence of long-term investment accessible mortgage loans. The current stock of mortgage loans represents only 1% of GDP (particularly low even for an emerging economy), and housing loans to individuals remain less than loans to developers (mostly public owned).

CONCLUSIONS

Housing is certainly considered one of the major factors to be borne in mind when processing social and economic planning. The provision of houses in Libya helps the citizens own their houses and that consequently contributes to the upgrading of living standards and the provision of the needs of the citizens. Housing in Libya, especially in some cities, indicates that housing of the low-income and poor especially in the cities required joint efforts between the public and private sector. Group houses were constructed, residences were provided to employees of companies and establishment, land parcels were distributed, and loans were offered by Real Estate Development Fund or banks in accordance with the housing policies laid down by the government of Libya. Some conditions should be taken into consideration for changes towards housing strategy in Libya:

1. Local authorities should perform a policy of substantial investments in the public sector and the creation of a viable infrastructure for the economy.
2. The encouragement of investments made by the private sector through providing suitable conditions for its investment.
3. The confrontation of important changes in the rural sector, such as demographic pressure on land, and related condition of lifestyle.

Moreover, between the builders and the buyers, the issue of build and sell concept is bugging both sides of parties. The advantage and disadvantage have been raised Government planning to introduce it in the housing industry. With all the housing issues above, there will never be a reduction in Government responsibility to encourage an integrated approach to the use of financial, institutional, human and physical resources in public, private and the so-called "third" sector – the community to solve the housing issues as a team.

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CFD ANALYSIS OF FLUID STREAMING IN ROTARY DRYER

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Abstract: The dryer in which drying of material is being done by rotation moving of the drying stands around which hot air is streaming represents an innovative technical solution. Counter-streaming movement of the rotor with drying stands through the stream of hot air enables a higher drying intensity. In order to get a clearer picture of the hot air streaming among the drying stands and the effects of the individual components on the streaming of fluid through rotary dryer, it is necessary to perform a detailed CFD analysis.
Keywords: Rotary dryer, streaming, drying, CFD

INTRODUCTION

Drying is the simplest and most natural way of all procedures for food conservation, by which food freshness is preserved given that most of free water is extracted from it. Drying may be carried out naturally on the sun (direct drying on the sun) or ventilation and heat may be added in order to accelerate drying process (electro, gas or diesel drying plants). Dry, warm air is ideal for drying but only if air temperature is strictly controlled. Convective dryer for fruits and vegetables is based on innovative solutions and complete control of all drying parameters (temperature, humidity and air circulation rate). During the first half of 2015 a prototype of innovative dryer for fruits and vegetables was successfully designed. In the dryer of Eco –Rotary type biomaterial is dried at low temperatures (max. T=55-70°C) and low humidiy (RH= 20-25%).

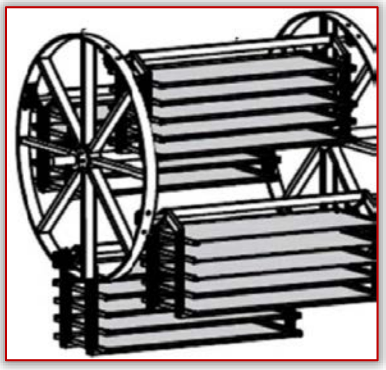

Figure 1. Representation of the rotary dryer interior

The operation principle of the innovative solution "Eco-Rotary Dryer" is reflected in the radial movement of the stands with the material for drying. On the other hand, pre-heated air is blown into the chamber to circulate around the material that is being dried in the opposite direction of the movement of the rotor with the drying stands. This counter-streaming movement enables the increase in the drying intensity as well as moving material for drying through various thermal zones in the drying chamber.

In order to determine the nature of the air streaming around the rotor and the drying stands with material for drying, a detailed CFD analysis was performed.

NUMERICAL MODEL

Defining boundary and starting conditions represents an essential step in conducting of the numerical simulation. Therefore, while defining boundary conditions, the specific features of the process were taken into account. For that purpose, four regional boundaries were defined:

- Fluid entrance (the boundary where entrance velocity and temperature are set up);
- Fluid exit (the boundary where it is defined for all fluid to exit the domains);
- Wall (the boundary where the value of thermal flux is defined);
- Internal construction (the boundary which is defined as being adiabatic);

On the basis of the data obtained from the thermal calculation, the following starting conditions have been defined:

Tabel 1. Starting data for calculating air streaming in the rotary dryer

Size	Value	Dimension
Air velocity	5	m/s
Air temperature	70	°C
Enviromental temperature	20	°C
Thermal flux (floor)	17.65	W/m^2
Thermal flux (ceiling)	9.39	W/m^2
Thermal flux (side walls)	17.07	W/m^2
Thermal flux (back wall)	17.21	W/m^2
Thermal flux (doors)	53.40	W/m^2

Spatial discretization was done by using polyhedral net while for representation of the results of the numerical simulation we have chosen several plains that are suitable for representing streaming of the fluids. In particular areas, the net optimatisation has been done with the aim to reduce the number of cells depending on the needs and wanted accuracy of the simulation results, which can be seen in the picture.

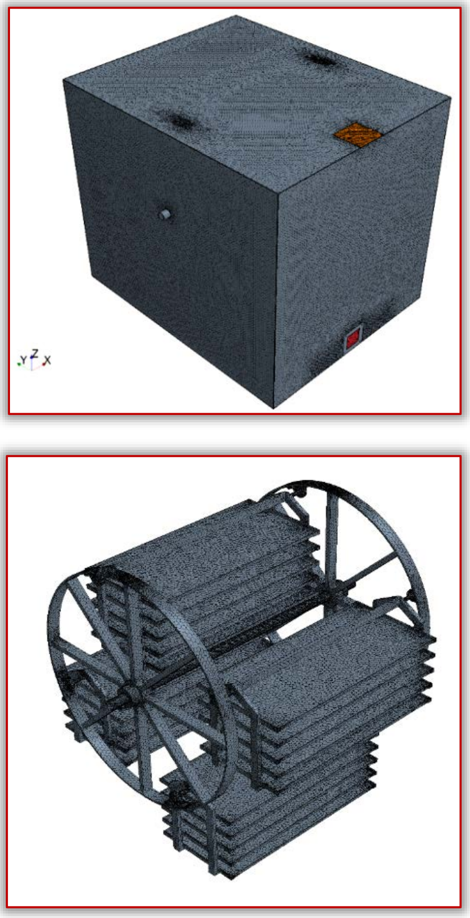

Figure 3. Numerical network of the model with defined boundaries

CFD ANALYSIS OF THE AIR STREAMING IN THE CHAMBER OF THE ROTARY DRYER

The Figure below shows the streaming of the fluid in the drying chamber where the nature of the air streaming around the stands with material for drying could be identified. It could be noticed that there is an intensive turbulent and almost symmetric streaming in the lower part of the chamber while the streaming in the upper part of the chamber is more even.

