



# ACTA TECHNICA CORVINIENSIS - BULLETIN of ENGINEERING



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**ACTA Technica CORVINIENSIS**  
BULLETIN OF ENGINEERING

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In a very short period the *ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering* has acquired global presence and scholars from all over the world have taken it with great enthusiasm.

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

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### General Aims

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

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

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**ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering** is an international and interdisciplinary journal which reports on scientific and technical contributions. The **ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering** advances the understanding of both the fundamentals of engineering science and its application to the solution of challenges and problems in engineering and management, dedicated to the publication of high quality papers on all aspects of the engineering sciences and the management.

You are invited to contribute review or research papers as well as opinion in the fields of science and technology including engineering. We accept contributions (full papers) in the fields of applied sciences and technology including all branches of engineering and management.

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**Invitation**

We are looking forward to a fruitful collaboration and we welcome you to publish in our **ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering**. You are invited to contribute review or research papers as well as opinion in the fields of science and technology including engineering. We accept contributions (full papers) in the fields of applied sciences and technology including all branches of engineering and management.

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

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*ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering seeking qualified researchers as members of the editorial team. Like our other journals, ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering will serve as a great resource for researchers and students across the globe. We ask you to support this initiative by joining our editorial team. If you are interested in serving as a member of the editorial team, kindly send us your resume to [redactie@fih.upt.ro](mailto:redactie@fih.upt.ro).*



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**Abstract:** Disasters, natural or manmade, are part of challenges faced by human beings while they are living on the earth in any community. One thing common with all the disasters is that they cannot be averted. For the nations, the task is to deal with circumstances emerging sequel to any disaster. This paper is focused on the analysis of Disaster Management (DM) system in place in Pakistan. It initiates with an insight into the challenges faced by the country while focusing only on major natural disasters like earthquakes and floods that are perpetually causing damage to life and property over the years. Nevertheless, other significant challenges have also been enlisted. This is followed by a review of the system that has been put in place by the government to deal with the situation created consequent to any disaster. In this part, a detailed analysis of the organization and functioning of various bodies has been discussed; highlighting the shortfalls in resources and the methodology employed to apply these resources. At the end, pertinent recommendations have been proffered to address the observed shortfalls. Mainly, the paper is a summary of a host of writings available on the issue, prepared with a focused approach towards core issues prevalent in our country with regards to disaster management. Apart from studying the articles and analyses available on the issue, direct consultation has also been made to official documents of concerned government bodies.

25. **HoKui LAN – SINGAPORE**  
**Abdelnaser OMRAN – MALAYSIA**

**EVALUATING THE UNDERSTANDING OF INDUSTRY TOWARDS BUILDING INFORMATION MODELLING TECHNOLOGY IN MALAYSIA**

133

**Abstract:** Building Information Modelling (BIM) has gained the attention in the construction industry especially within the Malaysian construction context. This paper generally aims to investigating the understanding of industry towards building information modelling technology in Malaysia. Study was carried out through a random questionnaire survey among the registered professional architects and graduate architects. Overall from this research, it was indicates that the level of BIM technology adoption in Malaysia is still low with percentage of 70 although it has been applicable in Asia. Therefore, it is suggested that government should take initiative to promote BIM in order to make more professional in the industry aware of this technology.

26. **Iulia ANGHEL – ROMANIA**

**TRANSITIONAL ECONOMY AND THE NEW ECONOMIC ROLES OF GENDER**

137

**Abstract:** The historical experience of communism becomes a heritage difficult to manage not only in the field of political culture, but especially in the sphere of economic relations. Romanian communism was characterized by a violent segregation of economic roles and by isolation of gender labor force inside some closed economic patterns. The dissolution of the totalitarian order did not solve the problem of economic inequalities, and gender discrimination remains an essential feature of transitional societies. Also, the persistence of economic dependence of women stimulated the aggravation of some previous social and economical cleavages such as: apparition of economic encapsulated enclaves, especially in the country side, stimulation of grey economy, due to the discrimination of women on accessing education, the conservation of a negative balance for gender participation in the field of private initiative. The entire phenomenon mentioned below affected the transition of the Romanian society towards a stabile and functional economical environment. This paper aims to explore the new roles of gender in the economy of transitional states, with a special focus on the Romanian post communist experience.

27. **Alaa M. DARWISH – IRAQ**

**STATIC AND DYNAMIC LOADING TEST OF A RAILWAY BRIDGE**

145

**Abstract:** A case study for assessing the strength of a recently mal constructed Iraqirailway bridge was carried out. The 48.5 m long Reinforced Concrete Bridge shows a Permanent deflection of more than 3 cm at its mid span panel. Responsible Authorities feared of the safety of this bridge and asked for Structural engineering consultancy. The overall bridge elements; piers, bearings, super structure and materials strength have been verified in details, but in this paper the concentration will be focused at a novel method used to perform a loading test. The heaviest available locomotive-weighing 120 tons- was used to conduct the static and dynamic loading test. Surveying team was instructed to tabulate the levels of selected points before and after the passing of the testing locomotive and during its stoppage at certain positions. The bridge showed an acceptable performance under the actual loading of the mentioned locomotive and also it complied with the resisting requirements of the Cooper E-80 standard loading for railway bridges.

28. **Dragoş MANEA, Carmen BRĂCĂCESCU, Cristian SORICĂ, Ilie DUMITRU, Sorin ANDREI, Evelin DAVID – ROMANIA**  
**RESEARCHES REGARDING THE MECHANO-PNEUMATIC DISTRIBUTION ON THE STRAW CEREALS SOWING MACHINES**

149

**Abstract:** This paper presents some theoretical considerations regarding the calculus, design and running of the mechano-pneumatic distribution devices which equip the straw cereals sowing machines. The distribution devices make the seeds measuring and their bleeding to the driven pipes for shovels. This measuring and bleeding process, named the seeds distribution process, affects over the main qualitative index of the sowing machine: flow rate stability, sowing norm, distribution uniformity on the working width, distribution uniformity on row. In paper there are accentuated the advantages of using these distribution devices types in contrast with the classical distribution devices.

29. **Jamiu K. ODUSOTE – NIGERIA****DESIGN AND FABRICATION OF A POLYTHENE/NYLON WASTES RECYCLING MACHINE**

153

**Abstract:** The traditional methods of disposing polythene/nylon wastes have proved to be relatively expensive and unhealthy. Recycling of these non-biodegradable wastes will be more economical, healthy and safer for the environment. Thus, the objective of this research work is to design and develop a motorized polythene/pure water nylon recycling machine, using locally available materials. The machine is designed to use fixed and rotary blades, which are rotated by high-speed electric motor. Heat is provided for softening of the polythene prior to shredding by the blades. Tests were performed on the recycled machine to determine its possible output, and the results showed that 30-40 kg of recycled flakes was produced per hour at a machine speed of 2880 rpm. The flakes are used with recycled plastic wastes and/or virgin materials for production of colored plastic product.

30. **Ottó SZABÓ – HUNGARY****STOCHASTIC MODELING OF HONING PROCESSES**

157

**Abstract:** More accurate description of abrasive manufacturing procedures can be done stochastic methods that is why their application are advantageous. The author have elaborated the stochastic mathematical model of abrasive microcutting systems and processes of the tools with undetermined edge-geometry and many edges that makes description of e.g. honing, grinding possible. The system of mathematically formulated relationships corresponds to the experimental observations. The elaborated method is applicable also to describe the abrasive wear processes at grinding or at machining. This method provides the ability to calculate and design the statistical parameters of the machined surface and the process.

\*\*\* **MANUSCRIPT PREPARATION – GENERAL GUIDELINES**

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The **ACTA TEHNICA CORVINIENSIS – Bulletin of Engineering, Tome VIII/2015, Fascicule 2 [April–June/2015]** includes scientific papers presented in the sections of:

- » **The 3<sup>rd</sup> INTERNATIONAL CONFERENCE INDUSTRIAL ENGINEERING and ENVIRONMENTAL PROTECTION – IIZS 2014**, organized in Zrenjanin, SERBIA (15<sup>th</sup> of October, 2014), jointly by the University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, SERBIA. The new current identification number of the papers are the # 7, 8, 10, 11 and 13, according to the present contents list.
- » **The 8<sup>th</sup> International Conference for Young Researchers and PhD Students – ERIN 2014**, organized by the Brno University of Technology, in Blansko - Českovice, CZECH REPUBLIC (April 23<sup>rd</sup>–25<sup>th</sup>, 2014). The current identification numbers of the selected papers are # 14 and # 16, according to the present contents list.
- » **The 3<sup>rd</sup> International Conference on Applied Sciences – ICAS 2014**, organized by the Politehnica University of Timisoara, Faculty of Engineering Hunedoara (ROMANIA) and Military Economics Academy of Wuhan (CHINA), in cooperation with the General Association of Romanian Engineers, branch of Hunedoara, in Hunedoara, ROMANIA (October 2<sup>nd</sup>–4<sup>th</sup>, 2014). The current identification numbers of the selected papers is # 26, according to the present contents list.
- » **The DISSEMINATION CONFERENCE of the Centre of Excellence at the University of Miskolc, entitled INNOVATIVE MECHANICAL ENGINEERING DESIGN and TECHNOLOGIES**, organized in Miskolc, HUNGARY (30<sup>th</sup> of January, 2015), jointly by the University of Miskolc, Miskolc, HUNGARY. The new current identification number of the papers are # 9, 12, 15, 21 and 30, according to the present contents list.

Also, the **ACTA TEHNICA CORVINIENSIS – Bulletin of Engineering, Tome VIII/2015, Fascicule 2 [April–June/2015]**, includes original papers submitted to the Editorial Board, directly by authors or by the regional collaborators of the Journal.



## BRAKING PROCESS INFLUENCE ON VERTICAL LOAD OF RAILWAY VEHICLES

<sup>1-3</sup>. University POLITEHNICA of Bucharest, Faculty of Transports, Department of Railway Rolling Stock, ROMANIA

**Abstract:** The paper investigates the effects of pitch phenomenon during railway vehicles braking process. The variation of vertical loads on bogies and axles are presented for the case of emergency braking, analysing also the influence of mechanical wheel slide prevention devices intervention. In simulations, experimentally acquired data of the air pressure evolution in the brake cylinders are used. The simulations results are presented and discussed. The effects on braking process are enhanced, including the case of poor wheel-rail adhesion. Conclusions regarding the pitch effects and operational consequences of mechanical wheel slide prevention devices actuation during braking actions are formulated.

**Keywords:** railway vehicle, pitch, braking, vertical loads, wheel slide prevention devices

### INTRODUCTION

The main target of the present study is to evaluate the evolution of axle vertical load variation determined by the pitch phenomena during braking actions, enhancing the effects of the action of wheel slide prevention devices that occur in the case of poor adhesion.

It is known that pitch phenomenon determines supplementary vertical loadings / unloadings on bogies and axles, modifying accordingly the adhesion forces. Given that in the case of railway vehicles the wheel-rail adhesion is essential for the starting tractive effort and critical in braking process, limiting both traction and braking capacities, concerns about the consequent effects of pitch phenomena are legitimate.

An extensive study concerning the pitch of locomotives was conducted by dr. G. Borgeaud, published in 1967 in the Bulletin of L'Al du Congrès des Chemins de Fer [1]. In his paper, the author presents theoretical aspects as well as examples of calculations of the vertical load variations for different types of locomotives and axle drive action modes. Regarding the specific problems of braking, comprehensive experimental and theoretical studies were performed regarding wheel-rail adhesion, pitch phenomena and its effects on braking process; the safety of traffic was also analysed [2, 3]. Researches on the pitch phenomenon on railway vehicles during braking actions were also performed by C.Cole [4], McClanachan [5], Burada [6], Cruceanu [7] Crăciun [8] and others.

Under the action of inertial forces to which the rail vehicle is subjected during braking, variations of vertical loads occur on the bogie and axle spindles, exerting the suspension elements, affecting the comfort and also the integrity and safety of passengers and freight.

In the present paper, based on a classical model of a passenger railway vehicle on bogies with two suspension levels, the vertical load variations during braking generated by pitch are presented. For an accurate determination of braking forces, essential for the development of the studied phenomenon, experimental values of the

brake cylinder air pressure evolution, in different operational-like cases, were performed on a computerised testing stand. A simulation program was used for evaluation of pitch effects during emergency braking actions, originally taking into account repeated actuations of mechanical wheel slide prevention devices. Results are discussed and analysed and the main conclusions are outlined.

### THEORETICAL BASES

During braking, the vehicle components are subject to supplementary loads due to inertia forces and to forces developed in the brake rigging. When a braking action is performed, inertia forces  $I_c$  and  $I_b$  appear at the level of vehicle body and, respectively, at the level of the sprung part of the bogies – see Figure 1 [7, 9, 10].

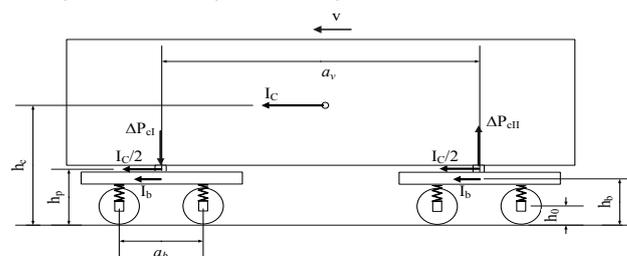


Figure 1. Forces acting on vehicle during braking

The body force of inertia  $I_c$  is transmitted evenly to bogies through the two links (pivots) and it is of the form:

$$I_c = m_c \cdot \ddot{x} \quad (1)$$

where  $m_c$  is the mass of vehicle body, and  $\ddot{x}$  is deceleration that develops during the brake action.

Because of the fact that this force can be considered to act in the centre of mass of the vehicle body, it produces a force couple (torque) which rotates the vehicle body about y axis, which is given by the following formula:

$$C_{yc} = m_c \cdot \ddot{x} \cdot (h_c - h_p) \quad (2)$$

where  $h_c$  is the height of the centre of mass of the vehicle body and  $h_p$  is the height of the connection point between the bogie and the vehicle body.

The pitch angle of the body caused by the action of the torque  $C_{yc}$  is [9]:

$$\varphi_{yc} = \frac{C_{yc}}{K_{xc}} \quad (3)$$

where  $K_{xc}$  is the body suspension longitudinal angular stiffness, given by:

$$K_{xc} = \sum_{i=1}^2 \sum_{j=1}^2 k_{cij} \cdot (x_{cij} - x_{c0})^2 \quad (4)$$

In eq. (4),  $x_{c0}$  is the  $x$ -coordinate of the centre of motion of the vehicle body;  $x_{cij}$  and  $k_{cij}$  are, respectively, the  $x$ -coordinates and the stiffness of the bogie-body suspension points.

Substituting equations (4) and (2) in equation (3), it becomes:

$$\varphi_{yc} = \frac{m_c \cdot \ddot{x} \cdot (h_c - h_p)}{\sum_{i=1}^2 \sum_{j=1}^2 k_{cij} \cdot (x_{cij} - x_{c0})^2} \quad (5)$$

For a railway vehicle equipped with two-axle bogies, characterized by elastic and geometric symmetry, we considered:

$$k_c = k_{cij}, \quad i=1,2, \quad j=1,2$$

$$x_{c11} = x_{c12} = x_{c1}, \quad x_{c21} = x_{c22} = x_{c2}$$

The variation of the vertical loads introduced, by rotating the box, which appears in the box - bogie connection points are:

$$\begin{aligned} \Delta P_{cl} &= -2k_c (x_{c1} - x_{c0}) \varphi_{yc} \\ \Delta P_{cll} &= 2k_c (x_{c2} - x_{c0}) \varphi_{yc} \end{aligned} \quad (6)$$

for:  $x_{c0} = \frac{a_v}{2}$ ,  $x_{c11} = x_{c12} = 0$ ,  $x_{c21} = x_{c22} = a_v$ ,

where  $a_v$  is the vehicle wheelbase, the load variations in the bogie - box connection points can be written:

$$\Delta P_{cl} = -\Delta P_{cll} = m_c \cdot \ddot{x} \frac{(h_c - h_p)}{a_v} \quad (7)$$

It can be observed that the first bogie in the direction of displacement is loaded, while the second one is unloaded.

On the bogie frame, there appears a rotation torque due to inertial forces, which develop at the level of the vehicle body and at the level of the sprung part of the bogie:

$$C_{yb} = m_b \cdot \ddot{x} \cdot (h_b - h_0) + \frac{1}{2} m_c \ddot{x} \cdot (h_p - h_0) \quad (8)$$

where  $I_b = m_b \cdot \ddot{x}$  is the force of inertia of the bogie sprung part ( $m_b$  - mass of the sprung part of the bogie),  $h_b$  is the height of the centre of mass of the bogie and  $h_0$  is the height of the centre of the axle.

The pitch angle of the bogie frame caused by the action of the torque  $C_{yb}$  is given by:

$$\varphi_{yb} = -\frac{C_{yb}}{K_{xb}} \quad (9)$$

where  $K_{xb}$  is the bogie suspension longitudinal angular stiffness, which, in the case of a bogie with two axles, is given by:

$$K_{xc} = \sum_{i=1}^2 \sum_{j=1}^2 k_{bij} \cdot (x_{bij} - x_{b0})^2 \quad (10)$$

In previous relationship,  $x_{b0}$  is the  $x$ -coordinate of the centre of motion of the bogie;  $x_{bij}$  and  $k_{bij}$  are, respectively, the  $x$ -coordinates and the suspension stiffness corresponding to each axle journal.

Substituting the relations (8) and (10) in (9), it becomes:

$$\varphi_{yb} = \frac{m_b \cdot \ddot{x} \cdot (h_b - h_0) + \frac{1}{2} m_c \ddot{x} \cdot (h_p - h_0)}{\sum_{i=1}^2 \sum_{j=1}^2 k_{bij} \cdot (x_{bij} - x_{b0})^2} \quad (11)$$

As a result of the action of torque  $C_{yb}$  and of load variations  $\Delta P_{cl}$  and  $\Delta P_{cll}$ , on each bogie, a vertical load variation occurs on each axle journal.

The vertical load variation can be written [6, 7, 9]:

$$\Delta P_{ij} = k_{ij} \cdot [\pm f_z + (x_{bij} - x_{b0}) \cdot \varphi_{yb}] \quad (12)$$

where  $f_z$  is the vertical deflection of the axle suspension caused by load variations  $\Delta P_{cl}$  and  $\Delta P_{cll}$  which is equal and of opposite sign for the two bogies – see equation (7).

Assuming elastic and geometric symmetry of the bogies:

$$x_{b11} = x_{b12} = x_{b1} = 0, \quad x_{b21} = x_{b22} = x_{b2} = a_b$$

$$x_{b31} = x_{b32} = x_{b3} = 0, \quad x_{b41} = x_{b42} = x_{b4} = a_b$$

$$x_{b0} = \frac{a_b}{2}, \quad k_{bij} = k_b, \quad i=1,2,3,4; j=1,2;$$

where  $a_b$  is the bogie wheelbase, then, the vertical deflection of axle suspension can be written:

$$f_z = \frac{\Delta P_{cl}}{4k_b} = -\frac{\Delta P_{cll}}{4k_b} \quad (13)$$

and the supplementary vertical loads on axle journals can be written as:

$$\Delta P_{11} = \Delta P_{12} = k_b \cdot [f_z + (x_{b1} - x_{b0}) \cdot \varphi_{yb}] \quad (14)$$

$$\Delta P_{21} = \Delta P_{22} = k_b \cdot [f_z + (x_{b1} - x_{b0}) \cdot \varphi_{yb}]$$

for the first bogie, and

$$\Delta P_{31} = \Delta P_{32} = k_b \cdot [-f_z + (x_{b2} - x_{b0}) \cdot \varphi_{yb}] \quad (15)$$

$$\Delta P_{41} = \Delta P_{42} = k_b \cdot [-f_z + (x_{b2} - x_{b0}) \cdot \varphi_{yb}]$$

for the second bogie.

### THE BRAKE CYLINDER AIR PRESSURE DETERMINATION

Experiments to determine the brake cylinder air pressure evolution were performed on the passenger vehicle brake system stand in the laboratories of the Railway Vehicles Department of the Faculty of Transport, in University POLITEHNICA of Bucharest.

The dedicated stand is equipped with the bogie brake equipment used in operation for passenger rail vehicles. The air distributor is KE-type and the brake cylinder has 305 mm in diameter. There is a mechanical M2-type of wheel slide protection device on each of the two axles of the bogie of the stand. An air pressure transducer takes the pressure evolution in brake cylinder during the braking actions. The sample rate is 0.02 s and acquired data are processed and stored on a dedicated computer.

The elements of interest in these determinations were the evolutions of brake cylinder air pressure during emergency braking actions, for the cases of normal and poor wheel-rail adhesion. The second

situation was simulated by repeated actuations of the wheel slide protection device.

The interest regarding the effects of such equipment actuation is justified by the fact that the action of mechanical wheel slide protection devices is generally exerted on all the braked axles of the vehicle. More than that, there are induced in the brake cylinders large air pressure variations, having a high rate of decrease, respectively increase after adhesion regaining [7].

Samples of the determined pressure evolutions in the braking cylinder are presented in Figure 2 – 3 corresponding to emergency braking actions.

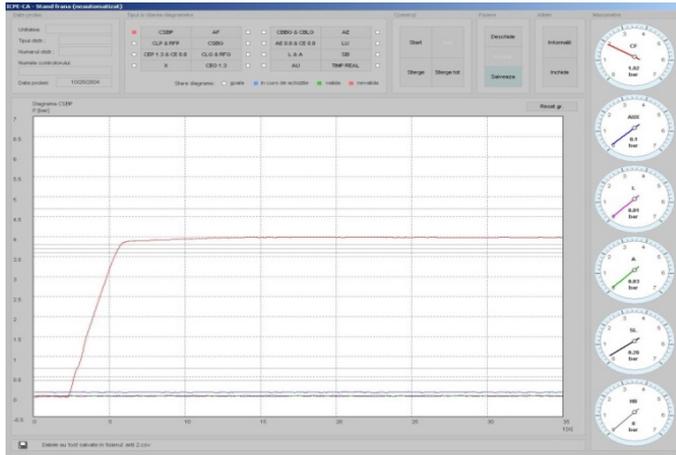


Figure 2. The evolution of pressure in the brake cylinder for the emergency brake action

Figure 3 emphasises the large and rapid air pressure variations in the brake cylinder determined by the repeated actuation of the mechanical wheel slide protection device during the first 10 s of the same braking action.

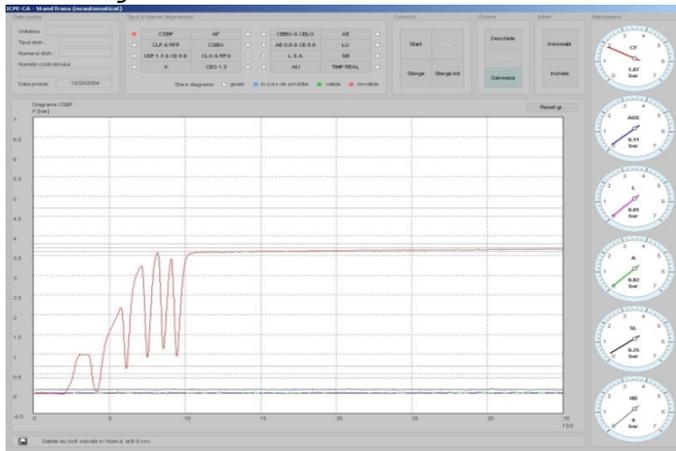


Figure 3. The evolution of the pressure in the brake cylinder with the actuations of wheel slide prevention devices at the beginning of the braking action

It is to expect that such evolution is going to have important influences on the instantaneous deceleration, hence on the pitch effects on the vehicle.

**SIMULATIONS ASSUMPTIONS AND DATA**

According to the main target of the present study and given the multiple factors influencing the development of pitch process during braking regime, a major preoccupation was to identify and eliminate,

as much as possible, any aspect potentially disturbing the direct influence of pressure evolution in brake cylinders experimentally determined.

Hence, certain constraints and simplifying hypotheses were assumed. Regarding the braking forces, their evolutions have relevant impact on the studied problem and, depending on the main braking system of the vehicle, can be determined [11]:

» for the case of disc brake equipped vehicle having individual self-adjusting brake rigging:

$$F_{b,i} = \left[ \frac{\pi \cdot d_{bc}^2}{4} \cdot p_{bc,i} - (F_R + R_{sa}) \right] \cdot i_t \cdot n_{bc} \cdot \frac{2 \cdot r_m}{D_o} \cdot \mu_d \cdot \eta_{br} \quad (16)$$

where:  $d_{bc}$  is the brake cylinder diameter,  $p_{bc,i}$  the instantaneous relative air pressure in the brake cylinder,  $F_R$  and  $R_{sa}$  the resistance forces due to the brake cylinders back spring and to the self-adjusting mechanism incorporated in the piston rod respectively,  $D_o$  the wheel diameter and  $r_m$  the medium friction radius. The dimensionless terms are:  $i_t$  the brake rigging amplification ratio,  $n_{bc}$  the number of brake cylinders of the vehicle,  $\mu_d$  the friction coefficient between brake pads and disc and  $\eta_{br}$  the mechanical efficiency of the brake rigging.

» for the case of cast iron shoe brake, with symmetrical brake rigging and self-adjusting mechanism on the main brake bar:

$$F_{b,i} = \left[ \left( \frac{\pi \cdot d_{bc}^2}{4} \cdot p_{bc,i} - F_R \right) \cdot i_c - R_{sa} \right] \cdot i_l \cdot n_{\Delta} \cdot n_{bc} \cdot \mu_s(P_s, V_i) \cdot \eta_{br} \quad (17)$$

The dimensionless terms are:  $i_c$  the central brake rigging,  $i_l$  the amplification ratio of the brake rigging's vertical levers,  $n_{\Delta}$  the number of triangular axles and  $\mu_s$  the friction coefficient between brake shoes and wheel tread which depends on the clamping force on each brake shoe  $P_s$  [kN] and on instantaneous running speed  $V_i$  [km/h].

Assuming that certain terms and factors representing constructive and functional characteristics are constant for the same vehicle during braking actions, one may be put in evidence that during the filling time the brake force for the brake disc is directly depending only on the instantaneous relative air pressure in the brake cylinder  $F_{b,i} = f(p_{bc,i})$ , while in the case of shoe brake, the dependence is more sophisticated due to the friction coefficient between brake shoes and wheel tread  $F_{b,i} = f(p_{bc,i}, \mu_s(P_s, V_i))$ .

Hence, a passenger coach equipped with brake discs was considered in simulations. It is to notice that in operation, exploitable braking forces develop only after reaching an approx. 0.4 bar pressure within the brake cylinder [12]. So, taking into account the adhesion influence and the experimentally determined data referring to the evolution in time of the air pressure in the braking cylinder  $p_{bc}(t)$ , the instantaneous braking forces during the process can be evaluated [13]:

$$F_b(t) = \begin{cases} 0 & \text{if } p_{bc}(t) < 0.4 \text{ bar} \\ p_{bc}(t) \cdot \mu_a \cdot m_v \cdot g & \text{if } p_{bc}(t) > 0.4 \text{ bar} \\ p_{bc,max} & \end{cases} \quad (18)$$

In eq. (18),  $\mu_a$  is denoting the wheel-rail adhesion coefficient,  $m_v = m_c + 2 \cdot (m_b + m_{nb})$  the mass of the vehicle,  $m_{nb}$  the unsuspended mass of the bogie,  $g$  the gravitational acceleration and  $p_{bc,max}$  the maximum air pressure experimentally determined for emergency braking in the cylinder.

Other relevant constraints and simplifying hypotheses are summed up as follows:

- » the vehicle is submitted to emergency braking, determining maximum possible deceleration;
- » mechanical wheel slide protection devices are considered because generate maximum possible deceleration variations during braking action;
- » the case of uniform distribution of the load per bogie and per wheel is adopted;
- » identical constructive and elastic characteristics of the elements of each suspension level;
- » the track is considered to have no curves or slopes, so only the main resistances were taken in account;
- » track irregularities are neglected.

Simulations were performed for an individual passenger coach and the main parameters are: mass of the vehicle  $m_v = 47$  t, mass of the sprung part of the bogie  $m_b = 5900$  kg, the height of the centre of mass for vehicle body  $h_c = 1.696$  m, the height of centre of mass of the bogie  $h_b = 0.608$  m, the elevation of the connection point between vehicle body and bogie  $h_p = 0.985$  m, the elevation of the axle spindles  $h_0 = 0.460$  m, the wheelbase of the vehicle  $a_v = 19$  m, the wheelbase of the bogie  $a_b = 2.560$  m, stiffness of the point of suspension of the box  $k_c = 5 \cdot 10^5$  N/m, stiffness of the point of suspension of the axle  $k_b = 6.45 \cdot 10^5$  N/m.

The initial velocity of the vehicle is considered 140 km/h and, for the maximum braking force value, the adhesion coefficient  $\mu_a = 0.1$  was taken into account.

The integration of the motion equation and numerical simulations were performed in Matlab using the solver ode45.

The main output parameters obtained with the simulation program are the time-histories evolutions of decelerations, vertical load variations on each bogie and axle spindles respectively, velocity and braking distance.

**NUMERICAL APPLICATION**

Simulations based on the previous presented data were performed for 20 s of emergency braking process. The main results of the numerical applications results for the cases of emergency braking action are presented in Figure 4... 8 in normal adhesion conditions and in Figure 9... with the actuations of the wheel slide prevention devices.

In the first case, the deceleration time history (see Figure 4) highlights first a small value at the beginning of the action, while only main resistant forces are implied and then the increase up to the maximal value of 1.0447 m/s<sup>2</sup>, corresponding to the maximum air pressure in the brake cylinders, followed by a slightly decrease determined by the

evolution of resistances recess while the vehicle is slowing down during the braking action.

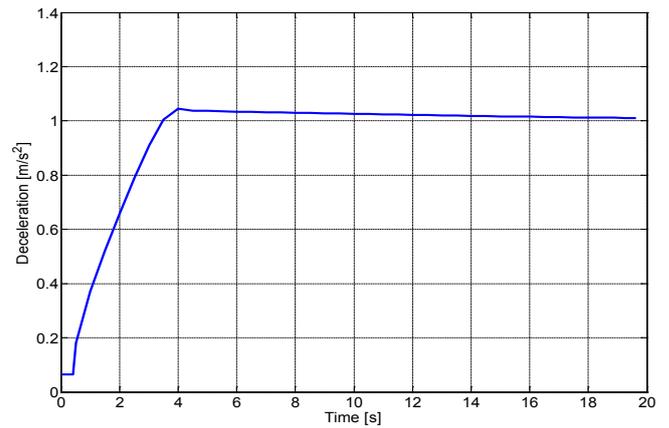


Figure 4. Deceleration in emergency braking action (normal adhesion conditions).

During the defined time duration, the brake distance reaches the value of 605 m and the vehicle's speed decreases from the initial value of 140 km/h to 72, 64 km/h (Figure 5).

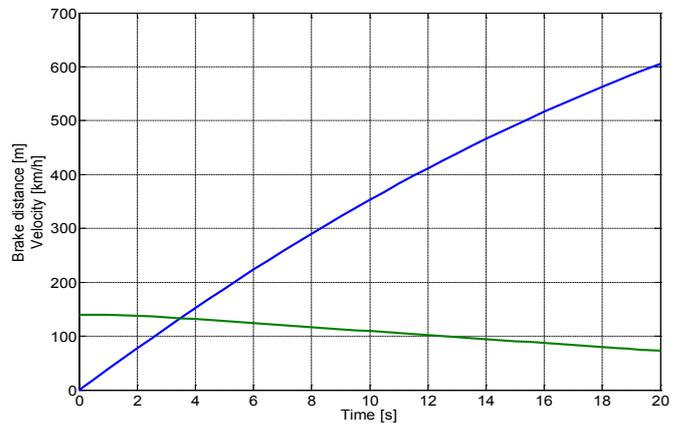


Figure 5. Brake distance and velocity during first 20 s of emergency braking action (normal adhesion conditions).

According to the deceleration evolution, the resultant vertical load variations ( $P_j$ ) on bogies and on each axle ( $P_{11} \dots P_{42}$ ) are presented in Figure 6, respectively 7. For identification, the number indexes of forces are in respect to the displacement direction. When the case, the second number index refer to the left side (odd numbers) and right side (even numbers) considering the vehicle's sense of motion.

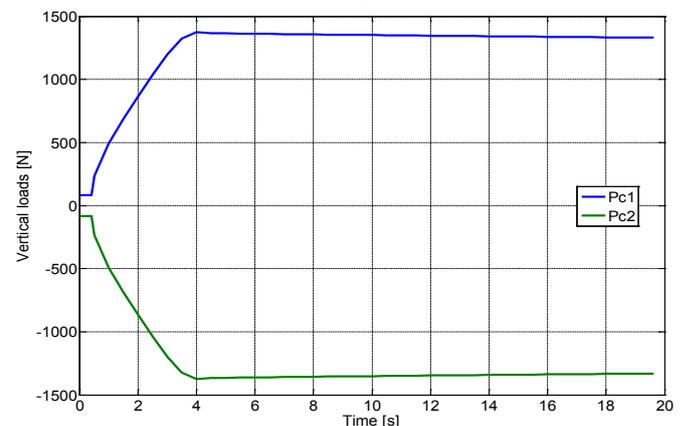


Figure 6. Variations of loads on the bogies of the vehicle (braking action in normal adhesion conditions).

As expected, the load variations are dependent of the deceleration evolution. The first bogie (towards the direction of movement) is supplementary charged, while the vertical load of the second one is correspondingly decreased (see Figure 7). Regarding the axles (see Figure 8), the results indicates supplementary loadings of the first and third axle, while the most unloaded are the second and the fourth, respectively.

This aspect deals with experiments highlighting a higher tendency of the fourth and second wheelsets of blocking during braking actions, as effect of vertical load decrease due to the vehicle's pitch [8, 14...16].

Interesting results were obtained in the case of occurrence of actuations of wheel slide prevention devices during the braking action (see Figure 9... 11).

The effects on braking process are presented in Figure 9: during the first 20 s, the braking distance is 36 meters longer than in the previous case (641 m) and the velocity decreases to the value of 81, 6 km/h (about 10 km/h higher than in the first case). These aspects indicate the decrease of braking capacity.

The determined vertical load variations ( $P_c$ ) on bogies and on each axle ( $P_{11} \dots P_{42}$ ) are presented in Figure 10, respectively 11. Basically, the general pitch effects are the same, determining supplementary loadings on the first bogie and on the first and third axle of the vehicle and correspondent decreases on the others. Still, important variations are revealed, load variation evolutions following the decelerations modifications during braking actions generated by the repeated actuation of wheel slide prevention devices.

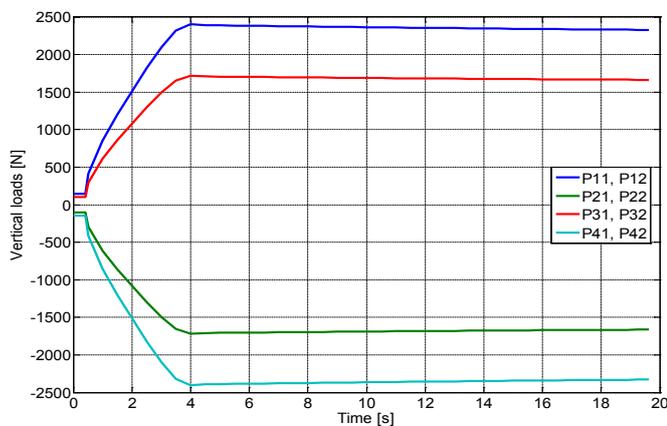


Figure 7. Variations of loads on the axle spindles (braking action in normal adhesion conditions).

In the second studied case, the deceleration evolution (see Figure 8) evidentiates important variations according to the braking forces modifications generated by the actions of the wheel slide prevention devices (see brake cylinder pressure time history in Figure 3). The deceleration increases with the increase of brake cylinders air pressure and correspondently falls when the wheel slide prevention device is actuated, generating a rapid decrease in pressure. The successive actuations conduct to high variations of the deceleration, the maximum instantaneous value reaching  $1,086 \text{ m/s}^2$ , increasing by 4 % as compared to the previous situation.

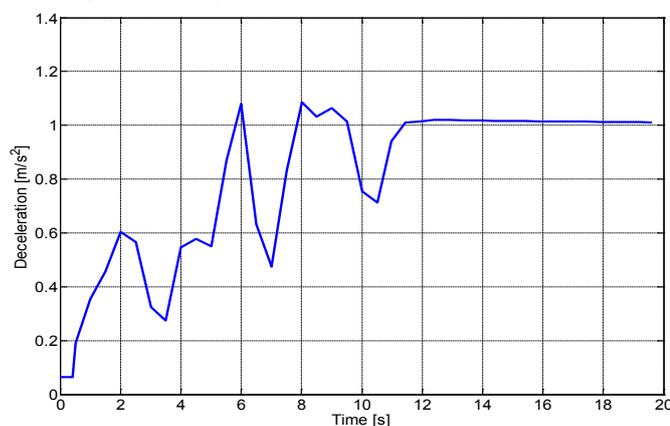


Figure 8. Deceleration during first 20 s of emergency braking action with actuation of wheel slide prevention devices.

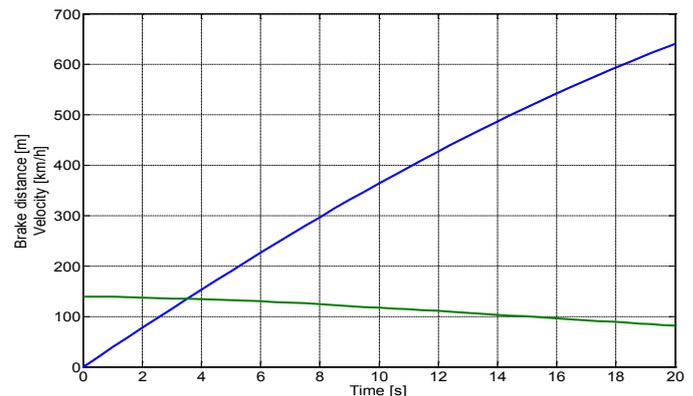


Figure 9. Brake distance and vehicle velocity with wheel slide prevention devices actuation.

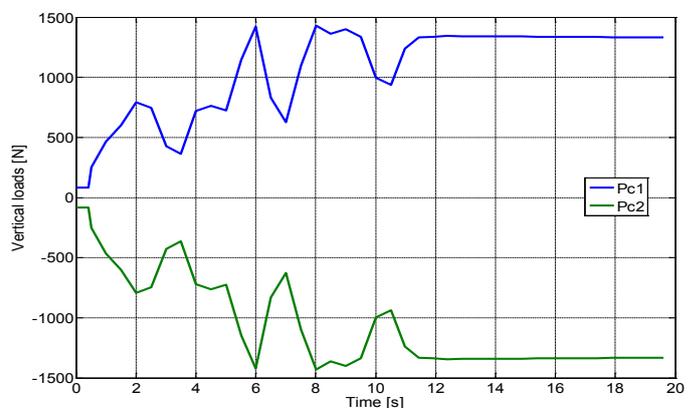


Figure 10. Variations of loads on the axle spindles (braking action in normal adhesion conditions)

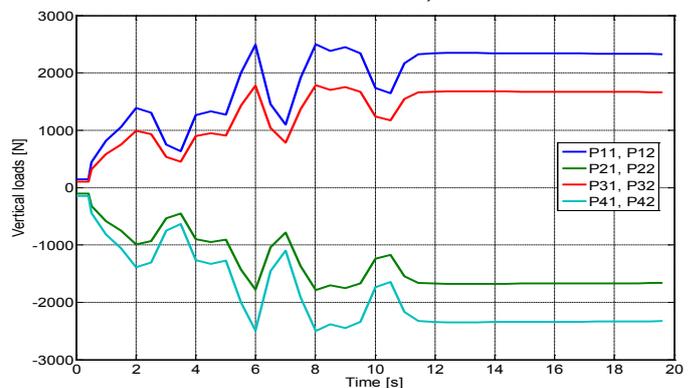


Figure 11. Loads variations in the axle spindles when the wheel slide prevention devices come into action

Regarding the braking process in the case of altered adhesion, the deceleration decrease during the actions of wheel slide prevention devices generates an instantaneous increase of vertical load on the axles, which combined with the important drop of braking force, accelerates the process of the initially brake cylinder air pressure regain. If the length of the low adhesion track is short, the rapid recovery of pressure minimises the brake power losses. On the contrary, if the length of the poor adhesion zone is important, in operation it is to expect repeated actuations of mechanical wheel slide prevention devices, almost in a periodically pulsating process. The average braking force may have high decrease, eventually accentuated by the rapid use of the compressed air from the auxiliary reservoir of the vehicle, affecting the safety of the traffic.

### CONCLUSIONS

The main influences of the actuation of mechanical wheel slide prevention devices upon the load variations during braking process can be summarised as follows:

- » the vertical load on axles is affected due to the vehicles' pitch during braking actions, with potential impairment of traffic safety;
- » simulations confirm a higher tendency of the fourth and second wheel sets in blocking during braking actions, as effect of vertical load decrease due to the vehicle's pitch;
- » the load variations evolution is determined by the deceleration variations generated by the air pressure evolution in the brake cylinders of the vehicle;
- » the effect of wheel slide prevention devices action on vertical load of the axles, combined with important drop of braking force, accelerates the process of the commanded brake force regain;
- » regarding the safety of the braking process, repeated wheel slide prevention devices actuations increase the braking distance and diminish the velocity decrease rate;
- » for short low-adhesion zones, the rapid recovery of pressure minimises the brake power losses;
- » on long poor adhesion zones the mechanical wheel slide prevention devices can affect the safety of the traffic, especially in the case of relatively high velocities and emergency braking actions. In such cases, electronic wheel slide prevention devices are required.

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## THE EVOLUTION OF CLOUD ROBOTICS: A SURVEY

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**Abstract:** Cloud robotics is a rapidly evolving field that allows robots to offload computation-intensive and storage-intensive jobs into the cloud. Robots are limited in terms of computational capacity, memory and storage. Cloud provides unlimited computation power, memory, storage and especially collaboration opportunity. Cloud-enabled robots are divided into two categories as standalone and networked robots. This paper surveys cloud robotic platforms, standalone and networked robotic works such as grasping, simultaneous localization and mapping (SLAM), monitoring.

**Keywords:** cloud-enabled robots, cloud robotics, cloud technologies, standalone and networked robots, Software as a Service, Platform as a Service, Infrastructure as a Service

### INTRODUCTION

Cloud Robotics (CR) is a term combination of cloud technologies and service robotics. The term “cloud-enabled robotics” was presented by James Kuffner for the first time at the IEEE RAS Int. Conference on Humanoid Robotics in 2010 [1]. Robots empowered with cloud technologies have been an important part of our daily lives. NIST [2] defines cloud computing as “a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.” Cloud Robotics has rapidly gained momentum with initiatives by companies such as Google, Willow Garage and Gostai as well as more than a dozen active research projects around the world.

The paper is organized as follows:

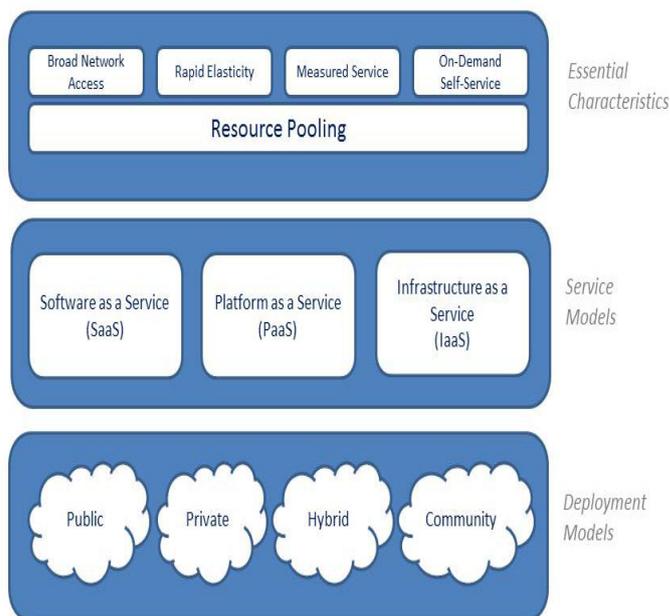
- » Section 1: Introduction.
- » In Section 2 cloud computing technologies are presented.
- » In Section 3 the cloud robotics platforms are illustrated.
- » In Section 4 cloud-enabled robots are presented.
- » Conclusions are given in Section 5.

### CLOUD COMPUTING TECHNOLOGIES

Cloud computing consist of three fundamental models as Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS) as shown on Figure 1. (1).

SaaS applications are served over the internet, thus eliminating the need to install and run the application on the users system [3]. They are managed from a centralized location and accessed remotely by a web browser or a mobile client. Google Apps is the most widely used SaaS application suit. PaaS refers to a computing platform served by cloud infrastructure. PaaS offers developers to get a hold of all the systems and environments required for the life cycle of software, be it developing, testing, deploying and hosting of web applications. Some

examples are Amazon Web Services (AWS) [4] and Microsoft's Azure [5]. IaaS provides the required infrastructure as a service. The client need not purchase the required servers, data center or the network resources. The essence of IaaS model is a pay-as-you-go financial model. Amazon and Microsoft are also IaaS providers.



**Figure 1.** Cloud computing infrastructure

Robots make significant socioeconomic impacts to human lives [6], [7]. For example, robots can do repetitive or dangerous tasks, such as assembly, painting, packaging, and welding. However, robots are limited in terms of computational capacity, memory and storage. Also they have physical constraints such as size, shape, power supply, motion mode and working environment [8]. Robots are usually used for industrial purposes, they are not commonly used in daily life because of their cost. Cloud computing can be used to enhance robots' capabilities.

Cloud computing technologies provide numerous advantages that can be valuable for the composition and running robot services. For example, complex computations of computation intensive applications can be offloaded in the cloud like what is done for Apple’s voice recognition service “Siri”. Connecting the robots to semantic knowledge databases hosted in the cloud will allow a large number of heterogeneous robots to share common sense knowledge [9].

The concept of “robot-as-a-service” (RaaS) refers to robots that can be dynamically combined to give support to the execution of specific applications. RaaS has three aspects of the system: structure, interface, and behavior. There can be many kinds of robot cloud units or intelligent devices. For example, robot cops [10], restaurant robot waiters [11], robot pets [12], and patient care robots [13]. These robots are distributed in different locations and can be accessed through CR platforms.

**CLOUD ROBOTICS PLATFORMS**

Developing software solutions for robots is difficult, because of varying hardware and non-standardized APIs. Robotics researchers, have created a variety of frameworks to manage complexity and facilitate rapid prototyping of software for experiments, resulting in the many robotic software systems currently used in academia and industry [14].

Stanford University and Willow Garage developed a generalized open source operating system called Robot Operating System (ROS) for robots. ROS is not only an operating system; rather, it provides a structured communications layer above the host operating systems of a heterogeneous compute cluster [15].

Rapyuta is an open-source cloud robotics platform. It serves a platform-as-a-service (PaaS) framework for robots. Rapyuta architecture depends on LxC [16] containers. It provides an environment to access RoboEarth [17] Knowledge Repository. Massively parallel computation, allowing humans to monitor or intervene robots and serving as a global repository to store and share object models, environment maps, and actions recipes between various robotic platforms are some of specifications of Rapyuta. It is a competitor of Rosbridge [18] in terms of communication [19].

Survivable Cloud Multi-Robotics (SCMR) Framework is designed, implemented and evaluated for heterogeneous environments. One of the challenges for cloud robotics is the inherent problem of cloud disconnection. The SCMR framework provides the combination of a virtual Ad-hoc network formed by robot-to-robot communication and a physical cloud infrastructure formed by robot-to cloud communications. The design trade-off for SCMR is between the computation energy for the robot execution and the offloading energy for the cloud execution. The SCMR framework uses Web Sockets protocol for communication between the individual robots and the cloud server. In case of cloud disconnection a virtual ad hoc cloud is created between the individual robots and the robot leader and the individual robots communicate with one another through the gossip protocol [20].