On the basis of the Figure below, it can also be noticed that the drying stands are not evenly streamed by the hot fluid. Moreover, the lower stands receive the most streamed fluid while those stands located just above the entrance of the air into the chamber get the least amount of the streaming hot fluid.

The streaming of the fluid could be noticed in more details in the characteristics fields that we have chosen for representation of the results.

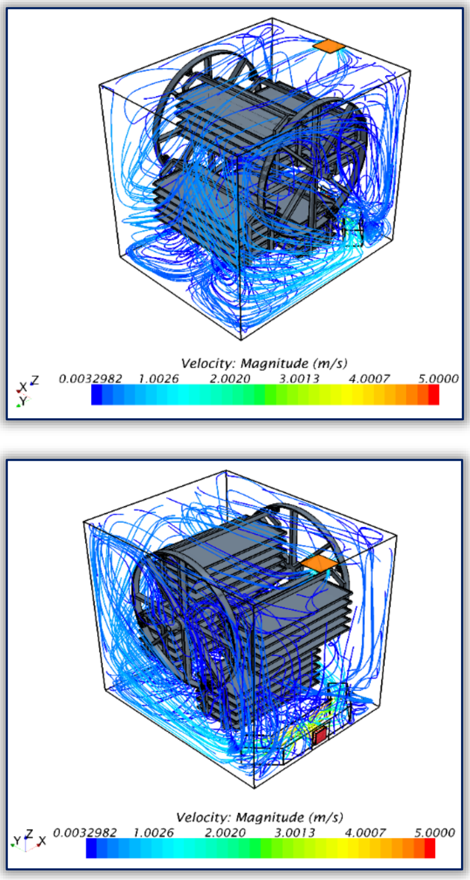

Figure 4. Representation of the fluid streaming in the drying chamber

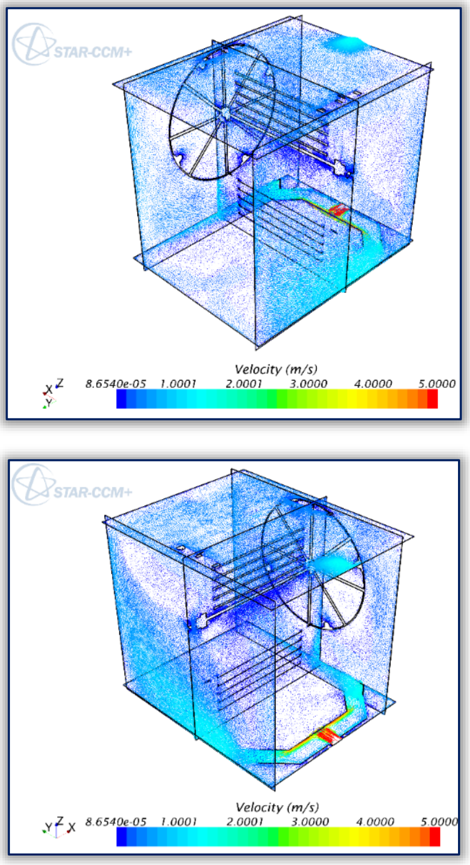

Figure 5. Representation of the vector-velocity fields in several cross-section lines

It is clearly visible that there is a significant decrease in the streaming of the fluid through distribution channels used to supply the hot air. Observing the streaming circuit in the Figure 5, there are visible zones of the intensive whirling of the air current alongside the chamber wall, as well as weak air streaming in the fields in the upper parts of the internal construction. Having in mind the distribution of the stands, it is evident that the stands will not be supplied with hot air with the even speed and, therefore, the drying process will be of different intensity in some zones.

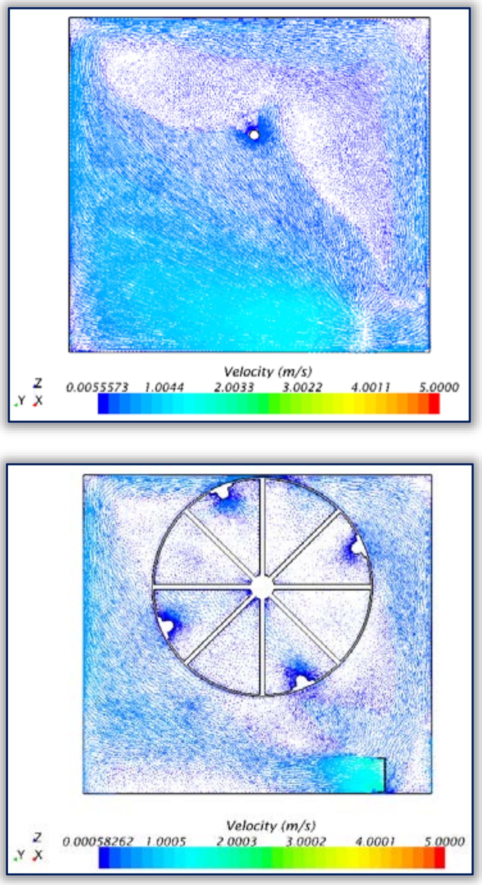

Figure 6. Left: Vector field of the speed alongside side wall, Right: Wheel.

It can also be identified that there are some places where there is need to position suitable fluid routers in order to balance even streaming around all the drying stands and thus improve the drying process.

Besides the influence of the speed of the air streaming on the drying process, there is also a particular influence of the temperature. Therefore, the temperature circuit in the chamber has also been shown. The analogy between thermal and speed field, where the highest thermal values are seen in those zones in which the speeds are the highest and the lowest thermal values are visible in the zones of the least speed values. In the thermal field, there is also visible thermal flux towards external surfaces. Uneven thermal distribution is also a consequence of the size of openness of the regulation flap that represents an additional distribution to the thermal uniformity. The orientation of the distribution channels is such that enables the hot air to hit the side walls with maximal speed while there is visible loss of the streaming energy.