Distributed Agents with Collective Intelligence (DAvinCi) is a software framework that provides the scalability and parallelism advantages of cloud computing for service robots in large environments [21]. It is implemented as a system around the Hadoop cluster with ROS as the messaging framework [22].

**CLOUD-ENABLED ROBOTS**

Robots have some constraints in terms of computational capacity, memory and storage. CR help them to overcome these challenges. Opportunity to use cloud allows cost effective robots to be produced. Robots can be classified as traditional robots and cloud-enabled robots. This paper focuses on cloud-enabled robots. A cloud technology not only empowers robots but also it allows them to network each other regardless of distance. Cloud-enabled robots are divided into two categories as standalone robots and networked robots. Classification of robots is shown in Figure 2.

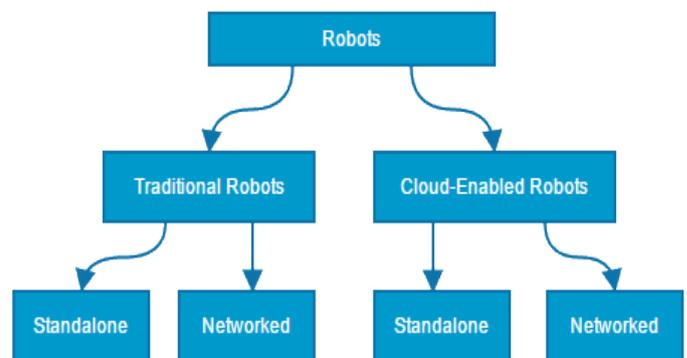


Figure 2. Classification of Robots

Standalone robots can benefit from cloud in terms of computation power, storage capacity and memory. However, networked robots can make networks, share their information through cloud and can perform collaborative works [23], [24], [25], [26]. CR infrastructure with standalone robots and networked robots is presented in Fig. 3.

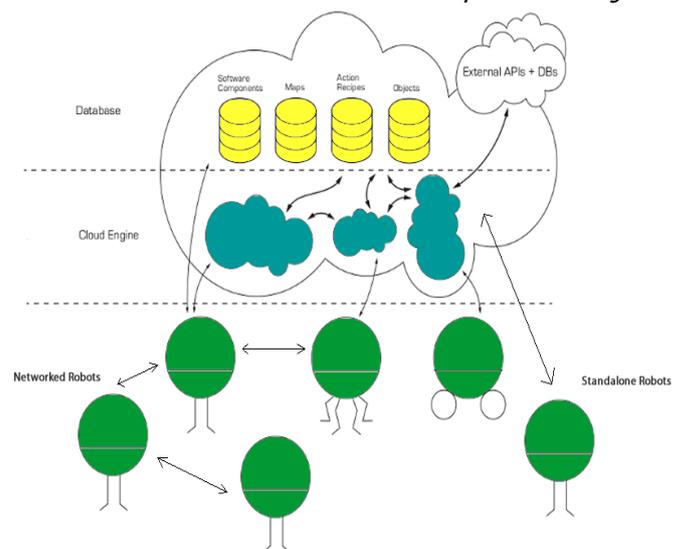


Figure 3. Standalone and Networked Robots

Robots can do a wide variety of works such as grasping, identifying objects, SLAM, monitoring, networking and some other actuating works. Robots can grasp formerly known objects easily. They can also grasp novel objects with the help of cloud. In [27], a study about

grasp planning in the presence of shape uncertainty and how cloud computing can facilitate parallel Monte Carlo sampling is presented. Kehoe et al focus on parallel-jaw push grasping for the class of parts that can be modeled as extruded 2-D polygons with statistical tolerancing. SLAM [28] refers to a technique for a robot or an autonomous vehicle to build a map of the environment without a priori knowledge, and to simultaneously localize itself in the unknown environment. SLAM is important in robotics and there are plenty of researches. It consists of statistical techniques such as Kalman filters, mapping and sensing. Riazuelo et al develop a cloud framework which name is Cloud framework for Cooperative Tracking and Mapping (C2TAM) [29]. This is a visual SLAM system based a distributed framework where the CPU-intensive map optimization and storage is allocated as a service in the Cloud, while a light camera runs on robots for tracking. The robots need only internet connection for tracking and cooperative relocation. C2TAM provides a database consisting maps can be built and stored, stored maps can be reused by other robots. A robot can fuse its map online with a map already in the database, and several robots can estimate individual maps and fuse them together if an overlap is detected. Virtual monitoring technology has been applied in more and more fields such as military, education, medical science, manufacturing engineering, and so forth. In order to realize resource sharing among all collaborating robots in a virtual monitoring system, cloud computing is proposed by combining professional computing equipment as a super virtual computing center. Zhang et al, proposed 3D virtual monitoring system based on CR. This system's architecture consist of communication language for agent communication, algorithm for cooperative working and conflict resolution. Prototype system is applied for the monitoring of fully mechanized coal-mining equipment [30]. Networking robots overcome the limitations of stand-alone robots by having robots, environment sensors, and humans communicate and cooperate through a network. Mateo et al, presented a work to decrease message overhead occurred because of communication. The proposed an information sharing model for group communication based on Brownian agent approach. In presented work they grouped robots in clusters with a cluster head to overcome message overhead [31]. Kamei et al, proposed prototype infrastructure of cloud networked robotics enables multi-location robotic services for life support [32]. Their study focuses on requirements in typical daily supporting services through example scenarios [33] that target senior citizens and the disabled.

### CONCLUSION

This paper presents cloud computing, cloud robotics and cloud interaction of robots. It surveys cloud platforms and cloud-enabled robotics studies. Standalone robots can benefit cloud technologies and networked robots can perform collaborative works. Networked cloud-enabled robots can share computation resources, information and data with each other and can access new knowledge and skills not learned by themselves. This is a new paradigm in robotics that we

believe leads to exciting future developments. Future works can focus on reliable connection, data offloading methods and ubiquitous networking among robots and cloud services.

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## DIGITAL WATERMARKING TECHNIQUES IN SPATIAL AND FREQUENCY DOMAIN

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**Abstract:** Digital watermarking is the act of hiding information in multimedia data, for the purposes of content protection or authentication. In ordinary digital watermarking, the secret information is embedded into the multimedia data (cover data) with minimum distortion of the cover data. Due to these watermarking techniques the watermark image is almost negligible visible. In this paper we will discuss about various techniques of Digital Watermarking techniques in spatial and frequency domains.

**Keywords:** Digital Watermarking, DWT, Discrete Wavelet Transform, DCT, Discrete Cosine Transform

### INTRODUCTION

With the recent technology advanced people are sharing more and more information among each other's. Some organizations like medicine, military are sharing data with are highly secretive and important. For secure communication people are using cryptography using secret key so that only authenticate receiver can decrypt the message and authentication of message remains intact. But cryptography raised suspicion among attackers and tries to attack the message to get the secretive messages. So, an approach of digital watermarking is used where authenticate multimedia data is embedded into original message. The receiver is then extracts the watermarked image and authenticates its novelty.

### DIGITAL WATERMARKING

Digital watermarking [18] [19] system consists of watermarking encoder and decoder. In watermarking encoder, the digital multimedia data (audio, video, and image), watermarked key and original message put as an input to generated watermarked data.

Types of Digital Watermarking:

1. **Visible:** This types of watermarking are perceptual to human eyes and can be used for authentication instantly.
2. **Invisible:** This type of watermarking are not perceptual to human eyes and requires watermarking extraction algorithm.

The digital watermarking system can be blind or informed. Blind watermark techniques are independent of cover image. In this technique while transmitting watermarked cover image if any noise is introduced into it then the decoder at the receiving end extract the distorted watermarked image because original cover image is not known to it. In case of informed watermarking techniques the watermarked image is dependent on cover image. While transmitting the hash value of cover image is calculated and incorporate into watermarked image. So that when the image is received at the receiver end the hash value of cover data is calculated and authenticate the data provided the original cover data is with the receiver.

In Digital watermarking systems there are three mutually exclusive parameters to evaluate performance.

1. **Quality:** Minimum distortion of original image after secret message has been embedded.
2. **Capacity:** Maximum size of watermark image embedded on cover data.
3. **Robustness:** Watermarked image should be withstanding any modification attacks.

These three parameters are tightly bound to each other. Trying to improve the performance of one parameter will affect the performances of other two.

This paper deals with invisible watermarking schemes. Here watermarking are not perceptual to human eyes.

Few important properties of Digital Water markings schemes are:

1. **Robustness:** This property states that the watermark image should resist any possible attach and remain detectable.
2. **Fidelity:** High fidelity means that the amount of distortion caused by the watermarked image to cover image remains imperceptible to human eyes.
3. **Capacity:** The number of bits of watermark image can be embedded into cover image without causing much distortion.

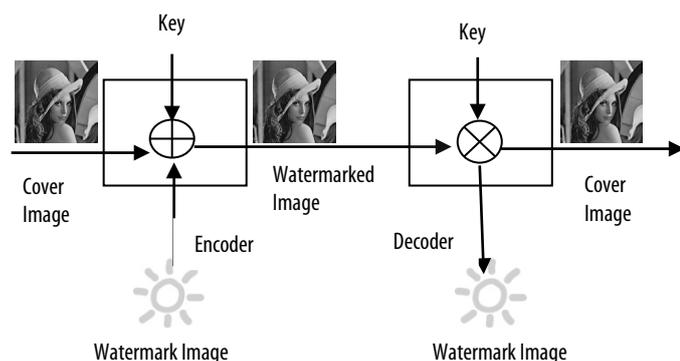


Figure 1. Watermarking Technique

4. **False Positive Rate:** This property state that the identification of watermark image into cover image which doesn't contain actually. Minimum false positive rate helps to identify watermarked cover image easily while decoding.

Applications of Digital Water markings are:

1. **Copyright:** Using Digital watermarking for copyright purpose helps to protect rights in content distribution. It is used to protect the rights of the owner.
2. **Authentication:** In order to authenticate the data and to detect tampering of message while transmission digital watermarking is used.
3. **Time Stamping:** Use of watermarking in this case helps to keep track about when the content was created, last used or last modified.

**STEGANOGRAPHY**

Similar to digital watermarking, for embedding secret messages, steganography is used to hide messages in cover data. The basic difference between Steganography and digital watermarking is that in digital watermarking the covert data is related to cover data but in steganography the covert data is not related to cover data.

Steganography is mainly distributed among two approaches: reversible and irreversible [2]. Using reversible technique the receiver can extract both the secret message as well as original cover image but while using irreversible technique the receiver can only extract the secret message from stego image leaving original cover image distorted.

Few irreversible techniques are:

1. Battisti et al [3] approach of data hiding using Fibonacci p-sequence number to reduce stego image distortion than traditional LSB technique.
2. Dey et al [4] [5] [6] proposed an improvement over Fibonacci p-sequence LSB data technique of Battisti et al [1] by decomposing pixel value using two approaches: Prime decomposition and Natural number decomposition technique.
3. Nosrati et al. [7] introduced a method that embeds the secret message using linked-list in RGB 24 bit color image

Some reversible data hiding techniques are:

1. Ni et al. [8] proposes a novel approach of data hiding using histogram shifting of original image
2. Kuo et al. [9] presented a reversible technique that is based on the block division to conceal the data in the image.
3. Tian [10] proposes a reversible data hiding technique using difference expansion.

Similar to cryptanalysis, steganalysis is a technique used to detect steganographic images as mentioned in paper [20].

**DOMAINS USED IN DIGITAL WATERMARKING TECHNIQUES**

Spatial Domain Techniques are techniques that operated directly on single pixel of an image.

$$f_i \xrightarrow{T_p(.)} g_i \tag{1}$$

where  $f_i$  is the original image,  $g_i$  is the modified image and  $T_p(.)$  is the spatial operator defined in a neighborhood  $p$  of a given pixel.

Frequency Domain Techniques are operated on frequency of an image.

$$f_i \xrightarrow{f_p} I_i \xrightarrow{-f_p} g_i \tag{2}$$

where  $f_i$  is the original image,  $I_i$  is the modified image after applying frequency transformation  $f_p$ ,  $g_i$  is the final modified image after implementing inverse transformation  $-f_p$ .

**DIGITAL WATERMARKING TECHNIQUES**

**Spatial Domain**

The simplest method of digital watermarking in spatial domain is using LSB (Least Significant Bit) insertion [17].

**Input:** Cover Image  $M_c$  and Watermark Image  $M_w$

**Process:**

1. Let  $M_{pixel}[i, j]$  is the pixel of Cover Image  $M_c$  at position width  $i$  and height  $j$ .
2. Let  $M_w$  is the secret image for watermarking. The length of  $M_w$  should be less than cover image  $M_c$ .
3. Loop though the cover image:
 
$$M_c = M_{pixel}[i, j] - M_{pixel}[i, j] \% 2;$$

$$M_c = M_c + M_w \% 2;$$

$$M_w = M_w / 2;$$
4. If the length and width of watermarked image is reached then end.

**Output:** Modified Image  $M_o$  having watermark image embedded in it. The advantage of LSB watermarking technique is its simplicity and the difference is not visible to naked eyes. But this technique has also having lot of disadvantages like LSB encoding is extremely sensitive to any kind of filtering or manipulation. An attack on the watermarked image is very likely to destroy the watermark image. Since this technique is not robust any attack will damage its authentication. From Fig. 2 we can see that after embedding secret message into the cover image there is significant change in original image histogram pattern suggesting it is being distorted.

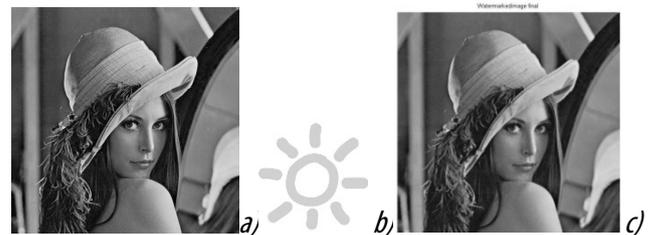


Figure 2. LSB Watermarking Technique (a) Cover Image (b) Image to be embedded (c) Watermarked Image

Tian [10] [11] proposes a digital watermarking technique using difference expansion using LSB. In this method the mean and average value of two neighboring pixel, with small difference value, is calculated. The calculated value is then check to see whether it is satisfying the expandable difference condition eq. (i) and once the condition is passed the new expanded difference is calculated eq. (ii). Finally the watermark image is embedded based on the calculated values. This technique also use location map to store the values to know which difference value have been selected which are used to

extract the image at the receiving end. This technique significantly improves the capacity of payload message and visual quality of embedded image.

$$2 \times h + b \leq \min(2(255-1), 21+1)$$

$$h' = 2 \times h + b$$

The algorithm's steps are:

1. Take two adjacent pixel values of  $x$  and  $y$
2. Find difference and average values of pixels.
3. Then expand into its binary form and add watermark bit right after most significant bit.

In the fig. 3 we have embedded image (b) into image (a) by using difference expansion. From the histogram of stego image (c) we can see that the watermark image is embedded on the difference of near pixel value which are expandable but the pixel having minimum intensity or zero value are not used much in this process.

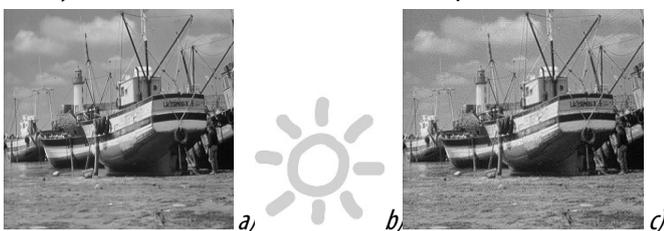


Figure 3. Difference Expansion using LSB (a) Cover Image (b) Watermark Image (c) Watermarked Image

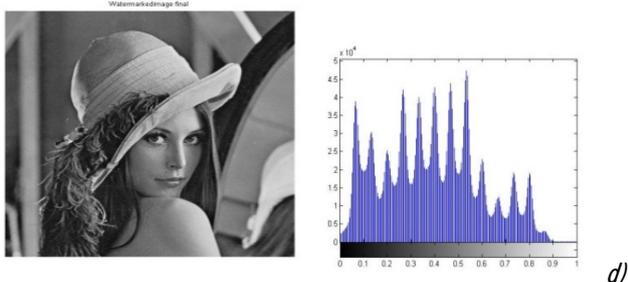
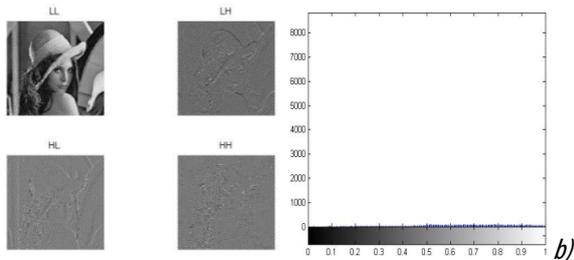
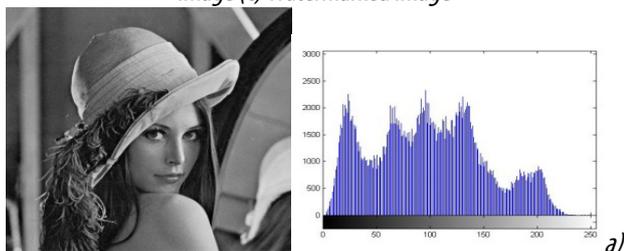


Figure 4. Discrete Wavelet Transformation (a) Cover Image (b) DWT Image (c) Watermark Image (d) Watermarked Image

**Frequency Domain**

**Discrete Wavelet Transform**

A lot of research papers used DWT for Digital watermarking techniques (i) [12] [13]. The frequency domain transform used here is Haar-DWT. A 2-dimensional Haar-DWT consists of horizontal and vertical operations. Detailed procedures of a 2-D Haar-DWT are described as follows:

**Step 1:** Pixels are scanned from left to right horizontally, add the value with neighboring pixels and store the sum on the left and the difference on the right as illustrated in Figure 1.4. The operation is repeated until all the rows are processed. Pixel sums represent the low frequency part (denoted as symbol L) while the pixel differences represent the high frequency part  $H$  (denoted as symbol H) of the original image.

**Step 2:** Pixels are scanned from left to right vertically, add the value with neighboring pixels and store the sum on the left and the difference on the right as illustrated in Figure 4. Repeat this procedure until all the columns are processed. At the end we LL, HL, LH, and HH bands are created. The LL sub-band is the low frequency portion and looks very similar to original cover image.

**Discrete Cosine Transformation**

DCTs [14] [15] [16] are used to convert image processing data from spatial domain to frequency domain into summation of series of cosine waves oscillating at different frequencies. For Image processing 2-D DCT technique is used and is given by:

$$DCT(i,j) = \alpha(i) \alpha(j) \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} f(x,y) \cos\left[\frac{\pi(2x+1)i}{2N}\right] \cos\left[\frac{\pi(2y+1)j}{2N}\right] \quad (3)$$

where  $i, j = 1, 2, 3, \dots, N-1$  and  $\alpha(i)$  and  $\alpha(j)$  is given by:

$$\alpha(i) = \alpha(j) = \begin{cases} \sqrt{\frac{1}{N}} & \text{if } i=0 \text{ or } j=0 \\ \sqrt{\frac{2}{N}} & \text{otherwise} \end{cases} \quad (4)$$

for  $i, j=0$

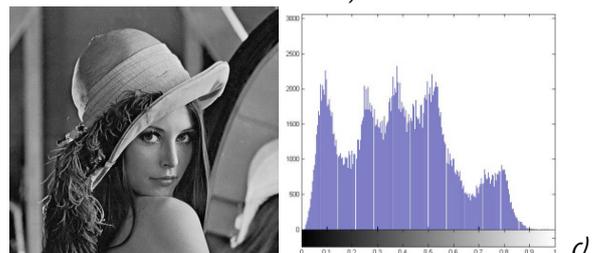
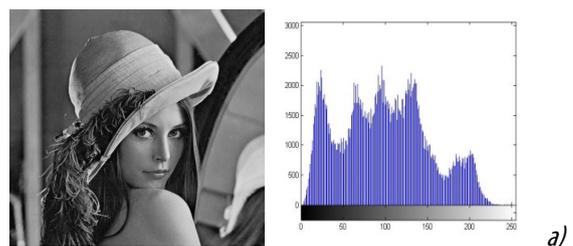


Figure 5. Discrete Cosine Transformation (a) Cover Image (b) Watermark Image (c) Watermarked Image

And inverse transform is given by:

$$f(i,j) = \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} f(x,y) \cos \left[ \frac{\pi(2x+1)i}{2N} \right] \cos \left[ \frac{\pi(2y+1)j}{2N} \right] \quad (5)$$

Algorithm of DCT:

1. Read the original Input Image
2. Resize the watermark image.
3. Resize the original image and watermark image for efficient partition in blocks.
4. Retrieve the  $8 \times 8$  sub-blocks of original image and apply DCT to each of them.
5. Apply the watermark into each of these sub-blocks and apply inverse transform.

### CONCLUSION

In this paper we described algorithms that belongs to spatial and frequency domain in the digital watermarking techniques. All these techniques are designed to exploit some aspects of the human visual system and made watermark image imperceptible. Many of these techniques rely either on transparency (low-amplitude) or frequency sensitivity to ensure the mark's invisibility. Digital watermarking explores are keep on exploring new methods in these areas and this paper helps to understand and gain knowledge for further researches.

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## EFFECT OF DIE AND SAND CASTING ON MECHANICAL BEHAVIOUR OF Al-Mg-Si ALLOY

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**Abstract:** This paper investigated the effects of die and sand casting methods on mechanical behaviour of Al-Mg-Si alloy, using die, sand and spin casting. The pure aluminium scrap, magnesium and silicon were subjected to chemical analysis using spectrometric analyser, thereafter the charge calculation to determine the amount needed to be charged into the furnace was properly worked out and charged into the crucible furnace from which as-cast aluminium was obtained. The mechanical properties of the casting produced were assessed by hardness and impact toughness test. The optical microscopy and experimental density and porosity were also investigated. From the results it was observed that magnesium and silicon were better dispersed in aluminium matrix of the die casting. It was observed from visual examination after machining that there were minimal defects. It was also observed that out of the three casting methods, spin casting possesses the best mechanical properties (hardness and impact toughness).

**Keywords:** Al-Mg-Si alloy, die, sand, mechanical properties, spectrometric analyzer

### INTRODUCTION

Casting is a fabrication process whereby a totally molten metal is poured into a mould cavity having the desired shape; upon solidification, the metal assumes the shape of the mould but experience some shrinkage [1]. Casting is the most economical.

A number of different casting techniques are commonly employed, including sand, die, investment, continuous and spin casting. Sand Casting probably the most common method, ordinary sand is used as the mould material [1]. A two-piece mould is formed by packing sand around a pattern that has the shape of the intended casting. A gating system is usually incorporated into the mould to expedite the flow of molten metal into the cavity and to minimize internal casting defects. It has been stated that when pouring temperature is lower than optimum, the mould cavity will not fill the gate or riser will solidify too rapidly and intercept directional solidification.

Die casting is a versatile process capable of being used in mass production of alloys having properties unobtainable by other manufacturing method [2].

Spin casting is both gravity and pressure independent since it creates its own force feed using a temporary sand mould held in a spinning chamber at up to 300-3000rpm as the molten metal is poured. The molten metal is centrifugally thrown towards the inside mould wall, where it solidifies after cooling. The casting is usually a fine-grained outer diameter, owing to chilling against the mould surface. Impurities and inclusion are thrown to the surface of the inside diameter which can be machined away [3].

Aluminium alloys have great use potential in the structural components in the aerospace and automobile industries mainly

because of their low density and high specific strength [4], also aluminum alloys have a wide diversity of industrial applications because of their high specific strength, light weight and corrosion resistance. Therefore these alloys motivate considerable interest to the aviation industries [5, 6]. Aluminium alloy for a cast component is based upon mechanical and corrosion properties it can achieve. Aluminium alloy casting properties result from three primary factors: casting alloy, melting and casting methods. The properties obtained from one particular combination of these factors may not be identical to those achieved with the same alloy in a different casting facility.

### EXPERIMENTAL MATERIAL AND METHODS

The materials used for the work were scraps of Aluminium purchased from Northern Nigeria Cable Processing Company Limited (NOCACO), Kaduna also Magnesium used. The silicon used was obtained from Engineering Materials Development Institute (EMDI), Akure, Nigeria.

**Table 1.** Chemical composition of basic materials (after casting)

Si	Fe	Cu	Mn	Mg
0.40	0.24	0.03	0.04	0.55
Zn	Cr	Ti	Al	
0.03	0.01	0.02	98.68	

The two casting methods were carried out for the work, they are:

- (i) Die
- (ii) Sand casting.

The patterns used were made of wood with diameters of 20 mm by 150 mm long. The patterns were made larger than the original dimension to compensate for shrinkage during solidification and machining operation.

Natural sand was used to prepare the sand mould, a mixture of silica sand with considerable amount of bentonite. The addition of bentonite improved the bonding strength. The moulding of the pattern was carried out using a moulding box comprising of cope and drag that gave rigidity and strength to the sand. Parting sand was properly applied for the easy removal of the mould from the pattern. The gating system was properly designed for smooth channeling of the molten metal into the mould cavities through the sprue, runner, in-gates and riser that were perfectly placed in position. The die mould was prepared using cast iron.

The cast aluminium scraps, magnesium and silicon were carefully worked out and charged into the furnace.

Crucible furnace was used for the melting of the charges. Prior to charging, the crucible furnace was checked to prevent leak of molten metal and also to guide against moisture, which can generate vapour during melting. Metallurgical factors in the choice of melting facilities related to the tendency of the charge to react with its surrounding, affecting composition control, impurity level and metallic yield were considered. The charged materials in the furnace were allowed to melt down (at 700°C) and then the furnace was switched off. The molten metal was tapped from the furnace, poured into the die mould and sand mould. The die cast was allowed to air cooled [2], together with sand cast.

The removal of the sand which stuck on the surface of the sand cast was carried out with the aid of sand blasting bar, sprue and ingates were also removed using hacksaw. Cleaning operation was also performed by grinding to smoothen the surface and unnecessary attachment on the surface of the metal to improve the appearance.

The determination of the experimental densities of the various casting products were carried out measuring the weight of the test samples using a high precision electronic weighing balance with a tolerance of 0.1mg. The weights of the measured samples were divided by their respective volume.

Experimental density,

$$\rho = \frac{\text{mass\_of\_sample}}{\text{volume\_of\_sample}} \quad (1)$$

The percentage porosity of the cast aluminium was determined by use of equation

$$\% \text{ volume porosity} = \frac{(\rho_{\text{cal}} - \rho_{\text{exp}})}{\rho_{\text{cal}}} \quad (2)$$

where  $\rho_{\text{cal}}$  = Theoretical Density ( $\text{g}/\text{cm}^3$ ),  $\rho_{\text{exp}}$  = Experimental Density ( $\text{g}/\text{cm}^3$ ) [7, 8]

The hardness for the sand and die cast were evaluated using a Vickers Hardness Tester (LECOAT 700 Microhardness Tester). The test specimens were polished to obtain flat and smooth surface finish after this, a direct load of 490.3 MN was applied on the specimens for 10 seconds and the hardness reading evaluated following standard procedures.

The specimens for the optical microscopy were properly polished using emery papers of various grit sizes ranging from 500µm to 50000µm. The fine polishing was equally ensured using a polycrystalline diamond suspension of particle sizes ranging from 10µm to 0.5µm with ethanol solvent, after which the specimens were etched in  $\text{HNO}_3$ . Hydrochloric acid was used to swab the surface before microstructural examination was performed using Datteng-Driven Metallurgical Software [9].

The toughness of the specimens were evaluated using (Honnsfield Balance) Impact Testing Machine, samples were machined to dimensions of 8mm diameter and 18mm length. The specimen was notched 2mm in (V shape) the value of the energies absorbed in fracturing the test - piece were measured in joule.

**EXPERIMENTAL RESULTS - MICROGRAPH**

Figure 1 - 2 shows representative optical micrograph for sand and die casting of Al-Mg-Si alloy. It is observed that magnesium and silicon were fairly dispersed in the aluminium matrix better in die casting than sand casting.

The microstructure of sand casting shows phases that were not evenly dispersed in the aluminium matrix while it is discovered there is strong clustering of  $\text{Mg}_2\text{Si}$  in certain area of matrix [10, 11].

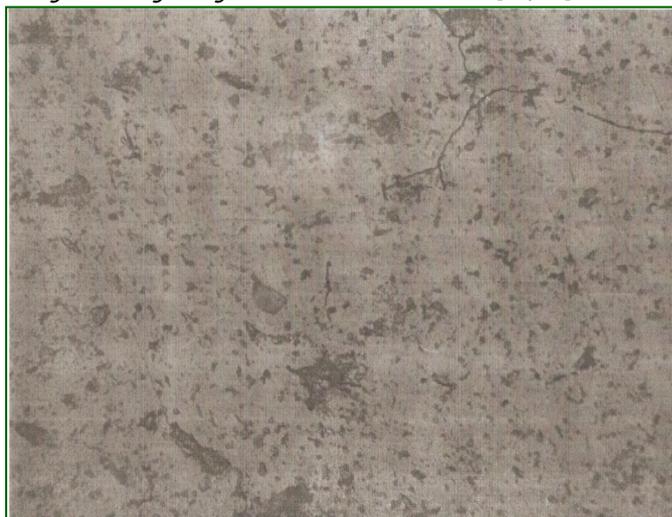


Figure 1. Microstructure of Sand Casting (X400)

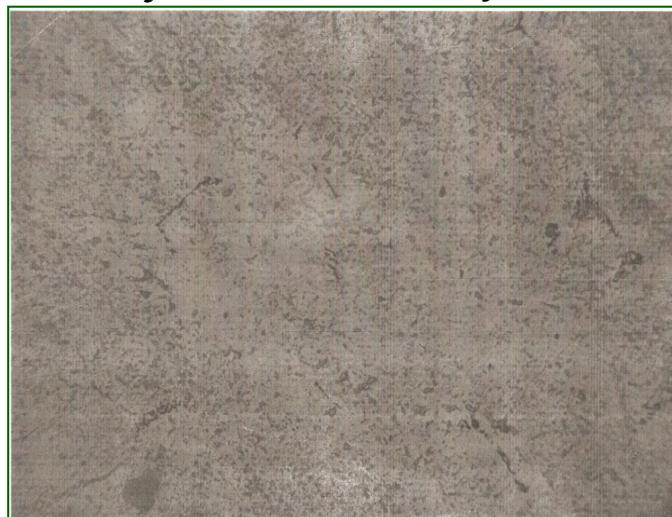


Figure 2. Microstructure of Die Casting (X400)

**EXPERIMENTAL RESULTS – MECHANICAL PROPERTIES**

It was observed from Figure 3 that sand casting has the higher hardness than die casting. The crystal lattices of Mg<sub>2</sub>Si precipitates show coherence with that of the α-aluminium, consequently, severe strain fields are created around these crystals which impede the motion of dislocations and thereby causing increased hardness of castings obtained in sand casting [11]. These two elements (magnesium and silicon) form the primary hardening phase (magnesium silicide, Mg<sub>2</sub>Si) in aluminium alloy 6063 [12-13].

The variation found in hardness of the two cast products may also be attributed to their porosity, density and the microstructure.

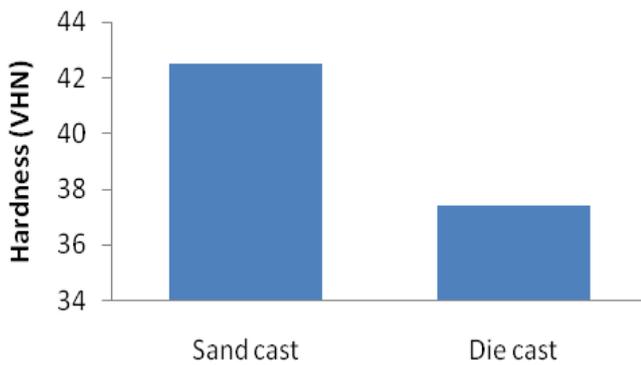


Figure 3. Hardness of Cast Aluminium Products

Table 2. Hardness of Cast Al-Mg-Si alloy Products

Specimen	Hardness (VHN)
Sand Casting	42.515
Die Casting	37.425

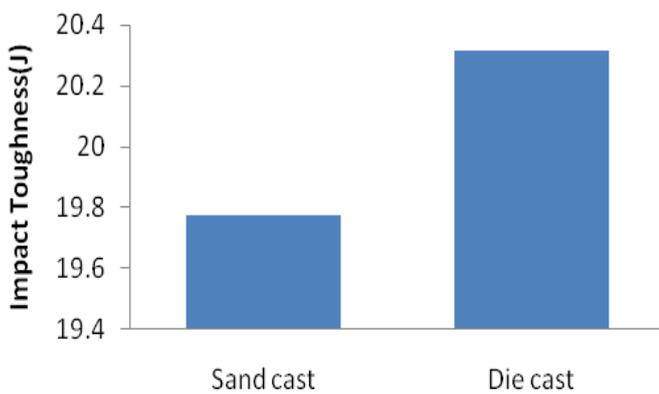


Figure 4. Impact Toughness of Cast Aluminium Products

Table 3. Impact Toughness of Cast Al-Mg-Si alloy Products

Specimen	Impact Value (J)
Sand Casting	19.773
Die Casting	20.314

From Fig 4, the impact toughness of die casting is superior to that obtained in sand casting. The results indicate that fairly distributed Mg<sub>2</sub>Si crystals in α-aluminium in die casting, this alloy exhibited better impact toughness in the die cast condition as compared with the same alloy subjected to sand casting, this is in agreement with Basavakumar [14].

**CONCLUSIONS**

In the research work, the effect of die and sand casting on mechanical behaviour of Al-Mg-Si alloy was investigated. On the strength of the results presented, the following conclusions were drawn:

- » The microstructure of the die casting revealed that magnesium and silicon were fairly dispersed in the aluminum matrix as compared to sand casting.
- » The hardness obtained from sand casting was better than that of die casting.
- » The products through die casting had a better impact toughness than sand casting

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## DETERMINATION OF THE GEOMETRIC PARAMETER THAT MORE AFFECTS THE QUALITY IN CASTING USING PREDICTION TOOLS

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**Abstract:** The determination of the geometrical parameter, of the wheel type piece, that most influences has in the occurrence of defects in the casting process it is proposed in this paper. Within the parameters used to study thickness of wheel rim, height of wheel rim, thickness of the central plate. Is used as a methodology, the combination of the Taguchi method with the simulation. An orthogonal array, the signal-to-noise (S/N) ratio, and analysis of variance are used to analyze the effect of selected process parameters and their levels on the casting defects. The results indicate that the selected process parameters affect the casting defects and are the height of wheel rim the most important. A simulation technique is used to verify the results, which indicated that this methodology is more efficient in determining the best geometric parameters for a wheel casting part.

**Keywords:** Taguchi's method, Risers, Simulation casting, ProCAST

### INTRODUCTION

The casting process has a large number of parameters that may affect the quality of castings. Some of these are controllable, while others are noise factors [1]. The variations in casting parameters chosen by different researchers [2] have led to significant variations in these empirical guidelines. A large number of experimental investigations linking risers geometric parameters with casting quality have been carried out by researchers and foundry engineers over the past few decades [3]. It has been recognized that risers geometric parameters design plays one of the key elements in casting quality [2].

Up to now, there are following optimization methods applying to the risers geometric parameters: the gradient search method, the finite element method (FEM)-based neural network method and the Taguchi method [4]. Taguchi [5] has introduced several new statistical tools and concepts of quality improvement that depend heavily on the statistical theory of experimental design. Some applications of Taguchi's methods in the foundry industry have shown that the variation in casting quality caused by uncontrollable process variables can be minimized [6].

Taguchi approach is suitable in using experimental design for (a) designing and developing products/processes so as to be robust to component variation; (b) designing products/processes so as to be robust to environmental conditions; and (c) minimizing variation around a target value.

During the 1990s, a lot of developments had been done for the foundry process [7]. Some of these programs were able to simulate the behavior of the molten metal close to reality, as the researchers studied the behavior of the molten grey cast iron during the filling of

different gating systems by optical means, and correlated the measurements to obtain the behavior by some simulators. By the end of the 1990s, the trial and error approach practices moved away from the real mould to the virtual one. According to Taguchi [1], the parameters, which exert a great deal of influence on the casting process, can be adjusted, to varying levels of intensity so that some settings can result in robustness of the manufacturing process. Barua et al. [8] used the Taguchi's method to optimize the mechanical properties of the Vacuum V-casting process. In their paper, they considered the effects of the selected process parameters on the mechanical properties of alloy casting and subsequent optimal settings of the parameters, which were accomplished using Taguchi's parameter design approach.

Noise factors are the variables, which influence the response variables. They may or may not be known. Special care should be taken to prevent the noise factors from interfering in the experimental results. Lipinski et al. [9] presented the numerical basis of Magmasoft, a commercial finite difference solver for the simulation of casting. Masters et al. [10] described a robust design method for reducing cost and improving quality in an aluminum re-melting process.

The literature review indicates that the Taguchi method is the best option for design of experiments when number of process parameter are involved in the process. Taguchi approach is suitable in experimental design for designing and developing robust products or processes irrespective of variation in process parameter (within set limits) and or variation in environmental conditions [11].

The present research as associated with the determination of critical geometric parameters of wheel type piece affecting shrinkage porosity, which involves various parameters at different levels and affects the casting quality. Considering these features of Taguchi method, it is used to reduce the % of rejection due to sand and moulding related defects by setting the optimum values of the process parameters of the green sand casting. In [11] Dabade have a picture with a methodology used to achieve optimized process parameters using DoE (Design of experiments), in this picture is show a complete diagram for the sand casting process. In our case is used the way that show the defect produced by the filling and solidification process.

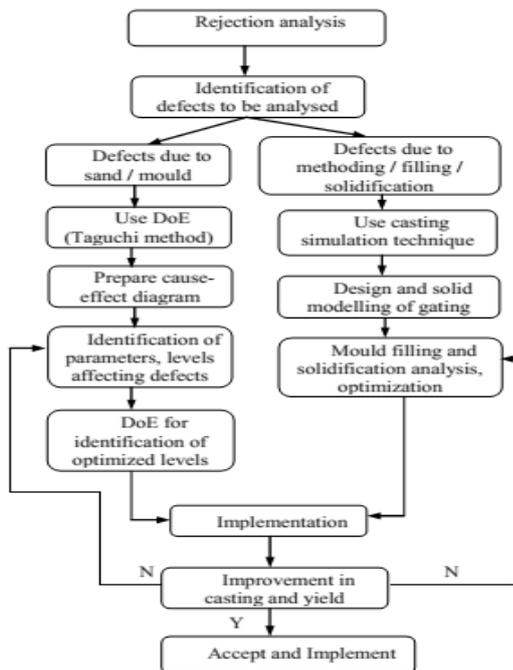


Figure 1. Complete analysis of the sand casting process design by Dabade

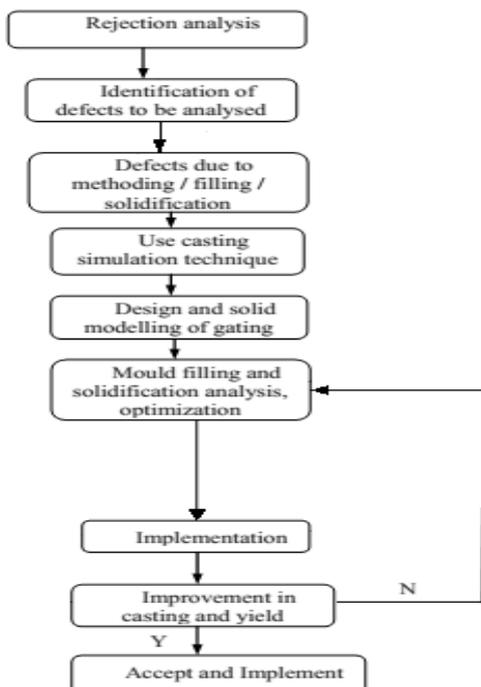


Figure 2. Related stage with the filling and solidification process

PROCESS PARAMETERS OF RISERS CALCULATION

The focus of this paper is on the robustness of the parameters of risers calculation and the case company is a foundry located in Villa Clara, Cuba. The basic steps for achieving the above target are summarized below [12]:

1. To select the most significant parameters that causes variations in the quality characteristics.
2. Casting defects have been selected as the most representative quality characteristics in the green sand casting process, as it is related to many internal defects (shifts, warpage, blow holes, sand drop, etc.). The target of the green sand casting process is to achieve “lower casting defects” while minimizing the effect of uncontrollable parameters.
3. Make the green sand casting process under the experimental conditions dictated by the chosen orthogonal array and parameter levels. Based on the experimental conditions, collect the data.
4. An analysis of variance (ANOVA) table is generated to determine the statistical significance of the parameters. Response graphs are plotted to determine the preferred levels for each parameter.
5. Beside the optimum settings of the control parameters and predict the results of each of the parameters at their new optimum levels.
6. Verify the optimum settings result in the predicted reduction in the casting defects.

An Ishikawa diagram (cause and effect diagram) is drawn to identify the parameters of risers calculation that may influence green sand casting defects as shown in Figure 3.

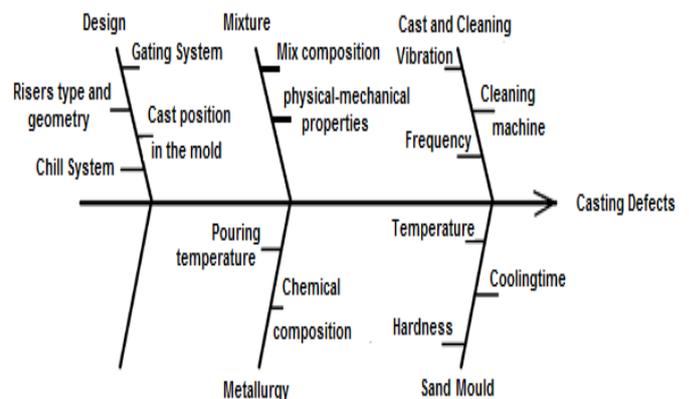


Figure 3. Cause and effect diagram

Table 1. Process parameters with their ranges and values at three levels

Parameter designation	Process parameters	Range	Level 1	Level 2	Level 3
A	Thickness of wheel rim (mm)	50-185	50	117.5	185
B	Height of wheel rim (mm)	150-600	150	375	600
C	Thickness of the central plate (mm)	50-140	50	95	140

To visualize the effect of process parameters on the casting defects, following parameters are selected:

- » Thickness of wheel rim (Factor A)
- » Height of wheel rim (Factor B)
- » Thickness of the central plate (Factor C)

The range of the parameters is show in the table 1.

The number of levels for each control parameter defines the experimental region. For each control factor, three levels are selected, out of which, one level is the starting level.

**SELECTION OF ORTOGONAL ARRAY**

Before selecting a particular orthogonal array to be used for conducting the experiments, two points must be considered

1. The number of parameters and interaction of interest.
2. The number of levels for the parameters of interest.

Therefore, the L9 orthogonal array is selected with 9 experimental runs and 3 columns. Taguchi has provided two tools to aid in the assignment of factors and interaction to arrays. The tools are: (1) the linear graph and (2) triangular tables. Linear graphs indicate various columns to which factors may be assigned and the columns subsequently evaluate the interactions of those factors [1]. The various factors and their interactions are assigned in each column of the L9 orthogonal array. The assigned L9 orthogonal array is shown in Table 2.

**Table 2.** L9 orthogonal array

Trials	Factor A	Factor B	Factor C
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

**CASE STUDY**

Once the parameters and parameter interactions are assigned to a particular column of the selected orthogonal array, the factors at different levels are assigned for each trial. The assigned experimental array is shown in Table 3.

**Table 3.** Experimental L9 array

Trials	Factor A	Factor B	Factor C
1	50	150	50
2	50	375	95
3	50	600	140
4	117.5	150	95
5	117.5	375	140
6	117.5	600	50
7	185	150	140
8	185	375	50
9	185	600	95

The experiments were conducted thrice for the same set of parameters using a single-repetition randomization technique [13]. The casting defects that occur in each trial conditions were measured. The average of the casting defects was determined for each trial

condition as shown in Table 4. The casting defects are the “lower the better” type of quality characteristics. Lower the better S/N ratios were computed for each of the 9 trials and the values are given in Table 4.

**Table 4.** Shrinkage defects values and signal-to-noise (S/N) ratio against trial numbers

Trials No.	Shrinkage volumen			Total	Average	S/N ratio
	1	2	3			
1	274.5	590.4	257.0	1121.8	373.9383	-52.1298
2	350.7	1758.9	1112.6	3222.2	1074.0820	-61.7170
3	1821.0	2027.0	2264.7	6112.7	2037.5540	-66.2164
4	500.9	684.2	570.1	1755.3	585.0983	-55.4164
5	1918.6	1586.0	1119.6	4624.2	1541.3877	-63.9502
6	2343.9	1924.1	1908.2	6176.1	2058.7155	-66.3134
7	206.6	808.4	273.7	1288.7	429.5713	-54.1003
8	1474.2	1234.5	1067.5	3776.1	1258.7159	-62.0742
9	2420.3	2576.2	1961.5	6958.0	2319.3383	-67.3619

**SIMULATION OF THE PROCESS**

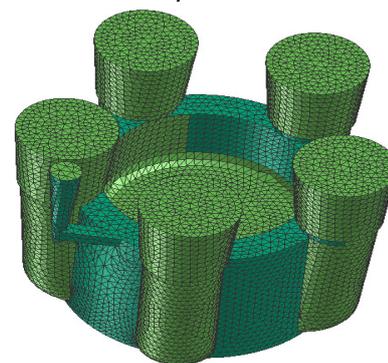
Version 2011 of the finite method based commercial software package ProCAST® was used for simulations of fluid flow during mold filling and the subsequent solidification. The software showed the defects product to the application of different geometrics parameters and different risers too.

Typical material properties were used. Assumptions made in the simulations with regard to heat transfer coefficients and initial temperatures are given in Table 5.

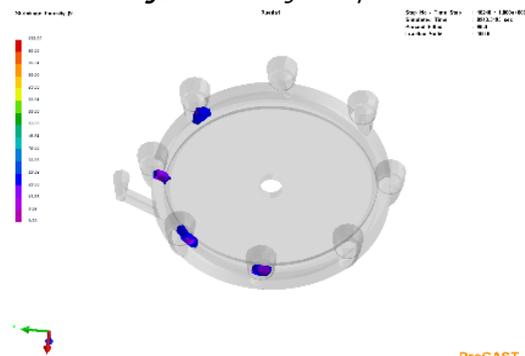
**Table 5.** Assumptions relating to software simulations

Interface	Heat transfer coefficients (Wm <sup>-2</sup> K <sup>-1</sup> )	Material	Initial temperatures (°C)
Steel alloy /sand mold	500	Sand mold	30
		Steel alloy (Ck45)	1540

Some pictures of the simulation process are shown below:



**Figure 4.** Meshing of the piece



**Figure 5.** Shrinkage porosity

**ANALYSIS OF EXPERIMENTAL RESULTS**

Analysis of experimental results was performed using Minitab 16 software and ANOVA plots obtained are given in table 6 and figure 6 respectively. ANOVA in table 6 indicates that the Height of wheel rim significantly influence the % of defects at 95% confidence level. The figure 6 indicates that the numbers of defects is minimum at first level of Thickness of wheel rim (A1), first level of Height of wheel rim (A1), and first level of Thickness of the central plate (C1).