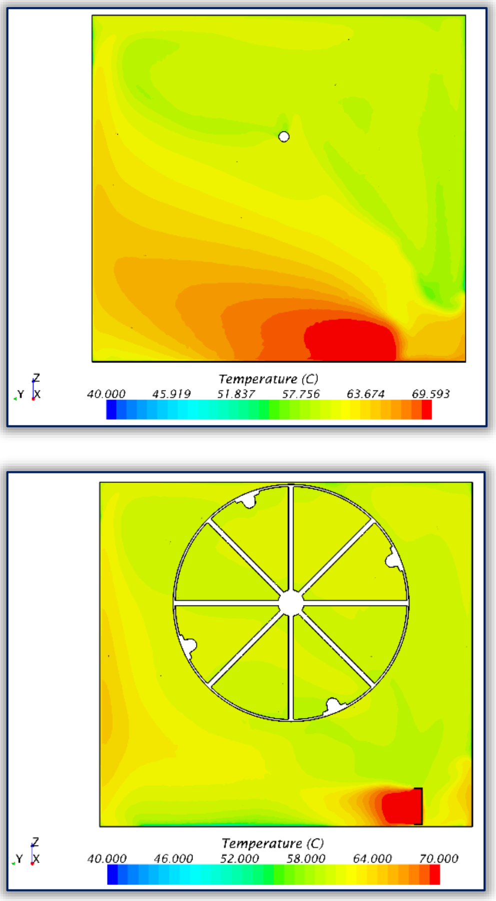

Figure 7. Thermal distribution in the chamber

CONCLUSION

Based on the results of the simulation, it can be concluded that the air streaming inside the chamber of the rotary dryer does not have a suitable feature for a biggest interval of the process parameters. In addition, the analysis of the air streaming has shown that the stands for drying do not receive even amount of the hot streaming fluid. There are visible places where directors of the air should be installed in order to decrease the streaming losses and to evenly direct the flow of the fluid towards the drying stands. A regulation blade should be mounted at the feeding channel of the hot air in order to direct the hot air depending on the required conditions of the drying process.

These changes would increase the drying intensity, lower duration of the drying process and increase the product competitiveness. By controlling drying parameters (temperature, humidity and air circulation rate) technological conditions in compliance with the required parameters of drying kinetics of many kinds of fruits, vegetables, forest fruits and medical herbs may be provided.

Note

This paper is based on the paper presented at 13th International Conference on Accomplishments in Mechanical and Industrial Engineering – DEMI 2017, organized by University of Banja Luka, Faculty of Mechanical Engineering, in Banja Luka, BOSNIA & HERZEGOVINA, 26 - 27 May 2017.

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THE NEED FOR SYSTEM ANALYSIS BASED ON TWO STRUCTURED ANALYSIS METHODS SADT AND SA/RT

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Abstract: The aim of this paper is to present the need for two methods of system analysis. The first method is the Structured Analysis Design Technique (SADT) method used in designing computer integrated manufacturing systems. The second method is the Structured Analysis for Real Time (SA/RT) method that consists in putting in evidence inside data flow diagrams elements dedicated to the control view. Then, we present a review on the two methods SADT and SA/RT and their applicability in the industrial and pedagogical fields. Thus, some applications of the SADT and SA/RT methods that have been presented in various researches are presented. Previous researches showed that any kind of system can be modeled using structured methods.
Keywords: System analysis; SADT method; SA/RT method; domain modeling

INTRODUCTION

Early in the system design process, a variety of a design method is usually dictated by what methods the designer has earlier used, not by an open selection process. In fact, particular interest in the use of graphical modeling methods and techniques to aid changes in system operations and the interactions of staff to effectively build and use modelling for analysis, design and communication of systems in the manufacturing industry.

Besides systems specification supposes two essential characteristics: temporal evolution of the system components and the system - environment interaction. Indeed, the complexity of relations between a system and its environment is especially verified in the domain of process conduct.

Among the techniques of system specification, we mention: (1) methods of analysis that permit to systematize and to canalize the various perceptions, (2) specification languages possessing syntax and very definite semantics, and (3) simulation languages.

Structured Analysis Design Technique (SADT), which was designed by Ross in the 1970s [1-3], was originally designed for software engineering but quickly additional areas of application were found, such as aeronautic, production management, etc.

SADT is a standard tool used in designing computer integrated manufacturing systems [4-6]. In fact, a significant complexity of automated manufacturing systems requires methods and tools which must allow preliminary safety analysis beginning right from the start of the design cycle [5].

In order to present how SADT is a proven design method, we present some researches in this paper: (1) the extended SADT method with respect to timing constraints and formalization, (2) the Safe-SADT method for dependability evaluation and (3) the augmentation approach for software development methods.

This paper can be loosely divided into six parts: First, we present the SADT method and second, we present the SA/RT method. In section three, we present a review on SADT and SA/RT and their applicability in the industrial fields. Then, we present some researches to augment the SADT method in order to take into account the timing constraints, the formalization and the dependability evaluation. Then, we present how structured analysis augments software development methods. Finally, the last section presents conclusion and future work.

PRESENTATION OF THE SADT METHOD

As the inventor of SADT, Ross was an early developer of structured analysis methods. Through the 1970s, along with other contributors from SofTech, Inc., Ross helped develop SADT into the IDEF0 (Icam DEFinition for Function Modeling) method for the Air Force's Integrated Computer-Aided Manufacturing (ICAM) program's IDEF group of analysis and design methods [7].

Although SADT does not require any specific supporting tools, several computer programs implementing SADT methodology have been developed. In fact, IDEF0, a function modeling building on SADT, is designed to characterize the decisions, actions and activities of an existing or prospective organization or system [8].

IDEF0 graphics and accompanying texts are presented in an organized and systematic way to gain understanding, support analysis, provide logic for potential changes, specify requirements and support system-level design and integration activities. IDEF0 may be used to model a wide variety of systems, composed of people, machines, materials, computers and information of all varieties, and structured by the relationships among them, both automated and non-automated.

For new systems, IDEF0 may be used first to describe requirements and to specify the functions to be carried out by the future system. As the basis of this architecture, IDEF0 may then be used to design an implementation that meets these requirements and performs these functions. For existing systems, IDEF0 can be used to analyze the functions that the system performs and to record the means by which these are done.

Figure 1 shows the Top-down, modular and hierarchical decomposition of SADT.

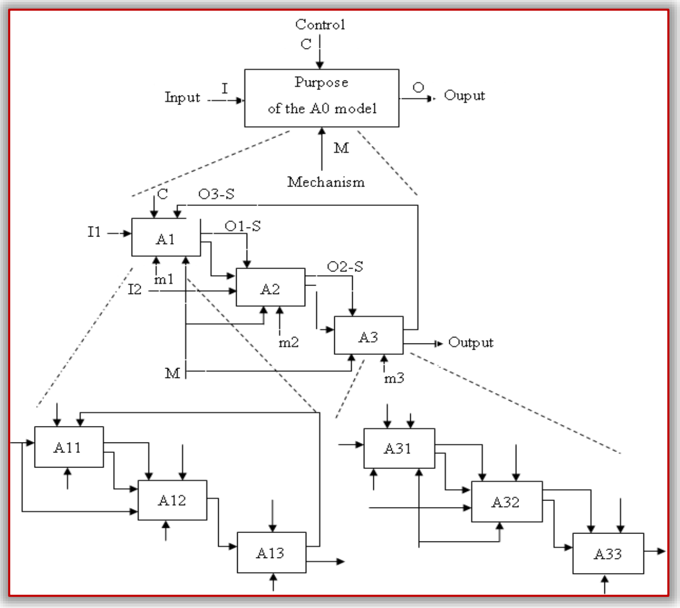

Figure 1. SADT method

The boxes called ICOM's input-control-output-mechanisms are hierarchically decomposed. At the top of the hierarchy, the overall purpose of the system is shown, which is then decomposed into components-subactivities. The decomposition process continues until there is sufficient detail to serve the purpose of the model builder. SADT/IDEF0 models ensure consistency of the overall modelled system at each level of the decomposition.

Unfortunately, they are static, i.e. they exclusively represent system activities and their interrelationships, but they do not show directly logical and time dependencies between them. SADT defines an activation as the way a function operates when it is 'triggered' by the arrival of some of its controls and inputs to generate some of its outputs. Thus, for any particular activation, not all possible controls and inputs are used and not all possible outputs are produced. Activation rules are made up of a box number, a unique activation identifier, preconditions and postconditions.

Preconditions and postconditions describe what is required for and what results from the activation. Both preconditions and postconditions are logical expressions of ICOM codes, where each ICOM code identifies a single control, input, output, or mechanism arrow for that particular box. When an ICOM arrow does not participate in activation, it is simply omitted from the precondition. Similarly, when some of the outputs of a box are produced during activation, the ICOM codes for those outputs not generated are omitted from the postcondition. A precondition expresses the required presence (or absence) of any of the objects associated with the inputs, controls, outputs, or mechanisms involved in the activity. A post condition indicates presence (or absence) after the activity has occurred.

In the following paragraph, we present the extended SADT with respect to timing constraints and formalization and a Safe-SADT method for dependability studies.

Extended SADT

There are many method used for representing the processes and the activities: one of the most known is the SADT method. In fact, this formalism adopts a static modeling of the process which is a chain of activities destined to understand, specify and do organization diagnosis. Furthermore, this formalism doesn't permit simulation for estimation purposes that need the data and temporal introduction.

Researcher Feller A. and Rucker R. [9], has proposed an extended SADT method and has described the need for such a method more than 30 years ago. This extended SADT method has been used in many applications with respect to timing constraints and formalization. One of these applications is a proposal of a gait of a physical and economic performance analysis.

However, the main adaptation that the Researcher has brought to the extended SADT formalism on the control arc that he thinks it more generally as a secondary input flow not necessarily intended to control the activity, this function can be provided by the trigger arc.

Safe-SADT

Dependability evaluation is a fundamental step in automated system design. However, the current dependability evaluation methods are not appropriate given the level of complexity of such systems. Given the ineffectiveness of the current methods, Researcher Bernard V. [10] has proposed the Safe-SADT formalism for dependability evaluation, an extension of the SADT method.

In this section, we present briefly in one hand the Safe-SADT model and in other hand, we show its applicability in industrial fields through two case study. In fact, dependability evaluation is crucial to controlling the risks associated with system failure, and for this reason, it is one of the fundamental steps in automated system design [11].

Indeed, the Safe-SADT approach deals progressively with complexity. Top-down and hierarchical, it focuses on the functions that the system must achieve through function entities and material entities. First, the system is described generally, and then the details are embedded as the analysis progresses. A Safe-SADT model is organized hierarchically.

At the top level, the system is summarized with a single global block A0. This block can be broken down at a lower level with more blocks that contain more information on the subsystems. This lower-level decomposition is performed until the parts that make up the overall system are listed (e.g., material entities within the operational architecture, which are specified at the bottom of a Safe-SADT block).

The advantage of this formalism is that it allows the formalization of functional interactions by integrating dependability parameters]. The Safe-SADT approach provides a block representation to graphically define complex systems in terms of functional requirement specifications (FRS).

Thus, the formalism allows complex systems to be described in terms of systems, subsystems, and the relationships between subsystems. Each system decomposition is defined with a Safe-SADT block with the objectives of clearly specifying the input functions, output functions, and material entities executing the input functions under some constraints. By means of significant example, Researchers, Cauffriez L. & al. [12], have presented a study on the use of field buses combined with intelligent sensors and actuators which are opening up new possibilities for building control systems. If field buses seem to be a good solution to improve the dependability, it could be also a trap due to the new possible failures they may introduce. They have studied these failures and their effects on dependability parameters. Some elements are presented in order to provide designers with means to assess dependability at each design step by integrating field feedback. Assessing dependability is too often limited to an evaluation at the end of the design process, which often involves reselecting previous choices. To sum up, this contribution constitutes a structured overview of field bus faults given to help users to select the most suitable field bus for their applications, both in control and measurement.

Researchers, Cauffriez L. & al. [13], have presented a computer-aided design tool software for modeling and comparing several architecture design choices early on in the design process. Its originality is based on operational architecture composed of function entities executed by material entities. A Monte Carlo approach allows simulation of "possible life history" and points out design's weaknesses using sensitivity analysis. The researchers have illustrated the tool functionalities with a temperature system. Possibilities for future research in terms of software development and industrial applications are provided.

PRESENTATION OF THE SA/RT METHOD

The SA/RT (Structured Analysis for Real-Time Systems) method was defined in the mid 80's by two research teams: Ward and Mellor [14], Hatley and Pirbhai [15]. Their works, carried out separately, propose real-time extensions of DeMarco's structured analysis. The extensions concern the addition of the control functionalities describing the dynamics of the system and the corresponding data processing [16].

The basic idea of this graphical method consists in putting in evidence inside data flow diagrams elements dedicated to the control view. A data flow diagram (DFD) provides a processes (activities) net drawing. A DFD expresses a representation means to depict inter-processes exchanges, in order to enlighten the control or data flows sent or received by each process when an execution is performed. Consequently, such a diagram shows a special activity whose role is to pilot the set of other activities. This control activity study is therefore tackled to describe the effective control logic [17].

Figure 2 shows the representation principles of the functional, the behavioral and the informational view of a system by means of the SA/RT method.