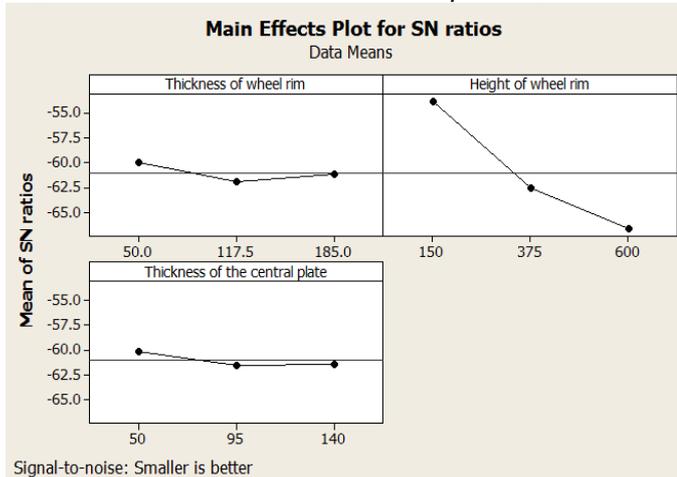


Figure 6. Main effects plot for S/N ratios

Table 6. Coefficients of estimated model for S/N ratios

Terms	Coef	SE Coef	T	P	
Const.	-61.0311	0.1625	-375.588	0.000	
Thicknes of wheel rim	50.0	1.0098	0.2298	4.394	0.048
	117.5	-0.8622	0.2298	-3.752	0.064
Height of wheel rim	150	7.1490	0.2298	31.109	0.001
	375	-1.5494	0.2298	-6.742	0.021
Thicknes of The central plate	50	0.8583	0.2298	3.735	0.065
	95	-0.4672	0.2298	-2.033	0.179

S = 0.4875  
 R-Sq = 99.8%  
 R-Sq(adj) = 99.3%

Fuente	P
Thickness of wheel rim	0.082
Height of wheel rim	0.002
Thickness of the central plate	0.125

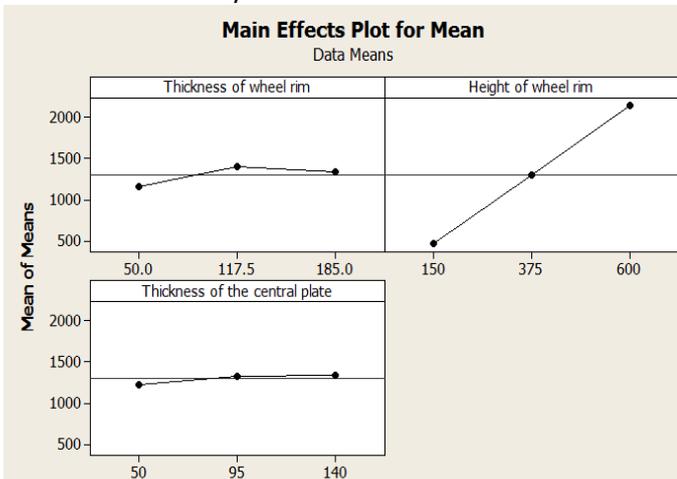


Figure 7. Main effects plot for mean

The tables 7 and 8 confirm that the parameter B or Height of wheel rim has the most significantly influence.

Table 7. Means of S/N ratios: Smaller is better

Level	A	B	C
1	-60.02	-53.88	-60.17
2	-61.89	-62.58	-61.50
3	-61.18	-66.63	-61.42
Delta	1.87	12.75	1.33
Rank	2	1	3

Table 8. Mean of means

Level	A	B	C
1	1161.9	462.9	1230.5
2	1395.1	1291.4	1326.2
3	1335.9	2138.5	1336.2
Delta	233.2	1675.7	105.7
Rank	2	1	3

A regression analysis contributes the following values:

**Regression Analysis: Defects 1 vs. Factor A-B-C**

The regression equation is:

$$\text{Defects 1} = -728 + 4.09(A) + 4.15(B) - 0.54(C)$$

S = 470.458

R-Sq = 83.7%

R-Sq(adj) = 74.0%

**Regression Analysis: Defects 2 vs. Factor A-B-C**

The regression equation is:

$$\text{Defects 2} = -76 + 0.60(A) + 3.29(B) + 2.49(C)$$

S = 262.328

R-Sq = 90.8%

R-Sq(adj) = 85.2%

**Regression Analysis: Defects 3 vs. Factor A-B-C**

The regression equation is:

$$\text{Defects 3} = -281 - 0.819(A) + 3.73(B) + 1.58(C)$$

S = 149.394

R-Sq = 97.5%

R-Sq(adj) = 95.9%

In the picture 9 is shown the result of application of the regression equation for each combination of geometric parameters.

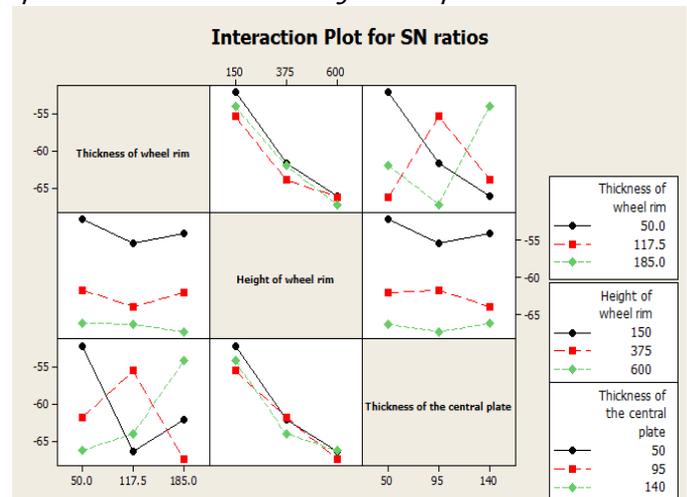


Figure 8. Interaction S/N ratio for smaller is better

Figure 2 shows the interaction between the thickness of wheel rim and the height of wheel rim (AxB), the thickness of wheel rim and the

thickness of the central plate (AxC) and the height of wheel rim and the thickness of the central plate (BxC). The S/N ratio value at (AxB) level 1 (50 mm) is a best interaction because of it gives the biggest delta value, and then followed by interaction (AxC) level 1 (50 mm). The thickness of wheel rim at level 1 (A1) and the height of wheel rim at level 1 (B1) have a maximum value.

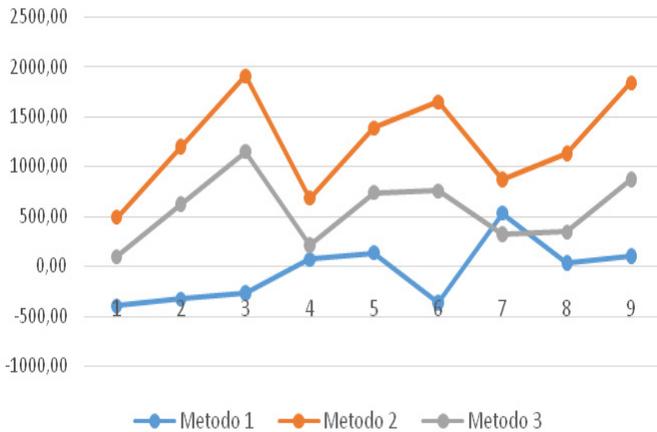


Figure 9. Final graph of the application of the regression equations for each method

**CONCLUSION**

- » The geometrical parameter, according to the results obtained in the experiment, most influential in the occurrence of defects produced by the shrinkage, is the Height of wheel rim.
- » The geometry values that shows fewer defects, for this experiment are:
  - Thickness of wheel rim: 50 mm
  - Height of wheel rim: 50 mm
  - Thickness of the central plate: 150 mm
- » Application of Taguchi method to determine the geometrical parameter that has the greatest influence on the presence of defects in castings is very important technique for the design of optimal casting.

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## ON THE SYNERGY BETWEEN DISTRIBUTED AND RECONFIGURABLE COMPUTING: CHALLENGES AND OPPORTUNITIES

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**Abstract:** This paper presents an analysis of the existing trends in distributed systems - particularly cloud computing – regarding the integration of hardware resources using a service orientation approach and identifies solutions to this challenge based on reconfigurable computing devices. The main structural components: instrumentation, computation and network infrastructure are being analyzed, and innovative approaches are proposed regarding a service-oriented integration using reconfigurable hardware. There is a current trend in cloud computing systems for introducing a new layer in the stack architecture model, specifically at its base, namely Hardware as a Service (HaaS) that makes hardware devices accessible through services using the cloud model. For this to be achieved two key points must be addressed: simplified hardware programming - through the development of hardware description services - and enhancing the system's portability by developing a Web service-based access. Last but not least, the paper links all these integration efforts to the most critical issue of the cloud computing systems – security – and proposes solutions based on reconfigurable hardware devices for overcoming them.

**Keywords:** Cloud computing, Reconfigurable hardware, Service-oriented Architectures, Middleware, Virtual instrumentation

### INTRODUCTION

Distributed computing systems are developing and spreading rapidly, and their particular form, cloud computing, is imposing itself as the next evolutionary phase of the Internet. Cloud computing, a revolutionary concept that provides software, infrastructure and storage resources to customers over the Internet in a scalable way, as services, raises new challenges regarding the integration of hardware devices. Having to face this task - developing a new level in the cloud architectural stack: Hardware as a Service (HaaS) - solutions can be found coming from another emerging field of the last decade: reconfigurable computing. These reconfigurable devices are now widely used, with numerous applications in various fields. They provide a high degree of adaptability and scalability, providing flexible solutions for developing versatile systems by minimizing requirements for dedicated hardware and optimizing power consumption.

This paper presents an analysis of the existing trends in distributed systems - particularly cloud computing – regarding the integration of hardware resources using a service orientation approach (SOA - Service Oriented Architectures) and identifies solutions to this challenge based on reconfigurable computing devices. The integration of such hardware resources in the cloud computing infrastructure using web services has the potential to meet the requirements of cloud systems regarding variations in resource demand and workload. Cloud services could gain in configurability and become more independent from the underlying hardware

resources; middleware also becomes more flexible, leading to a gain in price / performance ratio. The main structural components: instrumentation, computation and communication are being analyzed, and innovative approaches are proposed regarding a service-oriented integration using reconfigurable hardware.

### THE BACKGROUND FOR A SERVICE-BASED HARDWARE INTEGRATION

The service-oriented paradigm is a recent and innovative approach in the efforts to develop new technologies for hardware integration in heterogeneous distributed systems - in this case cloud computing. The main problem that needs to be overcome is the variety and diversity of hardware resources subject to integration - from "pocket" devices to large multi-processor systems.

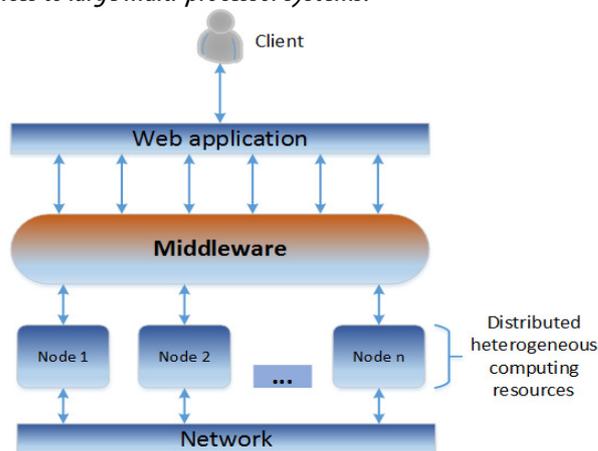


Figure 1. Integrating middleware in distributed computing systems

The functional characteristics of these hardware devices, such as energy consumption, storage and computing resources involved, inputs and outputs, the performance constraints (response times, real-time operation, etc.) raise the complexity of the integration effort. Thus, the efforts aim to develop a middleware that allows easy integration of different hardware resources in distributed systems using standard and neutral protocols and technologies (Figure 1).

Service Oriented Architectures and Web Services represent the latest step in the development of middleware technologies. This technology solves the problem of inter-operability and provides the basis for developing large-scale Internet applications. The term "middleware" defines an intermediate layer between the hardware (including its proprietary operating system) and distributed application that accesses it with the aim to mask the complexity of the distributed nature of the application, "hiding" away elements like memory management, network protocols and other functionalities (Geihs 2001).

Middleware technologies that allow the integration of applications are used for different purposes, from interconnecting hardware / software components of desktop or Web applications, to the development of systems that span over the Internet. Traditional technologies are quite limited when it comes to interconnecting heterogeneous software and hardware systems connected via the Internet. Web services and service-based architectures are designed specifically to meet these needs, focusing on interoperability and solving issues raised by the use of different platforms and languages (Figure 2). Thus, SOA is a solution that enables the integration of different technologies.

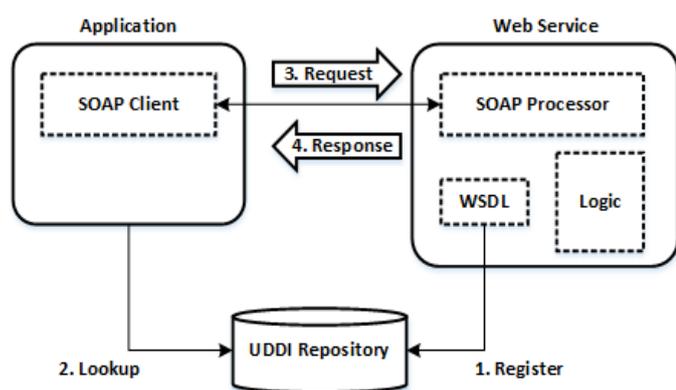


Figure 2. Generic functionality of a service-oriented architecture

Services are independent and autonomous applications and not classes or components closely related to a certain application. Services are designed to be installed on a network, possibly Internet, where they can easily be integrated into the applications where they are needed. Services do not need to know anything about the clients and must accept requests from anywhere, as long as the received messages comply with format recognized by the service and the security requirements are respected. Services can be installed and managed independently one from another and client applications and

service owners can modify the interface and functionality of a service at any time.

The scientific community credits service oriented architectures as a viable tool for developing a middleware based on web services, which can achieve a high-level abstraction of proprietary technologies for application developers, thus hiding the physical implementation of hardware devices or other functional aspects (network characteristics, etc.). A major advantage of hardware integration solutions based on Web services is that their architecture, relying on new standards (XML, SOAP, WSDL, UDDI, etc.), allows a unified approach to all hardware resources, despite the fact that each of them requires a specific integration methodology adapted to the particularities of the device.

It is obvious that in addition to the introduction of new technologies, a delicate process represents the ongoing transition from existing traditional architectures to new web service-based integrated ones. Numerous studies (de Deugt et al. 2006, Karnouskos et al. 2007) have been conducted and are ongoing regarding the implementation of Web service interfaces between different hardware devices and distributed corporate systems, especially given the concept of Internet of Things (IoT), which supports the integration of a variety of embedded systems using the Internet (Sommer et al. 2009).

Cloud architectural stack systems traditionally comprise three layers:

- » Infrastructure as a Service (IaaS) provides computing resources, storage and switching, relatively in a less structured way - the operating system is still in the cloud
- » Platform as a Service (PaaS): provides tools and integrated development environments in a more structured way than IaaS, the operating system running locally.
- » Software as a Service (SaaS) provides dedicated applications developed using stand-alone software modules, remote accessible (e.g. through APIs-Application Programming Interface)

Cloud computing architecture enables remote access to the resources physically situated at any location on the globe, in an approach that allows for accurate metering and billing on the "pay-as-you-go" principle (Armbrust et al. 2010). Using cloud computing infrastructure reduces costs, reduces efforts licensing new software tools and increases the flexibility of business processes, virtually eliminating many of the limitations existing in the traditional approach of a computing environment: space, time, power and cost.

Despite the strongpoints listed above, there are areas that cannot benefit from a cloud computing approach, due to technological impediments regarding resources integration (Raj, Schwan 2007); especially in the case where direct access to the hardware device is needed, like in the development of embedded systems. The need for access on the device level does not permit a cloud computing approach, because such access entails that the application is required to run on the same server to which that device is physically connected (Hovestadt et al. 2012); even if this impediment is resolved, a security problem remains, since granting direct remote access makes the

virtual environment no longer isolated from the outside (Szefer, Lee 2011).

All these issues have generated new research trend (Raj, Schwan 2007) that aims to introduce a new layer in the cloud computing stack architecture, specifically at its base: Hardware as a Service (HaaS), one that would allow the use of distinct hardware devices through services using the cloud computing paradigm.

### **A PERSPECTIVE ON RECONFIGURABLE HARDWARE ARCHITECTURES**

Reconfigurable hardware comprises devices that can change their internal organization "on the fly". This gives a high degree of flexibility in the implementation of circuits, since the hardware resources of these devices are configurable (and usually re-configurable) after production, thus raising the possibility to implement several different circuits using the same device over time.

Reconfigurable hardware devices are constituents for a new discipline, "Reconfigurable computing", that uses such devices (like FPGAs - Field Programmable Gate Array) to implement computing systems. These systems have impressive performance and other advantages like: high processing speed, low power consumption - the circuitry being application-optimized, reduced size, and so on. Reconfigurable hardware devices have a great potential due to high adaptability and scalability, reducing the need for dedicated circuitry, optimizing energy use and minimizing hardware resources required for specific applications.

Cloud computing, being an emerging field with an accelerated growth rate, provides a number of areas where, because of the advantages listed above, reconfigurable hardware can provide significant benefits. Especially considering the increasing amounts of data being moved to such cloud systems, a hardware-based feasible solution is required.

There are also several shortcomings, despite the strengths mentioned above, that impede widespread use of reconfigurable hardware systems; two in particular have been identified by researchers (Vuletic et al. 2004): the lack of unified and standardized programming models and the difficulty of integrating these resources due to their diversity and heterogeneity. It is desirable that application developers for reconfigurable systems can do this without having to bother with low-level details of the underlying hardware. Hardware description languages (HDL) is not an attractive tool for clients who develop applications using such resources. In this context, the integration of reconfigurable devices in the cloud must be accompanied by the development of "hardware description services", including new programming models that provide a high-level development environment, making developing and running applications on reconfigurable hardware attractive for cloud computing systems.

In the broad field of reconfigurable hardware architectures, a special place is occupied by Reconfigurable SoC's (System-on-Chip). This is a solution that integrates reconfigurable hardware with a microprocessor, a synergy exploiting both the flexibility of the

software design and the high performance of the hardware implementation. In this integration, the microprocessor is the one having full control over the entire system, being responsible for running the embedded software application and also for the reconfiguration of the programmable logic. These architectures, however, are subject to the same impediments, namely the lack of a unified programming methodology and a standardization of the interfaces (Vuletic et al. 2004). There is a variety of RSoC architectures, each platform having its own specific characteristics and integrated development tools (Mencer et al. 2001). The two directions of research identified as necessary to increase the attractiveness of RSoCs, namely to simplify programming and increase portability, can benefit from a service oriented approach; in the first case by the development of hardware description services (as mentioned above) and in the second case a Web service-based access for ensuring the possibility of programming, re-configuring and communicating with the remote device via the Internet. This creates an intermediary abstraction layer useful both for the programmer and the hardware engineer, thus obscuring the functional and constructive features of the hardware resources.

Service-oriented access to reconfigurable hardware facilitates the development of applications on these platforms, and a variety of fields can benefit from the advantages of this type of hardware implementations: cryptography and security solutions, digital signal processing (DSP), neural networks, control systems, etc. (Rodriguez et al. 2005).

Another application of the synergy between reconfigurable hardware and service oriented architectures is the transition from software to hardware services, namely the possibility of implementing such services on reconfigurable hardware platforms (Smith et al. 2006) ("hardware-accelerated services"). This brings substantial benefits, especially in the cases when various services are launched and executed sequentially over time.

### **SERVICE-ORIENTED INTEGRATION OF HARDWARE RESOURCES**

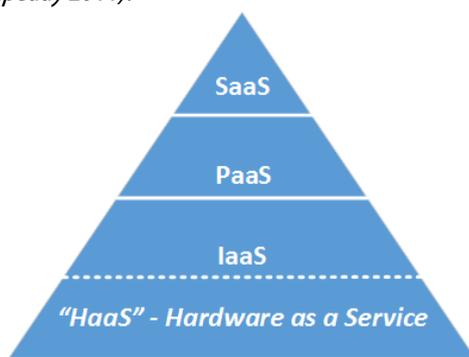
#### **Processing resources**

A decade ago it was common practice in the IT industry to invest in physical equipment and store it in a hosting company's facilities. However, the rapid evolution of the Internet has made this approach obsolete, as it can no longer meet the increasing reliability and availability requirements. Also, the big "static" data centers, growing to a considerable size and complexity, have become completely ineffective in terms of performance and energy consumption due to large variations in workload over time.

The emergence of cloud computing can be seen in these conditions as a natural evolutionary step, but one which also raises new challenges, the main one being linked to integration efforts of distributed computing resources. Thus, the reconfigurable hardware field also receives a boost because of the increasing need of dynamic hardware resources capable to respond in a scalable manner to sudden load changes.

In the cloud computing market, the companies can choose between two scaling solutions for the cloud data centers: horizontal (by increasing the number of stations - computing servers) and vertical (improving the individual performance of computing devices and network components). Both encounter drawbacks: first would greatly increase the power consumption of these data centers (consumption that is very high already, 10-30 times higher than the consumption of the office infrastructure of a company like IBM (Carter 2009)), the second is not feasible in the case of multi-CPU architectures, where the native clock frequency is approximately constant. Under these conditions, the expansion of cloud data centers is a current and urgent problem that needs to be dealt with.

Reconfigurable architectures (such as FPGAs) can play an important role in overcoming the issues described above, since it allows resource scaling in the cloud to a degree that cannot be achieved using conventional processors. New efforts are oriented to finding optimal solutions for integrating these architectures in the cloud through a unified approach that would allow the integration of processing resources, development environments and communication infrastructure. This research direction is the focus of several efforts coming from both the academic and industrial environments (Madhavapeddy 2011).



**Figure 3.** The cloud computing architectural stack having as base the emerging "HaaS" layer

Current research proposes methodologies and platforms for integrating hardware resources as cloud computing services into a new paradigm - Hardware as a Service (Figure 3). In (Stanik et al. 2012) the authors implement service access using hardware resources distributed over different geographical locations but also interconnected via a virtual bus. In the same manner, (Hovestadt et al. 2012) proposes ways to integrate hardware emulators using services, enabling the simulation and virtualization of a hardware system before the existence of a physical prototype.

In IaaS (Infrastructure as a Service) cloud services, equipment is provided to customers in the form of virtual machines controlled by a software hypervisor. Virtualization is therefore a key issue in a cloud computing system, each virtual machine being composed of hardware resources (CPU, memory and storage devices), and the overall performance depends on how these resources are virtualized and made available to customers dynamically and according to demand. Thus, any optimizations aim at managing hardware resource from the

virtualization perspective; current studies (Sefraoui et al. 2014) identify three ways to improve the performance of cloud systems:

- » Real-time "migration" of virtual machines from one physical node to another while maintaining the service functionality
- » Load balancing by managing the number and operation of servers for improved performance and scaling them depending on the workload
- » The dynamic reconfiguration of virtual hardware resources during their operation providing thus a real-time scaling of computing and storage resources as needed

The integration of reconfigurable hardware devices allows overcoming some inherent limitations of the traditional network virtualization solutions with generic microprocessor architectures. Reconfigurable hardware implementations (based on FPGAs) for network virtualization uses the FPGA to implement virtual routers benefiting from the platform's scalability that can easily adapted to possible changes in the network (Vaquero et al. 2011).

Another critical point in the cloud infrastructure vulnerable to heavy traffic situations is the reliability of the Web servers running the cloud services. Solutions to this issue were identified by implementing the Web services protocol stack in hardware - using FPGA architectures (Yu et al. 2011). This approach allows for a hardware accelerated web server to have a higher processing traffic rate, increased reliability and reduced processing time due to the pipelined implementation and direct execution in hardware, without a software operating system.

Cloud service performance can be enhanced by implementing hardware accelerated services ("Hardware Acceleration as a Service" - HAaaS) able to take over the execution of computational intensive tasks that require dedicated hardware resources and deploy them on reconfigurable devices such as FPGAs (Mershad et al. 2013). This way the execution speed increases substantially simultaneously with a decrease in energy consumption; cloud service providers can also increase their earnings by sharing these services with other providers -at their request- and by imposing higher tariffs to customers that require access to such "premium" services.

**Instrumentation**

Integrating instrumentation into cloud computing systems is a natural phenomenon given the raising need of remote access to a multitude of heterogeneous computing resources, communication infrastructure and measuring equipment/instrumentation. In this regard there are many implementations of instrumentation solutions integrated using service oriented architectures in grid computing systems sharable for academic and research purposes (Cheptsov et al. 2012).

Integrating instrumentation with the cloud computing concept would cause the instrument to "transcend" the physical equipment as cables and connections with a PC would be no longer necessary, and the software does not have to be tied to a specific system. The instrument would be perceived by the user as a Web page accessible

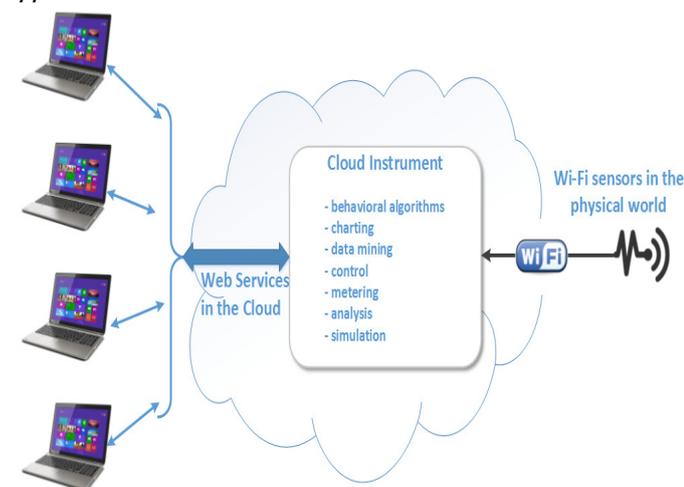
using any online device, even a smartphone. Many areas could benefit from such an approach to instrumentation (biomedical, weather, energy, construction, etc.) catalyzing research in this direction. This integration involves on one hand a new philosophy in designing and implementing sensors and measurement hardware resources - which according to the Internet of Things concept must be elements with increased connectivity, always online - and on the other moving related software resources from static local systems to cloud servers for greater accessibility and performance.

In a simplistic approach (displayed in Figure 4), a cloud instrument comprises a measuring device - one or more sensors - placed at a certain location, which is connected on-line by various technologies (Wi-Fi, for example). Measured data is converted into digital format and sent via the Internet to cloud servers where it is processed by specific software (control, analysis, metering, data mining, etc.), and the results are provided to users through the Web (Ghercioiu 2011).

Expansion of cloud computing in the field of instrumentation is a new research direction that describes concrete efforts in combining instrumentation and cloud computing both conceptually and technically. This research presents two possible approaches to this integration:

- a. Development of models and architectures that allow the integration of instruments and sensors into cloud systems; this direction must take into account the specifics of cloud computing offering IaaS type services.
- b. Development of specific instrumentation software cloud services according to the PaaS paradigm.

Currently SaaS cloud services can be used with instrumentation dedicated software, but the problem remains regarding their incompatibility with specific drivers needed for cloud computing architectures. These drivers can be considered an abstraction of the real instruments, which raises the need for a uniform integration approach of the cloud instrumentation.



**Figure 4.** Generic architecture of a "cloud" instrument  
Instrumentation as a cloud service is a conceptual paradigm that provides users with data acquisition instruments shared through the cloud computing infrastructure. Like any cloud service,

instrumentation services present a uniform access and management of these resources, enabling their efficient sharing between multiple users or institutions (academic or industrial), while the instrumentation devices are available physically in different geographical locations.

The development of instrumentation in the cloud must take into account a feature that makes such services somewhat unique - the fact that instrumentation that is a process in close contact with the measured object, which binds these services to real natural elements. This raises a new problem: the difficulty of real-time sharing of instruments for multiple accesses, thus requiring the implementation of resource scheduling services.

Virtual instrumentation is suitable for an approach using reconfigurable hardware devices because each tool performs an operation well defined and bounded, allowing their easy implementation in reconfigurable hardware. The implementation of virtual instrumentation using dynamically reconfigurable hardware platforms is a solution that increases their performance while raising their flexibility because of the reconfiguration potential. It also provides a better management of the complexity of such architectures, because the structure allows the co-existence of reconfigurable integrated scalable IP cores connected to the systems busses. This is particularly important in the case of an accelerated growth in complexity, a situation when reconfigurable instruments benefit from their adaptability and dynamic reconfiguration to meet the requirements. They also allow for an optimized design methodology based on an incremental approach (instrumentation can be updated without physical access by remotely upgrading the bitstream and thus changing - totally or partially - their internal configuration).

Virtual reconfigurable instrumentation is an attractive solution especially in the academic field, having the potential to facilitate student access to real experiences in the field of instrumentation while lowering necessary costs since the same hardware platform can be used to implement a variety of virtual instruments.

**Communication**

In the view of cloud computing, communication infrastructure undergoes a process of diversification and development, requiring ever increasing resources and also the ability to dynamically respond in real-time to customer requests for services. The constituent elements of the communication infrastructure, namely the network nodes (routers, switches, bandwidth control devices, so-called "load-balancing devices", etc.) must move from their traditional form, with static structure, to a new approach allowing dynamic reconfiguration. Traditionally, network components are sized according to the maximum needs for which that network is designed. In the case of cloud computing such an approach is totally inefficient because it doesn't allow for an optimal cost management of the working equipment. This is because in a cloud environment there are large variations in the workload, so there are times when equipment

designed to manage massive loads works with a very small volume of traffic. Another problem is the diversity of network services that co-exist in a cloud computing system, which hinder achieving the desired service performance because the "general-purpose" servers, while providing the desired flexibility, lack the needed performance and energy efficiency.

For these reasons a new approach to network nodes in cloud computing communication systems is needed, since the traditional implementation cannot provide an adequate response to situations where there is a high variation in the types of services required. Four basic requirements needing to be met by network elements have been identified in this research in order for the network to provide the performance required in cloud computing systems (Hayashi, Ueno 2010):

- a) Network processing speed
- b) Performance scalability
- c) Functionality scalability
- d) Reliability

Reliability is an important factor since the network infrastructure can act as a social infrastructure, which must guarantee the reliability of services that can be critical to users.

In this context, reconfigurable hardware architectures are a potential solution for a new approach to network nodes in cloud computing systems, an approach that meets the requirements listed above. Research in this area has shown that the dynamic reconfiguration feature integrated into the network nodes enables performance scaling for virtual devices and optimization in the network processing, thus improving the bandwidth and networking resource usage in cloud computing data centers (Hayashi, Ueno 2010).

The big reconfigurable hardware manufacturers have also directed their research towards this synergy of reconfigurable systems and networking, a relevant example are the efforts made by Xilinx to reach a transfer rate of 1 TB/s (currently their FPGAs provide 100G connectivity) by increasing SerDes (serializer - deserializer) resources' speed and by providing fabric support using large width data busses (Brebner 2011).

Another project, this time open-source, covering research in network systems based on reconfigurable hardware acceleration is NetFPGA. This is a platform that has now reached the second version - offering 10G support and being based on a Xilinx Virtex 5 FPGA; also having 4 10GigE SFP interfaces, one PCI Express for connectivity to the host system (Gen2 x8 channels), and on-board SRAM and DRAM memory. Research conducted on this platform highlights the advantages of implementing network nodes in reconfigurable hardware, which enables dynamic re-programming to adapt to different scenarios and needs, which is particularly important given the specifics of cloud computing systems (Rubow et al. 2010).

NetFPGA concept has raised significant interest among researchers, with several groups worldwide working in large research universities and forums (Cambridge, SIGCOMM, SIGMETRICS, CESNET, UNSW, etc.).

Experimental implementations have been developed comprising a wide range of applications: congestion control, DPI (Deep Packet Inspection) - FPX, monitoring packages - ICSI, PTP (Precise Time Protocol - for synchronizing between routers).

Networking solutions implemented using FPGA technology bring on one hand the great benefit of "field upgradeability" (one can re-configure the device remotely during run-time without physical accessing it), and on the other support for high performance packet processing and data transfer speeds higher than those obtained with software implementations (Rubow et al. 2010).

### SECURITY ISSUES

Cloud computing offers many advantages through its functional paradigm, namely massive computing and storage resources made available to customers as services using public cloud servers. This brings on the issue of dealing with critical data applications that require a high security level. Data security is the main problem blocking the widespread adoption of cloud computing, since customers are reluctant to store critical data in a remote system where they lack full administrative rights and which is physically situated in an unknown location.

Due to the cloud services' features, there is a shared responsibility of data security between two entities: client and provider. What are the specific responsibilities of each depends primarily on the type of cloud services provided (e.g. in the IaaS, the customer has the responsibility to secure everything from the operating system up - data and applications, while in the SaaS they are all managed by the provider) (Ogigau-Neamtii 2012).

The current cloud service security model requires client data to be encrypted during transit to / from cloud storage resources; however an important vulnerability arises when accessing and processing this data while it is stored physically in the cloud computing infrastructure. Security and data integrity cannot be guaranteed, as data can be accessed by malicious entities without the client knowing. Traditional software-implemented security solutions can provide limited protection and are exposed to attacks from within, exactly the kind of attacks most likely in the case of a cloud computing system. These limitations are generated by the structural and functional characteristics of systems, for example, unified memory spaces for both data and software expose the system to an attack that can change the program memory during operation.

These vulnerabilities identified above must be addressed by cloud service providers by stipulating solid security guarantees for clients in the SLA (Service Level Agreement). In order to be overcome, recent research has identified the need to move from traditional, software-based solutions, to a new perspective where trust is guaranteed by the solutions implemented in hardware. FPGA-based reconfigurable architectures are considered to have a good potential to solve a large part of the existing security vulnerabilities (Eguro, Venkatesan 2012).

A possible direction in which reconfigurable hardware architectures can provide additional security within cloud systems is their

integration as reliable computational modules. Reconfigurable hardware devices (such as FPGAs) can play such a role due to their isolated memory spaces, computing parallelism, dynamic partial reconfiguration and constructive bitstream protection methods. The device operates as a computing element with a high degree of autonomy (a system administrator cannot access the data and operations performed by the FPGA, low-level access to such a resource being impossible). Therefore, cloud customers could use these devices to run critical modules and operations.

Such integration allows for providing enhanced security guarantees that are absent in the current architecture of cloud servers; however, besides proper integration of these trusted platforms, a new approach on data classification is required. Non-critical data can be processed using traditional cloud infrastructure and sensitive data needing extra security is offloaded to such trusted reconfigurable hardware platforms. There is research to support that FPGAs due to their closed computational environment can be considered as homomorphic encryption emulators (an emerging encryption technique that allows operations to be performed on encrypted data with unencrypted result identical to that obtained when performing the same operations on unencrypted data) (Eguro, Venkatesan 2012). Such encryption has multiple applications for cloud computing and can thus ensure total protection of the critical data (which is always encrypted), maintaining and securing the functionality of the cloud services.

### CONCLUSIONS

In this paper we have highlighted the perspectives of hardware integration - especially reconfigurable resources like SoC/FPGA - using service-oriented architectures in cloud computing systems. This integration has the potential to provide technological solutions to the challenges generated by the diversity and heterogeneity of hardware resources.

The main objective is the development of a service-oriented middleware for enabling the easy integration of hardware resources in distributed systems using standardized technologies and protocols, thus achieving a high level abstraction of the technologies and specific features of the devices. Thus, service-oriented integration introduces an abstraction layer between the user and the underlying hardware and software resources, enabling a unified approach.

There is a current trend in cloud computing systems for introducing a new layer in the stack architectural model, specifically at its base, namely Hardware as a Service (HaaS) that makes hardware devices accessible through services using the cloud model. For this to be achieved two key points must be addressed: simplified hardware programming - through the development of hardware description services - and enhancing the system's portability by developing a Web service-based access.

In our perspective an important consequence of this integration is the ability to transcend services from software to hardware - implemented on reconfigurable platforms; bringing on improved

performance and increased service flexibility. In cloud systems, reconfigurable hardware can act as an accelerator for services that implement complex computational and resource-consuming tasks - leading to a new sub-paradigm HaaS: Hardware Acceleration as a Service.

This paper also analyzed issues regarding the integration of virtual reconfigurable instrumentation in the cloud. Uniform access and management of virtual instruments using the cloud model adds greater flexibility in their sharing between users and institutions, an important consideration given that they are usually situated in various geographic locations. Reconfigurable virtual instruments allow a better management of the complexity by enabling adding/removing of new functionalities using the partial reconfiguration feature.

The cloud network infrastructure also makes the subject of a new approach based on reconfigurable hardware solutions that allow the scaling of network resources according to the needs and real time traffic situations, improving the bandwidth and network resource usage in cloud data centers.

We consider that all the key points identified above must also take into consideration the security vulnerabilities of the cloud computing model. We propose that reconfigurable hardware resources integrated into the cloud can act as trusted platforms for running critical computations in secure conditions. Thus, shifting the security solutions from software to hardware is mandatory in order to provide effective counter-measures to the ever-growing security threats.

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## THE EXTENDED FINITE ELEMENT METHOD IN FATIGUE LIFE PREDICTIONS OF OIL WELL WELDED PIPES MADE OF API J55 STEEL

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**Abstract:** This paper presents an application of the extended finite element method (XFEM) in the modeling and analysis of simultaneous cracks propagations in a seam casing pipe made of API J55 steel by high-frequency (HF) contact welding. The geometry used in simulations is pipe with axial crack subjected to constant amplitude cyclic loads. Short theoretical background information is provided on the XFEM, as well as the demonstration of the method used for verification of computed stress intensity factors (SIFs). The obtained numerical results prove the efficiency of XFEM in the simulation of the axial cracks propagations in tube geometry. Some guidelines for improving the XFEM use in fatigue life predictions are also given.

**Keywords:** XFEM, seam casing pipes, axial surface crack, fatigue crack growth, fatigue life prediction

### INTRODUCTION

Pipelines are the most economical and safest way for oil and gas transport. However, majority of failures of welded steel pipelines occur due to insufficient resistance to crack initiation and growth, poor quality of welded joints and reduced capacity due to corrosion damage. Low-alloy steels are nowadays widely used for pipelines due to optimal combination of mechanical properties and weld ability, but their application for oil and gas pipelines is still related to failures.

The reliability of the oil rigs system is very important for the continued exploitation and for environmental protection as well. Therefore, the standards and recommendations for assessing the effects of cracks on the integrity of welded pipes were developed. However, welded casing pipes can also have an axial surface crack on the inner and/or outer surface, and be subjected to different loads, including external and internal pressure and axial loads (e.g. due to structure weight).

In order to keep pipeline safe and reliable in operation, its fatigue life is of utmost importance. The essential part in fatigue life prediction is to estimate precisely the maximum allowed pressure, as well as to evaluate fracture mechanics parameters, like stress intensity factor and J integral. So far, there are no detailed 3D finite element analyses of wide spectrum of outer surface cracks.

This paper presents an application of the extended finite element method (XFEM) in the modeling and analysis of simultaneous cracks propagations in a seam casing pipe made of API J55 steel by high-frequency (HF) contact welding.

The geometry used in simulations is pipe with axial crack subjected to constant amplitude cyclic load.

### Crack growth under cyclic loading

Crack growth under cyclic loading of machine parts and construction has a crucial influence on their lifetime. Therefore, of practical importance is to determine the relationship between the present stress state at the crack tip, which is at variable load determined by the stress intensity factor range  $\Delta K$ , and the crack growth rate  $da/dN$ . The crack growth to its critical size primarily depends on external loads and crack growth rate. Paris equation for metals and alloys, establishes the relationship between fatigue crack growth  $da/dN$  and stress intensity factor range  $\Delta K$ , using the coefficient  $C_p$  and the exponent  $m_p$ :

$$\frac{da}{dN} = C_p (\Delta K)^{m_p} = C_p (1,12 \cdot \Delta \sigma \cdot \sqrt{\pi \cdot a})^{m_p}$$

### Resistance to crack growth of API J55

Pressured welded pipes can be very sensitive to cracks and their stable or unstable growth. Therefore, it is important to identify reliable criteria for assessing the remaining lifetime of pressured pipes with cracks in base material and weld. In order to understand better the crack initiation and crack growth in casing pipes exposed to high pressures, high temperatures and chemically aggressive work environment in oil rigs, the material behavior control parameters at the crack tip and the fracture resistance should be expressed quantitatively.

Tests of the modified CT specimens were carried out at room temperature on a machine SCHENCK-TREBEL RM 100. Modified CT specimen thickness is  $d = 6.98$  mm (equal to the pipe wall thickness) [12]. Indirectly, through the critical J values  $J_{Ic}$ , the critical values of

stress intensity factor  $K_{Ic}$  are determined, i.e., calculated using the expression (1) and are given in Table 1:

$$K_{Ic} = \sqrt{\frac{J_{Ic} \cdot E}{1 - \nu^2}} \quad (1)$$

Using the expression:

$$K_{Ic} = 1,12 \cdot \sigma_c \cdot \sqrt{\pi \cdot a_c} \quad (2)$$

and taking into account the values of stress,  $\sigma = \sigma_c$  (where  $\sigma_c$  is fracture stress) approximate values of critical crack length ( $a_c$ ) for base material (BM), heat affected zone (HAZ) and weld metal (WM) were calculated.

Table 1. The values of  $K_{Ic}$  - pipe from service

Specimen	Temperature [°C]	$J_{Ic}$ [kJ/m]	$K_{Ic}$ [MPa m <sup>1/2</sup> ]	$a_c$ [mm]
BM-NR-E	20	35.8	91.4	14.4
HAZ-NW-E		48.5	106.4	19.6
WM-NW-E		45.7	103.3	18.5

Based on the obtained values of  $K_{Ic}$  for the base metal, HAZ and weld, the basic material (BM) has the lowest resistance to crack initiation and propagation.

**XFEM in fatigue life prediction**

The extended finite element method was developed to ease difficulties in solving problems with localized features that are not efficiently resolved by mesh refinement. One of the initial applications was the modeling of fractures in a material. A key advantage of XFEM is that in such problems the finite element mesh does not need to be updated to track the crack path. Morfeo/Crack for Abaqus relies on the implementation of the extended finite element (XFEM) method available in Abaqus. Morfeo/Crack for Abaqus is capable of performing crack propagation simulations in complex geometries. It calls Abaqus at each propagation step and between each step, then reads the Abaqus solution, recovers a richer, improved XFEM solution in a small area surrounding the crack and computes the SIFs. SIF values at crack tip determine the appropriate crack growth increment for crack. This procedure was performed 100 times in order to simulate incremental crack growth.

**Fatigue life predictions of pipes with axial surface crack**

The main technical characteristics of the oil rigs from where the observed pipe is are as follows:

- » Layerpressure (Kp-31): maximum=10.01 [MPa], minimum=7.89 [MPa].
- » layertemperature: T=65 [°C],
- » number of strokes of pump rod:  $n_{PR}=9.6$  [min<sup>-1</sup>]

The geometry used in simulations is pipe with axial surface crack in the base metal (BM), Figure 1. The pipe is made of API J55. On the outer surface of the pipe there is an initial axial surface crack with dimensions:  $a=3,5$  mm and  $2c=200$  mm.

The initial crack length used in the analysis was 200 mm, and it was 3, 5 mm deep. The growing crack was incremented at steps of 0.2 mm. Figure 2 shows crack at beginning (1<sup>st</sup> step- crack opening), figure 3,

after 7<sup>th</sup> step of propagation when the crack grows through the wall, while Figure 4 shows the crack at the end of XFEM simulation (step number 100). The final crack length at the end of simulation was 219.8 mm.

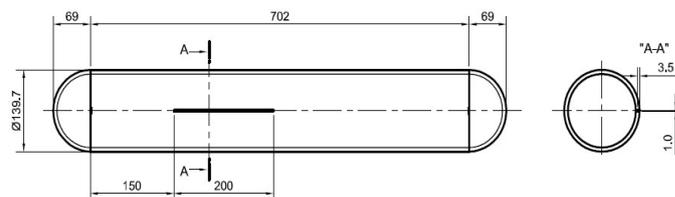


Figure 1. Pipe (pressured vessel) with an axial surface crack on the outer surface

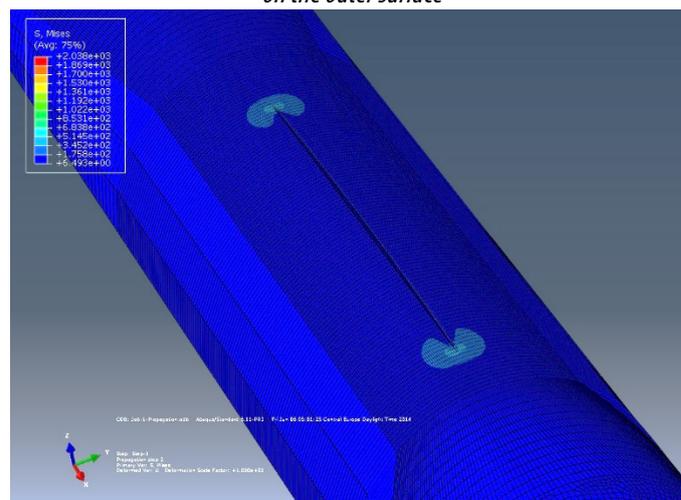


Figure 2. Step 1 - crack opening and Von Mises stresses at crack tips

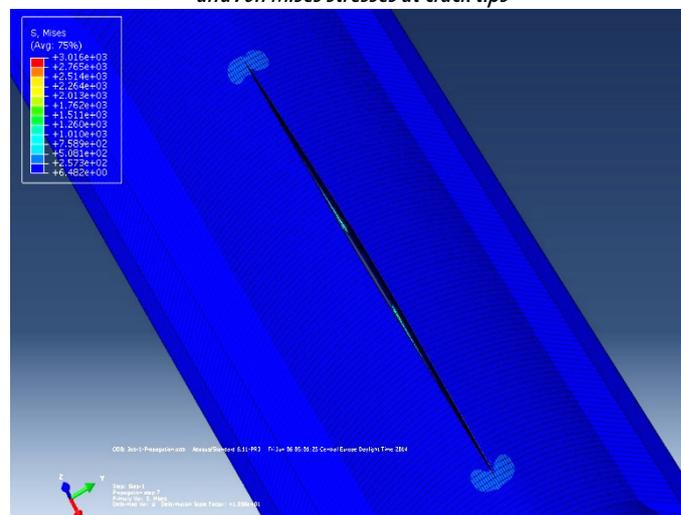


Figure 3. Von Mises stresses at 7<sup>th</sup> step – crack became through-wall

A finite element model of the pipe was created using the Abaqus software. Mesh was refined around the initial crack, and a uniform template of elements was used.

The prediction of crack growth rate and residual strength of pipe demands accurate calculation of stress intensity factors (SIFs). Morfeo/Crack for Abaqus calls Abaqus at each propagation step and between each step, then reads the Abaqus solution, recovers a richer, improved XFEM solution in a small area surrounding the crack and computes the SIFs.

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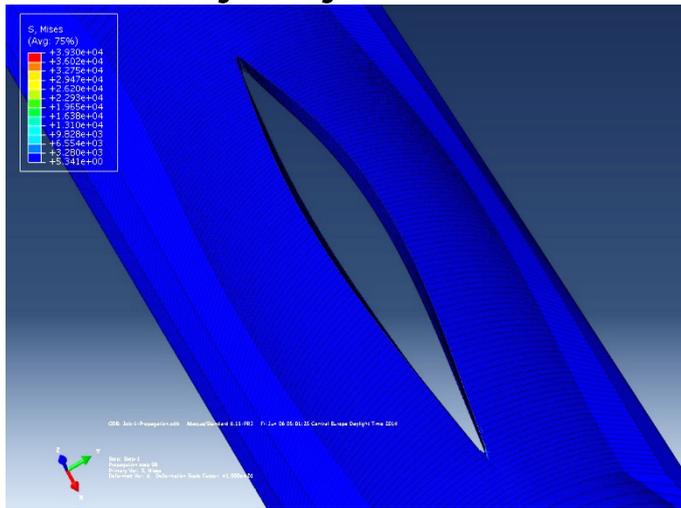


Figure 4. Final crack length at 100<sup>th</sup> step (219, 8 mm) and Von Mises stresses

SIF values at the crack tip determine the appropriate crack growth increment for the crack. This procedure was performed 100 times in order to simulate incremental crack growth. Some of the values obtained in Abaqus for every crack growth step are shown in Table 1. SIF values at the crack tip are shown in the last four columns. Those are equivalent SIF –  $K_{eq}$ , and respectively SIFs for modes I, II and III,  $K_I$ ,  $K_{II}$ , and  $K_{III}$ . Obviously, value  $K_I$  is more influential in crack growth than  $K_{II}$ , and  $K_{III}$ . Thus, it will be reasonable for further consideration to use stress intensity factor  $K_I$ , or even better  $K_{eq}$ , in fatigue crack growth prediction rates.