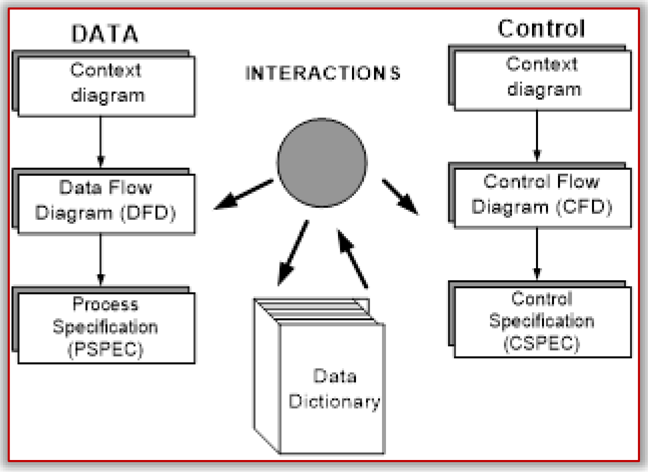

Figure 2. SA/RT method

The functional view of SA/RT method is modeled by means of the structured analysis tools. The graphic components of the model are data flows, data storages and processes. They are organized by means of specific construction rules into diagrams named Data Flow Diagrams (DFD). The first DFD is the context diagram. It gives the only system representation inside which are visualized the model borders. They define the limit between the system and its environment. The model is organized as a hierarchy of DFD, whose context diagram represents the highest level. Each DFD expresses a refinement of one immediate ancestor DFD such that the decomposed process is called father process of one of its son processes. At the bottom of the branching, the leaves identify atomic processes. Also called primitive, those processes cannot be described through DFD; we have to resort to another representation mode. This ultimate step of the functional modeling corresponds to the process specification (PSPEC) which is mainly done using textual languages.

- Informational aspect of the SA/RT method: The data and the events occurring at all the model stages are defined in a dictionary. As for the complex data storage, the WM approach predicts a modeling by means of Entity/Association diagrams used for modeling sizeable and complex data such as databases.
- The behavioral view of SA/RT: this aspect of the studied system is supported by tools which are able to take into account events needed to manage correct process execution. A control model is derived for each DFD drawn and supplies the control logic to be applied to their related sub-processes. So the control logic hierarchy is established upon the DFDs one. Each control unit specification is realized using automaton, or state transition table or array.
- SA-RT is the specification models that have been widely used in real-time system and software engineering applications. It is a generic method addressing both

system analysis and the design of real-time and complex systems.

- SA/RT diagrams deal with two views of the considered system: a static view, the structural description, and a dynamic view, the behavioral description. In SA/RT standards (though slightly different), the structural description is done by data flow diagrams (DFD) and the behavioral description is done by the control flow diagram (CFD) coupled with state transition diagrams (and/or process activation tables). For SA/RT specifications other tools are also used (including process specifications, data dictionary...) which are mainly textual tools.

REVIEW ON THE SADT AND SART METHODS

This section presents some studies of the SADT method and its applicability in the industrial and pedagogical fields that have been presented in various researches:

Researchers, Lezina, O.V. and Akhterov A.V. [18], have presented the structure of information component of pedagogical knowledge management system in the chair of technical university and the possibility of using the ontologies and SADT methodology for the design of information component of such system. In fact, the modern stage of social development, the emergence of the knowledge based economy; the rapid dissemination of educational information and telecommunication technologies, as well as modernization of the system of higher education makes new requirements to preparation of graduates. This requirement necessitates the need to create and use of flexible pedagogical knowledge management system.

Researchers, Yulian C. & al. [19], have investigated and analyzed the production workflow in small and medium toy manufacturing enterprises by SADT and simulation analysis. They find out that tracking information is incomplete and information flow and material flow are out-sync due to lacking material and production process collaboration in current system. Thus, the tracking objective creates a need for systems to collaborate material flow and production flow in manufacturing enterprises. In fact, material safety and traceability is of great importance in toy manufacturing because there have been tougher requirements on toy product safety imposed by new international regulations.

Researchers, Demri A. & al. [20], have proposed to employ SADT, FMEA, SEEA and Petri networks methods to study a mechatronic system. In fact, a study of system reliability is generally preceded by a functional analysis, which consists of defining the material limits, the various functions and operations realized by the system and the various configurations. This stage does not give information about the modes of failure and their effects. It is necessary to complete it by a second one taking into account the dysfunctions in order to model suitably a complex system with Petri networks.

Researchers, Plateaux R. & al. [21], have proposed to integrate the entire downward side of the design V-cycle in order to achieve to a modelling continuity through the different levels of design approach (requirements, functional, components and structural). For this, they have proposed a hybrid methodology based on several tools, languages and methodologies such as SADT, SysML, Modelica, in a single environment: Dymola.

Researchers, Wenan T. & al. [22], have proposed respectively SADT-based e-learning process architecture and an SOA-based knowledge management mechanism. After that, they have discussed the process management model of e-learning from an overall lifecycle perspective. At last, the corresponding knowledge management architecture is presented to further support this process management.

Researchers, Yahmadi R. & al. [23], have presented a degradation analysis of the lead acid battery plate during the manufacturing process. The different steps of the manufacturing process of plate such as manufacturing of lead oxide, paste mixing and manufacturing of grid, pasting, curing and drying are describe d by SADT. The general analysis of all the causes and potential factors causing a low quality of the plate during the manufacturing process is created by the Ishikawa diagram. This description is completed by the Causal Tree Analysis in order to seek the various possible combinations of events leading to the low quality of lead acid battery plate during the pasting, curing and drying process.

Researchers, Zenniz Y. & al. [24], have presented the dependability of an automatic detection and extinction system with Halon. The risk control and analysis is done using three analysis methods, SADT, FMEA and FTA. The objective of the research is dependability planning optimization with the identification of the potential risks and these consequences on system. The optimal recommendations must be proposed. Decision tools used to improve production will be proposed. To achieve these objectives a detailed description of process structure and the main principles of both methods are given. These methods are applied on the system with a comparative study between the results given by these methods.

Researchers, Puilk E. & al. [25], have developed Reconfigurable Manufacturing Systems (RMS). With their modular structure, they can be integrated in a short period of time. Though this leaves more time for product development, it does not exclude the industrialization risks. Since configuration of equipment only works reliably if its process technology is well understood, it is needed that poorly functioning manufacturing processes are detected and addressed in an early stage. Only then, sufficient time is available for corrective actions to be taken. This paper presents a scientific framework to model the development of RMS. The method has the capability to uncover manufacturing risks during early development. In combination with RMS, the freeze of system architecture can indeed be pushed backwards in time. The method uses the SADT. The process risks, as outcome of the analysis process, are ranked using a FMEA to determine the severity of their impact.

Researchers, Jimenez F. & al. [26], have developed models and tools for system design and synthesis of MEMS-micro based on SDL (specification description language), SA-RT and PNs. In fact, a main problem concerns the design of these varied circuits because it associates disciplines such as electronics, mechanics, chemistry, etc.

DOMAIN MODELLING STRUCTURED ANALYSIS METHODS

The domain modeling can bring correct and complete context to today's software development methods. In fact, SADT has over 35 years of domain modeling experience, across a vast number of problems involving systems ranging from tiny to huge, in a wide variety of industries [27].

Indeed, SADT is a proven way to model any kind of domain. Its power and rigor come from:

1) a synthesis of graphics, natural language, hierarchical decomposition, and relative context coding,
2) distinguishing controls from transformations,
3) function activation rules, and
4) heuristics for managing model complexity [4].

Furthermore, domain modeling is at the core of SADT, and when properly used, the method can produces holistic domain models that can address any level of complexity or abstraction. Thus, SADT can produce a set of very concise, small models, with tightly connected context and content.

The distinguishing, unique aspect of SADT is its ability to holistically describe an entire domain to any desired low level of detail, and to describe its context to any desired high level of abstraction. It is thus, SADT and SART have an extremely simple graphic language and a model creation technique that, from the same starting point of any particular subject, can describe:

1) all details (i.e. decompose complexity),
2) the context of that subject (i.e. context modeling).

CONCLUSIONS

In this paper, we have presented a research on two different methods of structured analysis which are SADT and SA/RT. Then, we presented a review on this kind of structured analysis used to software development methods by using SADT and SA/RT.

Since context preservation is crucial for domain modeling, SADT and SA/RT have merit for augmenting the software development methods. In fact, three of its core features are: context, model, and viewpoint. Not only can SADT and SA/RT correctly, comprehensively and consistently describe an entire domain and not just the immediate context of a software system, it can describe that domain in rich and varied ways using carefully designed in-context supplements. Moreover SADT and SA/RT methods have been invented for general purpose domain modeling. In fact, a set of graphical diagrams and supplements that correctly and completely describe the domain. So, an approach has been taken to providing benefits to software development methods by using SADT and SA/RT.

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USING SCADA APPLICATIONS IN WATER SUPPLY SYSTEM

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Abstract: The application of information technology has made it easier to apply all other technologies in everyday life. In this paper, the application of SCADA applications in the Pljevlja plumbing system is explained. Its main role is to utilize certain parameters for dosing chlorine in water. In this way, the primary aspect of this work is placed on the ecological aspect and on the preservation of human health. All other factors that are obtained by applying these applications are secondary, and among other things there is a reduction in error options, a reduction in the number of employees and savings. They are based on one or more implementation principles. Also, the paper describes methods, techniques and devices that allow the automated process of chlorine dosing in the water supply system.
Keywords: SCADA, water supply system, water treatment plants

INTRODUCTION

Water supply systems use water that needs to be processed to be used as potable. The most commonly needed processes are: sedimentation, filtration, disinfection [7]. The most common form of water disinfection is chlorination [22]. The parameters that are monitored during the treatment of water are variable and depend on the quality of the incoming water in the water treatment plant [14], [17]. The parameters that are monitored are physicochemical and microbiological water treatment plants are automated and the parameters are monitored and recorded continuously [8], [15], [20]. If such a change in the quality of the inlet water occurs, the water treatment devices cannot process it to the level of the quality of the drinking water, the probing devices send analogue or digital impulses to PLC ie. programmable logic controller. PLC is a device that is currently stopping water production in order to avoid complications related to the contamination of drinking water [4], [10], [18].

One of the most commonly used methods for water disinfection is the insertion of chlorine (or some chlorine compound) as a strong oxidizing chemical agent. In the water supply facilities, besides dosing various other chemicals for water preparation, chlorine is added as one of the usual disinfectants. The addition of chlorine can be in the form of gas (Cl2) or in the form of a liquid when one of the chlorine compounds is added. After the addition of chlorine, one part is spent on initial disinfection of water in the water supply and the other part remaining in water distributed to consumers. This residual amount of i.e. residual is controlled and maintained at a predetermined level, typically from 0.2 to 0.5 mg / l of chlorine that is in accordance with the officially legislation [6], [21]. Automation of the chlorination process greatly reduces the influence of the "human error" present during manual regulation. A well-tuned machine maintains an uninterrupted level of residual chlorine in the water, always at a given level, without the intervention of a human being. PLC Controller based on the continuous measurement of chlorine residual in water (using chlorine analyzer) increases or decreases chlorine dosing. This method of operation is called "Residual Management". There is also a different kind of management that is used if the amount of chlorinated water is variable. Less chlorine is added to the smaller amount of water, and in larger, proportionately more. The necessary information about the current flow of the controller is obtained from the appropriate flowmeter, and based on this increases or decreases the dosage. This type of management is called "Flow Control". The most complex management method is used if the water has variable chemical properties over time (and hence chlorine demand) and at the same time, variable flow. Then, "Flow and residual management" is performed, or combined management. Various machines used up to the last ten years have been designed as electromechanical or electronic circuits on an analogous principle of operation. Today, modern, digital, microprocessor devices are used in this field. In addition to the unlimited possibilities of programming and adjustment of the chlorine problem solving, they also enable remote communication with other computer devices, thus increasing the possibilities of automating and managing all devices on one water supply from a single command center SCADA ie. supervisory control and data acquisition system [4], [9]. Steel chlorine cylinders as well as dosing devices must be placed in a separate room (chlorine station) with forced ventilation, shower and drainage by sewage connection. On the outside of the chlorine station there is a cabinets with a gas mask and shower drain.

MATERIAL AND METHODS

Water disinfection ie. chlorination: involves the removal or destruction of pathogenic and optionally pathogenic microorganisms. In the course of disinfection or sterilization of water in microorganisms, gross disorders of the colloidal balance (due to the effects of physical, physical-chemical and chemical agents), and the disturbances of the balance of their fermentation system occur.

Irreversible physico-chemical changes of breathing fingers and other ferments of the metabolism of microorganisms are expressed in particular, which leads to inactivation and cell death. Water disinfection can be achieved in several ways: physical (prokating, ultraviolet rays - UV, ultrasound), chemical agents (lime, electrolytic silver, ozone, iodine, persistent acid and chlorination) [1], [3], [12], [16]. All the listed methods and agents, other than chlorination, are either expensive or inappropriate, and are rarely considered for the disinfection of large quantities of drinking water. Water is most often disinfected by using Sodium Hypochlorite or by using preparations that release a certain amount of active chlorine in water [13].

Disinfectant based on chlorine, in most cases, is introduced into the water in the form of a solution - dosing or injection. On the supply line through which water enters the facility, there is a pulse water meter, which, depending on the flow of water, sends an electrical impulse to the dosing pump, which disinfects (sputter) a disinfectant into the same tube from the tank with chlorine solution, in the position on which the device is located. The dosing pump is considered to be in the installation to dosage a certain amount of chlorine in the water [19]. Using the digital photometer or some other (less reliable) method at the end of the object, the index of residual chlorine in the tubes is checked. Chlorine acts destructively on the cells of all organisms, especially on microorganisms, because they do not tolerate even very small amounts of chlorine that the human organism does not respond to. The bactericidal effect of chlorine is very fast. Already within minutes or two, this gas inactivates most fermenting microorganisms in their metabolism. Chlorine is a particularly sensitive SH-fermenting microbial. In addition, it acts destructively and on protoplasm. Spores, algae, protozoa and cysts are relatively resistant to the effect of "normal chloride doses". Water chlorination is a cheap, reliable, highly efficient and tried process for water disinfection [5].