Table 2. Some of the values obtained in Abaqus for every crack growth step [x (front point coordinate): 50.7745]

Curvilinear abscissa along the crack front	y	z	$K_{eq}$	$K_I$	$K_{II}$	$K_{III}$
0	8.77E-05	69.4784	860.175	837.413	1.55444	1.65058
0.349	8.72E-05	69.1294	859.6	837.004	1.468	1.74059
0.698	8.68E-05	68.7804	859.072	836.648	1.38001	1.83133
1.047	8.64E-05	68.4314	858.595	836.348	1.29048	1.92288
1.396	8.59E-05	68.0824	858.175	836.113	1.19942	2.01528
1.745	8.55E-05	67.7334	857.82	835.95	1.10692	2.1085
2.094	8.51E-05	67.3844	857.54	835.868	1.01306	2.20247

The obtained relationship between equivalent stress intensity factor  $K_{ekv}$  and crack length  $a$ , Figure 5, shows tendency of increasing  $K_{ekv}$  with increased crack length  $a$ , while the crack was reached up to 210 mm. The largest increase in value  $K_{ekv}$ , as expected, was before the seventh step, when crack penetrates the pipe wall. In working conditions leaking starts here and the pipe is already failed. However, the pipe is still in use for simulation.

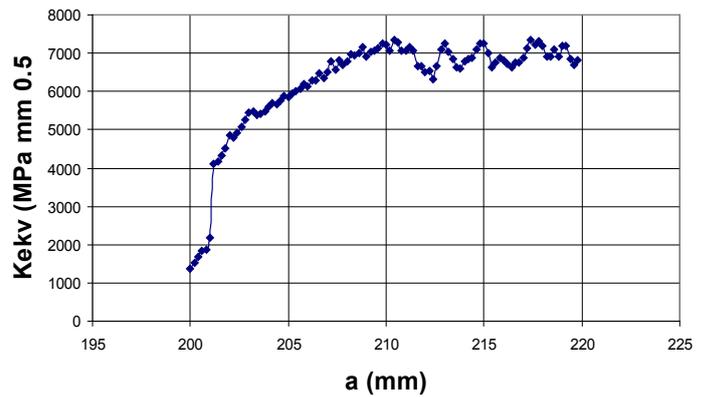


Figure 5. Obtained relationship between equivalent stress intensity factor  $K_{ekv}$  and crack length  $a$

The chart in Figure 6 shows the obtained relationship between steps and cycles number  $\log N$ .

After the seventh step, when the crack penetrates the pipe wall, the number of cycles becomes significantly lower and remains at about the same values until the final step, when the crack length is 219.8 mm.

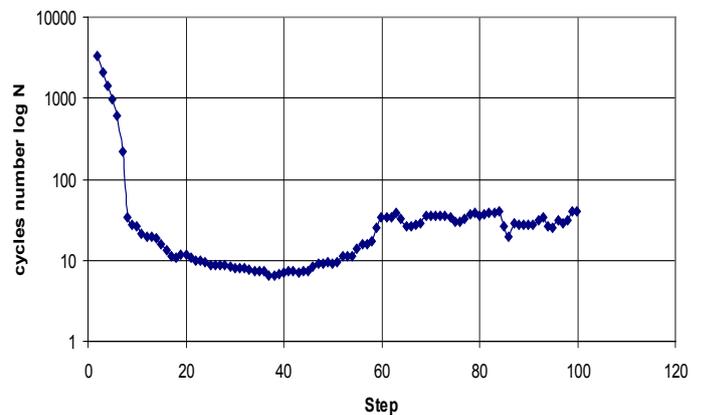


Figure 6. Obtained relationship between steps and cycles number  $\log N$

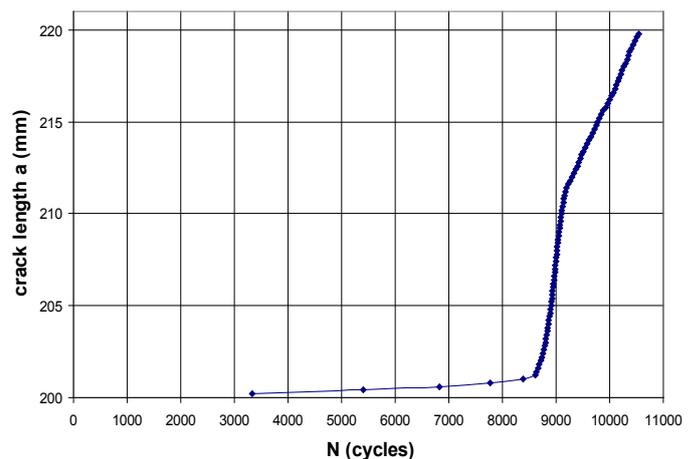


Figure 7. Obtained relationship between crack length  $a$  and number of cycles  $N$

The chart in the Figure 7 shows the obtained relationship between the crack length  $a$  [mm] and the number of cycles  $N$ . Obviously, after the seventh step, in which the crack becomes through-wall crack, while the further cracks growth requires a very small number of cycles.

The obtained stress intensity factor histories can be used to predict fatigue crack growth rates by using them as input data for AFGROW of NASGRO software.

#### CONCLUSION

Fatigue life predictions of welded seam casing pipes with axial surface crack on the outer surface of pipes, made of API J55 steel, was performed in this paper using XFEM.

Based on the critical value of stress intensity factor  $K_{Ic}$  for the base metal, HAZ and weld metal, the critical crack lengths were calculated. The results indicate that the basic material has the lowest resistance to crack initiation and propagation, and according to that, the analysis of crack propagation in basic material was performed.

The obtained numerical results prove the efficiency of XFEM in the simulation of the axial cracks propagations in tube geometry.

Majority of failures of welded steel pipelines occurs due to insufficient resistance to crack initiation and growth. However, during its life cycle, welded casing pipes are exposed to corrosion effects, augmented with high pressure and high temperature environment. Having in mind the predicted severe exploitation conditions, significantly lower remaining fatigue life of welded casing pipes is expected.

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## ***SMEs IN THE FUNCTION SUSTAINABLE DEVELOPMENT WITH ASPECT OF THE USE OF RENEWABLE ENERGY***

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**Abstract:** Production, distribution and consumption energy are activities that directly or indirectly affect all areas of human activity, but also on commercial and economic development of each country. At the end of the last century, the world has adopted the concept of sustainable development of communities, which in the area of energy, in addition to energy efficiency, raises the demand for increasing the use of renewable energy sources (RES) in order to meet the increasing total energy needs. In the world today there is a broad consensus that the concept of sustainable development brings hope for the rebirth of our planet, but also that the coming decade is critical for the implementation of this concept. The current crisis has caused a new sense of the need to respond promptly to a number of unsustainable trends in production, consumption, social relations, and habits of the people, and therefore should strive and provide conditions for the establishment of small businesses in this direction.

**Keywords:** SMEs, sustainable development, renewable energy sources

### **INTRODUCTION**

In an effort to increase part of total energy consumption, which comes from renewable energy sources, extensively around the world are taking many actions in the policy and legislative activities to promote and regulate the use of these energy sources. Within the framework of international and local financial institutions and organizations are established stable system of financing the construction and use of renewable energy, as well as research and education.

Developed countries as well as countries in transition and developing countries, defining short-term and long-term development strategy for the area, and the United Nations (UN), European Parliament and other relevant international organizations and institutions by their acts and directives define a very clear and precise directions and frameworks for these activity. The most striking political will to implement rapid introduction of renewable sources indicate countries of the European Union. The problem of climate change must solve urgent, reduce high energy consumption, especially in the transport sector, as well as to stop the disappearance of biodiversity and natural resources. The transition to a secure and sustainable economy with fewer negative effects on the environment will require in the near future, new economic policies at the global and local levels, as well as better strategic overview and management.

The European Union, our strategic objective of this decade, is deeply committed to the goals of sustainable development, which was confirmed by the European Strategy to 2020. The European Union will base its development on smart, sustainable and inclusive growth, knowledge-based, innovations economy that makes efficient use of resources, "green jobs" and the territorial and social cohesion. In this

kind of Europe will not be a place for the state to ignore the principles of economic, social and environmental sustainability. The EU is generally attributed to buildings occupying 40% of the energy consumption and one-third of greenhouse gas emissions [4].

In line with B&H's efforts to join the EU, B&H legislation will must in a very short time to align with European legislation. To make this possible, it is necessary to establish an organized system of measures that will enable rapid implementation of EU directives in B&H legislation and achieving goals. Local communities (municipalities / cities) are units in which they directly exercise rights and responsibilities of citizens and the framework in which implemented these requirements, in practically daily and direct contact local governments with citizens [5].

In a word, the immediate implementation of all policies, regardless of whether the policies adopted at the level of B&H or the Entities and Cantons are executed immediately at the local level.

Legal status, competences, duties and responsibilities of local communities are regulated entity regulations. Laws on local government in both entities have been prepared in accordance with the European Charter of Local Government, so as to contain a lot of similar solutions on specific issues relevant to the position of local communities. A both laws contain provisions about what is the local government. In both laws, the definition of local government is enshrined in Article 2 of the laws follows: "Local government includes the right and capacity of local governments, within limits of the law, to regulate and manage certain public affairs under their own responsibility and in the interest of the local population". Activities performed by the local government are also defined Laws.

In the Republic of Srpska has adopted the Law on Local Government (Official Gazette No.101/0442/05, 118/05), which regulates the legal status of local communities. The scope of activities of local government regulates in Articles 12 and 22, and about competences and responsibilities of municipalities to provide better living conditions of citizens.

**POTENTIAL OF RENEWABLE ENERGY SOURCES IN THE REPUBLIC OF SRPSKA**

The potential of renewable energy sources in the Republic of Srpska rehydro energy, biomass, wind energy, the potential of the sun and geothermal energy. Due to its natural characteristics, developed landscapes, quite developed hydrographic network, the Republic of Srpska in its regions the rich hydro energy potential. Catchment areas in the Republic of Srpska are: the Drina, Vrbas, Bosna, Sana, Neretva and Trebišnjica. The total technically exploitable potential watercourse in the Republic of Srpska, including border rivers is 13.505,06 GWh/year. Technically exploitable potential, which belongs to Republic of Srpska amounts to 10.027,5 GWh/year. Hydro energy potential is exploited in the Republic of Srpska 2.985,8 GWh/year, which means that there mainly in use 7.041,7 GWh/year hydropower potential [9].

In the Republic of Srpska planned about 130 small hydropower (0.5 <P<10MW), with a total capacity of 360 MW and the potential production of 1,500 GWh. Installed capacity and average annual production of micro and mini hydro power plants up to 500 kW is not currently known [9].

Forests of Bosnia and Herzegovina covers 2,371,062 hectares, which is about 40% of the total area. Of that 1,250,391 hectares or 53% are located in the territory of the Republic of Srpska. The forest is nearly half the territory of the Republic of Srpska. Forests are one of the most important natural resources of the Republic of Srpska. Development of the forestry sector and wood industry is very important for the development of the Republic of Srpska [9].

Agricultural biomass resources come mainly from agricultural residues, including corn, wheat, vegetables, oil seeds (sunflower, soybean and beet), and remnant so forchards and vineyards.

To date, in the Republic of Srpska wind energy is not used for energy purposes as it is not built a single commercial wind farms. Regional atlas wind REGIONAL RE-ANALYSIS uses global meteorological data and results obtained by using this model are not verified measurements on the ground. Assimilation of measurements of the characteristic points on the ground to give accurate results, however, and this wind atlas can be considered sufficiently representative for selection and macro location areas for construction of wind farms.

There is significant potential of solar energy in the Republic of Srpska. The number of hours of sunshine (insolation) in the northern part of the Republic of Srpska is about 2.000 hours per year, while the southern part is around 2.500 hours per year [9].

Larger, especially the northern part of the territory in the Republic of Srpska is very promising in terms of the presence of geothermal

energy resources and geothermal water. In that stands out Posavina, Semberija and Lijevče fields. The main geothermal sites are located in the Triassic and Cretaceous limestones and making them reservoirs of geothermal water temperature of 35 - 150°C.

**EMPIRICAL RESEARCH OF THE IMPACTS OF THE FUNCTION OF SUSTAINABLE DEVELOPMENT WITH ASPECT OF THE USE OF RENEWABLE ENERGY**

The process of research is conducted on the territory of the Republic of Srpska, regions: Bijeljina, East Sarajevo and Trebinje. Municipalities or local communities in which the interviewing was conducted are: Bratunac, Srebrenica, Milići, Vlasenica, Sokolac, East New Sarajevo, East Ilidza, Gacko, Nevesinje and Trebinje. Interviewed are holders of local/municipal authorities in the area, or by the competent departments municipal services, and associates have spent the survey on the project TEMPUS SD TRAIN.

From the aspect of the survey can conclude that the level of local communities that were the subject of research, knowledge about the subject and the organization are not very high. There are some indications that in the future plans to devote more attention to the segment of renewable energy sources and the development of sustainable energy infrastructure by the relevant departments.

**RESULTS AND DISCUSSION**

Results of the research are presented graphically of the Figure 1 to Figure 8. The lack which was discovered is that there is no responsible department in the municipal service which is competent that engages in with this issue.

From the local community till the local community those problems try to solve individuals from different departments as follows: Department of Economics and Department for Urbanism.

The most common problem that is encountered during the interview is to find appropriate interviewees that is relevant in terms of the survey and who can give answers to questions.

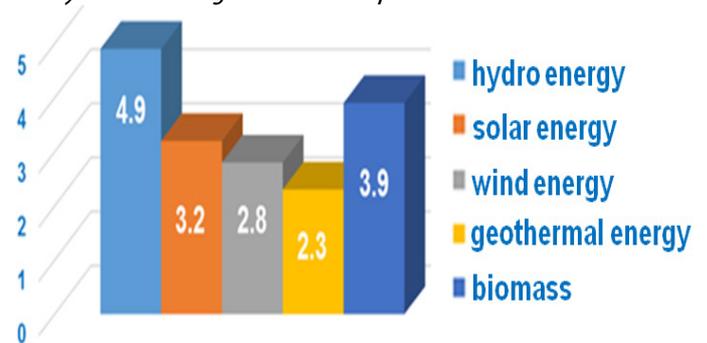


Figure 1. Assessment of potential renewable energy sources in the Republic of Srpska

From Figure 1 it perceives that the hydro-energy and biomass as a potential renewable energy sources have the highest ratings, averaging 4,9 and 3,9.

From Figure 3 it perceives that the number of new SMEs in the sector of energy production from renewable energy sources in the Republic of Srpska in the next five years will be increased, the assumption of 80% of respondents.

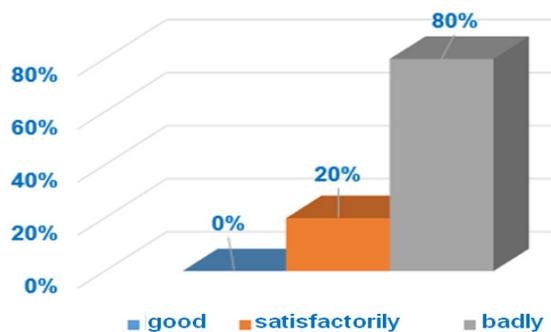


Figure 2. Assessment of current business situation and business activity production from renewable energy sources in the Republic of Srpska

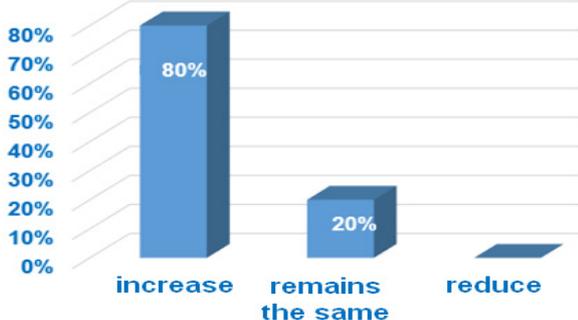


Figure 3. Number of new companies in the sector of energy production from renewable energy sources in the Republic of Srpska in the next 5 years

- legal barriers
- administrative barriers
- Lack of professional knowledge
- Lack of qualified workforce
- lack of understanding
- Difficult access to finance

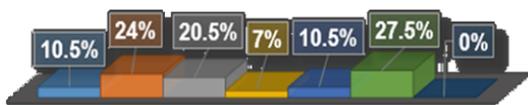


Figure 4. The most common problems encountered by companies engaged in the production of energy from renewable energy sources in the Republic of Srpska

Based on results and analysis of ABC perceives problems encountered by firms involved in the production of energy from RES in the Republic of Srpska, such as difficult access to finance, administrative barriers and lack of knowledge in a given area.

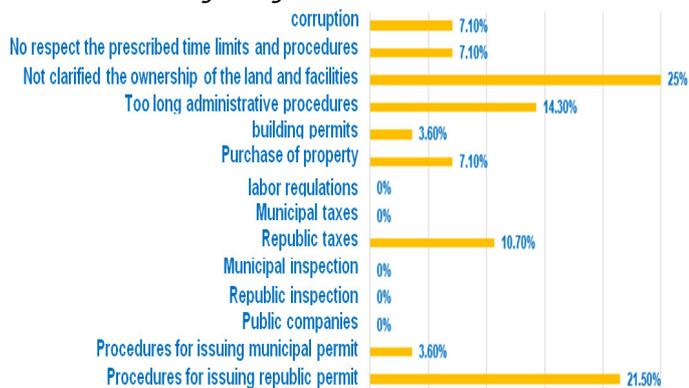


Figure 5. Administrative and regulatory measures which restrict business development firms dealing with production of energy from renewable energy sources

Based on results obtained and ABC analysis can be noted: administrative and regulatory measures which restrict business development firms dealing with production of energy from renewable energy sources, such as unclear ownership of buildings and land, as well as the procedure for the issuance of state licenses, following too long administrative procedures and the Republican taxes.

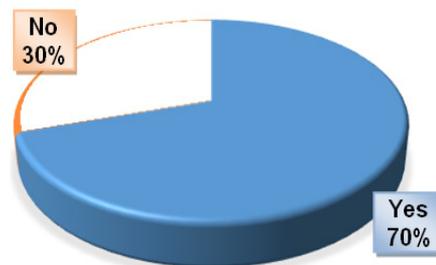


Figure 6. Is there a possibility that producers of RES-apply for some kind of credit for small and medium-sized enterprises in the Republic of Srpska

When asked whether in the Republic of Srpska is possible to producers of energy from renewable energy sources apply for some kind of credit for small and medium-sized enterprises in the area of renewable energy sources, we have received written responses stating institutions that offer some type of loan to IRB RS; Line ministries; International funds; UNDP; Commercial banks and other financial institutions; IPA; Fund for Environmental Protection and Energy Efficiency.

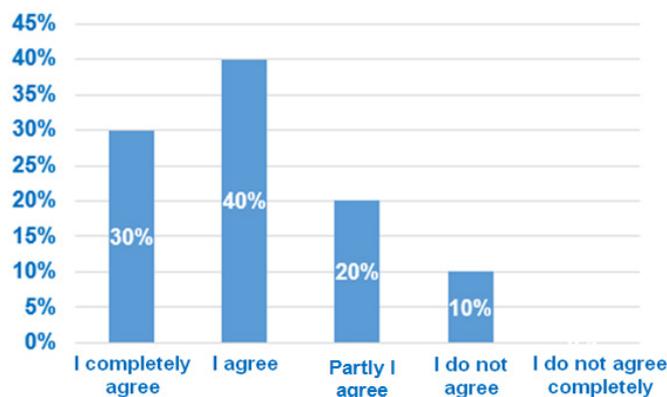


Figure 7. Use of renewable energy sources can provide the improvement of competitiveness of domestic companies in conditions of market globalization

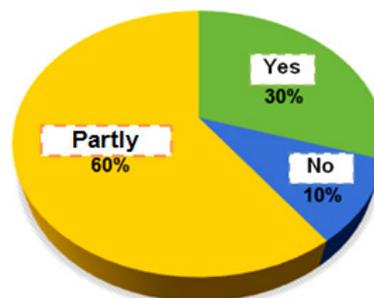


Figure 8. Is there cooperation between local communities and Universities in the Republic of Srpska, Institutes, consultant companies or other scientific knowledge environment from which to seek services in terms of initiating projects based on renewable energy sources and energy efficiency

**CONCLUSIONS**

*In B&H needs to work on the development of products and services related to renewable energy, or small businesses to design, manufacturing equipment, education, certification, and more. The Republic of Srpska and Bosnia and Herzegovina as a whole should accept the views of the European Union in terms of energy efficiency, not only because of its membership in the EU, but especially because it is the model that gave the best results. In this way the state should implement EU directives in a manner that responds to the social, economic and environmental conditions of B&H, ie on principles of sustainable development of B&H.*

*Energy efficiency is generally poorly promoted. It needs greater involvement of government and non-government sectors, educational institutions and the media to spread awareness and knowledge in the area of energy efficiency, as well as available sources of funding for projects in the area of energy efficiency and renewable energy sources. Activities to increasing the efficiency of energy use in buildings, industry, transport and others. As well as the use of renewable energy sources are just activities that promote employment. The impression gets that in many areas, especially when it comes to energy efficiency in buildings, the use of biomass is not recognized. Increasing energy efficiency (on energy use) is a measure that increases the cost of business, reducing the cost of the family budget, but at the same time encouraging the development of domestic production, and reduce the demand for imported energy. Using renewable energy sources (mainly biomass and small hydropower) to encourage domestic employment, and also reduce the demand for imported energy. Public-private partnerships are a good way to integrate the public interest and the ability of private management. It is necessary to establish the logistic of biomass (the chain of supply and use) to connect producers of energy (different stages) and equipment. It was pointed out that biomass is the most important renewable energy sources in B&H with the greatest potential and the effect on employment of local labour in the whole chain of exploitation and the technological and economic development of the local economy.*

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## AN EQUILIBRIUM PROBLEM OF CURVED COMPOSITE BEAM WITH INTERLAYER SLIP

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**Abstract:** In this paper an equilibrium problem of two-layered curved composite beam with flexible shear connection is considered. Both end cross sections of the considered curved beam are radially guided. The applied load acts in radial direction. Three types of load are considered. In Example 1 the curved composite beam is partially loaded by uniform radial load. In Example 2 on the whole upper part of the curved beam is loaded by uniform radial load. The third example deals with the concentrated radial load. In all three cases the solution for radial displacement and cross sectional rotations are obtained by Fourier's method and by the application of derived formulae the slip and the normal force, the shear force and the bending moment are determined.

**Keywords:** curved beam, composite, interlayer slip

### INTRODUCTION

Composite members have long been used in many civil engineering structures. In general they consist of two or more elements of the same or different materials connected by some means to form a single structural unit [5]. The problem of layered straight beam with imperfect shear connection has been studied for a long time. The first theory of this type of composite beams was developed by Newmark et al. [6]. The static analysis done by Newmark et al. [6] is based on the Euler-Bernoulli beam theory and become a basis of subsequent investigations of the layered beam with interlayer slip [7–10]. Above mentioned papers deal with straight layered beam. In [2] a two-layer ring with interlayer slip under the action of static load is analysed. In this paper we consider two-layered curved composite beam with imperfect shear connection whose deformation is in plane deformation. Our aim is to give the complete strength of materials solution of the equilibrium problem for curved composite beam with flexible shear connection shown in Figure 1. Both ends of curved composite beam are radially guided and the curvature is uniform. The formulation of the problem will be given in cylindrical coordinate system  $O r \varphi z$ . The plane  $z = 0$  is the plane of symmetry for the material, geometrical, loading and supporting conditions. Let

$$B_i = \{(r, \varphi, z) | (r, z) \in A_i, 0 \leq \varphi \leq 2\alpha\}, \quad (i=1,2) \quad (1)$$

be, where  $A_i$  is the cross section of beam component  $B_i$  whose elastic material has Young modulus  $E_i$  ( $i=1,2$ ) according to Figure 1. The connection of beam component  $B_1$  and  $B_2$  at their common cylindrical boundary  $\partial B_{12}$ , which is given by next equations

$$r = c, \quad 0 \leq \varphi \leq 2\alpha, \quad |z| \leq \frac{t}{2}, \quad (2)$$

in radial direction is perfect, but in circumferential direction may be jump in the displacement field. This possible jump is called the

interlayer slip. The applied radial load is  $f$  as shown in Figure 1. It is assumed that each curved layer separately follows the Euler-Bernoulli hypothesis and the load-slip relation for the flexible shear connection is linear. The paper presents solutions for radial displacement, slip, cross-sectional rotations and internal forces.

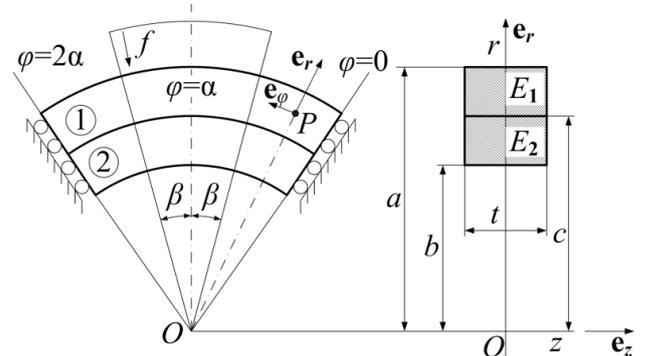


Figure 1. Curved composite beam

### GOVERNING EQUATIONS

Denote the unit vectors of cylindrical coordinate system  $O r \varphi z$   $e_r$ ,  $e_\varphi$  and  $e_z$ . The next displacement field will be used to describe the in-plane deformations of curved composite beam [2-4]

$$\mathbf{u} = u e_r + v e_\varphi + w e_z, \quad u = U(\varphi), \quad w = 0, \quad (3)$$

$$v(r, \varphi, z) = r \phi_i(\varphi) + \frac{dU}{d\varphi}, \quad (4)$$

$$(r, \varphi, z) \in B_i, \quad (i=1,2).$$

Application of the strain displacement relationships of the linearized theory of elasticity gives [1]

$$\varepsilon_r = \varepsilon_z = \gamma_{r\varphi} = \gamma_{\varphi z} = \gamma_{rz} = 0, \quad (5)$$

$$\varepsilon_\varphi = \frac{1}{r} \left( \frac{d^2 U}{d\varphi^2} + U \right) + \frac{d\phi_i}{d\varphi}, \quad (6)$$

$$(r, \varphi, z) \in B_i, \quad (i=1,2).$$

The strains given by Eqs. (5), (6) satisfy the requirements of the Euler-Bernoulli beam theory, only  $\varepsilon_\varphi$  is different from zero and all the shearing strains vanish. From the definition of interlayer slip  $s$  it follows that (Figure 1)

$$s(\varphi) = c[\phi_1(\varphi) - \phi_2(\varphi)]. \quad (7)$$

A detailed analysis gives the next expression for the interlayer shear force [2]

$$T(\varphi) = kc^2t[\phi_1(\varphi) - \phi_2(\varphi)], \quad (8)$$

where  $k$  is the slip modulus,  $t$  is the thickness of cross section and the common cylindrical boundary of  $B_1$  and  $B_2$  is given by  $r = c$  and  $|z| \leq t/2$ . Application of the Hooke's law gives for normal stress  $\sigma_\varphi$

$$\sigma_\varphi = E_i \left[ \frac{1}{r} \left( \frac{d^2U}{d\varphi^2} + U \right) + \frac{d\phi_i}{d\varphi} \right], \quad (9)$$

$(r, \varphi, z) \in B_i, \quad (i=1,2).$

The internal forces are defined as

$$N_i = \int_{A_i} \sigma_\varphi dA, \quad (i=1,2), \quad N = N_1 + N_2, \quad (10)$$

$$M_i = \int_{A_i} r\sigma_\varphi dA, \quad (i=1,2), \quad M = M_1 + M_2. \quad (11)$$

The connection between the shear force  $S$  and normal force  $N$  is as follows [3, 4]

$$S(\varphi) = -\frac{dN}{d\varphi}. \quad (12)$$

Combination of Eq. (9) with Eqs. (10), (11) yields

$$N_i = \frac{A_i E_i}{R_i} W + A_i E_i \frac{d\phi_i}{d\varphi}, \quad (i=1,2), \quad (13)$$

$$M_i = A_i E_i W + r_i A_i E_i \frac{d\phi_i}{d\varphi}, \quad (i=1,2), \quad (14)$$

where

$$\frac{1}{R_i} = \frac{1}{A_i} \int_{A_i} \frac{dA}{r}, \quad r_i = \frac{1}{A_i} \int_{A_i} r dA, \quad (i=1,2), \quad (15)$$

$$W(\varphi) = \frac{d^2U}{d\varphi^2} + U.$$

From Eqs. (10-14) it follows that

$$N = \frac{AE_0}{R} W + A_1 E_1 \frac{d\phi_1}{d\varphi} + A_2 E_2 \frac{d\phi_2}{d\varphi}, \quad (17)$$

$$S = -\left( \frac{AE_0}{R} \frac{dW}{d\varphi} + A_1 E_1 \frac{d^2\phi_1}{d\varphi^2} + A_2 E_2 \frac{d^2\phi_2}{d\varphi^2} \right), \quad (18)$$

$$M = AE_0 W + r_1 A_1 E_1 \frac{d\phi_1}{d\varphi} + r_2 A_2 E_2 \frac{d\phi_2}{d\varphi}. \quad (19)$$

Here, we introduce  $A, E_0, R$  which are defined as

$$A = A_1 + A_2, \quad E_0 = \frac{E_1 A_1 + E_2 A_2}{A}, \quad (20)$$

$$\frac{AE_0}{R} = \frac{A_1 E_1}{R_1} + \frac{A_2 E_2}{R_2}.$$

The next equations of equilibrium will be used [2, 3]

$$\frac{d^2N}{d\varphi^2} + N - f_r = 0, \quad (21)$$

$$\frac{dM}{d\varphi} = 0, \quad (22)$$

$$\frac{dM_1}{d\varphi} - K(\phi_1 - \phi_2) = 0. \quad (23)$$

$$K = ktc^3. \quad (24)$$

We note, the unit of  $k$  is force/(length)<sup>3</sup> and the unit of  $K$  is (force)/(length). Detailed forms of Eqs. (21-23) are as follows

$$\frac{AE_0}{R} \left( \frac{d^2W}{d\varphi^2} + W \right) + A_1 E_1 \left( \frac{d^3\phi_1}{d\varphi^3} + \frac{d\phi_1}{d\varphi} \right) + \quad (25)$$

$$+ A_2 E_2 \left( \frac{d^3\phi_2}{d\varphi^3} + \frac{d\phi_2}{d\varphi} \right) - f_r = 0,$$

$$AE_0 \frac{dW}{d\varphi} + r_1 A_1 E_1 \frac{d^2\phi_1}{d\varphi^2} + r_2 A_2 E_2 \frac{d^2\phi_2}{d\varphi^2} = 0, \quad (26)$$

$$A_1 E_1 \frac{dW}{d\varphi} + r_1 A_1 E_1 \frac{d^2\phi_1}{d\varphi^2} - K(\phi_1 - \phi_2) = 0. \quad (27)$$

In the present problem the boundary conditions can be formulated as

$$\phi_1(0) = 0, \quad S(0) = 0, \quad \left. \frac{dU}{d\varphi} \right|_{\varphi=0} = 0, \quad (28)$$

$$\phi_1(2\alpha) = 0, \quad S(2\alpha) = 0, \quad \left. \frac{dU}{d\varphi} \right|_{\varphi=2\alpha} = 0. \quad (29)$$

### SOLUTION BY FOURIER SERIES EXPANSION

We will use the next representation by Fourier series of applied radial load which is given by as (Figure 1)

$$f_r(\varphi) = -f[H(\varphi - \alpha + \beta) - H(\varphi - \alpha - \beta)], \quad (30)$$

$$f_r(\varphi) = f_0 + \sum_{j=1}^{\infty} f_j \cos \frac{j\pi}{\alpha} \varphi, \quad (31)$$

where  $f = \text{constant}$  is the applied radial load,  $H$  is the Heaviside function and

$$f_0 = -f \frac{\beta}{\alpha}, \quad f_j = -f \frac{2 \cos j\pi \sin \frac{j\pi\beta}{\alpha}}{j\pi}, \quad (32)$$

$(j = 1, 2, \dots).$

We look for the solution of considered equilibrium problem for  $U = U(\varphi), \phi_i = \phi_i(\varphi), (i=1,2)$  as

$$U(\varphi) = U_0 + \sum_{j=1}^{\infty} U_j \cos \frac{j\pi}{\alpha} \varphi, \quad (33)$$

$$\phi_i(\varphi) = \sum_{j=1}^{\infty} \phi_{ij} \sin \frac{j\pi}{\alpha} \varphi, \quad (i=1,2). \quad (34)$$

These functions satisfy all boundary conditions formulated by Eqs. (28), (29). Substitution Eqs. (31), (33), (34) into Eqs. (21-23) leads to the next system of equations

$$U_0 = -f \frac{R}{AE_0} \frac{\beta}{\alpha}, \quad (35)$$

$$\mathbf{A}_j \mathbf{x}_j = \mathbf{b}_j, \quad \mathbf{A}_j = [a_{mnj}], \quad (36)$$

$$\mathbf{x}_j = [U_j, \phi_{1j}, \phi_{2j}]^T, \quad \mathbf{b}_j = [f_j, 0, 0]^T,$$

$$a_{11j} = \frac{AE_0}{R} \left[ \left( \frac{j\pi}{\alpha} \right)^2 - 1 \right]^2,$$

$$a_{12j} = \frac{A_1 E_1 j\pi}{\alpha} \left[ 1 - \left( \frac{j\pi}{\alpha} \right)^2 \right],$$

$$a_{13j} = \frac{A_2 E_2 j\pi}{\alpha} \left[ 1 - \left( \frac{j\pi}{\alpha} \right)^2 \right],$$

$$a_{21j} = \frac{AE_0}{R} j\pi \left[ \left( \frac{j\pi}{\alpha} \right)^2 - 1 \right],$$

$$a_{22j} = -r_1 A_1 E_1 \left( \frac{j\pi}{\alpha} \right)^2,$$

$$a_{23j} = -r_2 A_2 E_2 \left( \frac{j\pi}{\alpha} \right)^2,$$

$$a_{31j} = \frac{A_1 E_1 j\pi}{\alpha} \left[ \left( \frac{j\pi}{\alpha} \right)^2 - 1 \right],$$

$$a_{32j} = -r_1 A_1 E_1 \left( \frac{j\pi}{\alpha} \right)^2 - K,$$

$$a_{33j} = K, \quad (j=1,2,\dots).$$

From the solution of system of linear equation (36) we obtain the expressions of deflection  $U(\varphi)$ , and cross-sectional rotations  $\phi_1(\varphi)$ ,  $\phi_2(\varphi)$ . Applications of formulae (10-14) give the expressions of internal forces and couples.

**EXAMPLES**

**Example 1**

The next data are used in Example 1:  $\alpha = \frac{\pi}{4}$ ,  $\beta = \frac{\pi}{16}$ ,  $f = 1$  [N],

$a = 0.04$  [m],  $b = 0.02$  [m],  $c = 0.03$  [m],  $E_1 = 10^{12}$  [Pa],  $E_2 = 8 \times 10^3$  [Pa],  $k = 80 \times 10^{10}$  [N/m<sup>3</sup>]. Figure 2 shows the deflection and the graph of slip function is shown in Figure 3.

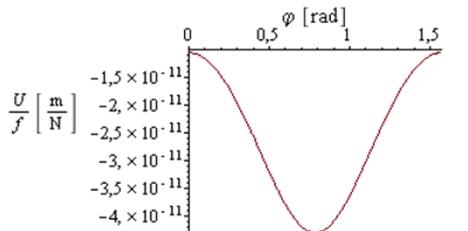


Figure 2. Plot of the deflection function

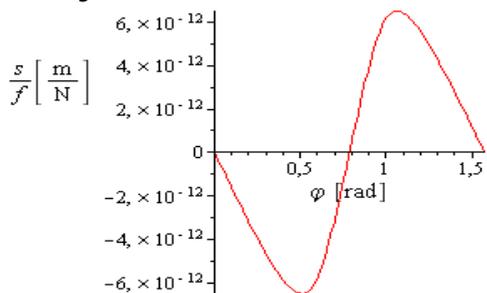


Figure 3. Plot of slip function

(37) The graphs of internal forces  $N$ ,  $S$  and bending moment  $M$  are presented in Figures 4, 5, 6.

(38)

(39)

(40)

(41)

(42)

(43)

(44)

(45)

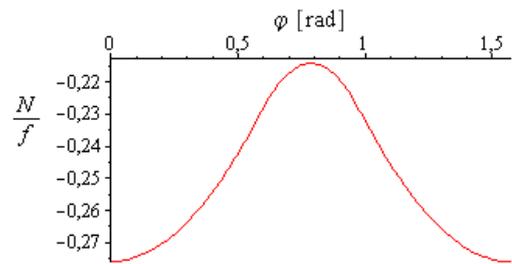


Figure 4. Plot of the normal force function

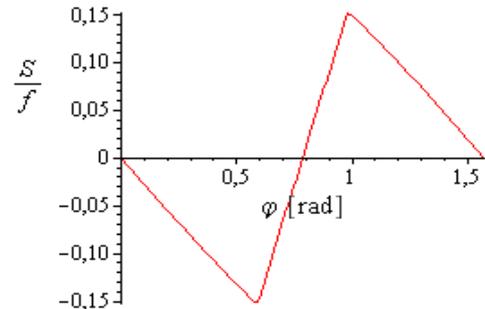


Figure 5. Plot of the shear force function

**Example 2**

In Example 2 the same data are used as in Example 1 except  $\beta$ , which is here  $\beta = \frac{\pi}{4}$  (Figure 7). In this case we have

$$\frac{U}{f} = -\frac{R}{AE_0} = -1.041279 \times 10^{-10} \text{ [m/N]}, \quad \phi_1 = \phi_2 = 0, \quad N = f,$$

$$S = 0, \quad \frac{M}{f} = R = -0.033737 \text{ [m]}.$$

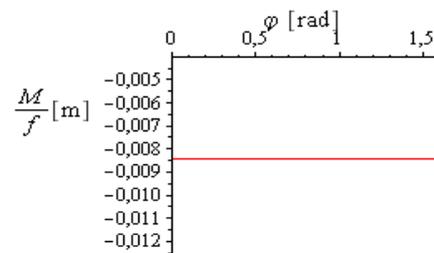


Figure 6. Plot of bending moment

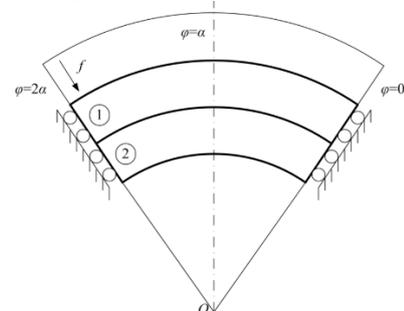


Figure 7. The case of  $\beta = \alpha$

**Example 3**

Example 3 deals with the case of concentrated load applied at  $\varphi = \alpha$  as shown in Figure 8. From equations of the third Section (Solution by Fourier series expansion) we obtain formulae concerned to the case of concentrated load by next limit calculation  $\beta \rightarrow 0$  and

$f \rightarrow \infty$  such that  $F = 2\beta f$  is a given finite value. The results of computations are shown in Figures 9-13. In Figures 9 and 10 the deflection function and the slip function are shown, the internal forces  $N$  and  $S$  are shown in Figures 11 and 12 and the graph of bending moment is presented in Figure 13.

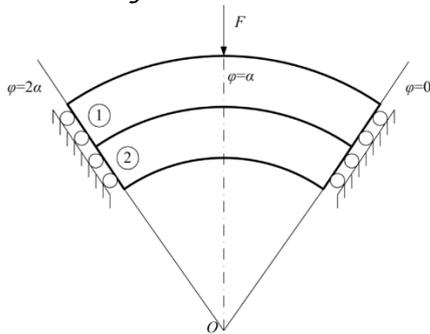


Figure 8. The case of concentrated load ( $\beta \rightarrow 0, f \rightarrow \infty$ )

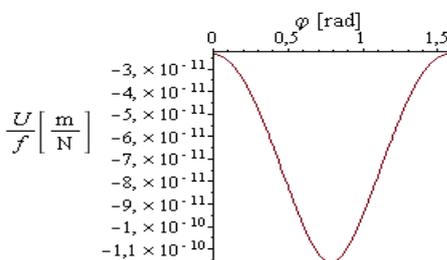


Figure 9. The plot of  $U$  for  $\beta \rightarrow 0, f \rightarrow \infty$

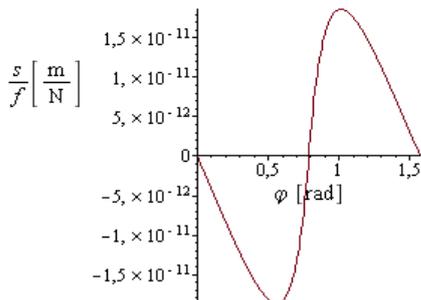


Figure 10. The plot of  $s$  for  $\beta \rightarrow 0, f \rightarrow \infty$

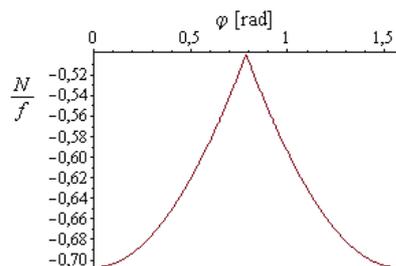


Figure 11. The plot of  $N$  for  $\beta \rightarrow 0, f \rightarrow \infty$

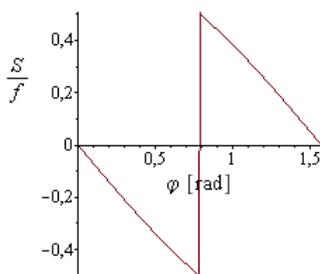


Figure 12. The plot of  $S$  for  $\beta \rightarrow 0, f \rightarrow \infty$

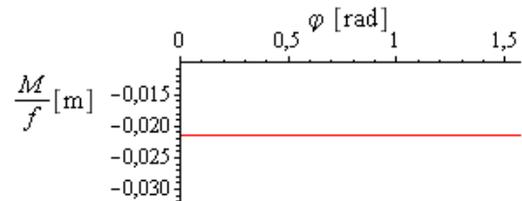


Figure 13. The plot of  $M$  for  $\beta \rightarrow 0, f \rightarrow \infty$

**CONCLUSIONS**

Paper presents the solution of a static problem of a two-layered composite curved beam with flexible shear connection for radial displacement, slip, normal force, shear force and bending moment. The applied load acts in radial direction and the end cross sections of curved beam are radially guided. The presented analytical, solution can be used as benchmark solution to check the validity of the different numerical methods, such as finite differences and finite element method.

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## EFFECT OF THE THERMOMECHANICAL TREATMENT ON CHARACTERISTICS OF THE Al-Mg-Si ALLOYS

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**Abstract:** It has long been known that it is possible to strengthen AlMgSi alloys by means of heat treatment and plastic deformation. Investigations in that direction resulted in the discovery of very interesting alloys with high physicomechanical parameters. In the paper are given the results of researches of composition and treatment parameters effects on hardening rolled sheets of the AlMgSiCu alloys. It is found that the hardening value depends on degree of deformation, deformation programme and copper content. It is shown that alloys subjected to less intensive deformation and those with larger copper concentration display a characteristically larger hardening effect.

**Keywords:** thermomechanical treatment, hardening

### INTRODUCTION

It has long been known that it is possible to strengthen AlMgSi alloys by means of heat treatment and plastic deformation. Investigations in that direction, such as [1, 2], resulted in the discovery of very interesting alloys with high physicomechanical parameters.

Although thermomechanical treatment is widely used, there are still many questions associated with the influence of cold plastic deformation, and particularly of a deformation programme combined with alloying, on hardening of AlMgSiCu alloys which remain unanswered. One would expect a change in the cold rolling programme to affect not only hardening but also the structure and residual stresses in the material [3].

Investigation made on copper [4], steel [5] and AlMgSi alloys [3, 6, 7] show that the distribution of stress at the deformation centre during rolling resulting from different deformation programmes gives rise to local changes at the deformation centre. We know [8] that the stress distribution at the deformation centre during rolling is determined by a set of geometric parameters; for instance, the pressure distribution depends on the ratio  $l/x_m$  ( $l$  is the length of the deformation centre;  $x_m$  – mean thickness of deformed specimen). The deformation is inhomogeneous at the centre and that has a strong influence on turn of the crystallites and on hardening [9, 10].

### EXPERIMENTAL

We have investigated two AlMgSiCu alloys. The first (denoted  $L_1$ ) contained 0-57%, the second ( $L_2$ ) 1-0,4% copper. The two alloys contained the same quantity of  $Mg_2Si$  phase – 1-5%. The aluminium used in preparation of the alloys was 99-99,5% pure.

After homogenization for a day at 520°C and preliminary rolling with annealing (15 min, 520°C) and quenching in cold water, sheets of the alloys were deformed to different degrees: 15, 30, 50, 70 and 80%.

After preliminary annealing for 30 min at 520°C in salt bath and quenching in water the specimens were aged for 10 min at 160°C.

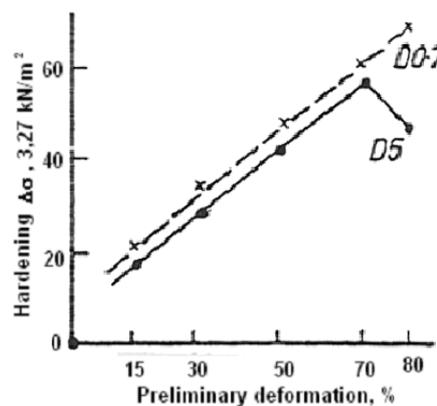


Figure 1. Relative hardening of alloy  $L_1$ , as a function of degree of deformation and deformation programme: • - D5; × - D0,7; □ - IA;  $\varphi=40^\circ$

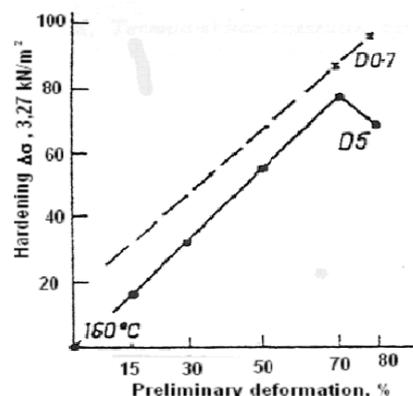
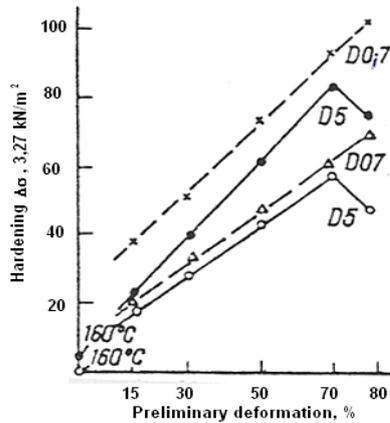


Figure 2. Dependence of relative hardening of alloy  $L_2$  on degree and programme of deformation. • - D5; × - 0,7; ■ - IA;  $\varphi=40^\circ$   
The aged specimen was deformed in two programmes. The first, with  $l/x_m \geq 5$ , involved a small number of passes, and will be denoted

as programme D5. The second, D0-7, with  $l/x_m \approx 0-7$ , involved a large number of passes. In both cases the rate of deformation was constant –  $0,73 \text{ sec}^{-1}$ . Hardening of the specimen was examined after initial ageing (IA) and initial ageing and deformation (IA+D). In order to determine hardening, the specimens were subjected to variable deformation by bending with a given maximum angle of bend [10].



**Figure 3.** Relative hardening of alloys  $L_1$  and  $L_2$  as function of degree and programme of deformation separately: alloy  $L_1$ :  $\triangle$  - D0,7;  $\square$  - IA;  $\bullet$  - D5; alloy  $L_2$ :  $\blacksquare$  - IA;  $\times$  - D0,7;  $\circ$  - D5;  $\varphi=40^\circ$

The increment of flow stress  $\Delta\sigma$  was determined relative to the flow stress for specimens after IA with angle bending  $\varphi=40^\circ$ . In order to eliminate the contribution of bending to hardening, the angles of residual bending  $\varphi_r$  were verified to be the same for the same instantaneous angle of bend  $\varphi$ .

**RESULT AND DISCUSSION**

The results are shown in Figures 1, 2 and 3. Figures 1 and 2 shows the dependence of relative hardening of the alloys as a function of degree of deformation and programme. The dependence of hardening of the alloys on copper content and degree of deformation and programme. The dependence of hardening of the alloys on copper content of deformation and programme is shown in Figure 3.

For both alloys, maximum hardening is obtained at 15% deformation (see Fig. 3). Hardening continues to grow with further increase in degree of deformation, but at a lower rate relative to the initial increment at 15%. A difference is first seen in the curves for the IA+D specimens after 70% deformation: for the less intensive deformation programme (Fig. 3, D0,7) hardening is greater than that achieved at 70%, while for the more intensive programme (Fig. 3, D5) it is lower.

The  $\Delta\sigma$  value for programmes D5 and D0,7 can be compared with the hardening value after IA+D.

It turns out that the hardening effect is greater for programme D0,7 than for D5, and greater for alloy  $L_2$  than  $L_1$ .

The results show that, other conditions being equal, the copper content in AlMgSi influences hardening of the alloys (see Fig. 3). The hardening value of specimens of alloy  $L_2$  after IA and IA+D is higher than for similar specimens of alloy  $L_1$  (see Fig. 3). We assume that copper is responsible for higher dispersion of the inclusions, increasing the number of nucleation centres [11, 12] and thereby improving

corrosion resistance and the mechanical parameters of the AlMgSi alloy.

**CONCLUSION**

All the specimens had identical treatment before deformation, that is, they had identical structure, and identical thickness after rolling. We can therefore say that the observed differences in hardening of AlMgSi alloys are due to: a) difference in copper content and b) use of different deformation programmes.

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## THE ROLE OF GIS IN ENERGY AUDIT OF PUBLIC LIGHTING

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**Abstract:** Public lighting is a small but very important part of electricity consumption in every country. Energy audit of public lighting is one way of fulfilling energy policy of EU and is a legal obligation in Croatia since 2014. The audit must be conducted every 5 years according to the Ordinance on energy audits of buildings and energy certification of buildings which regulates the obligation to conduct energy audits of public lighting. Auditing is done according to the national methodology for energy audits of buildings. Geographic Information System is not specified as a tool for energy audit but in practice it is very useful. This paper describes the usage of open source GIS tools in energy auditing of public lighting system.

**Keywords:** energy audit, GIS, public lighting system

### INTRODUCTION

Public lighting (PL) is a very important part of electricity consumption in every country. PL has an aspect of security, because it provides visual conditions which ensure normal transport and communication in public traffic areas. Furthermore, a very specific aspect of PL is providing the psychological and physical safety of people and property. Another aspect of PL importance is generation of specific aesthetic atmosphere and attractiveness of inhabited areas (illumination of squares, parks, buildings and monuments) [1]. Public lighting represents 0.1 percent of total energy consumption, but its significance is far greater than the modest energy representation. Street lighting must meet criteria to ensure visibility, visual comfort and energy efficiency that must be considered in the designing process. Requirements for public lighting, especially road lighting are defined with EN 13201 [2]. As an example for the writing of this paper, the energy audit of a small lighting system with four supply point and 135 lamps was taken. In order to prepare a report on the conducted energy audit, GIS tool was used for mapping of system components. Energy audit conducted according to methodology includes: gathering basic information about the user, the analysis of available project documentation, a description of the public lighting system with mapping of the existing installation, measuring the existing light quantities, measuring electrical quantities, the analysis of energy consumption bills and proposal for measures to improve energy efficiency.

### TECHNICAL REQUIREMENTS ON PUBLIC LIGHTING

The basic aspects of PL can be divided into three areas:

1. **Functionality** - the primary function is to provide the minimum required uniform illumination values without discomfort glare;

2. **Aesthetics** -the play of light and shadow creates a special atmosphere;
3. **Cost-effectiveness** - the total cost includes the cost of construction, design, management, maintenance and energy required for the unobstructed operation.

### PL Functionality

Functionality refers to obtaining luminance levels, luminance uniformity, degree of glare limitation, lamp spectra and effectiveness of the visual guidance. Level of luminance isn't important as uniformity and spectra, because of scotopic/photopic characteristics of the eye [2].

### Cost-effectiveness

Cost-effective criteria is based on the efficiency of the used light source. Classic light sources (based on incandescent) are gradually eliminated in the EU (the Directive on Energy Efficiency). There is a large variety of modern light sources on the market. For PL purposes, the following contemporary light sources are available:

- ✓ High-pressure sodium (HPS) 80-140 lm/W, CRI 20-30; 1900-2800 K, life time 10,000 - 24,000h
- ✓ Metal-halide lamp 100 lm/W, CRI 68, 4000-5000 K, life time 20.000h
- ✓ Mercury-vapour lamp (abandoning technology) 30-60 lm/W, CRI 20-60, 6800 K life time 20,000
- ✓ Fluorescent 45-105 lm/W, CRI 65-75, life time 10,000 - 45,000h
- ✓ LED/OLED 115 lm/W, CRI 65-75, 6500 K, life time - 50,000h
- ✓ Light Emitting Plasma HEP/LEP 120 lm/W, CRI 75-90, 5600 K, life time 50,000h

Color Rendering Index (CRI) is a measurement of a light source's accuracy in rendering different colors. Requirements which are placed on the lamp are in compliance with standards, proper distribution of

the light output, glare limitation (through shaping and shading, the cut-off, semi cut-off, not cut off) and mechanical consistency [1].

**MAPPING OF PL**

There are numerous ways to map installation, the easiest one is to use GSM smart phone with GPS. Accuracy of public GPS systems is in the range of 3 to 10 meters. In areas with distance between lamps of 30 meters, this is quite satisfactory. Mapping of existing installation is done with Android Open Street Map tracker application which exports data in GPX format with waypoints that we entered during audit [3]. Small change is made in the optional xml file (more info in [4]) to provide the necessary menu entries for PL, as can be seen in Fig. 1.

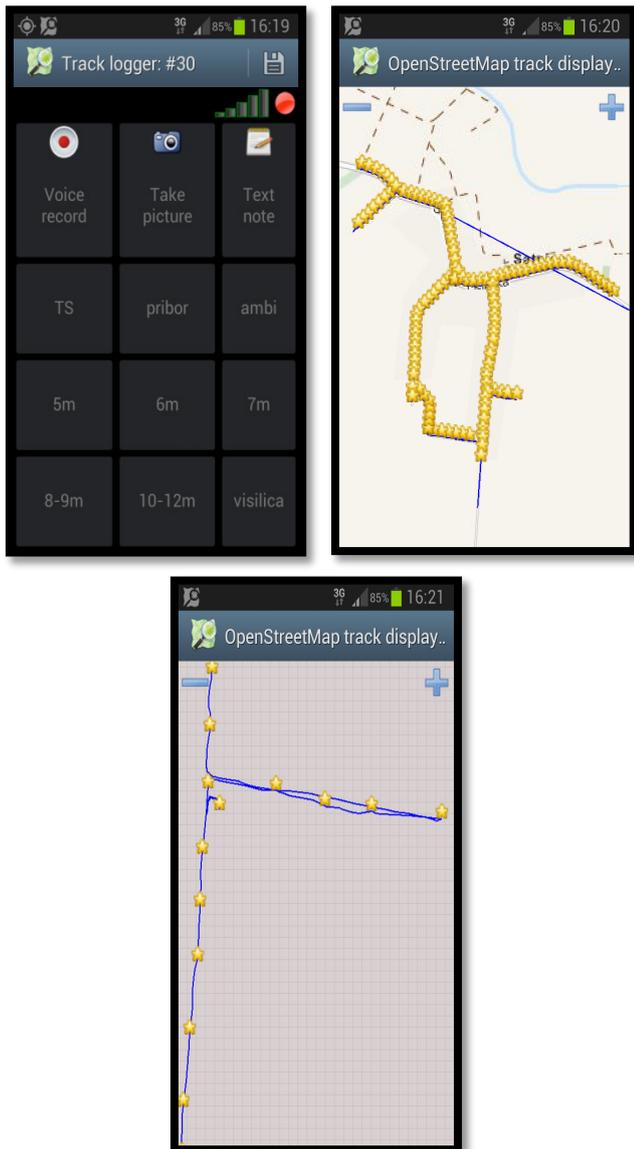


Figure 1. OpenStreetMap tracker layout, mapped PL system and mapped details

We found that layouts customization should be done after walk-through audit in order to ensure optimal layout menu that matches with the system elements on field. During tracking it is important not to enter elements twice and to check that tapped element is correctly entered (wait for the confirmation). After finishing mapping we can upload data to open street map server or download the GPX file on computer.

**GIS data processing**

Data collected by mapping is exported (in GPX file) as the GPS Exchange Format that can be reviewed as a text but it is more useful to use GIS editor. In Fig. 2. we can see waypoints for collected data: latitude, longitude, elevation, time and name of waypoint. Name reveals type of lamp, High Pressure Sodium, power of lamp 150 W, producer of lamp, power supply through self supporting cable bundle SKS and height of the concrete pillar. There are other data in the GPX file, but for the energy audit, waypoint is data that we entered through OpenStreetMap tracker layout.



Figure 2. Insight into the GPX file

Benefit of GIS usage can be seen when we open GPX file in GIS editor. For this propose we used QGIS a free and open source Geographic Information System [5]. We could use JOSM, an extensible editor for OpenStreetMap (OSM) written in Java, but QGIS provides much more for further PL analysis. On Fig. 3 it can be seen open GPX file.

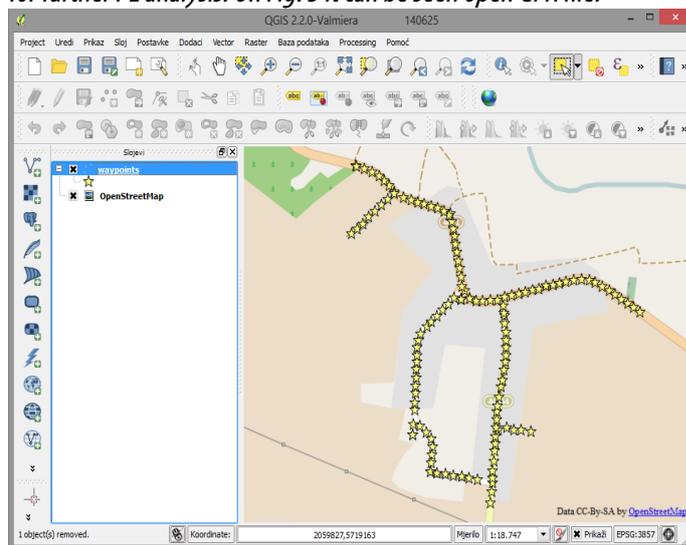
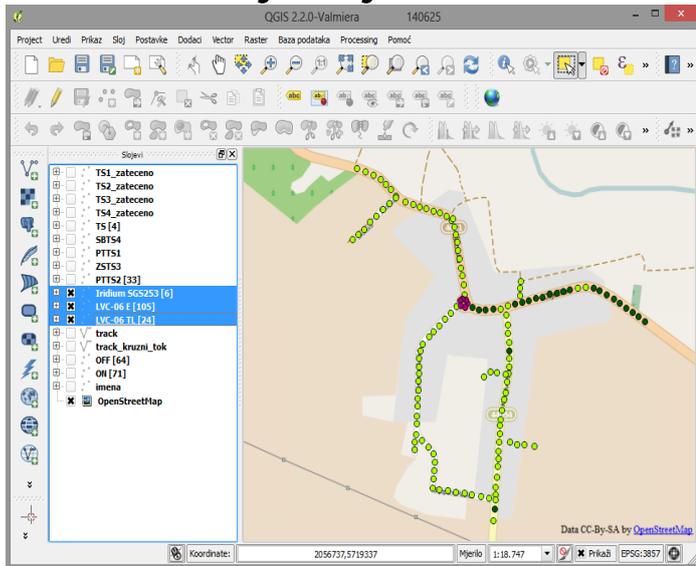
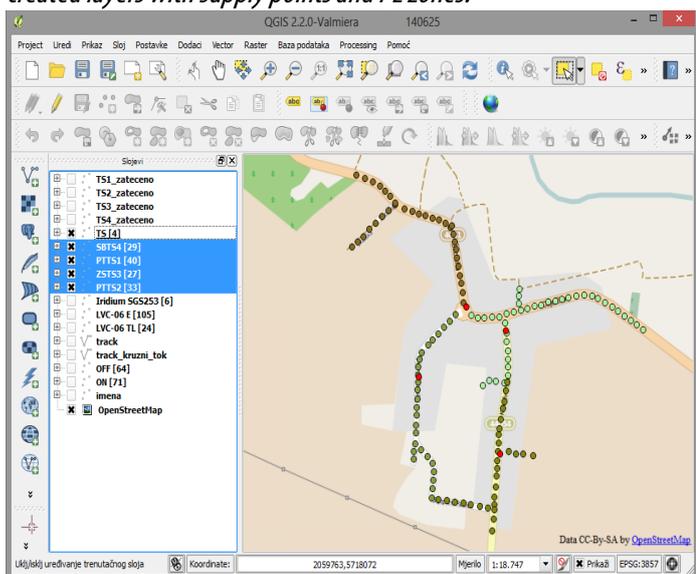


Figure 3. Data from GPX file in QGIS

Entering in attribute table of waypoints and grouping according to the attributes new layers can be made as presented on Fig. 4. Comparing Fig. 3 and 4., we can notice that some elements are missing, better to say we did not see lamps in two side streets during first round of mapping. In the second round, they are mapped and merged with existing records.

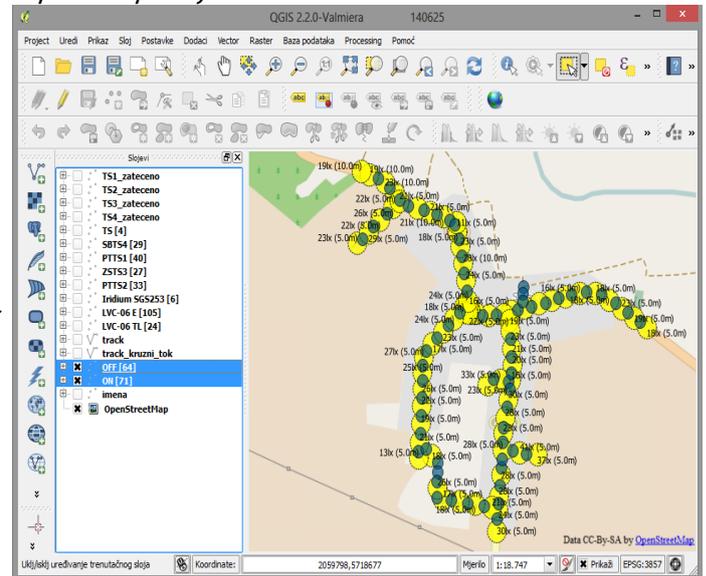


**Figure 4.** Newly created layers with lamps types and position  
Highlighted layers on the left side contain position of three type of lamps that we accounted during the audit. As can be read, there are 6 Philips Iridium, 105 TEP LVC-06E and 24 TEP LVC-06TL lamps installed in the system. In order to define zones of lighting, electrical measures were made in supply points. In order to define zones of lighting, electrical measures were made in transformer stations on all PL lines. During measurement on active line, active lamps are marked visually in order to define zone of lighting. Energy balance must be determined, measured power in supply point must correspond to the consumption of active lamps. It is important to note two things. First, measurement must be performed when the system enters the steady state, 6-12 minutes after switching on depending on the type of lamps. Second, while analyzing energy balance consumption, ballast and all possible losses must be taken into account. After measurement, we come to the situation shown in Fig. 5. newly created layers with supply points and PL zones.

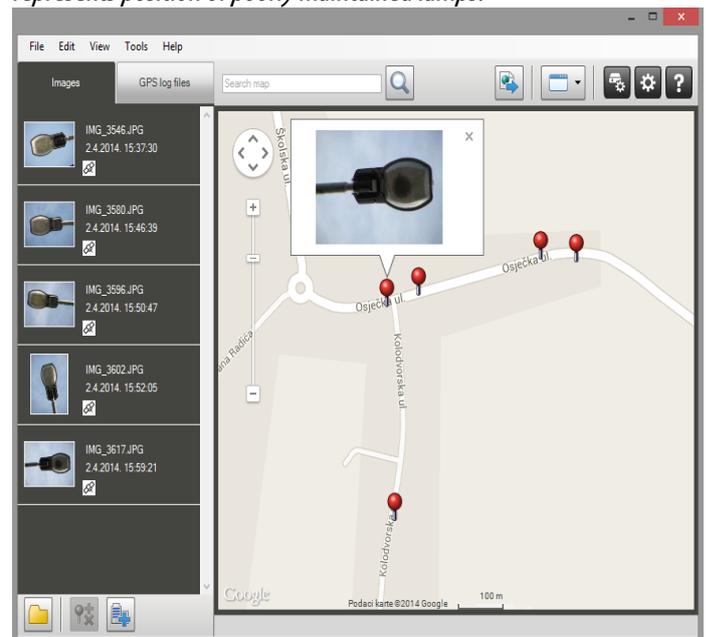


**Figure 5.** Newly created layers with supply points and PL zones  
Once becoming familiar with the system, its zones and electricity consumption, the only thing remaining is to determine the light levels on road surface. Measurements must be conducted during night while

system is in function and traffic is minimal. Data obtained by measurements of illumination is mapped in order to determine position of lamps with failure or poor maintaining. Fig. 5 presents lighting levels in lx measured on road surface. As we can see from Fig. 6 every second lamp is out of function due to savings of electricity. Turning off every second lamp is not a recommended measure, because a decrease of luminance uniformity results in a longer time required to spot objects on road.



**Figure 6.** Layers with illumination measurement data  
In addition to the usage presented above, GIS can be used for geo-tagging of photo documentation, which is an integral part of every energy audit. Easiest way is to use camera with GPS but pictures can be added manually on mapped lamps. Fig. 7. presents photos taken with camera that have integrated GPS. Documented lamps on picture represents position of poorly maintained lamps.



**Figure 7.** Layers with illumination measurement data  
**CONCLUSION**  
Public lighting is important because it provides visual conditions for normal transport and communications in public traffic areas. In

*Croatia, the Act on Energy Efficiency in Direct Consumption is an ordinance on energy audits of buildings and energy certification of buildings. The ordinance lays down the obligation to conduct energy audits of public lighting every 5 years. An energy audit is a systematic process of acquiring the appropriate knowledge about existing energy consumption, and can be performed only by an authorized physical person or legal entity. PL infrastructure includes: lamp posts, lighting fixtures, light sources and management system. Mapping of the lighting system is the easiest way to conduct energy audit of PL because collected data is momentary digitalized.*

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## OPTIMUM DESIGN OF WELDED STIFFENED PLATE STRUCTURE FOR A FIXED STORAGE TANK ROOF

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**Abstract:** The optimization problem of a welded fixed roof for a vertical storage tank is studied. The load from snow and from a 150 mm soil layer is considered. The roof is constructed from stiffened sectorial trapezoidal plate elements and radial beams. The stiffeners are of halved rolled I-section and the radial beams are constructed from rolled I-sections. To find the minimum cost solution the thickness of the base plate, the position, number and size of circumferential stiffeners, the size of radial beams as well as the number of sectors is varied. The distances of stiffeners are non-equidistant. In the cost function the cost of material, welding and painting is taken into account.

**Keywords:** welded fixed roof, optimization, vertical storage tank

### INTRODUCTION

In 1960 the first author has designed a roof structure for a series of storage tanks. The roofs constructed from welded stiffened plate sectorial elements have been suitable for carrying the load of a 150 mm soil layer used to decrease the evaporation loss of stored liquid (kerosene).

From this time the design of stiffened plates has been the main research theme for the first author. The problem of selecting the optimal number of stiffeners led to the structural optimization and the authors have worked out a lot of studies in the field of optimum design of metal structures.

Since the welding is an expensive technology, the decrease of cost of welded structures is an important task for designers. Therefore, our research group, based on international welding time data, has developed a suitable cost analysis. The adaptation and development of effective mathematical optimization methods made it possible to use an optimum design system for the economic (minimum cost) design of welded structures [1]-[4].

In the present study this economic design method is applied for a fixed storage tank roof constructed from stiffened plate sectorial elements and radial beams. In the optimization procedure the optimum values of the following structural characteristics are sought: number and size of radial rolled I-section-beams, the thickness and the transverse non-equidistant stiffening of the deck plate elements. The roof is designed to carry the snow load as well as the load of 150 mm thick soil layer mentioned earlier. Since the deck plate sectorial elements are trapezoidal and the deck plate thickness should be constant, the transverse stiffening is designed as non-equidistant. The variable distance of stiffeners is calculated from the condition that the deck plate of given thickness should fulfil the bending stress constraint in each part between two stiffeners.

### LOADS

Snow load is calculated according to Eurocode 1 [5]

$$s = \mu_1 C_e C_t s_k \quad (1)$$

$\mu_1 = 0.8, C_e = C_t = 1, s_k = 1.25 \text{ kN/m}^2$ , thus  $s = 0.8 \times 1.25 = 1.0 \text{ kN/m}^2$ .

Soil load: 150 mm thick layer of a humid light sand of bulk density 17  $\text{kN/m}^3$

$$p_s = 0.15 \times 17 = 2.55 \text{ kN/m}^2.$$

Snow and soil together  $s + p_s = 3.55 \text{ kN/m}^2$ , multiplied by a safety factor of 1.5.  $p_M = 5.325 \times 10^3 \text{ N/mm}^2$ .

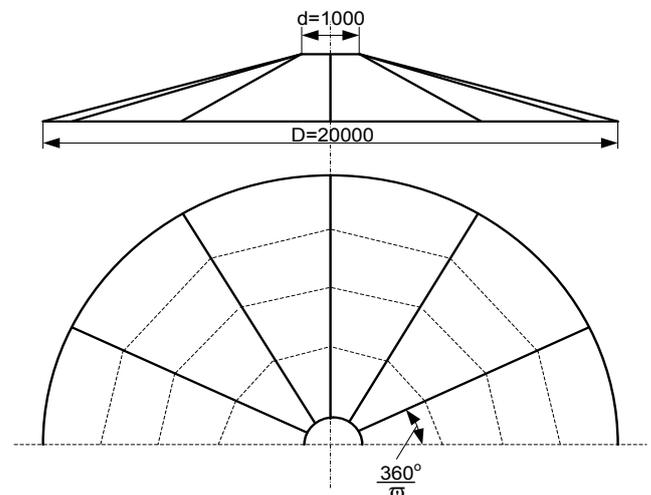


Figure 1. A fixed tank roof

Safety factor for the self mass of sectorial elements is 1.35, and for self mass of radial beams is 1.1.

### NUMERICAL DATA

Storage tank diameter  $D = 20 \text{ m}$ , inner ring beam diameter  $d = 1.0 \text{ m}$ , roof angle  $\alpha_0 = 15^\circ$ .

Length of a radial beam  $L = 9500 / \cos 15^\circ = 9835 \text{ mm}$ . The characteristic sizes of a trapezoidal deck plate  $x_A = 518, x_B = 10353 \text{ mm}$ .  $a = 180/\omega$ , where  $\omega = 10, 12, 14, 16$  is the number of sectors. The length of stiffeners is calculated for given  $\omega$ :  $y_i = x_i f_{\omega}$ , where  $f_{\omega} = 2 \tan \alpha$ .

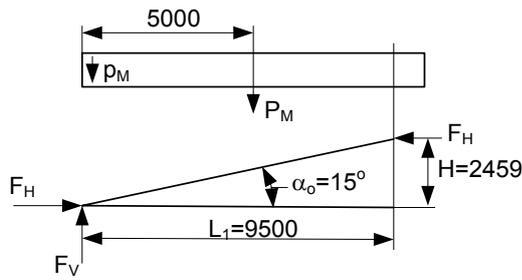


Figure 2. Forces from the roof load

**DESIGN OF SECTORIAL STIFFENED DECK PLATE ELEMENTS**

**Calculation of stiffener distances ( $x_{0i}$ )**

These distances are determined using the condition that the maximum normal stress due to bending in each plate element between stiffeners should not be larger than the yield stress. The maximum bending moment in a deck plate element is calculated approximately for a simply supported rectangular plate according to Timoshenko [6]

$$M_{i \max} = \beta_i p_M a_i^2 \quad (2)$$

where  $a_i$  is the smaller side length and  $\beta_i$  is given in function of  $b_i / a_i \geq 1$  in Table 1.

Table 1. Bending moment factors

$b/a$	1	1.1	1.2	1.3	1.4	1.5	1.6	
$10^4 \beta$	479	554	627	694	755	812	862	
$b/a$	1.7	1.8	1.9	2.0	3.0	4.0	5.0	>5
$10^4 \beta$	908	948	985	1017	1189	1235	1246	1250

The values of Table 1 are approximated by the following expressions

$$\beta_i = \beta_{\xi_i} \text{ if } x_i - x_{i-1} \leq x_i f_\omega \text{ i.e. } x_i \leq \frac{x_{i-1}}{1 - f_\omega} \quad (3)$$

$$\beta_i = \beta_{\eta_i} \text{ if } x_i - x_{i-1} > x_i f_\omega \quad (4) \text{ where}$$

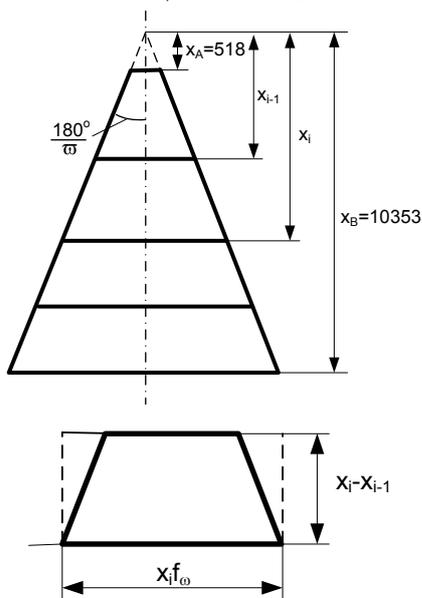


Figure 3. Stiffener distances and a part of the base plate

$$\beta_{\xi_i} = a_0 + b \xi_i + c \xi_i^2 + d \xi_i^3 + e \xi_i^4 \quad \xi_i = \frac{x_i f_\omega}{x_i - x_{i-1}} \quad (5)$$

$$\beta_{\eta_i} = a_0 + b \eta_i + c \eta_i^2 + d \eta_i^3 + e \eta_i^4 \quad \eta_i = \frac{x_i - x_{i-1}}{x_i f_\omega} \quad (6)$$

$$a_0 = -0.08022658, b = 0.180443, c = -0.061636, d = 0.009575, e = -0.00056537$$

From equation

$$M_{i \max} = f_{y1} t^2 / 6 \quad (7)$$

$t$  is the deck plate thickness,  $f_y = 235$  MPa is the yield stress,  $f_{y1} = f_y / 1.1$  using equation (2).

$$r_i = \sqrt{\frac{t^2 f_{y1}}{6 \beta_i p_M}} \quad (8)$$

and the sought stiffener distance is

$$x_{0i} = r_i + x_{i-1} \text{ if } x_i \leq \frac{x_{i-1}}{1 - f_\omega} \quad (9)$$

$$x_{0i} = \frac{r_i}{f_\omega} \text{ if } x_i > \frac{x_{i-1}}{1 - f_\omega} \quad (10)$$

The value of  $x_{0i}$  can be obtained by iteration with a MathCAD program.

It should be noted that in this calculation the transverse bending moments are neglected but the plate elements are calculated as simply supported and it is also neglected that their edges are partially clamped.

**Design of stiffeners**

A stiffener is subject to a bending moment

$$M_{si \max} = p_M s_i x_i^2 f_\omega^2 / 8 \quad (11)$$

where  $s_i = \frac{x_{i+1} - x_{i-1}}{2}$

and the effective plate width

$$s_{ei} = \left( \frac{1.8}{\beta_{0i}} - \frac{0.8}{\beta_{0i}^2} \right) s_i \quad (12)$$

where

$$\beta_{0i} = \frac{s_i}{t} \sqrt{\frac{f_y}{E}}, \text{ but } \beta_{0i} \geq 1 \quad (13)$$

$E = 2.1 \times 10^5$  MPa is the elastic modulus.

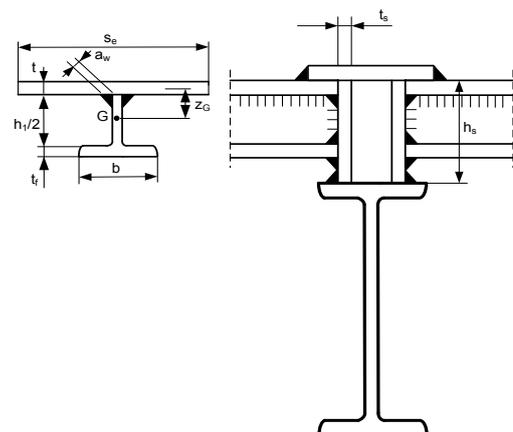


Figure 4. Cross-section of a stiffener and connection to the radial beam

The required section modulus is given by

$$W_{0i} = \frac{M_{si \max}}{f_{y1}} \quad (14)$$

(6) The cross-sectional area of a stiffener of halved rolled I-section and the effective plate part

$$A_{ei} = \frac{h_i t_{wi}}{2} + b_i t_{fi} + s_{ei} t, \quad h_{fi} = h_i - 2t_{fi} \quad (15)$$

The distances of the gravity centres  $G_i$

$$z_{Gi} = \frac{1}{A_{ei}} \left[ \frac{h_i t_{wi}}{2} \left( \frac{h_i}{4} + \frac{t}{2} \right) + b_i t_{fi} \left( \frac{h_i + t - t_{fi}}{2} \right) \right] \quad (16)$$

and 
$$z_{Gfi} = \frac{h_i + t - t_{fi}}{2} - z_{Gi} \quad (17)$$

the moments of inertia

$$I_{yi} = s_{ei} z_{Gi}^2 + \frac{h_i^3 t_{wi}}{96} + \frac{h_i t_{wi}}{2} \left( \frac{h_i}{4} + \frac{t}{2} - z_{Gi} \right)^2 + b_i t_{fi} \left( \frac{h_i + t - t_{fi}}{2} - z_{Gi} \right)^2 \quad (18)$$

The section moduli are defined as

$$W_{yi} = I_{yi} / z_{0i} \quad (19)$$

where  $z_{0i}$  is the greater of  $z_{Gi}$  and  $z_{Gfi}$ .

The required stiffener profile is selected from Table 2 to fulfil the stress constraint

$$W_{yi} \geq W_{0i}$$

**Table 2.** Ub profiles used for halved rolled i-section stiffeners

UB profile	h	b	t <sub>w</sub>	t <sub>f</sub>
152x89x16	152.4	88.7	4.5	7.7
168x102x19	177.8	101.2	4.8	7.9
203x133x26	203.2	133.2	5.7	7.8
254x102x25	257.2	101.9	6.0	8.4
305x102x28	308.7	101.8	6.0	8.8

**Cost calculation for a sectorial stiffened plate element**

The fabrication sequence has two parts:

(a) Welding of the base plate from 7 elements using SAW (Submerged Arc Welding) butt welding. The length of the plate (9835 mm) is divided into 7 parts welded together with 6 butt welds using SAW technology. The total length of welds is

$$L_{w1} = 30783 f_{\omega} \quad (20)$$

and the cost is calculated as

$$K_{w1} = k_w \left( \Theta_1 \sqrt{7 \rho V_1} + 1.3 C_{w1} t^2 L_{w1} \right) \quad (21)$$

where  $k_w = 1.0 \$ / \text{min}$ ,  $\Theta_1 = 2$ ,  $\rho = 7.85 \times 10^{-6} \text{ kg/mm}^3$ ,  $C_{w1} = 0.1559 \times 10^{-3}$ ,

$$V_1 = \frac{10353 + 518}{2} 9835 f_{\omega} t = 53.4581 \times 10^6 f_{\omega} t \quad (22)$$

(b) Welding of stiffeners to the base plate and to two edge radial plates to complete a sectorial plate element using fillet welds:

$$K_{w2} = k_w \left( \Theta_2 \sqrt{(n_{st} + 3) \rho V_2} + \sum_i T_i + T_s \right) \quad (23)$$

where  $n_{st}$  is the number of stiffeners,  $\Theta_2 = 3$ ,

$$V_2 = V_1 + V_s + \sum_i V_{sti} \quad (24)$$

the volume of the edge radial plates is

$$V_s = 2 \times 9835 h_s t_s \sqrt{1 + 0.25 f_{\omega}^2} \quad (25)$$

$t_s = 6 \text{ mm}$ ,  $h_s$  equals to the stiffener maximum height + 30 mm,

the volume of a stiffener is

$$V_{sti} = A_{sti} x_i f_{\omega}, \quad A_{sti} = \frac{h_i t_{wi}}{2} + b_i t_{fi} \quad (26)$$

welding time for a stiffener is

$$T_i = 1.3 C_{w2} a_w^2 2 x_i f_{\omega} + 1.3 C_{w3} a_w^2 2 (2 h_i + 4 b_i) \quad (27)$$

where  $C_{w2} = 0.2349 \times 10^{-3}$ ,  $C_{w3} = 0.7889 \times 10^{-3}$

constants for SAW and SMAW (Shielded Metal Arc Welding) fillet welds, respectively,  $a_w = 3 \text{ mm}$ , the second part is multiplied by 2, since the welding position is mainly vertical.

The time of welding of the two edge radial plates to the base deck plate is

$$T_s = 1.3 C_{w3} a_w^2 L_s, \quad L_s = 2 \times 9835 \sqrt{1 + 0.25 f_{\omega}^2} \quad (28)$$

Material cost of a complete sectorial element is

$$K_{m1} = k_m \rho V_2, \quad k_m = 1.0 \$ / \text{kg} \quad (29)$$

The painting cost of a complete sectorial element is

$$K_{p1} = k_p S, \quad k_p = 28.8 \times 10^{-6} \$ / \text{mm}^2, \quad (30)$$

$$S = S_s + \sum_i S_{sti} + 2 \times 53.4581 \times 10^6 f_{\omega} \quad (31)$$

$$S_s = 2 \times 9835 h_s \sqrt{1 + 0.25 f_{\omega}^2} \quad (32)$$

$$S_{sti} = (h_i + 2 b_i) x_i f_{\omega} \quad (33)$$

The total cost of a sectorial element is

$$K_s = K_{m1} + K_{w1} + K_{w2} + K_{p1} \quad (34)$$

Results of cost calculation for a sectorial element of  $\omega = 12$  show that the minimum cost corresponds to the thickness of  $t = 4 \text{ mm}$ . Therefore the further calculations are performed for this thickness only. Table 3 shows the calculated stiffener distances and sizes for  $\omega = 12$  and  $t = 4 \text{ mm}$ .

**Table 3.** Stiffener distances and sizes for  $\omega = 12$  and  $t = 4 \text{ mm}$

$x_i$ mm	h mm
518	-
2197	152.4
3314	152.4
4299	152.4
5248	152.4
6184	152.4
7114	152.4
8041	152.4
8968	177.8
9600	177.8

The cost parts in \$ for this sectorial element are as follows:  $K_m = 1259$ ,  $K_{w1} = 212$ ,  $K_{w2} = 639$ ,  $K_p = 2001$ , the total cost for one element is  $K_s = 4112$ .

**DESIGN OF RADIAL BEAMS**

Radial beams of rolled I-section are subject to bending and compression. The load is calculated from snow and soil load ( $p_M$ ), the mass of a sectorial element ( $q$ ) and the self mass ( $\rho_i A_i$ ):

$$p = p_M + q + \rho_i A_i, \quad q = \rho_i V_2 / L_i, \quad \rho_i = 7.85 \times 10^{-5} \text{ N/mm}^3, \quad L_i = 9500 \text{ mm} \quad (35)$$

The maximum bending moment is

$$M_{r,max} = p L_i^2 / 8 \quad (36)$$

The compression force is

$$N_H = F_M \cos 15^\circ + F_V \sin 15^\circ \quad (37)$$

where

$$F_V = P_M = p L / 2, \quad L = 20000 \text{ mm},$$

$$H = 9500 \sin 15^\circ = 2459 \text{ mm} \quad (38)$$

$$F_H = \frac{1}{H} \left[ F_V L_1 - P_M \left( \frac{L}{2} - \frac{d}{2} \right) \right] = 2.0333 P_M \quad (39)$$

It should be noted that the load acting on the half tank side only causes smaller forces acting on radial beams.

Stress constraint for bending and compression according to Eurocode 3 [7]

$$\frac{N_H}{\chi A_r f_{y1}} + k_{yy} \frac{M_{r \max}}{W_{y1} f_{y1}} \leq 1 \quad (40)$$

where

$$\chi = \frac{1}{\phi + \sqrt{\phi^2 - \bar{\lambda}^2}}, \phi = 0.5 \left[ 1 + 0.21(\bar{\lambda} - 0.2) + \bar{\lambda}^2 \right] \quad (41)$$

$$\bar{\lambda} = \frac{10353}{r \lambda_E}, \lambda_E = \pi \sqrt{\frac{E}{f_y}} = 93.9 \quad (42)$$

$r$  is the radius of gyration,  $A_r$  is the cross-sectional area,

$$k_{yy} = 0.95 \left( 1 + 0.6 \bar{\lambda} \frac{N_H}{\chi A_r f_{y1}} \right) \quad (43)$$

The suitable rolled I-profile is selected from an Arcelor product catalogue using the British UB profiles.

**COST OF A RADIAL BEAM**

Material cost

$$K_M = k_m \rho V_R, V_R A_r L_R, L_R = 9825 \text{ mm}, \quad (44)$$

cost of welding to the inner ringbeam and to the tank shell

$$K_W = k_w \left[ \Theta_2 \sqrt{\rho V_R} + 1.3 C_{w3} a_w^2 2x2(2h_1 + 4b) \right] \quad (45)$$

the factor of 2 is used since the welding is mainly vertical.

Cost of painting

$$K_P = k_p (2h_1 + 4b) L_R \quad (46)$$

Total cost of a radial beam

$$K_R = K_M + K_W + K_P \quad (47)$$

**ADDITIONAL COST**

Material, welding and painting of a deck plate of size 200x6x9825 connecting the sectorial elements as well as welding of the sectorial elements to the radial beam

$$K_A = k_m \rho V_A + 1.3 C_{w2} a_w^2 4 L_R k_w + k_p 200 L_R \quad (48)$$

$$V_A = 200x6L_R \quad (49)$$

Total cost of the whole roof structure

$$K = \omega (K_s + K_R + K_A) \quad (50)$$

**OPTIMIZATION RESULTS**

Table 4 and 5 summarize the results (masses and costs) for different values of  $\omega$  for a sector and for the whole roof

Table 4. Masses in kg and costs for a sector containing a sectorial element and a radial beam

$\omega$	$\rho V_s$	$K_s$ \$	$\rho V_R$	$K_R$ \$
10	1600	5046	806	1352
12	1259	4112	729	1248
14	1072	3556	588	1078
16	927	3081	588	1078

It can be seen that  $\omega = 14$  and  $\omega = 10$  gives the minimum mass and minimum cost for the whole roof, respectively. It should be noted that

the case of  $\omega = 8$  is unrealistic, since in that case the sectorial element has not a trapezoidal but a circular sector form, which needs also partial radial stiffeners beside of the circumferential ones and the cost increases.

Table 5. Masses in kg and costs for the whole roof

$\omega$	$\rho V_{\text{roof}}$	$K_{\text{roof}}$ \$
10	24060	66550
12	23856	67400
14	23240	68470
16	24240	70650

**CONCLUSIONS**

Minimum cost design of a fixed roof of a vertical steel storage tank is worked out for a numerical model structure. Load of snow and a soil layer is considered. The roof is constructed from sectorial stiffened plate elements and radial beams. The number of sectors is varied between 10 and 16. The sectorial elements are circumferential stiffened with halved rolled I-section stiffeners welded to the base plate. The non-equidistant distances of stiffeners are calculated so that the plate parts are equally stressed. The radial beams are constructed from rolled I-sections. The cost function contents the cost of material, welding and painting. The cost calculation shows that the minimum roof mass and cost corresponds to the number of sections of 14 and 10 respectively.

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## APPLYING THE BDD ELECTRODE IN THE PROCESS OF REMOVING PHARMACEUTICALS BY ELECTROCHEMICAL OXIDATION

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**Abstract:** Pharmaceuticals and their metabolites are inevitably emitted into the waters. The adverse environmental and human health effects of pharmaceutical residues in water could take place under a very low concentration range; from several  $\mu\text{g/l}$  to  $\text{ng/l}$ . These are challenges to the global water industries as there are not enough efficient processes for removing these pollutants. An efficient technology is thus sought to treat these pollutants in water and wastewater. Research involving electrochemical oxidation of emerging contaminants using BDD electrode is relatively new and more relevant information is still needed to obtain the desired result. The present work reports experimental results of the electrochemical oxidation of Ibuprofen (Ibu) solutions using boron-doped synthetic diamond (BDD) electrode. Electrochemical characterization of Ibu in a solution of  $0,05 \text{ M Na}_2\text{SO}_4$  using cyclic voltammetry (CV) and the results of Ibu electro oxidation using BDD electrode with current density of  $30 \text{ mA/cm}^2$  during 6 hours were shown. By using UV-VIS spectrophotometry and determination of Chemical Oxygen Demand (COD) decrease of the initial Ibu concentration has been shown, from  $375 \text{ mg/l}$  to  $70 \text{ mg/l}$  or  $81,4\%$  and decrease of COD value from  $960 \text{ mg O}_2/\text{l}$  to  $210 \text{ mg O}_2/\text{l}$  or about  $78\%$ , with a specific charge of  $36 \text{ A h/l}$ .

**Keywords:** BDD electrode, ibuprofen, electrochemical oxidation

### INTRODUCTION

The main source of water resources contamination with pharmaceutical products (PPs) are humans and animals treated with different medicaments. In the case of human consumption, it depends on the location of consumers such as private households, hospitals, schools or retirement facilities. Their main route of entry to the aquatic environment is through excretion and wastewater cycle. Nevertheless, expired PPs are also often discarded and may find their way to the environment via landfill leachate and/or wastewater effluent [1]. It has been found out in a survey conducted in South Eastern England that  $63.2\%$  of the people disposes unwanted or expired pharmaceuticals in the household waste,  $21.8\%$  returns them to pharmacists and  $11.5\%$  empties them into the sink or toilet. A small percentage takes them to municipal waste sites that have special waste facilities [2]. Consequently, there are efforts to mitigate this problem by the proper disposal of unused pharmaceuticals. In Europe, drug take-back programs for expired pharmaceuticals are established [3]. This means that it is necessary for the member states of the European Union (EU) to make sure that appropriate collection systems are available for unused or expired pharmaceuticals [4].

Pharmaceuticals taken up by humans or animals are generally absorbed and are subjected to biodegradation/metabolism inside the body. This process alters the chemical structure of the active molecules, which often results in a change in the physicochemical and pharmaceutical properties. Incomplete metabolism in the body and subsequent excretion may lower or enhance water solubility [5]. The pharmaceuticals and their bioactive metabolites thus continually

enter the aquatic environment as excretion via urine or feces into raw sewage, either treated or untreated [6]. A study conducted by Castiglioni et al. [7] about the removal of pharmaceuticals in six sewage treatment plants in Italy demonstrated a low overall removal rate of mostly below  $40\%$ . As such, wastewater treatment plants do not offer a viable barrier against pharmaceuticals.

Pharmaceuticals present in the environment can also come from hospital sources. A study about the presence of selected human pharmaceutical wastes in hospital effluents was conducted by Thomas et al. [8]. It was found that analgesics and beta-blockers were detected in high concentrations with paracetamol having the highest maximum concentration from all selected pharmaceuticals with values ranging from  $178 \mu\text{g/l}$  up to  $1300 \mu\text{g/l}$ . Alternatively, the source of veterinary pharmaceuticals found in the environment can be due to direct and indirect releases. Direct release to the environment is usually through application in aquaculture. On the other hand, indirect release can also occur through the administration of pharmaceuticals to animals being treated, commonly via run-off and leaching of animal excretion [9].

Ibuprofen (Ibu) or 2-(4-isobutyl phenyl) propionic acid, is the first of the non-steroidal anti-inflammatory drugs (NSAID) derived from propionic acid which is sold in many countries. It is important to emphasize that in 2005 this drug took 17th place on the list of the most commonly prescribed medications in the United States [10] or  $2300 \text{ t/year}$ . Studies were also performed in countries such as Germany, Spain, Switzerland, France, Italy, Sweden, Canada and Denmark, where the quantifications for Ibu in wastewater effluents

varied from 60 to 3400 ng/l [11]. In numerous studies, the analysis of concentrations of pharmaceuticals found in surface waters, detected were concentrations of ibuprofen from 0.05 to 0.28 mg/l [12]. Considering all these facts, it is vital to develop a process with significant potential to remove pharmaceuticals residue.

WWTP effluents have been considered as an important source of micro pollutants for aquatic environments; therefore advanced treatment technologies such as ozonation [13] and activated carbon filtration [14] as well as a combination of ozone and hydrogen peroxide [15] are required to reduce the emission of micro pollutants via WWTPs effluents.

The wide application of boron-doped synthetic diamond (BDD) electrodes extends to more specific areas, for instance, the electrochemical oxidation or reduction of emerging contaminants such as pharmaceuticals, which also received more attention in recent years because of their growing presence in the environment. Moreover, there is also research studies aimed at comparing the performance of BDD electrodes with Pt electrodes for the electrochemical oxidation of pharmaceuticals. The oxidation of ibuprofen yielded better results in favor of the BDD anode in comparison with Ti/Pt/PbO<sub>2</sub> electrode [16]. Also the results showed that the substrate was destroyed faster on a Pt anode but complete mineralization was only achieved on the BDD anode in all media. This is because intermediates such as carboxylic acids are completely converted into CO<sub>2</sub> with the BDD while they remain stable in solution using Pt electrode [17].

Several research studies are available in the literature, mostly on the electrochemical oxidation of individual pharmaceuticals such as sulfamethoxazole and acetaminophen on BDD electrodes. Li et al. [18] investigated the oxidation of sulfamethoxazole, an antibiotic, at a BDD anode using sodium sulfate (Na<sub>2</sub>SO<sub>4</sub>) as background electrolyte. Mineralization with high current efficiency was achieved with not known toxic by-product formation as a result of partial oxidation.

Research involving electrochemical oxidation of emerging contaminants using BDD electrode is relatively new and more relevant information is still needed to obtain the desired result. This paper presents experimental results of the electrochemical oxidation of Ibu solutions using BDD electrode.

**MATERIAL AND METHODS**

The pharmaceutical certified product Ibu was of analytical grade (99.6 %) and provided by the Pharmaceutical Laboratory Galenikaa.d., Beograd, Serbia. Stock solution of ibuprofen, concentration of 0.375 g/l was prepared in 0.05 M Na<sub>2</sub>SO<sub>4</sub>. The solution Na<sub>2</sub>SO<sub>4</sub> was made by using Na<sub>2</sub>SO<sub>4</sub> salt p.a. quality provided by Centrohém, Stara Pazova, and demineralized water.