The success of chlorination of water depends on:

- Types of chlorine preparations.
- Biological peculiarities of microorganisms - less or higher sensitivity of wet organisms to chlorine. The residual chlorine value was determined at the earliest 30 minutes from the beginning of chlorination.
- Homogenization and contact of the chlorine preparation with water.
- Temperature - at lower temperatures, water disinfection is slower. At 10°C it is necessary to double the amount of chlorine at 20°C.
- Meteorological conditions - sunlight accelerates the process of disinfection and the loss of active chlorine from the water.
- pH value of water - The optimum pH of water for chlorination is 6.2 to 6.5 [6], [21].
- Water miscibility - reduces the efficiency of chlorination, and the water must always be cleaned and filtered.
- Organic matter - consumes a certain amount of chlorine, so the dose must be increased. That is why "chlorine test" is performed, that is, the "chlorine demand - chlorine number".

Figure 1 shows the screen in the control room of the city Pljevlja water supply, which monitors all wells in the city and their parameters (amount of water, etc.) on-line.

Figure 1. The on-line monitoring wells parameters

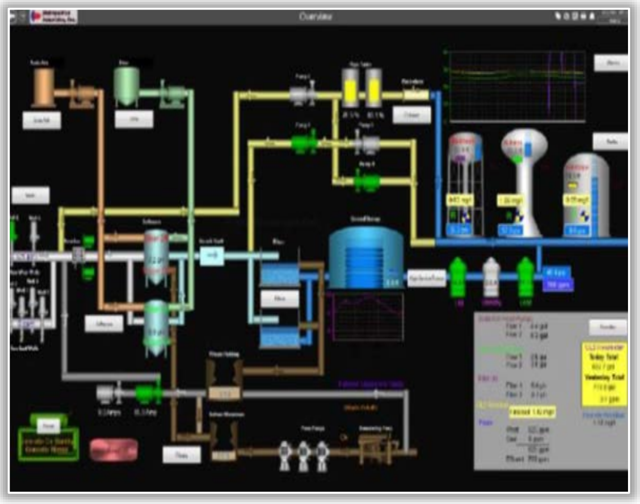

Figure 2. A functional scheme for drinking water

In Figure 2 is presented a functional scheme for drinking water. The icons inserted as a parameters are measured within the given devices. The parameters that are measured and monitored are following:

- the amount of raw water entering the system,
- voltage of well pumps (working and spare),
- the acidity of the flywheel (water and chemicals to be dosed),
- new in tanks (water and chemicals),
- the water's water content and the amount of chlorine in the residual,
- the valve position on-off.

Based on the parameters of the system as it automatically corrects itself. The boundaries of the parameters that are monitored can be in permitted intervals or may jump out of the allowed intervals. Upon receipt of signals that the PLC system recognizes and if the associated parameters are equal to the allowed limits, a certain alarm is activated. After that, the system switches to a higher degree of protection.

It is important to note that the complete PLC system can also be connected with mobile devices. Figure 3 shows the hardware connection with back-up data because the system is in on-line mode and it is necessary to have stored data for a certain period. There is also monitoring one of the wells with data tracking with included data transfer to the mobile device with the android system.

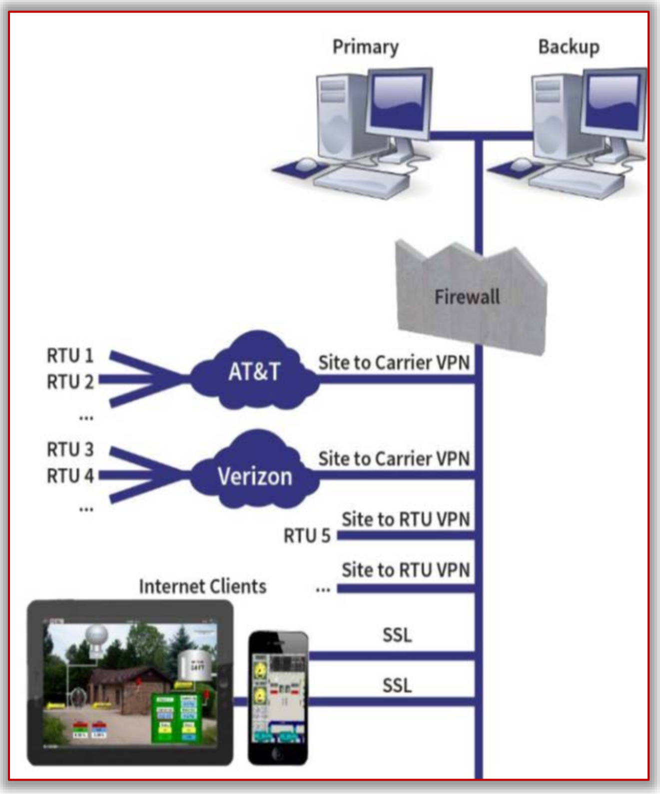

Figure 3. The hardware connection with back-up data

PRESENTATION AND DESCRIPTION OF THE AUTOMATED CHLORINE DOSING SYSTEM IN DRINKING WATER

The automatic gassing dosing system consists of the following elements:

» bottles with laced chlorine,
» collecting lines for bottles with chlorine valves, carriers,
» two doses - vacuum regulator mounted on bottles and connected to an automatic switch an automatic switch whose function is that once a bottle is emptied, the chlorine is automatically switched over and the chlorine dosage from the other bottle,
» flow meter - rotameter (measuring tube with dosing valve) showing flow in gr / h of chlorine,
» injector from mixing hose,
» pump for increasing the water pressure for securing the formation of a vacuum,
» PLC Device and control valve.

A scheme for chlorination of water with neutral chlorine gas chloride is shown in Figure 4.