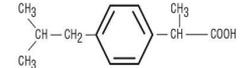
Cyclic voltammeter (CV) experiments were carried out in the custom designed three-electrode system which consisted of a standard calomel reference electrode (SCE) (Hg/Hg<sub>2</sub>Cl<sub>2</sub> in 3.5 M KCl, E = + 0.250 V vs. NHE at 25 °C), coiled platinum wire as a counter electrode and a highly BDD working electrode at the cell bottom with a surface of 0.8

cm<sup>2</sup> bounded by a chemically resistant rubber o-ring. Cyclic voltammeter experiments were performed by potentiostat – galvanostat Gamry G300 control.

Electrochemical experiments were conducted at room temperature (22–25 °C) in a 250ml cell, using batch mode. BDD (20cm<sup>2</sup>) electrode was used as anode, and stainless steel foils, with an identical area to the anodes, were used as cathodes. All anodic oxidation assays were performed under galvanostatic conditions, with imposed current densities of 30mAcm<sup>-2</sup>, which is characterized in previous works as the optimum current density for the Ibu oxidation on BDD [16], for a volume of 100 ml of solution. A potentiostat/galvanostat, model PAR EGG, was used as the power supply.

The basic solution of Ibu in 0.05 M Na<sub>2</sub>SO<sub>4</sub> had characteristics according to Table 1.

**Table 1**

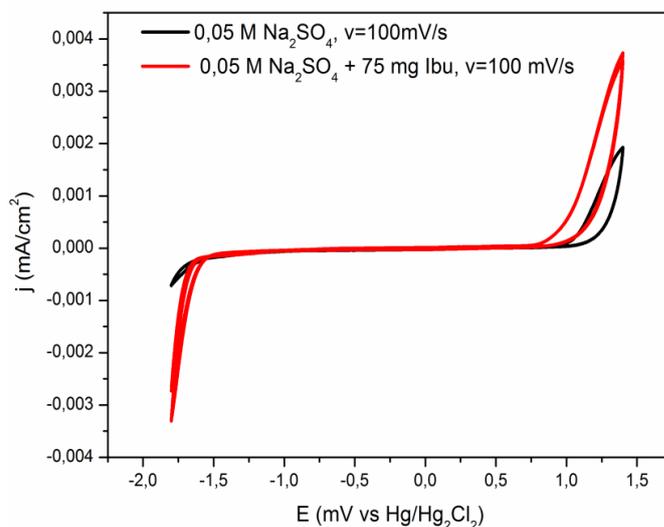
Ibuprofen	c, mg/l	pH	COD, mg O <sub>2</sub> /l
	375	6	960 ± 35

The change in the concentration of Ibu was monitored by UV-Vis spectrophotometer (Shimadzu UV 1800) at a wavelength of 264 nm and calibration curves. Chemical Oxygen Demand (COD) determinations were made following the titrimetric method, according to standard methods [19].

**RESULTS AND DISCUSSION**

**Electrochemical characterization**

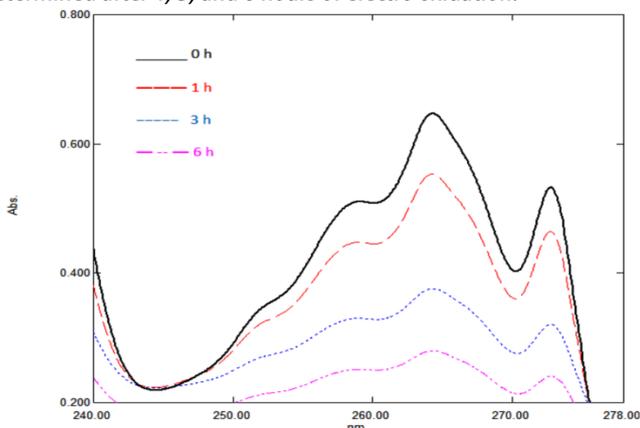
Cyclic voltammogram of Ibu solution containing 0,05 M Na<sub>2</sub>SO<sub>4</sub> with BDD electrodes are shown in fig. 1. At the potential higher than 0,75 V vs. Hg/Hg<sub>2</sub>Cl<sub>2</sub>, the current density increase with adding Ibu. The increased current density may result from the direct electro oxidation of Ibu at BDD electrode. When the potential exceeds 1.3 V, the anodic currents increased largely with potential, which may be result of electro oxidation of Ibu plus the evolution of oxygen. With the evolution of oxygen, the active species such as hydroxyl radicals, H<sub>2</sub>O<sub>2</sub>, or O<sub>3</sub> can be produced, which lead to the indirect oxidation of Ibu.



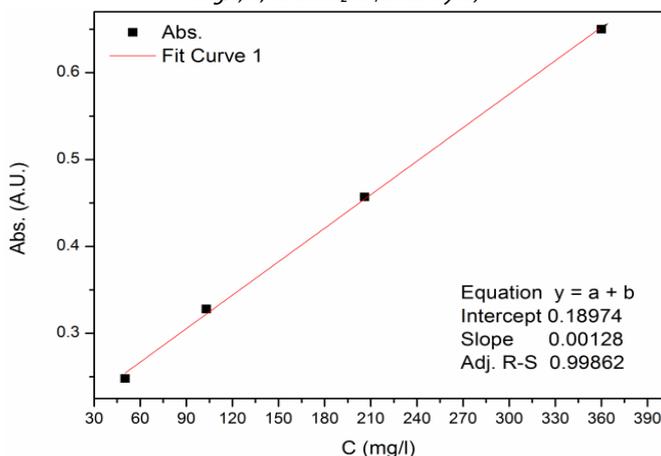
**Figure 1.** Cyclic voltammograms of Ibuprofen (1,83mM/l) in 0,05 M Na<sub>2</sub>SO<sub>4</sub> solution at BDD electrode

**Effect of electro oxidation of Ibu at BDD electrode**

Electro oxidation of Ibu, initial concentration of 375 mg/l, is performed on BDD electrode. The change in the concentration of Ibu was monitored by UV-Vis spectrophotometer after 1, 3 and 6 hours of electro oxidation. According to the spectro-photometric results, Figure 2, Ibu solution has two peaks (264 and 272 nm). Based on the literature data [20] for the determination of Ibu, the peak at 264 nm was selected. The concentration of Ibu present in each sample was calculated by determining the value of absorbance for each sample at the peak of 264 nm and by using the calibration curve. Figure 2 shows decrease in absorbance values for peak typical for Ibu (264 nm). Based on the calibration curve, Figure 3, Ibu concentrations were determined after 1, 3, and 6 hours of electro oxidation.



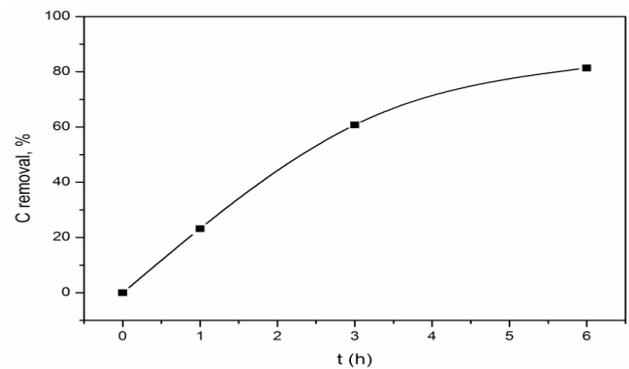
**Figure 2.** Electro oxidation of Ibu at BDD electrode at various reaction times: UV-Vis spectra of reaction of Ibu solution (initial Ibu concentration 375 mg/l; 0,05 M Na<sub>2</sub>SO<sub>4</sub> electrolyte)



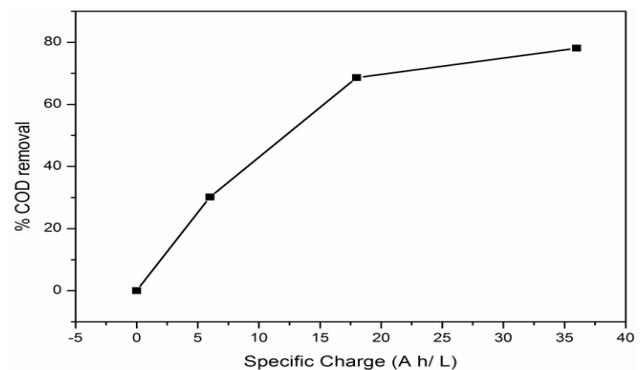
**Figure 3.** Calibration curve of Ibu in 0,05 M Na<sub>2</sub>SO<sub>4</sub> at 264 nm. It was observed extremely decreasing in initial Ibu concentration over the time of 1, 3 and 6 hours from 375 mg/l to 288, 147, and 70 mg/l, respectively. The highest percentage of Ibu removal was 81,4%, after 6 hours of electro oxidation, Figure 4. These results suggested that the intermediates were produced at the initial reaction time, which were degraded with the extension of reaction process.

The possibility of Ibu removal by electro oxidation was additionally confirmed by determining the value of COD in the Ibu solution after 1, 3 and 6 h, in relation to specific charge, Figure 5. The obtained results showed a COD reduction of 78% compared to the solution with the

initial concentration of Ibu, after 6 h of electro oxidation on BDD electrode.



**Figure 4.** Decrease in the concentration of Ibu in solution after different times of electro oxidation at BDD electrode



**Figure 5.** Variation of COD removal as a function of the specific charge passed during electrolysis of Ibu performed with BDD electrode

No remarkable degradation of Ibu was achieved at anodic potential below 1.2 V, for which H<sub>2</sub>O electrolysis nearly cannot occur, which indicated that the contribution of direct oxidation is not significant. The other possible mechanism responsible for the Ibu degradation is indirect oxidation mediated by several oxidants produced from the oxidation of water. Reactive oxidants such as •OH, O<sub>3</sub>, H<sub>2</sub>O<sub>2</sub>, and •O<sub>2</sub><sup>-</sup> can be considered as candidate oxidants [21]. The most common oxidation is the •OH radicals formed by the one-electron oxidation of water. Additionally, other reactive oxidants can also be responsible for the Ibu degradation.

**CONCLUSION**

The aim of this study was to examine the possibilities of Ibu removal from aqueous solution in the reaction of electro oxidation on BDD electrode. The effective removal of Ibu from aqueous solutions using BDD anode has been shown. Regarding the Abs (264 nm), for the current densities of 30 mV/cm<sup>2</sup> Ibu removal from aqueous solution can be possible up to 81%. The possibility of Ibu removal by electrochemical degradation was also confirmed by the results of COD which have demonstrated the removal of 78% compared to the initial value.

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## COMPUTER ASSISTANCE PROGRAM USED FOR THE OPTIMAL UTILIZATION OF STORAGE RACKS & PALLETS IN THE BEARINGS MANUFACTURING PROCESS

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**Abstract:** Well designed storage facility is the heart and soul of every logistic system. The subject of detailed storage solution and layout is so far inadequately covered. My goal was to create a software program that would support companies in their selection of ideal types of storage racks and pallets to store various materials on inside their warehouse. For this purpose, I've decided to specifically focus on the concept of weight load and storage capacity utilization as an optimal criteria as part of a system application. This criteria belongs to the most important vantage points according to which storage equipment is selected in real practice. In today's market, there exist a great deal of companies that offer various types of racks and pallets. The structure of available data however (e.g. company e-catalogues) is highly diverse and as a result doesn't offer automatic processing and devising. This is why I have made it my goal to design a clear cut database which stores only those parameters of racks and pallets that are important for work with a computer system when searching for an optimal solution. The actual structure of the proposed database, lets the computer program choose optimal racks and pallets from stored data, conduct capacity calculation of a warehouse as well as draw a possible layout of the proposed number of racks and pallets stored inside a storage facility. The key solution for creating similar computer programs is in fact a well designed database of specific objects (e.g. pallets) used in technological planning.

**Keywords:** software, optimization, logistics, storage facility, console shelving, weight utilization

### INTRODUCTION

The main aim of my work was to design a computer program that help support companies with designing of technological projects in the field of logistics that focus on selecting most suitable storage equipment inside their facility (console shelving and pallets). One condition was that the created software had to have reached a stage where it would enable an ordinary user with basic knowledge of Windows to work with it easily. Working with the computer system had to be uncomplicated so that not only project organizations, but more so companies who are considering to build new storage facility or those who are thinking of rennovating existing warehouses can utilize the program effectively. The expected ways of software application is extensive and ranges from selection of optimal types of pallets and the most ideal way of storing parts inside each pallet taking into consideration its capacity and weight utilization, to a complex design of optimal racks and pallets and their manner of arrangement inside a storage facility. I've particularly stressed upon the versatility when designing the computer program. The user for instance, can him/herself simply update the database in such a way so that the result generated by the system can always be implemented in a real life practice.

First of all, it is necessary to determine the required capacity of the warehouse. In the course of production of metal bar components,

initially, semi-completed parts for these components are stored in a bundle of long rods. When we look at the cross-section profile of stored material with a circulatory shape stacked together, there exist a variety of ways one can store these rods on a single level of a rack. All possible laid down options is considered and implemented by the program. This way, the user for instance, can immediately view the changes to the utilization of specific type of racks during a changeover from a triangular profile to a bundle of stored material with a hexagon shaped cross section profile. After entering the manufacturing process, these rods, stored on racks, can be further divided into parts and later stored inside pallets (storage boxes) of an interim storage facility awaiting expedition [2,6].

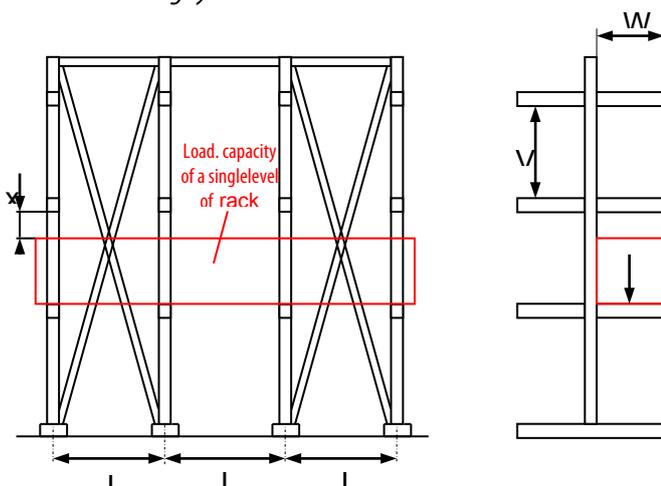
### SELECTING AN OPTIMAL SHELVING SYSTEM

Lets' clarify the methods used by the program when selecting an optimal rack. The system initially goes through the database of storage racks and then calculates each holding weight. It then tries to find out true length of metal rods to be stored on the rack, given that the user has a certain idea of the range of size of metal rods to be stacked up in a pile (e.g. 1,7 m – 2 m). The selection of an optimal length of metal rods is conducted for every type of console within the database with respect to the distance of supportive stands. The computer program helps determine the final length of the bar for use with optimal size of shelving. On the other hand, the user

him/herself, can also enter fixed length of the bar (if known) into the system which must be strictly observed. As a result, the system finds out the number of supportive stands needed in order to accommodate the storage of selected size of the bars.

When calculating weight utilization and storage capacity, the program takes into account the max. number of bars that can be conveniently stored on a single floor of brackets. This quantity of bars is limited to the load bearing capacity and dimensions of the brackets. The load carrying capacity of one floor can be calculated as a product of a load of a console shelf and the number of supportive stands which the system has proposed [3]. The weight load capacity of a storage console is stored in a computers' database which can be later accessed by the system and used for evaluation of every type of shelving system. The computer system is also capable of selecting additional parameters such as length of the brackets, vertical distance between each bracket and the amount of brackets on a stand needed for individual storage rack.

The max. number of metal bars stored on a single floor of a storage rack is further limited to its optimal utilization. The system attempts to reduce the max. accessible loading capacity to create space for comfortable stacking up and pulling out piles of stored material. An optimal utilization of space and loading capacity is there for achieved. Metal bars can additionally be stored in bundles. A metal bar with a circulatory cross-section profile such as a pipe, can be stored in variety of ways. The user can choose to store rods in a bundle shaped into a hexagon, pyramid, triangle or a rhombus. All these types of stock piles are supported in the system. On the basis of selected diameter of metal rods, weight of the rods, the geometry of the shelf floor and its load bearing capacity, the computer program can, with the help of algorithm, calculate the amount of rods that can be put together in a stack and the number of stock piles conveniently stored on a single level of the shelving system.



$L$  – length of a single rack (mm)  
 $W$  – width of a bracket (mm)  
 $V$  – vertical distance between top and bottom bracket (mm)  
 $x$  – additional space to allow convenient loading and unloading of stock piles off the rack (mm)

Figure 1: Diagram of an assembled console shelf [3]

Fig. 1 represents a double sided bracket storage system assembled from four metal stands [3]. The symbol “ $L$ ” marks the distance between each supportive stand, which is at the same time the smallest possible width of the rack. The total dimensions of an assembled storage console is in this case three times the length of “ $L$ ”. A single floor of the rack is formed by four storage brackets having a depth of “ $W$ ”. The symbol “ $V$ ” marks a vertical distance between two storage brackets. The symbol “ $x$ ” on the other hand represents a safety margin for an optimal stacking up and pulling out piles of material off the rack. The coloured rectangle highlights an area which can be used for storing metal bars.

Inside the computers' database you will find all the accessible variety of racks arranged in a descending order according to their weight utilization – see fig. 4. Every type of rack can be displayed with an overall expense of purchase, depending on the total numbers required. The cost burden is calculated from the price of a single free standing rack entered into the database. The first rack listed is the number one choice of rack selected by the program. The system simultaneously displays concise data as well as the anticipated number of racks required for the proposed storage capacity of a warehouse to store rod shaped material. The computer system also makes a list of the floor space necessary to store racks. (This however relates purely to the net space area that later must be expanded to make way for a road path, checking station and other much needed ground space [3,6]).

**SELECTION OF AN OPTIMAL PALLET**

As was mentioned earlier, only a certain percentage of material can be stored inside pallets. The pallet with the best space utilization, according to its size, is selected as the number one choice. Naturally, it cannot exceed its load carrying capacity. The storage capacity of a pallet is calculated by the system as a portion of a sum of a cubature of a part packed in a virtual smallest possible rectangular box packaging, the max. number of packaged material stashed inside a pallet and the internal dimensions of the pallet [3]. As a general rule, the virtual rectangular box can be stored in six different positions inside a carrier unit. If the virtual packaging has a square shaped (cross-section) profile, then the number of possible laid down positions is reduced down to 3. (Stored vertically, horizontally and width-wise).

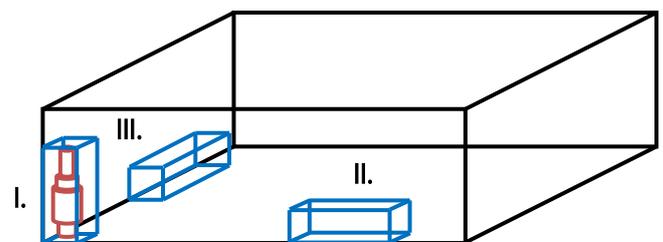


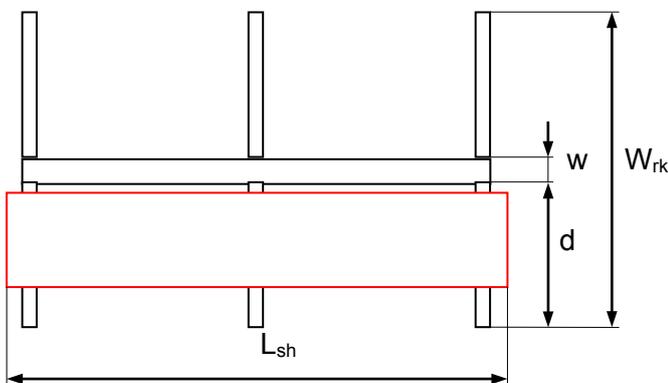
Figure 2: Possible laid down positions of virtual rectangular box packaging (with a square cross section profile) used to store various component parts of a semi product inside a pallet

The system progressively analyses each type of pallet stored in its database and then determines the best size of the pallet to be used

and the best laid down position of the packaged material stored within it, in order to prevent wastage of space and enhance its max. storage capacity. The internal storage utilization of a pallet is expressed as a percentage.

**THE LAYOUT PROPOSAL OF A WAREHOUSE**

The term “layout” of a warehouse relates particularly to a ground plan of a hall and its ideal distribution of storage racks and pallets [3]. The database of racks also contain figures relating to the depth of two wall brackets (in case of reversible racks), that together with the width of its supporting columns give the overall breadth of a rack. See fig. 3. The system selects the type of rack (when the width of the rack is known) to be used to store rods of specific lengths (assuming the length of the stored bundle of rods is known). The product of the two figures determines the total surface area a rack will occupy inside a warehouse. If we were to multiply the total surface area ( $m^2$ ) of one rack shelving with the required number of racks, we will obtain net surface area of a ground floor designated for the rack shelving in a warehouse. The computer program automatically sketches a detailed ground plan of a hall together with the proposed layout of storage racks with respect to the established span length of a hall, its ground surface area that the rack will need to occupy, the nominated number of racks, the size of gaps between each free standing racks and the space between racks and the walls of the hall. See fig. 5. Similarly, it is possible to calculate the net ground floor area of a hall allocated for the storage of material inside pallets (based on the external size of pallets and the max. number pallets capable of being stacked up on top of each other).



$W_{rk}$  – width of a rack (m);  $d$  – depth of a storage rack (m);  $w$  – width of a support stand (m);  $L_{sh}$  – length of a sheaf stored on a single level (m)

**Figure 3: Ground plan of a rack shelving system holding sheaf of metal rods USER-DEFINED INTERFACE OF THE CREATED COMPUTER SYSTEM AND THE USE OF DEVELOPMENTAL TOOL**

The computer system was developed with the aid of a developmental tool known as Delphi (from Borland company), which combines strong set of visual tools for the purpose of creating all parts of applications [5]. The nominated user defined interface enables simple and user friendly working with the system. The following pictorials contain main electronic forms for entering initial data and enabling visualization of results based on different stages of the design process of a storage facility.

**DATABASE OF FREE STANDING RACKS AND PALLETS**

The database of racks contain all the parameters of a rack shelf necessary for its optimal selection. The supportive stands placed behind each other in a row create a so called „composed module rack” long enough to accommodate storage of rod piles – see above.

The database of rack shelving contain the following parameters: internal identification code of a rack, its manufacturing code, name of manufacturer, load bearing capacity of a storage bracket (kg), length of a storage bracket (mm), number of storage brackets on 1 support stand, length of 1 rack (mm), width of a rack (mm), vertical space between storage brackets (mm) and price of 1 rack stand (EUR).

The database of a pallet (carrier box) once again contain all the parameters of a pallet which are important for algorithmic selection of an optimal type of pallet. For its selection, it is of paramount to have access to inner dimensions of a pallet as well as its load carrying capacity. In order to calculate net floor plan of a warehouse reserved specifically for the storage of pallets (excluding work space, checking stations etc.), it is also important to know its outer dimensions and the weight of a pile. These figures can also be entered into the database. The cost of a pallet is also another component of the database. The system uses this figure to help calculate total price of a nominated pallet using analogous method as in the case of a rack.

Optimal shelving	Weight util. of a storage racks (%)	Price of racks (EUR)
Internal code: RACK004	92.88	1070000
Manufacturer: Company_X	RACK003	80.92
Length of a bracket (mm): 600	RACK006	73.25
Height between brackets (mm): 500	RACK005	73.25
Num. of brackets per support stand: 4	RACK001	60.08
Length of 1 shelf unit (mm): 650	RACK002	42.37

**Figure 4: Electronic form for entering basic data and selecting an optimal rack**

The database of pallets contain the following parameters: internal identification code of a carrier box, manufacturing code of a carrier box, name of manufacturer, load carrying capacity of a pallet (kg), weight of a pile (kg), inner dimensions (mm), outer dimensions (mm), price of a pallet (EUR).

Number of racks: 107

Width of racks (mm): 480

Length of racks (mm): 650

Total length of racks (mm): 650

Width of a hall (m): 12

Distance away from a wall of a hall (mm):

X0: 700

X2 min: 500

Y0: 700

Space between racks (mm):

X1: 800

Y1: 200

Overhang of a bundle of stored material into aisle Y1: 350

Draw a layout

The diagram shows a grid of racks within a hall of width 12m. Dimensions X0, X2, Y0, and Y1 are indicated. Y1 is labeled as 'overhang of bundles'. The total length of racks is 650mm.

Figure 5: Form used for entering complimentary data that is vital for generating a diagram of a rack field

### CONCLUSION

By creating a simple database of important object parameters used in technological planning and applying optimal rules over these objects, it becomes possible to greatly support the actual process of technological design. The user of the program, this way obtains a tool, which enables him/her to carry out hypothetical analysis „what would happen if...“ (what if analysis). The key foundation for creating similar computer program for the purpose of searching for an optimal solution is clearly the use of a unified database of objects of technological design (in this case racks and pallets). Without such a database, it is not possible to carry out such optimization. Lately, there has been a developmental advancement in the field of information technology. Despite so, no easily accessible central database of technological design objects with a uniform structure exists that would enable the application of a computer program search for an optimal solution. If we were to take a look at the subject of console shelving, despite of seeing vast content of advertised material on the Internet on currently manufactured types of racks and a list of their retailers (mainly inside e-catalogue) the structure of such data is extremely diverse. It is not farfetched to think about whether or not it would be more convenient to come up with a project such as central internet relational database as mentioned above. The editing of this data would be done directly by retailers, knowing that it would assist users to both manually (search through an internet database) or by means of computer program assistance to specifically select their products that would suit them most.

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## FASTER CALCULATION METHOD FOR UNSTEADY FLOW IN TUBE

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**Abstract:** Several methods are known for the calculation of unsteady flow in long tubes having a small-diameter. In case of long pipes having a small-diameter radial change of status indicators are neglected, we consider only the tube longitudinal changes. Most of the calculation methods are based on the finite difference method or the method of equal scale interval characteristic. The common feature of these methods is that the condition for their stability is the fulfilment of the Courant-Friedrich-Lewy condition. This paper shows a faster method for calculation unsteady flow in tube. The governing equations are reduced to three first-order quasi-linear ordinary differential equations. They are solved on the time scale interval analytically. The quickness of this method is given by the used stability condition.

**Keywords:** unsteady flow, CFD, stability condition

### INTRODUCTION

Several methods are known for the calculation of unsteady flow in long tubes having a small-diameter. In case of long pipes having a small-diameter radial change of status indicators are neglected, we consider only the tube longitudinal changes [1]. Most of the calculation methods are based on the finite difference method or the method of equal scale interval characteristic. The common feature of these methods is that the condition for their stability is the fulfilment of the Courant-Friedrich-Lewy condition. This means that for a given spacing step the time step has to fulfil the following equation:

$$\Delta t \leq \frac{\Delta x}{\max(a+w)}, \quad (1)$$

i.e. the time scales must be less than or equal to the spacing scale divided by the maximum of the sum of the speed of sound and speed of flow. In this paper we show the correlations for frictionless flow in horizontal tube.

### THE GOVERNING EQUATIONS

The continuity equation:

$$\frac{d\rho}{dt} + \rho \frac{\partial w}{\partial x} = 0. \quad (2)$$

The equation of motion:

$$\frac{dw}{dt} + \frac{1}{\rho} \frac{\partial p}{\partial x} = 0. \quad (3)$$

Energy equation (Thermodynamics I.):

$$\frac{dh}{dt} - \frac{1}{\rho} \frac{dp}{dt} = \frac{4k}{D\rho} (T_k - T). \quad (4)$$

Thermodynamic properties of fluid:

$$p = p(\rho, T), \quad (5)$$

$$h = h(p, \rho). \quad (6)$$

Based on (6)

$$dh = \left. \frac{\partial h}{\partial p} \right|_{\rho} dp + \left. \frac{\partial h}{\partial \rho} \right|_{p} d\rho. \quad (7)$$

can be written.

Using (7) in the equation (4) it can be written as follows:

$$\left( \left. \frac{\partial h}{\partial p} \right|_{\rho} - \frac{1}{\rho} \right) \frac{dp}{dt} + \left. \frac{\partial h}{\partial \rho} \right|_{p} \frac{d\rho}{dt} = \frac{4k}{D\rho} (T_k - T), \quad (8)$$

after rearranging it we get

$$\frac{\left( \left. \frac{\partial h}{\partial p} \right|_{\rho} - \frac{1}{\rho} \right) dp}{\left. \frac{\partial h}{\partial \rho} \right|_{p} dt} + \frac{d\rho}{dt} = \frac{4k}{D\rho \left. \frac{\partial h}{\partial \rho} \right|_{p}} (T_k - T). \quad (9)$$

Using the

$$\frac{\left( \left. \frac{\partial h}{\partial p} \right|_{\rho} - \frac{1}{\rho} \right)}{\left. \frac{\partial h}{\partial \rho} \right|_{p}} = - \frac{1}{\left. \frac{\partial p}{\partial \rho} \right|_s} = - \frac{1}{a^2} \quad (10)$$

correlation

$$a^2 \frac{d\rho}{dt} - \frac{dp}{dt} = \frac{4a^2 k}{D\rho \left. \frac{\partial h}{\partial \rho} \right|_{p}} (T_k - T) = b_3. \quad (11)$$

can be written

Expressed in equation (2)

$$\frac{d\rho}{dt} = -\rho \frac{\partial w}{\partial x}, \quad (12)$$

and substituting it into equation (11) we get

$$-a^2 \rho \frac{\partial w}{\partial x} - \frac{dp}{dt} = b_3, \quad (13)$$

i.e.

$$-a^2 \rho \frac{\partial w}{\partial x} - \frac{\partial p}{\partial t} - w \frac{\partial p}{\partial x} = b_3. \quad (14)$$

Taking the equation (14) and adding it we get  $a\rho$  -times the equation (3), i.e.

$$\left. \begin{aligned} -a^2 \rho \frac{\partial w}{\partial x} - \frac{\partial p}{\partial t} - w \frac{\partial p}{\partial x} &= b_3 \\ \frac{\partial w}{\partial t} + w \frac{\partial w}{\partial x} + \frac{1}{\rho} \frac{\partial p}{\partial x} &= 0 \quad / \cdot a\rho \end{aligned} \right\} +, \quad (15)$$

to give the

$$a\rho \left[ \frac{\partial w}{\partial t} + (w-a) \frac{\partial w}{\partial x} \right] - \left[ \frac{\partial p}{\partial t} + (w-a) \frac{\partial p}{\partial x} \right] = b_3 \quad (16)$$

correlation. This means that along the characteristic (line)

$$\frac{dx}{dt} = w - a \quad (17)$$

the following ordinary differential equation is satisfied:

$$a\rho \frac{dw}{dt} - \frac{dp}{dt} = b_3. \quad (18)$$

Similarly, let's consider now the equation (14) and subtract the  $a\rho$  -times the equation (3) from it:

$$\left. \begin{aligned} -a^2 \rho \frac{\partial w}{\partial x} - \frac{\partial p}{\partial t} - w \frac{\partial p}{\partial x} &= b_3 \\ \frac{\partial w}{\partial t} + w \frac{\partial w}{\partial x} + \frac{1}{\rho} \frac{\partial p}{\partial x} &= 0 \quad / \cdot a\rho \end{aligned} \right\} - \quad (19)$$

and multiplying the correlation obtained by  $(-1)$ :

$$a\rho \left[ \frac{\partial w}{\partial t} + (w+a) \frac{\partial w}{\partial x} \right] + \left[ \frac{\partial p}{\partial t} + (w+a) \frac{\partial p}{\partial x} \right] = -b_3 \quad (20)$$

This means that along the characteristic (line)

$$\frac{dx}{dt} = w + a \quad (21)$$

the following ordinary differential equation is satisfied:

$$a\rho \frac{dw}{dt} + \frac{dp}{dt} = -b_3. \quad (22)$$

The equation system consisting of the partial differential equations (2), (3) and (11) is the following:

$$\left. \begin{aligned} \frac{\partial p}{\partial t} + w \frac{\partial p}{\partial x} + \rho \frac{\partial w}{\partial x} &= 0 \\ \frac{\partial w}{\partial t} + w \frac{\partial w}{\partial x} + \frac{1}{\rho} \frac{\partial p}{\partial x} &= 0 \\ a^2 \left( \frac{\partial p}{\partial t} + w \frac{\partial p}{\partial x} \right) - \frac{\partial p}{\partial t} - w \frac{\partial p}{\partial x} &= b_3 \end{aligned} \right\} \quad (23)$$

and we get its solution from solving the (11), (18) and (22) ordinary differential equations along the corresponding characteristics:

$$\left. \begin{aligned} a^2 \frac{dp}{dt} - \frac{dp}{dt} = b_3, \quad \frac{dx}{dt} = w \\ a\rho \frac{dw}{dt} + \frac{dp}{dt} = -b_3, \quad \frac{dx}{dt} = w + a \\ a\rho \frac{dw}{dt} - \frac{dp}{dt} = b_3, \quad \frac{dx}{dt} = w - a \end{aligned} \right\} \cdot \quad (24)$$

**MATHEMATICAL BACKGROUND**

Let's consider the following partial differential equation [2], where  $u = u(x, t)$  and where  $c$  and  $k$  are constants:

$$\frac{\partial u}{\partial t} + c \frac{\partial u}{\partial x} = k. \quad (25)$$

Let's take  $c > 0$ , and make the following initial and boundary conditions known.

Initial condition is the following if  $x \geq 0$ :

$$u(x, 0) = f(x), \quad (26)$$

and boundary condition is at  $x = 0$ :

$$u(0, t) = g(t). \quad (27)$$

Let's formulate the total differential of function  $u$ :

$$du = \frac{\partial u}{\partial t} dt + \frac{\partial u}{\partial x} dx \quad (28)$$

and when expressed we get the total derivative of  $u$  by  $t$ :

$$\frac{du}{dt} = \frac{\partial u}{\partial t} + \frac{dx}{dt} \frac{\partial u}{\partial x}. \quad (29)$$

Comparing the left-hand side of equation (25) and the right side of equation (29) we can write

$$\frac{du}{dt} = k \quad (30)$$

and

$$\frac{dx}{dt} = c. \quad (31)$$

Solving the ordinary differential equations (30)&(31), the solution is

$$u = kt + F(x) \quad (32)$$

and

$$x = ct + x_0, \quad (33)$$

where  $x_0$  is the location coordinate in the  $t = 0$  moment.

Based on initial condition (26) the value of  $u$  in the  $t = 0$  moment is:

$$u(x, 0) = F(x_0) = f(x_0). \quad (34)$$

So the solution of the initial value problem is

$$u(x, t) = kt + f(x_0), \quad (35)$$

when  $x_0 \geq 0$ .

Denoted  $x_0$  from (33) formula

$$u(x, t) = kt + f(x - ct), \quad (36)$$

can be written when  $x - ct \geq 0$ .

If  $x_0 = x - ct < 0$ , then the solution is calculated from the boundary

condition according to following (Figure 1) [3]:

$$u(x, t) = k \frac{x}{c} + g \left( t - \frac{x}{c} \right). \quad (37)$$

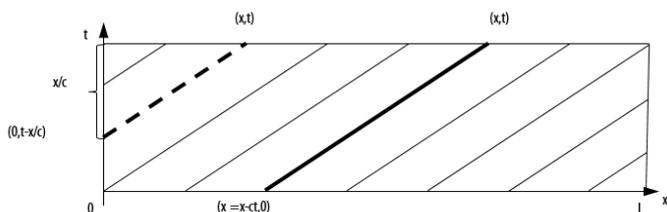


Figure 1. Characteristics

If  $c < 0$ , then at location  $x=L$  we specify the boundary condition, i.e.

$$u(L, t) = g(t). \tag{38}$$

In this case the solution is the following:

$$u(x, t) = kt + f(x_0) = kt + f(x - ct), \tag{39}$$

when  $x_0 = x - ct \leq L$ , and

$$u(x, t) = k \frac{x-L}{c} + g\left(t - \frac{x-L}{c}\right), \tag{40}$$

when  $x_0 = x - ct > L$ .

If the  $c$  is constant, the intersection of characteristics is not possible.

If the  $c = c(x, t)$  is a function, then differential equation (31) has only one solution for the given  $[0, t]$  time interval (i.e. the characteristics do not intersect each other [4]), only if the function  $c = c(x, t)$  can fulfil the Lipschitz condition. The Lipschitz condition is as follows [5]:

$$|c(x_2, t) - c(x_1, t)| \leq L_c |x_2 - x_1|, \tag{41}$$

where  $L_c > 0$ . Using that,  $dx = x_2 - x_1$ , and

$$c(x_2, t) = c(x_1, t) + \frac{\partial c}{\partial x} dx \text{ we get}$$

$$\left| \frac{\partial c}{\partial x} \right| \leq L_c. \tag{42}$$

Expressing  $c$  from equation (33) we get

$$c = \frac{x - x_0}{t}. \tag{43}$$

Using this the Lipschitz condition reformulates as follows:

$$\left| \frac{x_2 - x_0}{t} - \frac{x_1 - x_0}{t} \right| = \left| \frac{x_2 - x_1}{t} \right| \leq L_c |x_2 - x_1| \tag{44}$$

and rearranging it we get

$$L_c \geq \left| \frac{1}{t} \right|. \tag{45}$$

Comparing the equations (42) and (45) it can be written that the function  $c$  fulfils the Lipschitz condition when

$$\left| \frac{\partial c}{\partial x} \right| t < 1 \tag{46}$$

correlation is met.

### THE SOLUTION OF THE SYSTEM OF EQUATIONS

Returning to system of equations (24), let's consider the equations quasi-linear and quasi-constant coefficient equations. Quasi-linear and quasi-constant coefficient equations mean the coefficients are functions but now their values are constant as at the beginning of time interval. Let's solve the system of equations in the time interval  $t=0$  and  $t=\Delta t$  and on the location interval  $x=0$  and  $x=L$ .

Introducing the following notation:

$$a_1^2 \rho - \rho = u_1, \tag{47}$$

$$w_1 = c_1, \tag{48}$$

$$b_3 = k, \tag{49}$$

$$a_2 \rho_2 w + \rho = u_2, \tag{50}$$

$$w_2 + a_2 = c_2, \tag{51}$$

$$a_3 \rho_3 w - \rho = u_3, \tag{52}$$

$$w_3 - a_3 = c_3. \tag{53}$$

Based on them system of equations (24) can be written as follows:

$$\frac{\partial u_1}{\partial t} + c_1 \frac{\partial u_1}{\partial x} = k, \tag{54}$$

$$\frac{\partial u_2}{\partial t} + c_2 \frac{\partial u_2}{\partial x} = -k, \tag{55}$$

$$\frac{\partial u_3}{\partial t} + c_3 \frac{\partial u_3}{\partial x} = k. \tag{56}$$

Thus the system is falling into three partial differential equations and according to above their solutions are the followings:

$$u_1(x, t) = \begin{cases} kt + f_1(x_0) & \text{ha } c_1 t \leq x \leq L + c_1 t \\ k \frac{x}{c_1} + g_{1,0} \left( t - \frac{x}{c_1} \right) & \text{ha } x < c_1 t \\ k \frac{x-L}{c_1} + g_{1,L} \left( t - \frac{x-L}{c_1} \right) & \text{ha } x > L + c_1 t \end{cases} \tag{57}$$

$$u_2(x, t) = \begin{cases} -kt + f_2(x_0) & \text{ha } x \geq c_2 t \\ -k \frac{x}{c_2} + g_{2,0} \left( t - \frac{x}{c_2} \right) & \text{ha } x < c_2 t \end{cases} \tag{58}$$

$$u_3(x, t) = \begin{cases} kt + f_3(x_0) & \text{ha } x \leq L + c_3 t \\ k \frac{x-L}{c_3} + g_{3,L} \left( t - \frac{x-L}{c_3} \right) & \text{ha } x > L + c_3 t \end{cases} \tag{59}$$

Adding together the equations (50) and (52) and arranging it we get

$$w = \frac{u_2 + u_3}{a_2 \rho_2 + a_3 \rho_3}. \tag{60}$$

Subtracting equation (52) from equation (50), arranging it and using relation (60) we get

$$\rho = \frac{a_3 \rho_3 u_2 - a_2 \rho_2 u_3}{a_2 \rho_2 + a_3 \rho_3}. \tag{61}$$

In terms of the equation (47) and by using relation (61) we get the following formula for density:

$$\rho = \frac{1}{a_1^2} \left( u_1 + \frac{a_3 \rho_3 u_2 - a_2 \rho_2 u_3}{a_2 \rho_2 + a_3 \rho_3} \right) = \frac{a_3 \rho_3 (u_1 + u_2) + a_2 \rho_2 (u_1 - u_3)}{a_1^2 (a_2 \rho_2 + a_3 \rho_3)} \tag{62}$$

The uniqueness of the solution is ensured by the fulfilment of the Lipschitz condition. In this case equation (46) is the following:

$$\max \left( \left| \frac{\partial c_1}{\partial x} \right|, \left| \frac{\partial c_2}{\partial x} \right|, \left| \frac{\partial c_3}{\partial x} \right| \right) \Delta t < 1. \tag{63}$$

Switching over from differentials to differences can be written that

$$\Delta t < \frac{\Delta x}{\max(|\Delta c_1|, |\Delta c_2|, |\Delta c_3|)} \quad (64)$$

must be met.

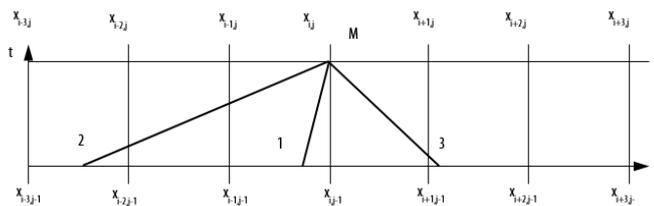


Figure 2. Symbols of characteristics

**BOUNDARY CONDITIONS**

If point M is at the inlet of pipe and inflow is here, only the characteristic line from point 3 exists (Figure 3), and according to these and based on the equation (59) the relation between speed and pressure at point M must be able to meet the following.:

$$p = p_3 + a_3 \rho_3 (w - w_3) - k \Delta t. \quad (65)$$

This means that if the speed and density are given, then the pressure can be calculated or if the pressure and density are given, the speed can be calculated.

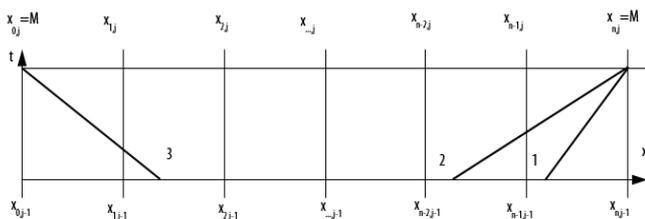


Figure 3. Boundary conditions

If point M is at the end of the pipe and outflow is here, only the characteristics that depart from points 1 and 2 exist. If here the speed is given, then according to (58) the pressure- and according to (57) the density can be calculated, namely as follows:

$$p = p_2 + a_2 \rho_2 (w_2 - w) - k \Delta t, \quad (66)$$

$$\rho = \rho_1 + \frac{1}{a_1} (p - p_1) + k \Delta t. \quad (67)$$

It is taken as a special case when inflow is not at the inlet of pipe. It means that  $w_{0,j} = 0$  (Figure 4.).

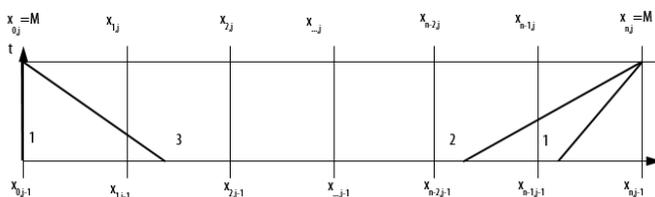


Figure 4. Boundary conditions without inflow

In this case the characteristic that depart from point 1 also exists at the inlet of pipe. Thus, the properties of point M that is at inlet of pipe can be computed as follows:

$$w = 0, \quad (68)$$

$$p = p_3 - a_3 \rho_3 w_3 - k \Delta t, \quad (69)$$

$$\rho = \rho_1 + \frac{k \Delta t + (p - p_1)}{a_1^2}. \quad (70)$$

**CONCLUSIONS**

The essence of the method presented here is that the system of equations which describes the flow is reduced to three first-order quasi-linear partial differential equations, which are solved on the  $\Delta t$  time interval where the coefficients of equations are calculated from the status indicators that are known at the beginning of the time interval. The quickness of this method is given by the used stability condition. Here Lipschitz condition (64) must be used instead of Courant-Friedrichs-Lewy condition (1). This means that the calculated time scale for the fixed space scale is not related to the absolute value of the speed of sound and that of the flow speed only their rate of change. In a particular case ( $a_{max} = 391,8 \text{ m/s}$ ;  $w_{max} = 40,3 \text{ m/s}$ ) of Figure 5 shows the time function of the number of calculation step.

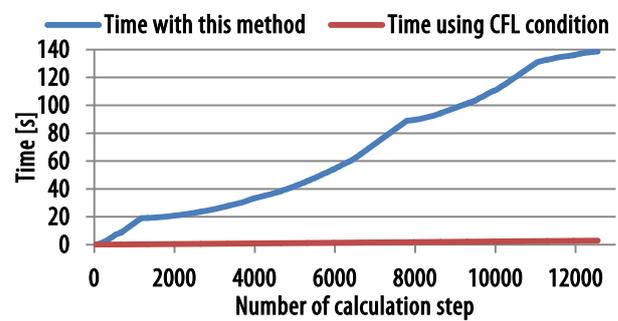


Figure 5. Comparison of methods

**ACKNOWLEDGEMENTS**

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## EXPERIMENTAL VERIFICATION OF OPTIMIZED ANALYTICAL CALCULATION OF HEAT TRANSFER IN FIN PIPE HEAT EXCHANGERS

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**Abstract:** Recently, modern CFD methods based mostly on finite elements or finite volumes are widely used for calculations of heat transfer problems. However, these numerical methods are in general very depended on a correct set-up of boundary conditions and on other parameters as well and therefore even this tool can easily give incorrect results. Therefore an appropriate and comfort verification of numerical CFD calculation has always high importance. The article deals with improved analytical calculation of heat transfer in heat exchangers equipped by fins on the air side (fluids: water-air). The validity and accuracy of used equations and relationship was experimentally verified on a car engine cooler (i.e. heat exchanger with fins – water – air). The calculation method and its correlation with experimental results are presented in this paper. The test was carried out in laboratories of Institute of Thermal Power Engineering at STU Bratislava.

**Keywords:** car cooler, fin heat exchanger

### INTRODUCTION

Recently, modern CFD methods based mostly on finite elements or finite volumes are widely used for calculations of heat transfer problems. However, these numerical methods are in general very depended on a correct set-up of boundary conditions and on other parameters as well and therefore even this tool can easily give incorrect results. Therefore an appropriate and comfort verification of numerical CFD calculation has always high importance. One of such verification methods is to use classical analytical heat transfer methods based on thermal equations. An improved method for calculation of heat flux in finned pipes (in fact tube heat exchangers with outside fins) by classical analytical method is presented bellow. An experimental verification of this method by measuring of a car heat exchanger (engine cooler) is presented as well. The fluids water on inside of heat exchanger pipe and air on the outside fined side of the heat exchanger were considered in this verification.

A role of fins on the air side of water-air heat exchangers is generally known – due to lower convection heat transfer coefficient on the air side is needed an improvement of heat flux on this side of heat exchanger by enlarging surface. A typical representative of this type of heat exchangers is a car cooler for engines where the engine coolants are cooled by surrounding air. Analytical calculations of this type of heat exchangers by criterial equations are recently used only occasionally. And because such a “classical” analytical calculation method can be used as a useful verification method for widely used CFD calculations, we verified the accuracy of these analytical equations by experimental measurements on real car coolers. The test

was carried out in laboratories of Institute of Thermal Power Engineering at STU Bratislava.

The second reason for publishing this analytical calculation method is to get it known for younger generation of technical public, because these relationships are available above all in older literatures published a few decades ago.

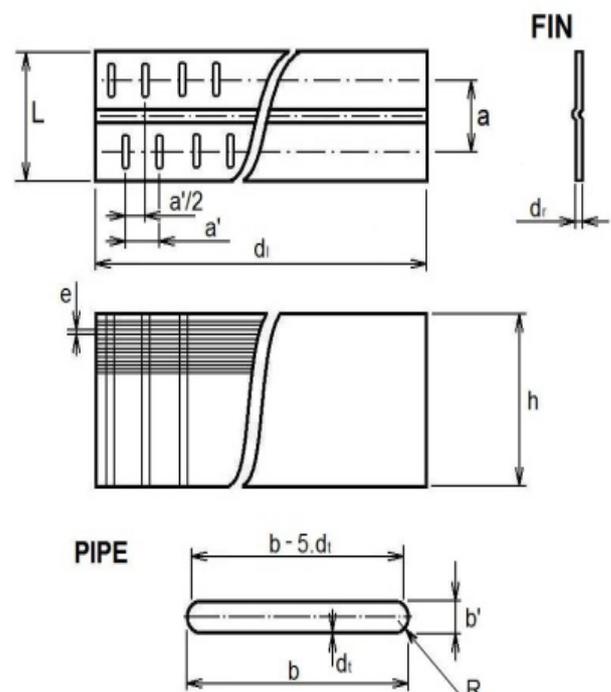


Figure 1: Base dimensions of heat exchanger

**BASIC HEAT TRANSFER EQUATIONS FOR RECUPERATIVE HEAT EXCHANGERS**

The basic equation of heat density in heat exchanger with two fluid flows is the well known

$$[dQ/dS] = k(t_{liq} - t_{gas}) \tag{1}$$

Where  $k$  is total heat transfer coefficient and  $(t_{liq} - t_{gas})$  is a temperature difference between liquid and gaseous fluids.

Because thin-walled pipes are used in these types of heat exchangers, the total heat transfer coefficient can be expressed as

$$k_v = \frac{1}{\left(\frac{1}{\alpha_v} + \frac{1}{(S_k / S_c)\alpha_k}\right)} \tag{2}$$

where  $\alpha_v$  virtual convection heat transfer coefficient applied on the whole surface on the air side of heat exchanger including fins,  $\alpha_k$  convection heat transfer coefficient on the water side,  $S_c$  is total outside surface and  $S_k$  inside pipe surface (water side of the heat exchanger) and - of course heat flux on outside of the exchanger then is:

$$Q = \alpha_v S_r (t_r - t_p) \tag{3}$$

The total heat flux on the air side of heat exchanger is given by addition of heats transferred both by fins and by pipes surface, thus

$$Q = \alpha_r S_r (t_r - t_p) + \alpha_i S_i (t_i - t_p) \tag{4}$$

Convection heat transfer coefficients  $\alpha_r$  and  $\alpha_i$  are different in appr. 20% but due to  $S_r \gg S_i$  we can consider  $\alpha_r \approx \alpha_i$ . The variables and values with sub-index "r" are connected with fin.

Supposing that  $\alpha_i$  not substantially changed with fin temperature, we can define the fin efficiency as

$$\eta_r = \frac{\alpha_r S_r (t_r - t_p)}{\alpha_r S_r (t_i - t_p)} = \frac{t_r - t_p}{t_i - t_p} \tag{5}$$

Where  $t_r$  is average fin temperature and  $t_i$  is the temperature on the root of the fin. By this fin efficiency we rewrite the equation (4) as

$$Q = \alpha_r S_r \left( \eta_r + \frac{S_i}{S_r} \right) (t_i - t_p) \tag{6}$$

By applying (3) is possible to express virtual heat transfer coefficient  $\alpha_v$  by the convection heat transfer coefficient of real fin

$$\alpha_v = \alpha_r \left[ 1 - \frac{S_r}{S_c} (1 - \eta_r) \right] \tag{7}$$

The expression in brackets is efficiency of enlarged heat exchanger surface at the air side

$$\alpha_v = \alpha_r \left[ 1 - \frac{S_r}{S_c} (1 - \eta_r) \right] \tag{8}$$

By using equation (7) and (8) there is possible to rewrite (2) in following form

$$k_v = \frac{1}{\left(\frac{1}{\eta_r \alpha_r} + \frac{1}{(S_k / S_c)\alpha_k}\right)} \tag{9}$$

Thus, the fin efficiency at boundary condition for thin flat fins with the constant cross-section can be expressed as

$$\eta_r = \text{tgh}(ml) / (ml) \tag{10}$$

where

$$m = 2\sqrt{\alpha_r / (\lambda_r \delta_r)} \tag{11}$$

$l$  is effective fin length given in our case by half of cross distance between pipes of heat exchanger,  $\delta_r$  thickness of the fin. The expression (10) is shown on the graph bellow.

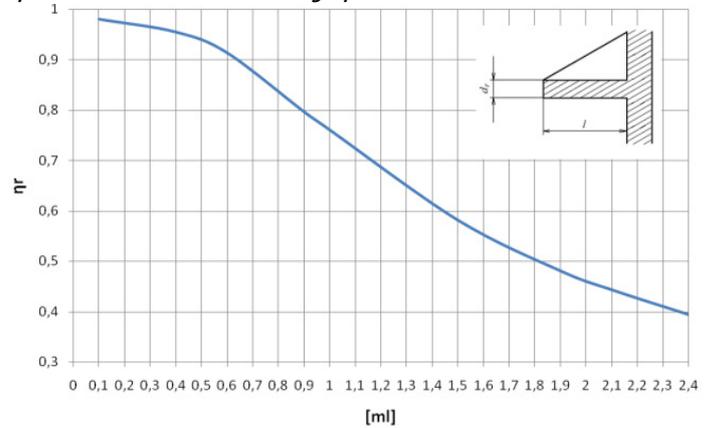


Figure 2: Efficiency of straight fine

To determine the heat transfer rate ( $W$ ) of this exchanger, a set of another dimensionless parameters is used, particularly efficiency of heat exchanger

$$\varepsilon = \frac{Q}{Q_{max}} = \frac{W_k (t_{k1} - t_{k2})}{W_{min} (t_{k1} - t_{p1})} = \frac{W_p (t_{p2} - t_{p1})}{W_{min} (t_{k1} - t_{p1})} \tag{12}$$

where  $W_{min}$  is smaller heat capacity from the used fluids and  $W_{max}$  the bigger ones.

Then we need also

$$NTU = (k_v S_c) / W_{min} \tag{13}$$

and ratio

$$W_{min} / W_{max} \tag{14}$$

The general relationship between them is

$$\varepsilon = f(NTU, W_{min} / W_{max}) \tag{15}$$

which can be expressed even graphically.

From the heat exchanger efficiency given by the graph bellow is possible to determine the output temperatures of both fluids.

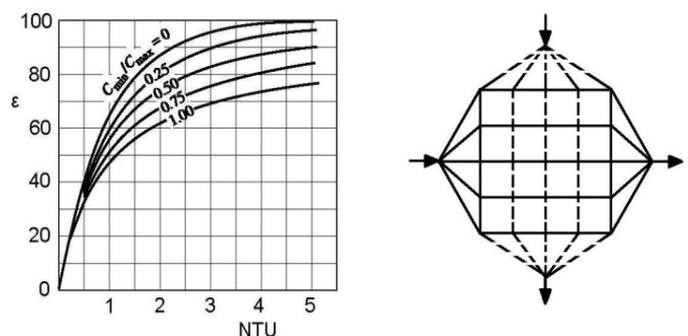


Figure 3: Efficiency of cross flow heat exchanger (unmixed flows)

For determination of NTU (number of transfer units) the calculation of total heat transfer coefficient  $k_v$  from (9) is needed.  $\alpha_r$  in (9) is obtained from criterial equations for convection flows in pipes. Nusselt number which is needed for determination of  $\alpha_k$  was obtained from the well known equation in [1]

$$Nu = K \cdot Pr^{0.43} \quad (16)$$

The relationship between the constant  $K$  and Prandtl number  $Pr$  is in the table below.

Table 1. The constant  $K$  and Prandtl number  $Pr$

$Re_k \cdot 10^3$	2.2	2.3	2.5	3.0	3.5	4.0	5.0	6.0	7.0	8.0	9.0	10.0
$K$	2.2	3.6	4.9	7.5	10.0	12.0	16.5	20.0	24.0	27.0	30.0	33.0

The determining temperature was the mean temperature of water in exchanger and the determining dimension was the hydraulic diameter of the pipe.

Determination of convection heat transfer coefficient  $\alpha_i$ : There were used experimental results measured at a heat exchanger with similar geometry [2], where the determining dimension is the hydraulic diameter of the air channel.

From the graph ( $St \cdot Pr^{2/3}$ ) (Stanton, Prandtl) is then obtained the convection heat transfer coefficient  $\alpha_i$  and at the end also the total heat transfer coefficient  $k_v$ . Then we can finally finalize the calculation of cooling output of the heat exchanger.

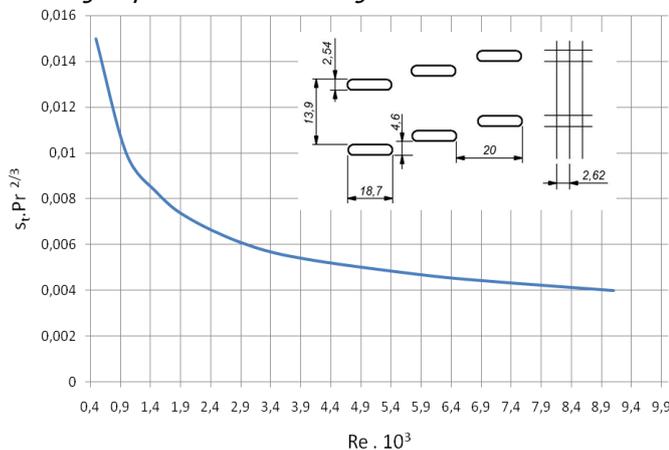


Figure 4: Relation between  $St.Pr^{2/3}$  (Stanton, Prandtl) and Reynolds number

**CALCULATION METHOD IN STEPS – SUMMARY**

- a) Obtaining geometry data of heat exchanger (Lengths, surfaces, volumes, diameters...)
- b) Mean water velocity in pipes at 353 Kelvin. The air velocities are given: in front of exchanger as 7 m/s and 11 m/s at 303 Kelvin
- c) Calculation of Reynolds numbers  $Re$  on water side and air side – using  $\alpha_i$  (picture 4) and  $\alpha_k$  (eq.4)
- d) From (10) and (11) is calculated the fin efficiency  $\eta_f$  (pict.2) and from (8) efficiency  $\eta_v$
- e) From (9) is calculated the total heat transfer coefficient  $k_v$ .
- f) From (13) and (14) and from flows are calculated parameters  $NTU$  and  $W_{min} / W_{max}$
- g) From the graph (pict.3) is determined the heat exchanger efficiency  $\epsilon$
- h) From (12) are (by estimate) determined the unknown temperatures of air and water so that their mean values were in coincidence with given values
- i) At the end, from the equation  $Q = W_k(t_{k1} - t_{k2}) = W_p(t_{p2} - t_{p1})$  can determined the cooling output (capacity) of the heat exchanger.

**EXPERIMENTAL VERIFICATION AND CONCLUSION**

The theoretical calculation model was verified by heat exchanger applied as a car cooler for petrol engines with volume 1300 -1500  $cm^3$ . The front side of the heat exchanger was 0.138  $m^2$ , water flow  $1.6 \cdot 10^{-3} m^3 s^{-1}$ . The fins were calculated as flat ones. The material was steel, heat conductivity  $\lambda = 50 W/(m K)$ . Arranging of experimental workplace with measurements on heat exchanger is visible on Picture 5. Hot water was obtained and stored in 650 litres water tank with electrical heating unit. Hot water temperature was set on 80°C with operating velocities 7 and 11 m/s regulated by pump (P1).

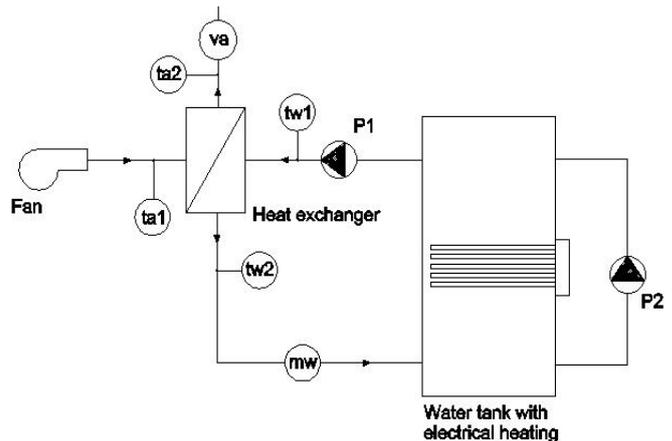


Figure 5: Scheme of measurement workplace

Measured variables are temperatures (thermocouple type K) and flows on inlet and outlet on both sides of heat exchanger. Placement of temperature sensors on the water side is visible on picture 6. Temperature of air was obtained as average temperature from three sensors placed through all cross section of air channel in inlet and outlet side of heat exchanger.

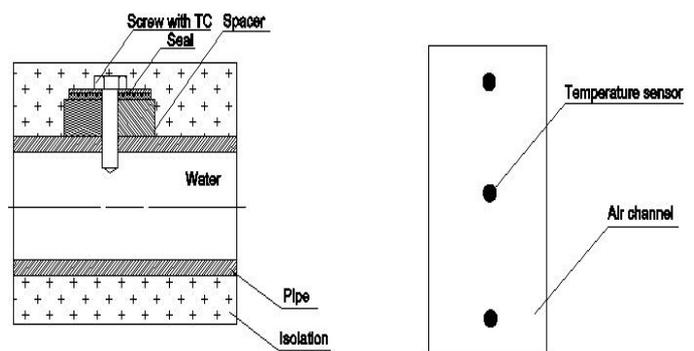


Figure 6: Placement of temperature sensors (left - water side, right - air side of heat exchanger)

The accuracy – or coincidence between the presented calculation method and experimental results varied between – 9.28% and +16.3%.

This accuracy is very acceptable for purposes like approximate verification of CFD calculations of heat exchangers or even for frame non-computer calculations of these types of heat exchangers. When higher calculation accuracy is needed then a profound experimental verification comes in place – or even a well validated and verified CFD calculation.

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## THE EFFECT OF NATURAL RUBBER ON THE FLEXURAL PROPERTIES OF COCONUT COIR (COCOS NUCIFERA) REINFORCED RED SAND COMPOSITES

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**Abstract:** In order to dramatically improve the mechanical properties of ceramic materials for structural applications, the ceramic material can be bonded with natural rubber and reinforced with natural fibre. Sand and water has been used for ages as the basic component in the development of building materials which can still be found in remote parts of Nigeria. This work studies the effect of natural fibres and rubber on the flexural properties of processed red sand for structural applications. This research was carried out using processed red sand as the matrix, natural rubber as the binder and coconut coir as reinforcement. Measured volume of natural rubber was mixed thoroughly with coconut powder/coir and poured into detachable mould and then compacted for about 10 minutes under an applied load of 25 kN to produce a composite material. The cast composite was detached from the mould and cured in air at room temperature for 28 days. Flexural and water absorption tests were carried out on the cured samples. The best composition was gotten from sample C<sub>1</sub> which has 700g red sand, 150g natural rubber and 4g of 10 mm fibre length which emerges as the best material in flexural and water repellent properties.

**Keywords:** Natural rubber, coconut coir, processed red sand, flexural properties and water absorptivity

### INTRODUCTION

Increased environmental awareness and consciousness all over the world has enhanced a widespread of interest in natural fibre and its applications in various fields. Natural fibres are now considered as unique alternatives to synthetic fibres for use in various fields. The utilisation of natural fibres as reinforcement in both thermoplastics and thermosets matrix composite have provide positive environmental benefits with respect to ultimate disposability and best utilization of raw materials. Currently, studies on use of lignocelluloses bio-fibres in place of synthetic fibres as reinforcing materials are being pursued vigorously. These bio-fibres are being extensively used for the production of cost effective eco-friendly bio composites [1].

The advantages of natural fibres over traditionally reinforcing materials such as glass fibre, carbon fibre etc. are their specific properties, easy availability, light weight, ease of separation, enhanced energy recovery, high toughness, non-corrosive nature, low density, low cost, good thermal properties, reduced tool wear, reduced respiratory irritation, less abrasion to processing equipment, renewability and biodegradability. The World Commission on Environment and Development suggested the following definition for sustainable development: "sustainable development is the development that responds to the needs of the present, without abandoning the ability of future generations to supply their own needs". The influence of sustainable development on culture,

economy, and ecology is of global significance, but there are specific measures for particular regions [2].

The major function of fibres in the matrix is in delaying and controlling tensile cracking of the matrix, their uses give rise to technical benefits that can be utilized in load bearing members and in semi-structural elements. The vegetable fibre reinforced cement structures have their applications tuned towards the production of panel for components where the ductility is an important characteristic [3].

These natural available fibres can be used in improving the properties of other materials during the development of composite materials. A composite material is defined as a combination of two or more materials that results in better properties than when the individual components are used alone. A composite is designed to display a combination of the best properties of each of the component materials [4].

Natural organic fibres have a very important role in alleviation of housing problem. They do not only occur in luxurious abundance in many parts of the world but can also lead directly to energy savings conservation of the world's most scarce resources and protect man and his environment. Natural vegetable plants and fibre have thus a unique irreplaceable role in the ecological cycle. Their natural abundance, plentiful supply, relative cheapness and swift replenish ability are the strongest argument to utilize them in the construction industry [5].

Natural rubber (abbreviated to NR) primarily comprises polyisoprene and is harvested from the milky white latex of a number of species of plants which flourish in the tropics, above all from the Spurge family. The rubber tree (*Hevea brasiliensis*) has achieved considerable commercial importance. It is made up of the following compositions (Water: 55-70%, Rubber: 30-40%, Resin: 1.5-2%, Protein: 1.5-3%, Ash: 0.5-1%, Sugar: 1-2%)[6]. Natural rubber mixtures possess the following properties: high static tensile strength (15-22 MPa); high elongation (600-900%); excellent elasticity at low temperature (up to  $-10^{\circ}\text{C}$  doesn't change substantially); poor ozone and degradation stability; good confectionability because of excellent crude adhesion [7]. Natural rubber is a significant type of polymeric material; it is widely used due to its high and reversible deformability. Since the essential modulus and strength of neat rubber are low, an additional reinforcing phase is necessary for the practical uses of rubber materials [8].

The presence of natural rubber in the composite will gelatinise the processed red sand and impact it with ductility. This will also enhance the flexural strength of the composite at the long run.

Sand and water has been used for ages as a basic component in the development of building materials which can still be found in remote parts of Africa. Red sands and natural organic fibres on the other hand are new area of research for applications in building materials, their natural abundance, availability, relative cheapness and ability to be replenished are the strongest arguments for their utilization in the construction industry

The goal of this research was to apply synergetic potentials imbedded in the blend of ceramic (processed red sand), polymer (natural rubber) and Natural fibres (coconut coir). Ceramic material will provide compressive strength and thermal stability while polymer (natural rubber) will provides elastic strength. The natural fibre will act as the reinforcement to strengthen the composites. It is expected that the combination of these naturally occurring materials will lead to improved strength of the developed composite materials for structural applications. Figure 1 show the picture of a collapse building due to brittle fracture property of the mixture of red sand and water that was used for the production of the building blocks.



Figure 1: Picture of collapsed building from red sand blocks

## MATERIALS AND METHODS

The materials used for this research work includes: coconut coir (fibres and powder form); natural rubber; red sand; water; ammonia solution; cellophane sheets; 150 x 50 x 35mm detachable metallic mould; sieve shaker; sieves; beaker; Pestle and mortar; shaker water bath; flexural moulding machine; universal testing machine and digital weighing machine.

## PRODUCTION OF COCONUT COIR FIBRES AND PARTICULATES

The coconut coir (fibres and particulates) was procured from coconut fruits, after being harvested from a coconut tree, and sun dried for about two months to ease its extraction process. The coconut coir (fibre and particles) were manually extracted by detaching the outer layer (husk) of the coconut from its nut, followed by beating the coconut husk using mortar and pestle for easy extraction of both the fibres and particles respectively. Figure 2 show the coconut coir and the extracted particles.

The extracted fibres were carefully measured by meter rule into three different lengths of; 10, 15 and 20 mm and each fibre were carefully and neatly sized using scissors according to their appropriate fibre lengths. The various dimensions of the extracted fibres were treated separately in different beakers for easy separation. The particulate coconut coir on the other hand was treated before size analysis was carried out. Sizing was carried out using different sieve sizes from where 425 and 300 $\mu$  sizes are sorted out and used.

## Chemical Treatment

The extracted coconut coir was treated with sodium hydroxide (NaOH) by dissolving 120 g of sodium hydroxide in 3000cm<sup>3</sup> of water and stirred thoroughly with a stirring rod to form sodium hydroxide solution. The coconut coir was soaked in the solution and then transferred into the shaker water bath where it is left for 4hours at a temperature of 50 $^{\circ}\text{C}$ . After this process is carried out, the treated fibres were removed from the water bath, washed with tap and distilled water to obtain a pH of about 7 followed by sun drying for 5 days.



Figure 2. Sun drying of coconut coir (left) and extracted coconut coir particle (right)

**PROCUREMENT OF NATURAL RUBBER**

The natural rubber (5 litres) was gotten from rubber tree plantation at Federal College of Agriculture, Akure(FECA) which was mixed with ammonia solution for preservation. The constituent of natural rubber was as shown in Table 1.

**PROCUREMENT OF RED SAND**

The red sand used for this research was gotten from Afuze, Owan east local government, of Edo State, Nigeria where such sand was highly found and used for building construction. The Geographical map of Edo State and Owan East Local Government where the red sand was gotten from can be seen below in Figures 3-4. The red sand was processed by cleaning and sieving from where the exact sieve sizes were obtained.

**MIXING AND COMPACTION OF THE COMPOSITE COMPONENTS**

Processed dried mass of red sands were mixed together with dried coir fibre/particulate accordingly in predetermine proportions of the components. The entire mixture was thoroughly mixed and then poured to fill up the 100 x 30 x 20 mm mould and compacted with laboratory made compacting machine at a pressure of 20 KN for 5minutes. Prior to compaction, the top of the compacting mould was covered with cellophane sheet to enhance easy removal of the composite from the mould and prevent delamination. Once compacted, the mould was disassembled and the cast composite was removed and then transferred to a wooden board where it is allowed to cure in air for 28 days in the laboratory as shown in Figure 5. The composites were prepared for flexural and water absorptivity tests.



Figure 3: Map of Edo State

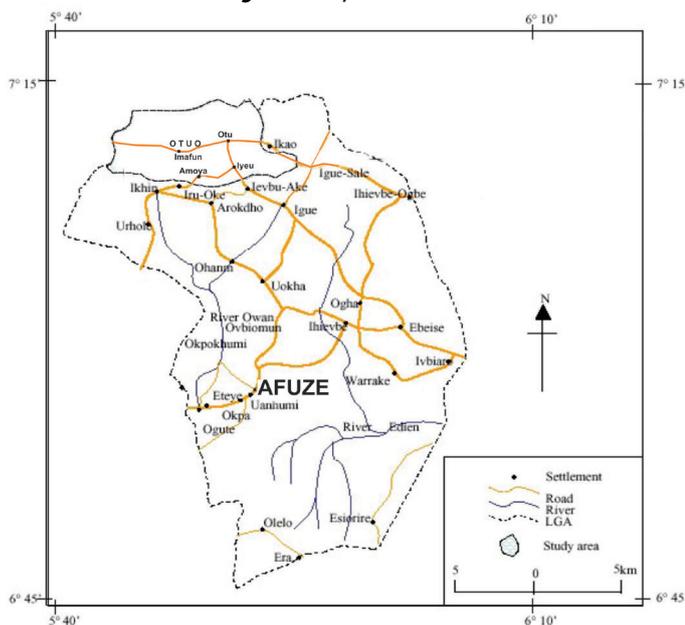


Figure 4. Map of Owan East Local Government



Figure 5. Composite samples prepared for flexural test

**Composite Formulation**

For the production of the composites, the formulation consists of five series of different samples which are; A, B, C, D and E while the control sample was denoted as F. The compositions were as shown in Tables 1-6.

Table 1: Formulation table for the developed composites from the addition of coir particles of 300 μ

Sample	300μ Red Sand (g)	Natural Rubber (g)	300μ Coir Particles (g)
A <sub>1</sub>	700	170	14
A <sub>2</sub>	700	190	28
A <sub>3</sub>	700	210	42
A <sub>4</sub>	700	220	56
A <sub>5</sub>	700	140	-

Table 2: Formulation table for the developed composites from the addition of coir particles of 425 μ

Sample	300 μ Red Sand (g)	Natural Rubber (g)	425 μ Coir Particles (g)
B <sub>1</sub>	700	170	14
B <sub>2</sub>	700	190	28
B <sub>3</sub>	700	210	42
B <sub>4</sub>	700	220	56
B <sub>5</sub>	700	140	-

**Table 3:** Formulation table for the developed composites from the addition of 10 mm coir fibre

Sample	300 $\mu$ Red Sand (g)	Natural Rubber (g)	10 mm Coir Fibre (g)
C <sub>1</sub>	700	150	4
C <sub>2</sub>	700	170	8
C <sub>3</sub>	700	190	12
C <sub>4</sub>	700	210	16

**Table 4:** Formulation table for the developed composites from the addition of 15 mm coir fibre

Sample	300 $\mu$ Red Sand (g)	Natural Rubber (g)	15 mm Coir Fibre (g)
D <sub>1</sub>	700	150	4
D <sub>2</sub>	700	170	8
D <sub>3</sub>	700	190	12
D <sub>4</sub>	700	210	16

**Table 5:** Formulation table for the developed composites from the addition of 20 mm coir fibre

Sample	300 $\mu$ Red Sand (g)	Natural Rubber (g)	20 mm Coir Fibre (g)
E <sub>1</sub>	700	150	4
E <sub>2</sub>	700	170	8
E <sub>3</sub>	700	190	12
E <sub>4</sub>	700	210	16

**Table 6:** Formulation table for the control

Sample	300 $\mu$ Red Sand (g)	Water (g)
F	700	130

**PROPERTIES TEST**

The dried composite samples were made to undergo both flexural and water absorption tests as follows;

**Flexural Test**

The flexural test was carried out using Instron Universal Tensile Testing Machine that works on a three point flexural technique. The test speed was 50.00mm/min over a span of 100.00mm.

**Water Absorptive Test**

Since this material is likely to come in contact with water as a building material, so it will be necessary to carry out water absorptivity test to determine the extent to which the formed composite can absorb water.

In determining the water absorption property of the composite samples, each of the composite were weighed in air and then immersed in 700cm<sup>3</sup>. This test was done for 7 hours for the various samples of the composite. The composite were weighed in air when dried with the aid of an electronic weighing balance and then soaked into water. The weight after 7 hours was taken once they are removed and cleansed. The weight gained was used to determine the water absorptive.

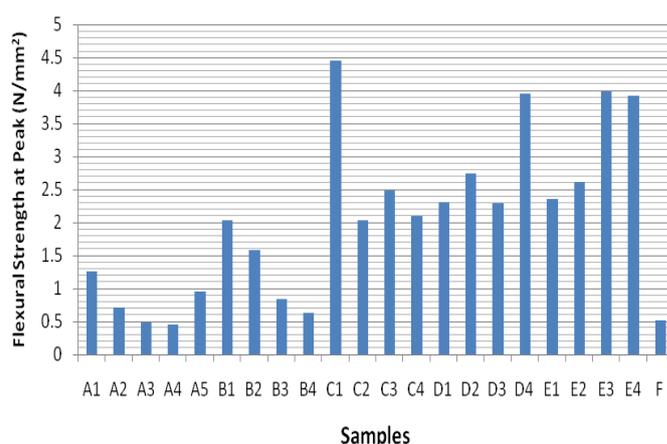
**RESULTS AND DISCUSSION**

The results were as shown and discussed below.

**Flexural Test**

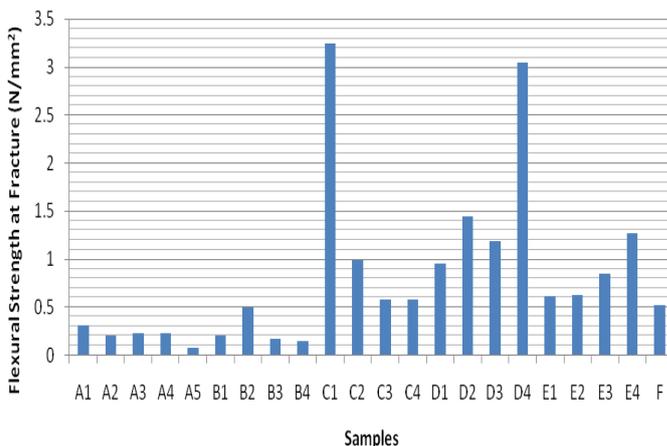
Figure 6 shows the flexural strength at peak results for the samples. Considering the influence of coir particulate and fibre on the composites, it was observed that the fibre gave better enhancement

of strength compared to the particles in all as revealed from the results.



**Figure 6:** Flexural Strength at Peak against Samples

While all the fibre lengths show excellent perform at different levels compared to the control, the particulate show that 425  $\mu$  gave better results in all compared to 300  $\mu$  particles and the control. Also, the results showed that, the flexural strength at peak reduces as the particle content increases. However, it was observed from the results that, sample C<sub>1</sub> with composition (700: 150: 4) g has the highest flexural strength at peak with a value of 4.45N/mm<sup>2</sup>. This was followed by sample E<sub>3</sub> with composition (700: 190: 12) g which has a value of 3.98N/mm<sup>2</sup>. However, the control sample, F with composition (700: 130) g has a very low value of 0.51 N/mm<sup>2</sup>. With these results, it is obvious that the addition of natural rubber and coconut coir fibre sand 425  $\mu$ particulate respectively are potential means for the development of good and strong building materials for structural applications.



**Figure 7:** Flexural Strength at fracture against Samples

Figure 7 shows the bending strength at fracture results for the composite samples. Similar trend with flexural strength at peak was obtained with respect to the performance of coir fibre and particle in the developed composites. However, there is deviation from this trend with respect to the performance of the particles because the 300  $\mu$  particulate reinforced samples tends to give better results compared to 425  $\mu$  particulate reinforced samples. From the results, it was observed that sample C<sub>1</sub> with composition (700: 150: 4) g has the highest flexural strength at fracture with a value of 3.25

$N/mm^2$  followed by sample  $D_4$  with composition (700: 210: 16) g having a value of  $3.04N/mm^2$ . It was revealed from the graph that, the control sample F, with composition (700: 130) g has a fracture value of  $0.51 N/mm^2$  which is the same with the flexural strength at peak value. This shows that the material, as a ceramic material, is brittle and display brittle fracture property unlike the developed composites that exhibit ductile fracture. This was actually the goal of this work so as to avoid sudden failure in service. From the results, it was observed that the failure mode of the developed composites were different from that of the control sample. Nevertheless, the coir particulate reinforced samples exhibit poor fracture property with respect to the control.

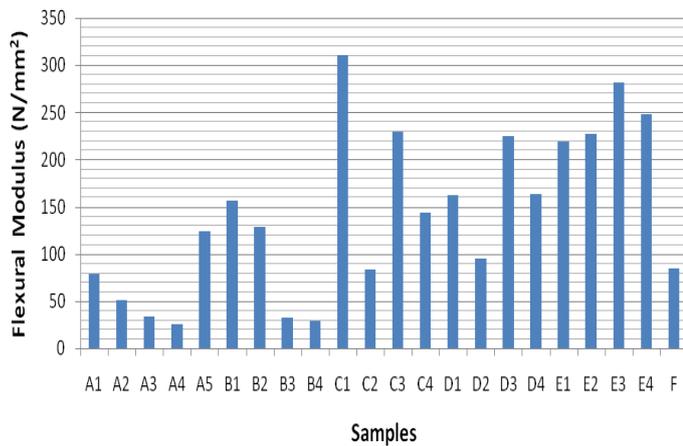


Figure 8: Flexural Modulus against Samples

The response of the materials to flexural modulus test was shown in Figure 8. From the results, it was observed that coir fibre reinforcement gave better enhancement in most of the samples compared to the particulate reinforcement. The performance of the particulate reinforced samples was similar to that of the bending strength at peak. From the results, it was observed that sample  $C_1$  with composition (700: 150: 4) g has the highest flexural modulus with a value of  $310.06N/mm^2$  followed by sample  $B_2$  with composition (700: 140) g which has a value of  $302.37N/mm^2$ . This further confirms that, the addition of coconut coir and natural rubber to processed red sand is a potential way to develop of good and strong composites for structural applications.

The results of the flexural properties have shown that sample  $C_1$  is the best composite. This was the case since is the only sample that has consistence results in all by emerging the best under in all the flexural properties examined. This actually means that the addition of natural rubber and 10 mm fibre length of low content are the best material combination for the development of good and low cost structural materials.

**Water Absorptivity of the Composite samples and the control**

The results of the water absorption properties were as shown in Figure 9. It was observed from the plot that, the rate of water absorption tends to increases as the amount of natural rubber increases. This was due to the fact that, the natural rubber contains water in its composition as stated by Sajeev et al [6]. Nonetheless, particulate reinforced samples, series A-B, absorbed more water than

the fibre reinforced samples, series C-E. This suggests that the particles encourage the absorption of water than the fibre which implies that early degradation and failure of the composites will occur with the use of particulate reinforcement compared to fibre. However while sample  $D_4$  was found to dissolve gradually as a result of loss in weight with time, the control sample F was found to have dissolved in water before the 6<sup>th</sup> hour. These show that, samples  $D_4$  and F are materials that can experience catastrophic failure if subjected or encountered constant water challenge in service. The result has revealed that the addition of natural rubber and coconut coir can help stabilize the water absorption tendency of the developed composites if adequately or properly regulated.

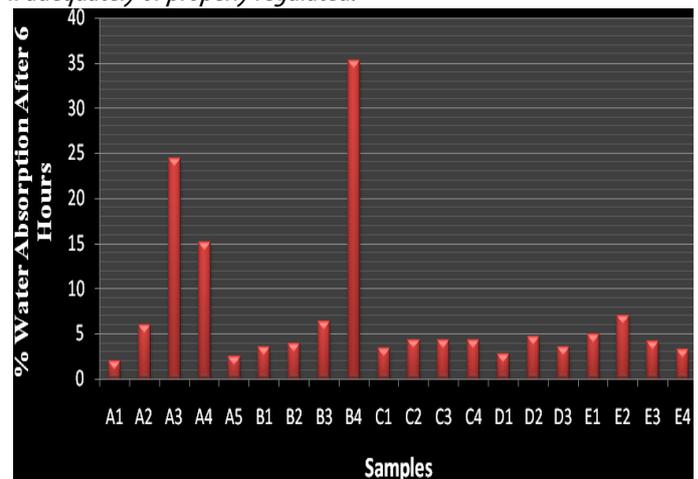


Figure 9: Graph of water absorption test on the samples after 7 hours

**CONCLUSIONS**

The results of the research into the influence of natural rubber and coconut coir on the flexural and water absorption properties of processed red sand reinforced composites has revealed the possibility of blending these materials together for the development of ductile fracture materials for structural applications. The work also show that by this development, the thermal property of polymers can be enhanced since the developed composites will not burnt easily due to the presence of ceramic based material. These materials are biodegradable materials which made them to be environmental friendly. From the results, the following can also be deduced;

- » The use of natural rubber as a binder for red sand produced better flexural properties than the conventional water bonded red sand samples.
- » Addition of coir fibres gave better flexural and water repellent properties compared to coir particles as well as the unreinforced samples. The best composition was gotten from sample  $C_1$  which has 700g processed red sand, 150g natural rubber and 4g of coir fibre of length 10 mm.
- » The rate at which coir fibre reinforced samples absorb water is lower than that of coir particle reinforced samples.

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## ANALYSIS OF THE EAF METAL CHARGE STRUCTURE

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**Abstract:** The steelmaking process and the steel quality are greatly influenced by the metal charge used, both in terms of assortment and quality. Regarding steelmaking, in the current stage people are interested in the oxygen converters and electric arc furnaces. In case of oxygen converters, the metal charge consists of about 80% liquid pig-iron, the balance of 20% being scrap, and in case of electric arc furnaces, the charge is 100% solid and consists of scrap. The paper presents the results of analyzing the structure of the charge intended for ultra-high power EAFs, with eccentric bottom tapping (E.B.T.), 100 tonnes capacity. In the cases we have studied, the charge consisted of scrap (types: E1, E2, E5, and E100), internal & purchased ferrous skulls, and ferrous materials from internal recycling & disposal. We monitored 98 heats, analysing the structure of the metal charge, the additives introduced directly in the metal charge throughout the steelmaking process, the propellant materials and the oxygen blown into the metal bath. The results are shown in graphical form, based on which we made a technological analysis, presented in this paper.

**Keywords:** ultra-high power EAFs, steelmaking process, steel quality, metal charges, technological analysis

### INTRODUCTION

The technical revolution of the human society requires increasingly resistant materials, safe in operation, which can be obtained in qualitatively and economically competitive conditions.

Among the materials used in the construction of machinery, equipment, vehicles, etc., the steel still occupies the predominant place, being materials which, in addition to the wide variety and high value properties, have the advantages to be obtained at lower costs, have a long life operation and can be recycled 100% [1,2,3,4].

To reduce the weight of constructions (industrial buildings, equipment, machinery, vehicles, etc.) and to immobilize smaller quantities of steel in the long life operation constructions, the unalloyed steels tend to be increasingly replaced by quality carbon steel, low and medium alloyed.

But, the technical development entailed the growth to a great extent of the scrap sources, by decommissioning of the machinery, equipment, plants, steel construction, vehicles, etc., obsolete and worn out, and by obtaining larger amounts of manufacturing debris (due to increased production), determining the steel to be largely made from scrap. By reintroducing the scrap in the manufacturing process, not only the iron is recycled, but also the alloying and harmful elements. Therefore in steel, besides the prescribed elements, which are designed to ensure the required quality of steel, can be also found foreign elements, usually known as tramp elements. Any chemical element can be either alloying element in some steel grades (except for manganese and silicon, which in the carbon steels are found as accompanying elements, at a concentration of less than 0.80% Mn and less than 0.50% Si, respectively), or trace element in others, according to the influence on the steel properties [1,2,3,4].

The limits on the percentage of elements contained in steel are presented in Table 1.

**Table 1.** Minimum limits for alloying elements [2].

Element	% min	Element	% min
Al	0.10	Co	0.10
Bi	0.10	Cu*	0.40
B	0.008	Mn	0.80
Cr*	0.30	Mo*	0.08
Ni*	0.30	Si	0.50
Nb**	0.05	Te	0.10
Pb	0.40	Ti**	0.05
Se	0.10	W	0.10
V**	0.10	La	0.05
Zr**	0.050	Others***	0.05

\* If the elements are in combination with one or more elements found in the respective steel heat, it is required to assess the percentage of each element and the total content, which must be 70% of the sum of the limits specified for each element.

\*\* The rules above apply also to the combinations of these elements.

\*\*\* Without taking into account: C, P, S, N, O.

Currently, the oxygen converters and electric arc furnaces are of interest for the steelmaking process. The development of high productivity equipment for steelmaking, i.e. oxygen converter and ultra-high power electric arc furnace, enabled us to prove that some steelmaking phases, as deoxidation and alloying, hinder or cancel the economic effect of the intensive processes of melting and refining, which take place in the high productivity metallurgical units, by means of oxygen [1,2].

To obtain competitive economic effects, the transfer outside the metallurgical equipment of these technological operations was a great technological solution, especially since it was associated with the continuous casting technology.

In these new technological conditions, a particular importance has the structure and quality of the metal charge, in terms of chemical composition, origin and charge preparation.

**STUDY OF THE PROBLEM**

Given the above, for the analysis of the charge structure we monitored 98 steel heats made at an electric furnace steel plant equipped with an electric arc furnace of EBT type and a continuous casting plant with 5 strands, the semi-finished products obtained being blooms, billets and round profiles.

The parameters monitored at those 98 steel heats, intended to produce steel tubes, were:

- » components of the metal charge: scrap (types: E1, E2, E5, E100), internal and purchased ferrous skulls, scrap from internal recycling or disposal;
- » auxiliary materials for slag formation: dolomite, foaming material, coke, Topex Ca, Topex;
- » additives for the refining process: lime, graphite, carbon (injectors), oxygen (injectors), oxygen (lance), gas (injectors);
- » additives for the deoxidation process: ferro-manganese, ferro-silicon and ferro-silico-manganese;
- » duration of the technological stages until tapping (included);
- » electrical energy consumption;
- » limits of variation and average values for the monitored parameters;
- » content of trace elements unusable as alloying elements at the end of the melting stage;
- » content of trace elements that can be used as alloying elements at the end of the melting stage;

During the steelmaking process, the charge structure was carefully monitored, along with its dimensional appearance and slag content, either concerning the internal steel skulls (collected from the slag dumps) or purchased. Also, we visually appreciated the quality of the prepared scrap (E1, E2, E5, and E100) and the scrap originated from disposals, concerning the content of rust, nonferrous metals, soil, sand, etc.

Below, we graphically presented the obtained results, based on which we performed a technological analysis of the conducted research.