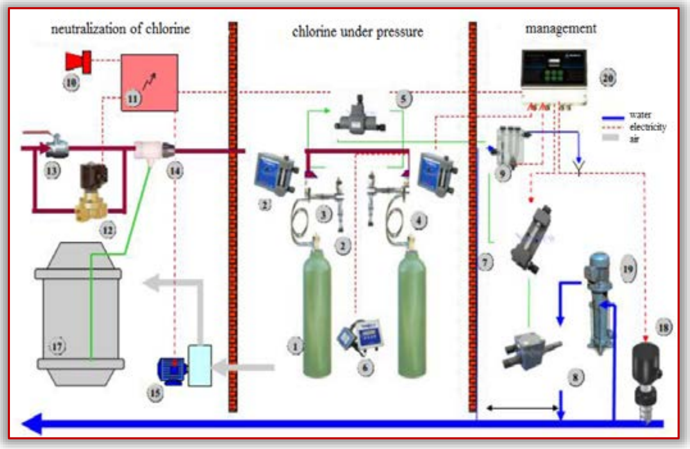

Figure 4. A scheme for chlorination of water with neutral chlorine gas chloride
1- bottles for chlorine; 2- gas vacuum regulators; 3- collecting line with pressure gauge; 4- flexible tube; 5- automatic vacuum switch; 6- the chlorine detector probe in the air; 7- electromotor valve with rotameter; 8- coupling; 9- measuring cell of chlorine in the residual, EMEC; 10- signal trumpet; 11- electrical cabinet; 12- electromagnetic valves; 13- globe valve manually; 14- coupling for neutralization; 15- centrifugal valves; 16- diffusers; 17- Reservoir neutralization solution V = 200l; 18- prick flowmeter; 19- pump for pressure boosting; 20- PLC

PLC controller is an Electronic Microprocessor Device. It has its inputs to which electrical information is given on the state of the process, and exits through which it commands the process. Communication with a person is done through the Operational Panel, or a remote digital connection with a PC. Boils with chlorine and dosing equipment must be stored in a separate room (chlorine station) with forced ventilation, shower and drainage with sewage connection. On the outside of the chlorine station there is a cabinet and a switch to turn on the fan. In the room, the free chlorine indicator is connected to the alarm device (chlorine detector), which activates the neutralization system in case of chlorine expulsion.

The floor in the chlorine station must be carried out with the fall towards the drainage in the drain. If accidentally, due to some malfunction, the gas chlorine emitted into the atmosphere would result, an environmentally very dangerous situation would occur. The presence of chlorine in the air is controlled by an electronic device - chlorine detector.

Special electrochemical probes are used to measure the concentration of chlorine in the air, and the electronic device includes a chlorine neutralization plant from the air. The ejector within the device compulsorily inserts contaminated air through a filler that discharges with the neutralization liquid that is driven by the recirculation pump. In such a forced movement of polluted air and neutralizing liquid, and neutralizing chlorine from the air.

This process lasts until the concentration of chlorine in the air drops below the given level. All activities are recorded by PLC device and send it to the database server and auto-record is done. PLC in addition to data transfer, the device also provides the ability to download data with USB flesh, as shown in Figure 5.

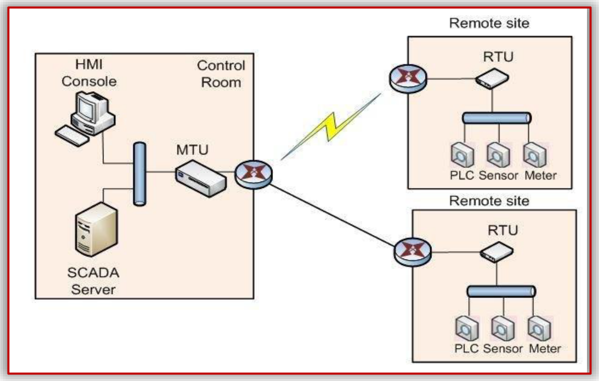

Figure 5. Data transfer and storage

RESULTS AND DISCUSSION

Water entering the city water supply network should be chlorinated continuously, in order to prevent secondary infections. The effective dose of chlorine is determined by experiments. The adjusted concentration is independent of the amount of water flow, because the regulation system automatically maintains a constant concentration of the active chlorine.

In the city Pljevlja core supplied with drinking water from the water supply system there are about 19,000 consumers. The water is provided from the Otilovići Reservoir, the river Cehotina and Breznica and several sites. Considering that Pljevlja is surrounded by mountains in the period from February to May, there is snow melting and accumulation of larger quantities of water. This leads to water blur and deterioration of quality. Then special attention is paid to the water treatment system and quality control.

Raw water is collected in wells. Well pumps pump water into the precipitator. In the precipitator, physical impurities are deposited and aeration is performed. Water meters are installed in the precipitator. Measurement level meters are level ultrasonic or float system. When water is precipitated and reaches a certain level of water, the water is transferred to the filtration. From the filter fields, water is pumped into the reservoirs via filter pumps. Disinfection of water is carried out in the reservoirs and sent via the water supply system to consumers.

The work of well and filter pumps, water level measurement and automatic process control are carried out by PLC [2]. Everything is controlled and monitored in the main control room of the water supply system where the SCADA system for control and data transmission is installed [9]. Also, the main operatives, quality managers, laboratory heads, technical directors have the ability to receive signals over a mobile network [11].

Special attention is paid if parameters that deviate from the given parameters, then the system reports an error and sends the alarm signals. In the plant and control room, signal lights and sirens have come down. All employees who have the authorization to monitor and control the value of SMS messages on mobile devices. The most important parameters whose measurement is monitored are:

- chlorine in the water,
- temperature,
- pH value,
- flow,
- chlorine in the air,
- pump working,
- the system of neutralization.

The measured values are stored in the database. Chlorine is dosed with a vacuum system in the reservoir. In the tank after the dosing and disinfection of the chlorine volume measurement probe in the residual measured value, it sends the signal 04-20m. PLC. a controller that opens / closes the electromotor valve on chlorine bottles.

The dosage is also carried out according to the flow of water by applying to PLC the device programmates chlorine dosing through the openness of the electromotor valve. According to the standards it is desirable that water goes to consumers with 0.5 g $Cl2$ / m3 to consumers. Without the pump, the system could not function. Two pumps are always installed [19]. One pump is working and the other is a spare pump. PLC the screen is monitored which pump is on, the number of hours of operation and the number of pumps turning on.

CONCLUSIONS

Processing information about input water quality includes measurement activities: input, processing via PLC, output, storage and control. An input as a data resource is an activity that determines the operation of an automated system that, with its activities, brings the measured values to an acceptable level. All input and output parameters are stored on the main database every day in real time which is in accordance with the work of author [14].

Within the SCADA system, applications are integrated: hardware, software, databases, procedures and frames - CASE technology. Also in process discussed in this work, there is an exchange of data exchange among employees and the possibility of common tool access, which allows employees to call a number of different tools in the same way, from the menu and compare the outputs of chemical dosing, pump operation, opening filter the fields in the way they need. In this way, the primary aspect of this work is placed on the ecological aspect and on the preservation of human health. All other factors that are obtained by applying these applications are secondary, and among other things there is a reduction in error options, a reduction in the number of employees and savings.

Note

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