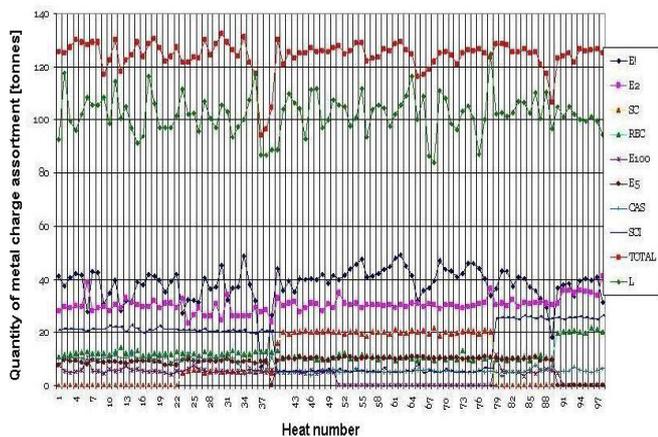


Figure 1. Variation of the EAF charge composition (EBT type)

1-FeMn; 2-SiMn; 3-FeSi;

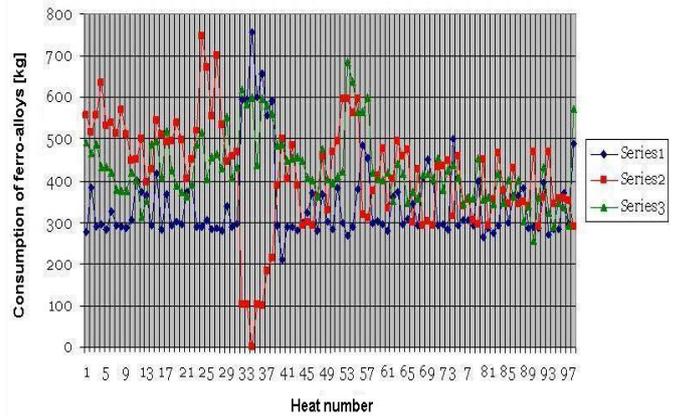


Figure 2. Variation of the ferroalloy amounts at tapping

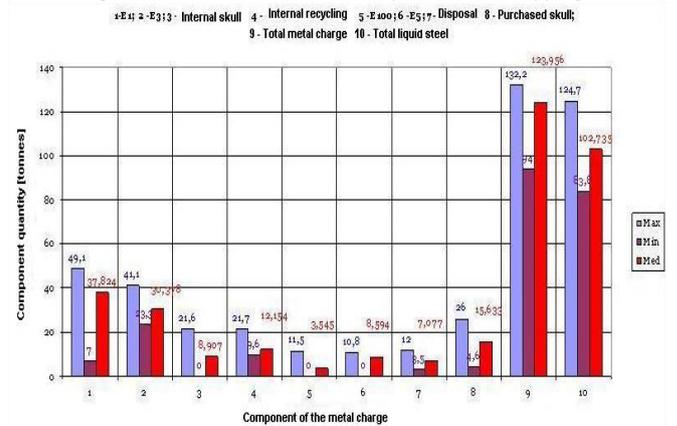


Figure 3. Variation limits of the metal charge components

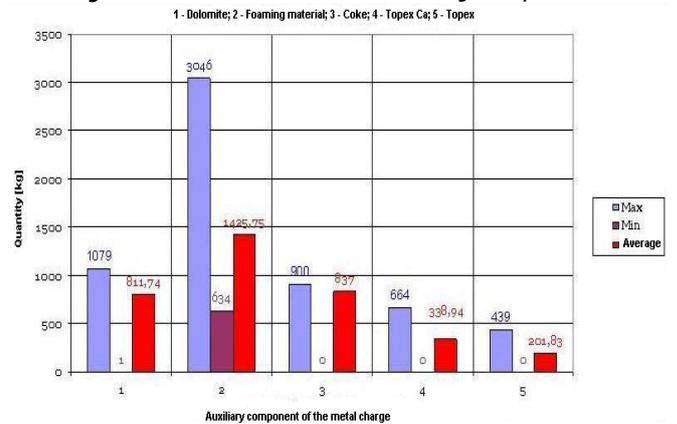


Figure 4. Variation limits of the auxiliary components in the metal charge

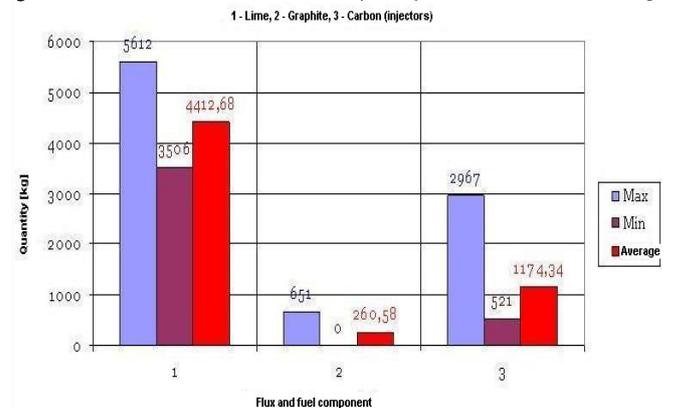


Figure 5. Variation limits of the non-metal components added during the steelmaking process

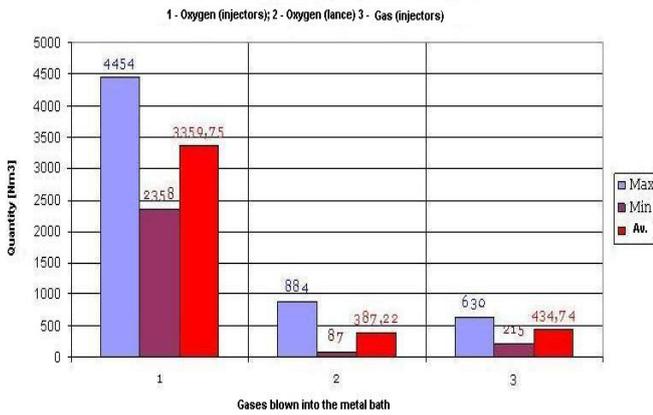


Figure 6. Variation limits of the gases injected into the liquid bath

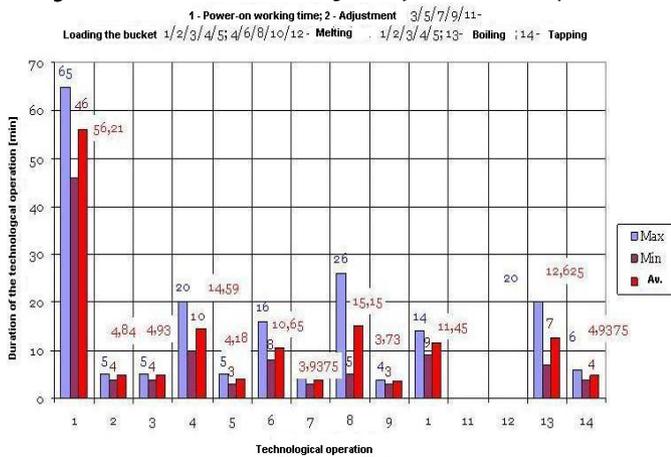


Figure 7. Variation limits of the technological stages

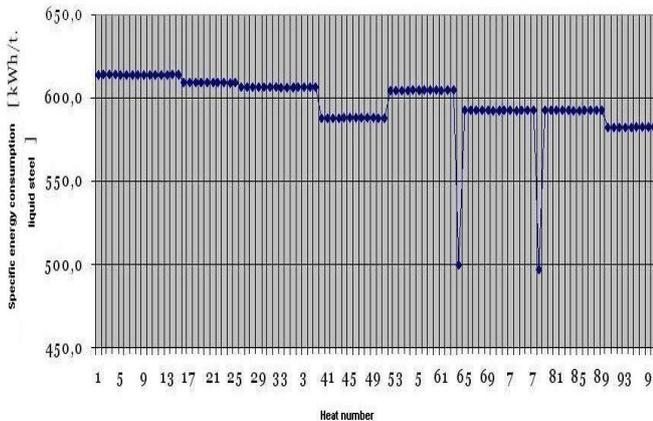


Figure 8. Variation of the specific consumption of electrical energy - distribution plot

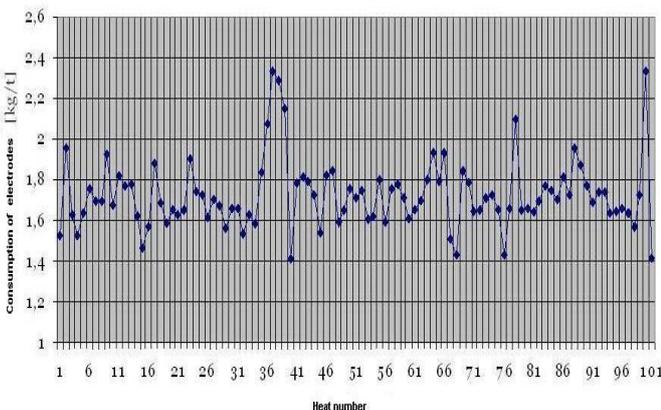


Figure 9. Variation of the electrode consumption

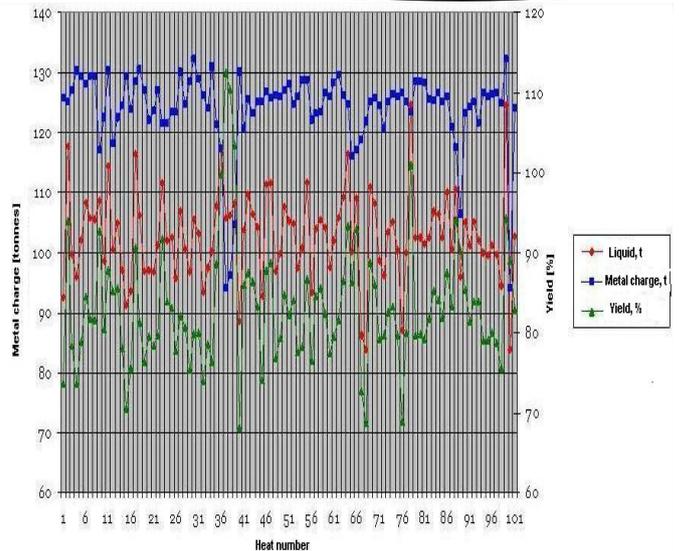


Figure 10. Variation of the metal charge weight, liquid steel weight and yield

Cu: Max. 0,52% Min. 0,026% Av: 0,2524% Ni: Max. 0,211% Min. 0,087% Av: 0,127%  
 Sn: Max. 0,0642% Min. 0,0192% Av: 0,0267%

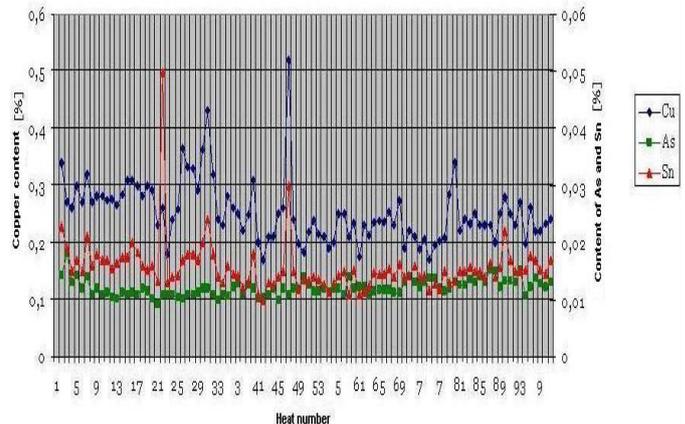


Figure 11. Variation of trace elements (Cu, As, Sn)

Cr: Max. 0,11% Min. 0,017% Av: 0,055% Ni: Max. 0,211% Min. 0,0092% Av: 0,012%  
 Sr: Max. 0,05% Min. 0,01% Av: 0,0156%

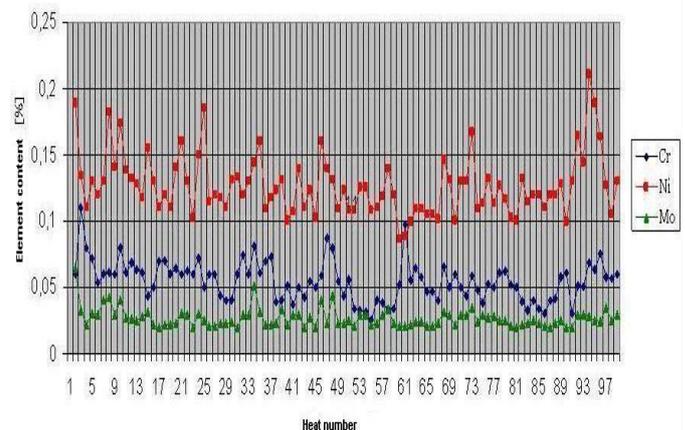


Figure 12. Variation of trace elements (Cr, Ni, Mo)

TECHNOLOGICAL ANALYSIS

The following technological aspects resulted from the technological analysis of the graphical charts presented in the figures 1-12:

- » Regarding the metal charge composition, the types of scrap E1 and E2 have the largest share in total metal charge (Figure 1 and

- Figure 2), their average being 38% and 30%, respectively; the variation of the scrap quantities, especially E1 and, to some extent, E2, is reflected in the variation of the total charge and yield;
- » Having in view the high level of scrap preparation, it is advisable that the quantity of these assortments to not fall below the average value (or their sum to not fall below the sum of their averages) - Figure 3;
  - » Regarding the internal skull consumption, it reached 21.6 tonnes/heat, with the remark that at some heats this was not a charge component, the average value being 8.91; in several cases, the skulls had high slag content, reason why this assortment have been rejected in some cases;
  - » Also, the consumption of purchased skulls (external) varied from 1.6 tonnes to 26 tonnes/heat, the average value being 15.63 tonnes/heat; in terms of quality, these skulls did not raise special problems;
  - » The scrap arising from internal recycling varied within wide limits, from 9.6 to 21.7 tonne/heat, its average value being 12.16 tonne/heat; this scrap assortment has a good quality, it is advanced prepared and comes from the whole technological process; when using this type of scrap, the chemical composition of the heat can be predicted within narrow limits;
  - » Regarding the scrap arising from disposals, its quantity did not exceed 12 tonne/heat, fact that is correct in principle, because the origin of the scrap is not precisely known and, therefore, it can bring Cr, Ni, and Mo in the analysed steel; these elements are considered tramp elements, and their percentage in steel should be limited;
  - » A particular attention should be paid to the components E5 and E100, because this assortment can bring non-ferrous materials (can be turnings mixed with non-ferrous alloys);
  - » The materials introduced in the metal charge (in bucket) varied within pretty wide limits, the only component present in every metal charge being the foaming material; the metal charges of some heats did not contain dolomites or other materials (Figure 4);
  - » The data presented in figures 5 and 6 show that the material additions made during the steelmaking process, although varied within wide limits, were well correlated with the metal bath composition;
  - » By analysing the data presented in Figure 7, we can see that there are real possibilities to reduce the period when the furnace is power supplied, the maximum duration being 65 min, minimum: 46 min, and average: 56 min; the reduction of the power supply duration leads to the reduction of electricity and electrodes consumption;
  - » Also, the analysis of the main technological stages durations (Figure 7) shows clearly the possibility of shortening the technological operations; by increasing the scrap processing level, we can achieve these requirements;
  - » Regarding the consumption of ferroalloys (Figure 2), we can see a wide variation, but the ferroalloys consumption is correlated with the metal charge and the liquid steel quantity; the ferro-manganese and ferro-silicon consumptions increase with the reduction of silico-manganese consumption;
  - » The electric energy consumption (Figure 8) varied from 582 to 614 kWh/tonne of liquid steel; if we take into account the yield, this can be considered a normal variation; an advance preparation of the metal charge leads to the reduction of the specific energy consumption;
  - » At 2 heats, the energy consumption was 497 and 503 kWh/tonne of liquid steel, respectively, explained by the fact that the furnace was completely emptied for repairing the hearth, and thus the quantity of liquid steel was larger;
  - » A significant variation was obtained at the specific consumption of electrodes (Figure 9), which varied within wide limits, from 1,41 to 2,36 kg/tonne of metal charge; this variation is due to the metal charge quality and the yield, whose values were sometimes low;
  - » From the data presented in Figure 10, are resulting very wide variations of the metal charge weight, liquid steel weight and yield, the main cause being the metal charge quality, i.e. the share of the non-metallic components in the assortment of the metal charge;
  - » the metal charge weight varied from 94 to 132.2 tonnes, the average being 124.18 tonnes; the liquid steel weight varied from 83.8 to 124.7 tonnes, the average being 102.70 tonnes; regarding the yield, the minimum value was 68.10 and the average was 82,95%;
  - » From the presentations shown in Figure 11, we can see that the trace elements Cu and Sn had wide variations, due to the use of light scrap containing food packaging and copper from various electrical equipments, the maximum limits being exceeded at 3 heats (at one heat the contents of Cu and Sn were exceeded, and at one heat only the content of Sn was exceeded), while the arsenic varied within quite narrow limits and did not exceed the maximum limit;
  - » Regarding the trace elements Cr, Ni, and Mo, which are alloying elements for the alloy steels, although the Cr and Ni contents had wide variations (especially the Ni content), the maximum limits were not exceeded.
- The analysis performed showed the influence of the metal charge structure and quality on the steelmaking process, and the justification for extending the results throughout the manufacturing process.
- CONCLUSIONS**
- Synthesizing the research results, we can conclude the followings:
- » the electric arc furnace of EBT type is the most appropriate unit for processing scrap in order to obtain steel, both in terms of charge

quality and the number of scrap assortments introduced in the charge;

- » the charge structure may vary within wide limits in terms of assortment, provided to be advanced prepared;
- » the metal charge weight varied within wide limits due to the variation in the share of different assortments of scrap;
- » the scrap assortment structure did not result in exceeding the content of trace elements that could lead to heat downgrading;
- » the quality of scrap and skull is reflected in the yield;
- » in practice, the charge quality is also determined by economic considerations, who are depending on the steel grade, which obviously varies from one steel plant to another.

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## ELECTROCHEMICAL STUDIES AND CYCLIC VOLTAMMETRY OF PARACETAMOL AT CLAY MODIFIED CARBON PASTE ELECTRODE

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**Abstract:** A Cyclic voltammetry (VC) method for the determination of trace amounts of paracetamol at carbon paste electrode modified with Clay (Clay-CPE) is proposed. The results showed that the Clay-CPE exhibited excellent electro catalytic activity to paracetamol. A quasi-reversible redox process of paracetamol at the modified electrode was obtained. The concentration of paracetamol and measuring solution pH was investigated. This electrochemical sensor shows an excellent performance for detecting paracetamol. The sensor was successfully applied to the determination of paracetamol in a real sample tablets with satisfactory results.

**Keywords:** Modified electrode; Cyclic voltammetry; Clay; Paracetamol.

### INTRODUCTION

Paracetamol (I, N-acetyl-p-aminophenol, acetaminophen) is a long-established and one of the most extensively employed "over the counter" drugs in the world. It was first used in medicine by Von Mering in 1893. However, it was first discovered to have both analgesic and antipyretic properties in the late 19th century. It is noncarcinogenic and an effective substitute to aspirin for patients with sensitivity to aspirin [1]. Unlike aspirin, however, paracetamol's anti-inflammatory activity is considered weak and is, thus, not routinely used in inflammatory conditions such as rheumatoid arthritis. Nevertheless, it is used to reduce fever cough and cold, and reduce mild to moderate pain, including instances of tension headache, migraine headache, muscular aches, chronic pain, neuralgia, backache, joint pain, general pain and toothache [2–4]. It is also useful in osteoarthritis therapy [5] and it is sometimes used for management of cancer pain. Recent research suggests that paracetamol may help to protect from changes leading to hardening of arteries that cause cardiovascular disease [6]. It also remains the analgesic of choice for people with asthma [7]. There is also some evidence to suggest that paracetamol may offer some protection against ovarian cancer [8]. Paracetamol shows no propensity to be addictive, even in people who use it frequently. When used in proper therapeutic dose, paracetamol is readily metabolized. Overdoses of paracetamol produce toxic metabolite accumulation that causes acute hepatic necrosis, inducing morbidity and mortality in humans [9]. Thus, it is very important to have an analytical technique for the determination of paracetamol in pharmaceutical preparations.

Several analytical techniques such as titrimetry [10], spectrophotometry [11], spectrofluorometry [12], voltammetry [13], HPLC [14], TLC [15], colorimetry [16], Fourier transform infra red spectrometry [17], and many other methods are proposed for the determination of paracetamol. Since voltammetric techniques are more selective, less costly and less time-consuming, they are widely used for the determination of paracetamol in pharmaceutical preparations. Shuyan et al. described a relatively simple and rapid electrochemical method by cyclic voltammetry using glassy carbon electrode for the detection of paracetamol in 1.0 M HCl solution [18]. Voltammetric determination of paracetamol at chemically modified electrodes [19,20], boron doped diamond film electrode [21] and at other electrodes [22–25] have also attracted attention, however, the lowest detection limit of 1.2  $\mu$ M is reported at nafion/ruthenium oxide pyrochlore chemically modified electrode. Owing to their novel optical, electronic, magnetic and catalytic properties gold nanoparticles are one of the most intensively studied and one of the most popular materials to be assembled on electrodes [26]. It has been reported that the small size of gold nanoparticles allow the conductive materials to come into the vicinity of the active process providing bioelectrocatalytic activity that can be utilized in the construction of biosensors [27]. It also provides some important functions for electroanalysis [28,33]. Gold nanoparticles-modified electrodes are used increasingly in many electrochemical applications since they have the ability to enhance the electrode conductivity and facilitate the electron transfer, thus, improving the analytical selectivity and sensitivity. Normally peculiar binding molecules are used to assemble gold nanoparticles on the electrode surfaces [29,30]

but this may alter the conducting properties of the modified electrode [31]. Recently, Oyama et al. [32] have presented a new method to fabricate a gold nanoparticles attached indium tin oxide (Au/ITO) electrode without using peculiar binding molecules. The present work reports the differential pulse voltammetric determination of paracetamol at a physiological pH of 7 using clay modified carbon paste electrode. The modified electrode shows a strong catalytic function towards the oxidation of paracetamol.

**EXPERIMENTAL**

**Apparatus and software**

Voltammetric experiments were performed using a voltalab potentiostat (model PGSTAT 100, Eco Chemie B.V., Utrecht, The Netherlands) driven by the general purpose electrochemical systems data processing software (voltalab master 4 software) run under windows 2007. The three electrode system consisted of a chemically modified carbon paste electrode as the working electrode a saturated calomel electrode (SCE) serving as reference electrode, and platinum as an auxiliary electrode.

**Electrodes**

Modified electrodes were prepared by mixing a carbon powder and the desired weight of clay. The body of the working electrode for voltammetric experiments was a PTFE cylinder that was tightly packed with carbon paste. The geometric area of this electrode was 0.1256cm<sup>2</sup>. Electrical contact was made at the back by means of a bare carbon.

**Procedure**

The initial working procedure consisted of measuring the electrochemical response at Clay-CPE at a fixed concentration of paracetamol. Standard solution of paracetamol was added into the electrochemical cell containing 100 mL of supporting electrolyte.

The mixture solution was kept for 20 s at open circuit and deoxygenated by bubbling pure nitrogen gas prior to each electrochemical measurement. The cyclic voltammetry was recorded in the range from -0,7 V to 1V. Optimum conditions were established by measuring the peak currents in dependence on all parameters. All experiments were carried out under ambient temperature.

**RESULTS AND DISCUSSION**

**Surface characteristics**

The morphology of the electrode surface of Clay was observed by scanning electron microscopy (Figure 1).

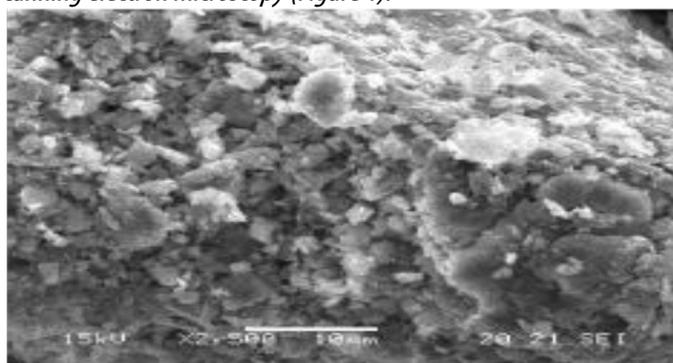


Figure 1: Scanning electron micrograph of Clay paste electrode.

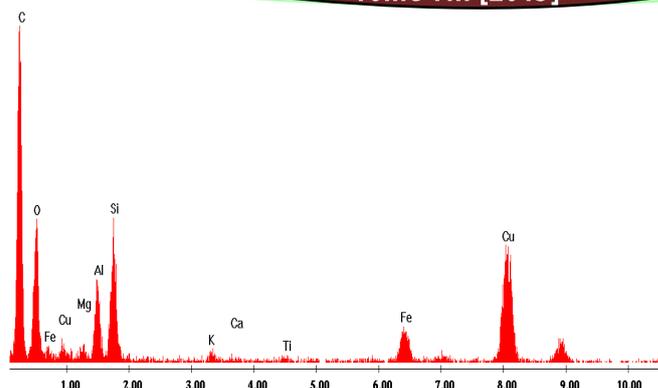


Figure 2: Chemical composition treated clay.

We find that the matrix is formed by compact particles fractions between 1 and 15 μm. Clay treaty has the following chemical composition given by transmission electron microscopy (TEM): O (22%), Mg (5.4%), Al (22.4%), K (2.7%), Ca (1%), Ti (1.8%) Fe (17.1%), Si (27.8%) and more metals order ppm (Figure 2). An examination of clay modified carbon paste electrode indicates some kind of agglomeration.

**Electrochemical behavior of Clay-CPE**

Figure 3 shows a cyclic voltammograms (CV) in the potential range -0.7 V to 1 V recorded, respectively, for carbon paste and clay modified carbon paste electrode at 100mV.s<sup>-1</sup>. The voltammograms take different forms. No peak is observed in the case of Clay-CPE, it is recognized that carbon surface was effectively modified by clay.

Figure 4 shows, paracetamol exhibits a pair of redox waves on the Clay-CPE with Epa (anodic peak potential)=0.5V and Epc (cathodic peak potential)=0.15V.

Scheme shows the paracetamol undergone oxidation and reduction.

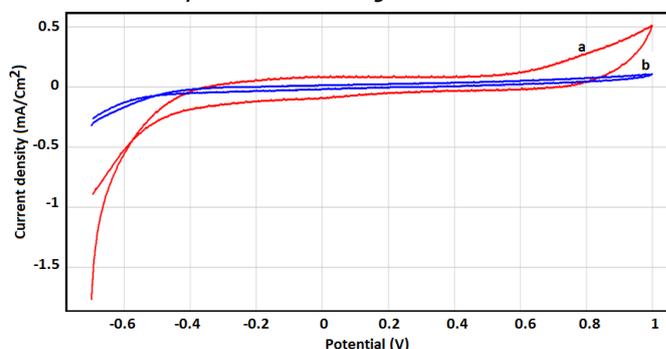


Figure 3: Cyclic voltammograms recorded for CPE (a) and bare Clay-CPE (b), in 0.1 M K<sub>2</sub>SO<sub>4</sub> at 100 mV/s.

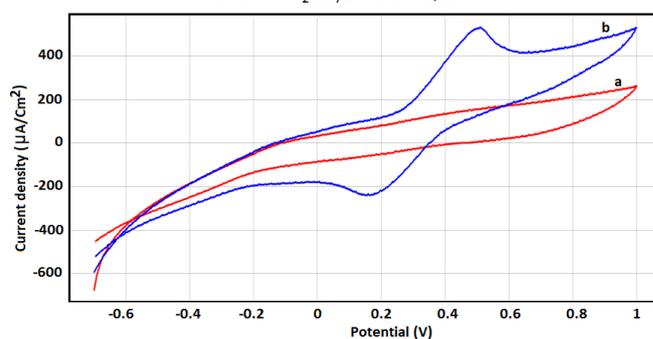
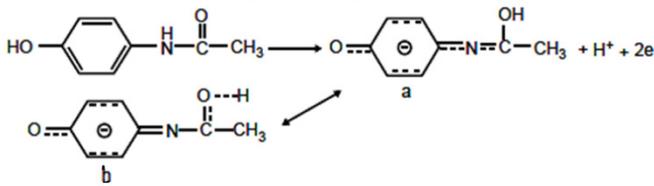


Figure 4: CVs recorded for 2.64 mM paracetamol at pH=7 at bare Clay-CPE (a) and Clay-CPE/paracetamol (b), scan rate 100 mV/s, preconcentration time (tp)=3min.



Scheme: The redox mechanism of paracetamol.

**OPTIMIZATION OF EXPERIMENTAL CONDITIONS**

Optimum conditions for the electrochemical response were established by measuring the peak current in dependence on all parameters.

**Influence of accumulation time**

The effect of the accumulation time is investigated (Figure 5); this significantly affects the oxidation peak current of paracetamol. The peak current of 3.96 mmol L<sup>-1</sup> paracetamol increases greatly within the first 3 min. Further increase in accumulation time does not increase the amount of paracetamol at the electrode surface owing to surface saturation, and the peak current remains constant. This phenomenon is due to the cavity structure of clay-CPE that improves the ability of the electrode to adsorb electroactive paracetamol. Maybe this is attributed to the saturated adsorption of paracetamol on the Clay-CPE surface. Taking account of sensitivity and efficiency, accumulation time was 3 min in the following experiments.

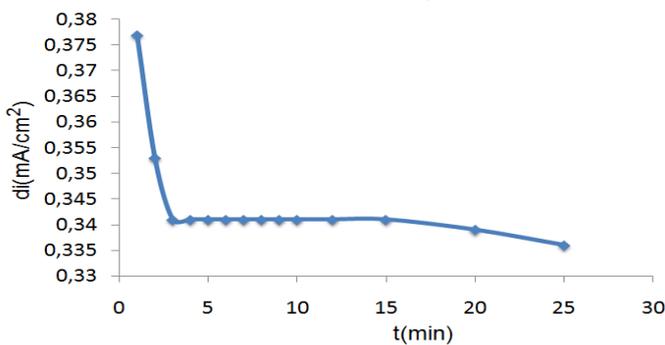


Figure 5: Effects of accumulation time on oxidation peak currents of 3.96 mmol L<sup>-1</sup> paracetamol at Clay-CPE, supporting electrolyte is K<sub>2</sub>SO<sub>4</sub> 0.1M (pH=7).

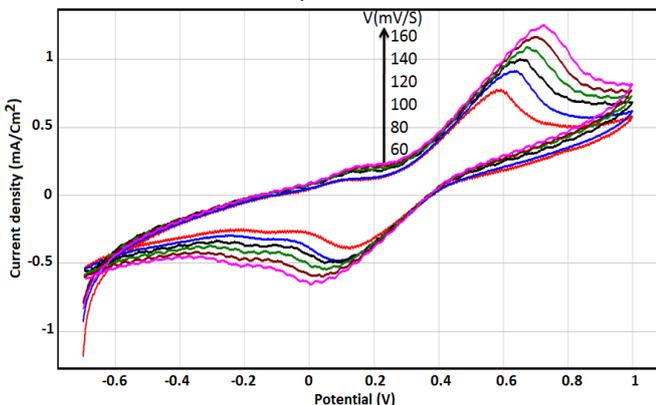


Figure 6: CVs acquired on Clay-CPE with 5.28 mM paracetamol in the buffer solution at different scan rates from 60 to 160mV.s<sup>-1</sup>. Inset is the plot of the peak current of paracetamol versus scan rate.

**Effect of scan rate**

The effect of scan rates on the redox paracetamol at the clay modified carbon paste electrode was investigated by cyclic voltammetry (Figure

6). The redox peak currents increased linearly with the scan rate in the range from 60 to 160mV.s<sup>-1</sup> indicating that paracetamol is adsorbed onto Clay-CPE surface.

The figure 7 shows the linear relationship between the scan rate anodic peak and cathodic peak currents of paracetamol at Clay/CPE. The linear regression equations:

$$I_{pa} = 0.004V + 0.514 \quad R^2 = 0.989$$

$$I_{pc} = -0.002V - 0.217 \quad R^2 = 0.987$$

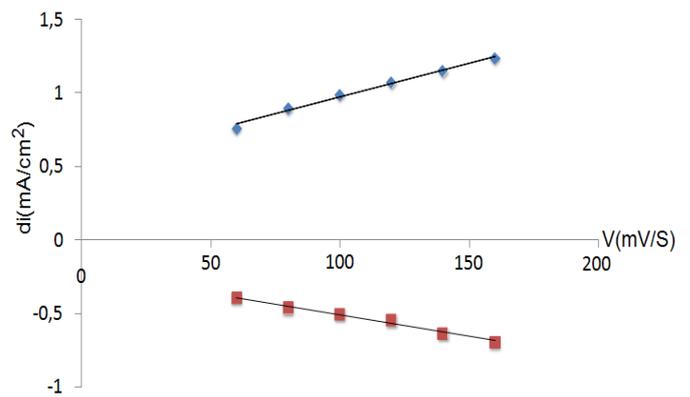


Figure 7: Plot of peaks area versus scan rate

**Calibration graph**

Figures (8,9) shows respectively the CV and SWV curves of different concentration of paracetamol at Clay/CPE was increased from 1.32 mM to 6.6 mM at pH 7. Both the anodic and cathodic peak current increases linearly with the concentration of paracetamol.

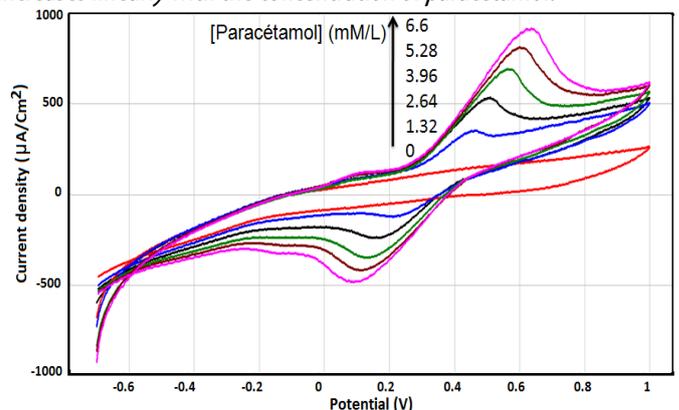


Figure 8: Cyclic Voltammograms of different concentration of paracetamol (1.32mM to 6.6mM) at Clay/CPE in 0.1 M K<sub>2</sub>SO<sub>4</sub> PH=7, Scan rate 100 mV/s.

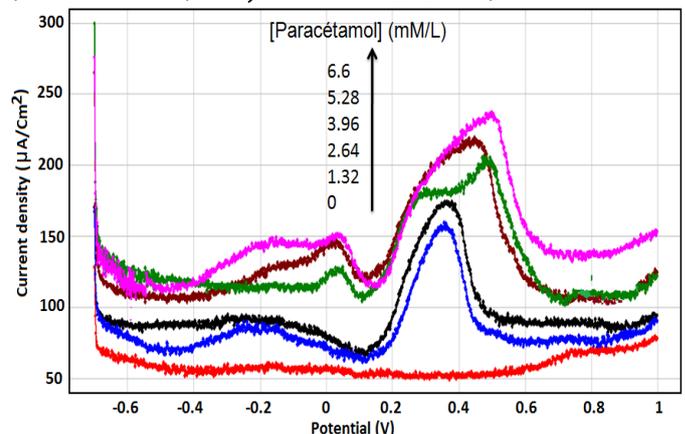


Figure 9: Square Wave Voltammograms of different concentration of paracetamol (1.32mM to 6.6mM) at Clay/CPE in 0.1 M K<sub>2</sub>SO<sub>4</sub> PH=7

The calibration curve for the CV peak current for paracetamol oxidation and reduction vs. paracetamol concentration (Figure 10) shows excellent linearity.

The linear regression equations:

$$I_{pa} = 0.144 [\text{Paracetamol}] + 0.112 \quad R^2 = 0.981$$

$$I_{pc} = -0.078 [\text{Paracetamol}] - 0.013 \quad R^2 = 0.989$$

The linear behavior of the calibration curve further indicates that the process is basically diffusion controlled within the studied concentration range.

Modification of carbon paste surface by clay remarkably improves the reactivity of Clay/CPE towards the oxidation and reduction of paracetamol.

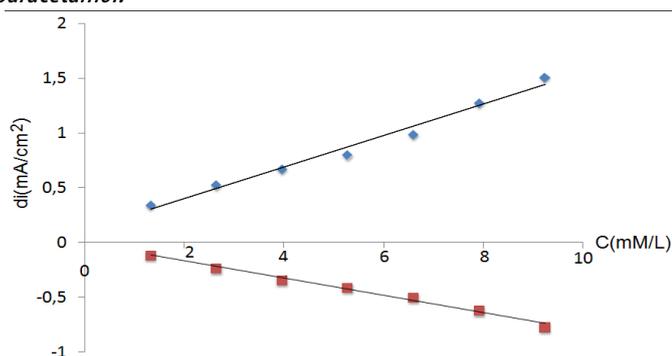


Figure 10: Plot of peaks area versus added concentration of paracetamol.

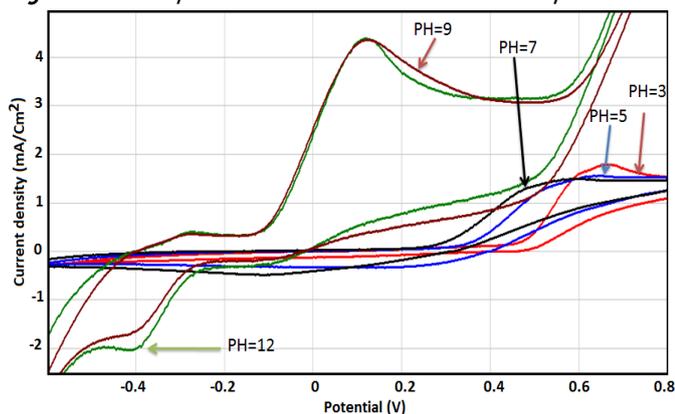


Figure 11: Cyclic Voltammograms of different pH on the oxidation and the reduction of paracetamol at the Clay modified CPE.

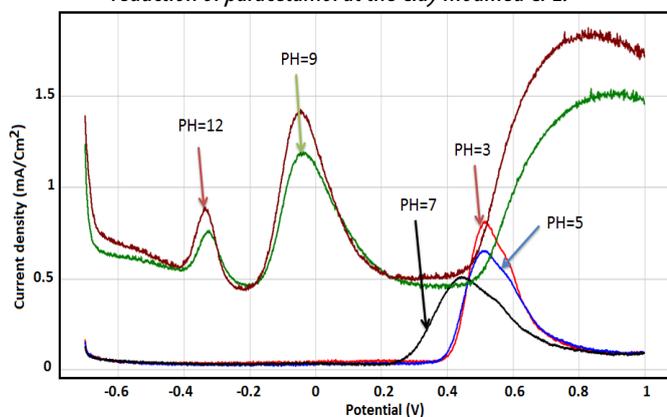


Figure 12: SWV for the effect of pH on the oxidation and the reduction of paracetamol at the Clay modified CPE.

### Influences of pH

The effect of pH on the voltammetric response of paracetamol was studied in the range of pH 3-12. Figures (11, 12) shows respectively

the cyclic voltammograms and square wave voltammograms recorded at different values of pH to 6.24 mM paracetamol. The pH solution has a significant influence on the peak current and the peak potential of the catalytic oxidation peak and the reduction peak of paracetamol.

Figures (13, 14) shows respectively the effect of pH on the current density and the peak potential for paracetamol oxidation and reduction.

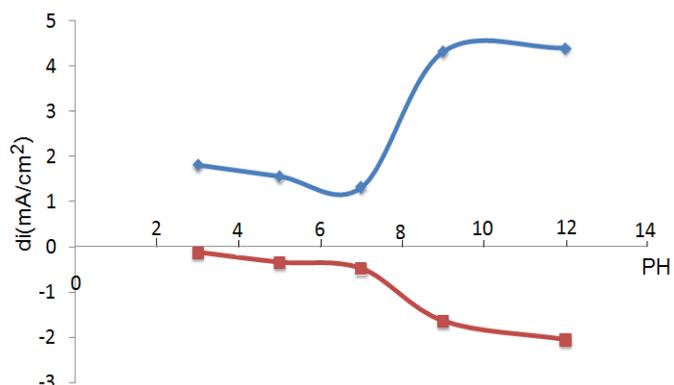


Figure 13: Plot of the relationship between solution pH and the oxidation and reduction peak Current.

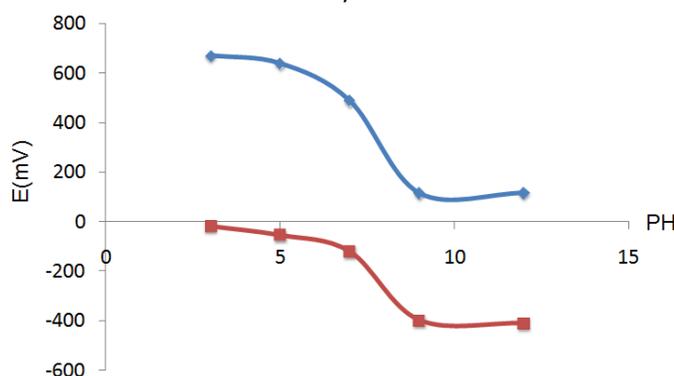


Figure 14: Plot of mid-potential of paracetamol peaks versus pH values

### ANALYSIS OF COMMERCIAL SAMPLES

In order to evaluate the performance of the analytical methodology described above, the determination of paracetamol at Clay-CPE was carried out in commercial sample. The analytical curves were obtained by CV experiments in supporting electrode (Figure 15). It was founded that the peaks currents increase linearly versus paracetamol added into the buffer solutions (Figure 16).

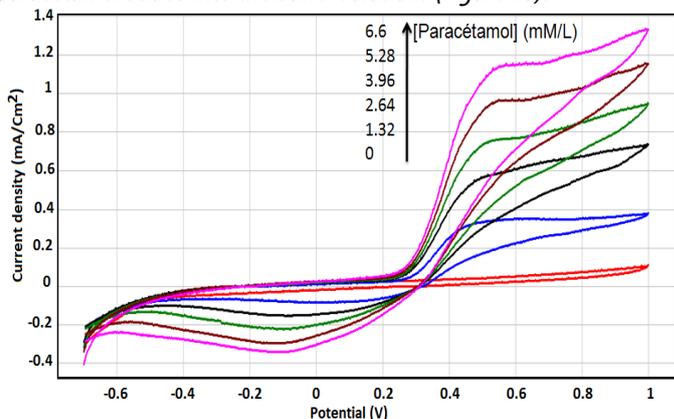


Figure 15: Cyclic Voltammograms of different concentration of paracetamol (1.32mM to 6.6mM) at Clay/CPE, Scan rate 100 mV/s.

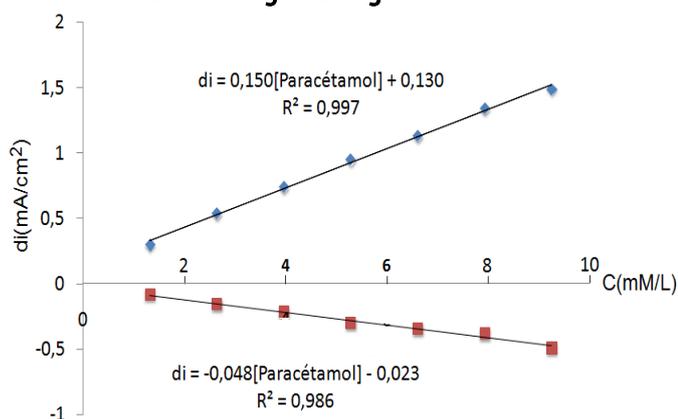


Figure 16: Plot of peaks area versus added concentration of paracetamol.

**CONCLUSION**

In this work, electrochemical behavior of paracetamol was evaluated using the voltammetric measurements. A novel method is described for the determination of paracetamol which is simple, quick and sensitive with a low cost of analysis.

The method has been satisfactorily applied to the determination of paracetamol in pharmaceutical formulations. The clay modified carbon paste electrode exhibited a stable and reproducible response for paracetamol. The modifier is not soluble in water, non-toxic, and not a pollutant.

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## EFFECT OF DIFFERENT ELECTRODE SHAPE VARIATION ON SURFACE ROUGHNESS OF MILD STEEL DURING EDM

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**Abstract:** EDM machining process that removes metals by electric spark erosion is widely used in automotive and aerospace industries. Such industries demand parts that follow very stringent tolerances for dimensions and topology. Many research involving state-of-the-art methods (numerical, computational, or experimental etc.) have been carried out to predict and compare surface roughness variation. This research has been conducted to compare the variation of surface roughness produced in EDM of mild steel specimens using two different type of electrode shape of circular and rectangular copper electrode. Machining was performed on a CNC JS EDM machine, commonly used for industrial production of dies and molds. Three machining parameters: Pulse on ( $T_{on}$ ), Pulse off ( $T_{off}$ ), and Gap Voltage ( $V$ ) were used to investigate the effect of process parameter on surface roughness for two different shape electrodes. Surface roughness values ( $R_a$ ) were measured using surface Profilometer and a novel Digital Image Processing (DIP) technique, previously developed by the authors. The surface roughness produced in both the cases was then compared and it was observed that better surface finish was attained in the case of the round electrode.

**Keywords:** EDM, Surface Roughness, Machining Parameters, Digital Image Processing, Electrode Shape

### INTRODUCTION

Electrical-Discharge Machining is one of the oldest and most widely used unconventional machining processes. The usefulness of this method stems from the fact that no contact between the work-piece and tool is necessary for the machining to occur [1]. Thus, no mechanical cutting forces are necessary to remove unwanted material. This has led to the use of EDM in a manifold of industrial applications such as: machining of dies and tools, aerospace and automotive components, mirror finishing, and machining involving transient and tough alloys [2]. Since, material is removed by fusion and vaporization, by plasma discharges through the dielectric, miniature crater formation at the machining site is unavoidable. Such rough surface, if unchecked, can lead to sliding friction between moving surfaces and ultimately to heat generation, wear, and failure. These phenomena are also a source of energy loss and additional head costs at industries [3]. Many research works carried out for the prediction and optimization of the surface roughness in different machining processes [4]. Alauddin et al. [5] used Response Surface Methodology (RSM) and ANOVA to predict the surface finish in end-milling of Inconel 718. In this study Design Expert Software (DOE) has been used to conduct 13 experiments in order to build a statistical model for surface roughness. Suresh et al. [6] developed statistical models for milling operations. They were able to achieve valuable insight into the interaction of various machining parameters on machining response. Alam et al. [7] used RSM to model surface roughness produced in high speed end milling of Ti-6Al-4V alloy and subsequently predicted the minimum roughness attainable using DF. There maximum desirability was 95.63%, which was experimentally verified using a 3 factors and 3 levels full factorial CCD model in DOE. The prediction and subsequent comparison of the resultant surface

roughness, is therefore, a crucial and important research area. Anayet U Patwari et al. [8] used a well known approach for the predicting surface roughness in End milling of medium carbon steel with Titanium Carbide Inserts. Their method was the utilization of Response Surface Methodology (RSM) and specifically a small Central Composite Design (CCD) for surface roughness model generation. The authors of this paper had previously used a similar 3 factors:  $T_{on}$  (On Time),  $T_{off}$  (Off Time), and  $V$  (Gap Voltage); and 5 level (-1.414, -1, 0, 1, 1.414) rotatable CCD model in RSM, to develop the mathematical model for predicting surface roughness, ' $R_a$ ' produced using circular electrodes in machining mild steel specimens in EDM [9]. The DOE software, in this case, suggested a quadratic model based on insignificant lack of fit and a confidence level of 95% by ANOVA analysis. The predictions of the developed model was verified using both a surface Profilometer and a digital image processing technique developed by Anayet U Patwari et al. [10]. This research has been conducted to compare the variation of surface roughness produced in EDM of mild steel specimens using two different type of electrode shape of circular and rectangular copper electrode. Machining was performed on a CNC JS EDM machine, commonly used for industrial production of dies and molds. Three machining parameters: Pulse on ( $T_{on}$ ), Pulse off ( $T_{off}$ ), and Gap Voltage ( $V$ ) were used to investigate the variation effect on surface profile. Surface roughness values ( $R_a$ ) were measured using surface Profilometer and a novel Digital Image Processing (DIP) technique.

### EXPERIMENTAL SETUP

**EDM machine:** For the EDM process, JS EB 600L CNC EDM, in the IUT machining laboratory was utilized. The advantage of this machine is that it has a built in computer terminal and software. Figure 1 is a photograph of the EDM machine used. For performing the

experiments the work piece, electrode and the dielectric fluid of the EDM machine was chosen very carefully after extensive literature review and commercial availability. In this study used kerosene as the preferred dielectric because it is cheap, available, and commonly used in industries.

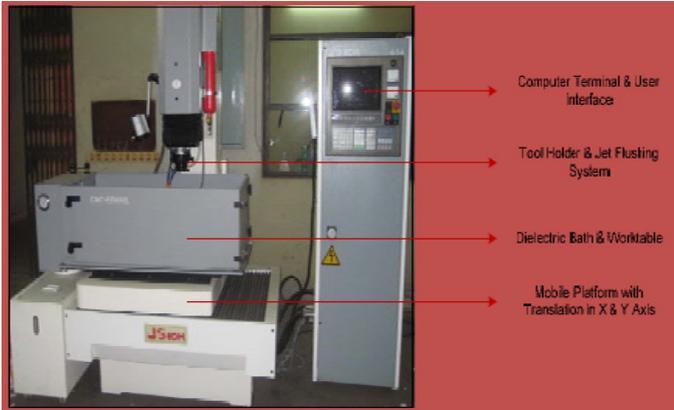


Figure 1: Photograph of the CNC EDM machine used.

EDM is mostly used to machine steel dies and tools. Thus, for this investigation and research purpose, mild steel was used as the work-piece material. A coarse mild steel plate was taken and it was grinded and polished accordingly to investigate the effects on electrode shape on surface roughness very carefully. The shape of the work piece dimensions is shown in figure 2.

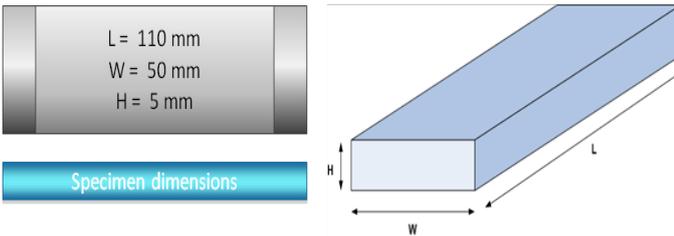


Figure 2: Work-piece specimen's dimensions

**Electrode and Process parameter:** The most common electrode materials for EDM are graphite and copper. Though graphite gives lesser electrode wear and good machinability compared to copper, copper electrode is used in this research as it gives greater material removal rate and is less costly. Two electrodes with the same cross-sectional area but different geometric shapes, circular and rectangular, were used. Figure 3 is a schematic of the electrodes' dimensions.

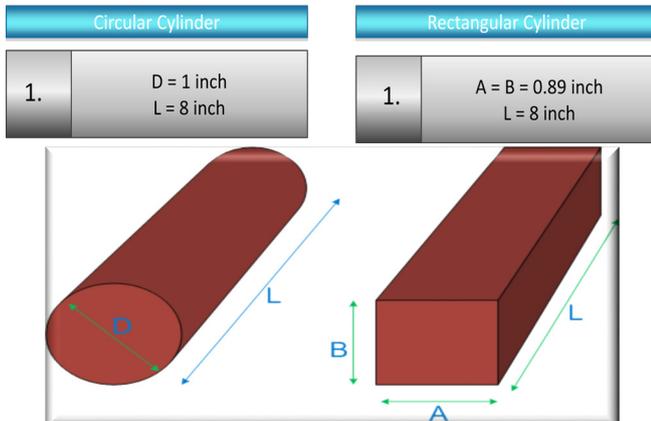


Figure 3: Schematics of the electrodes with dimensions

The different process parameters to investigate the effect of size of electrode on surface roughness are shown in Table 1.

Table 1: Different process parameters used in experimentation

No	Process parameters	Lowest	Low	Center	High	Highest
1	On T, T <sub>on</sub>	80	120	300	700	1000
2	Off T, T <sub>off</sub>	5	6	10	16	20
3	Gap Voltage, V (volts)	50	55	70	90	100

**SURFACE ROUGHNESS MEASUREMENTS**

The surface roughness of the machined mild steel specimens was measured using two different techniques: surface Profilometer and DIP. The DIP process, previously developed by the authors, was used as it greatly automated the measurement process and aided in visualization. The measurements of the surface Profilometer, a well established surface topography tool, were used as the benchmark for the DIP process. The Mitutovo SURFTEST was used, which is a contact Profilometer. It can measure small surface variations in vertical stylus displacement as a function of position. It can typically measure small vertical features ranging in height from 10 nanometers to 1 millimeter. The disadvantage of the profilometer is that it only samples a small linear section of the specimen. The surface roughness, in both cases, was measured using digital image processing [10]. Figure 4 illustrates the logic sequence for the DIP measurements.

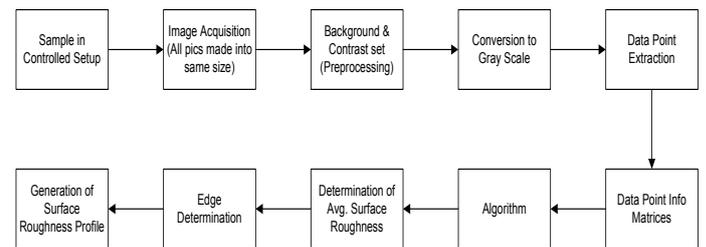


Figure 4: Flow diagram of the digital image processing [10]

Image acquisition was done in a controlled setup and using a metallurgical microscope MMB 2300. Figure 5 shows the photograph of the microscope.



Figure 5: Photograph of the metallurgical microscope

**On/off and brightness control**

Digital image processing involves the application of computer logic and algorithm to analyze images. For the analysis, image processing toolbox efficiently processes the samples' images represented as n by m 2-D matrix form. The acquired RGB images were resized,

keeping their aspect ratios intact, to standardize the comparison. Grey scale and binary conversions were performed. The peaks and valleys of the surface roughness showed up as bright and dark regions in the grey scale images and stored each resized image as a 2-D matrix, where each column corresponded to a 'strip' of the image and contained pixel intensity values. The output matrices were then used to plot surface roughness profiles, surface contour maps, and 3-D contour surfaces. Figure 6 illustrate the typical graphical outputs for the purpose of visualization in DIP [10].

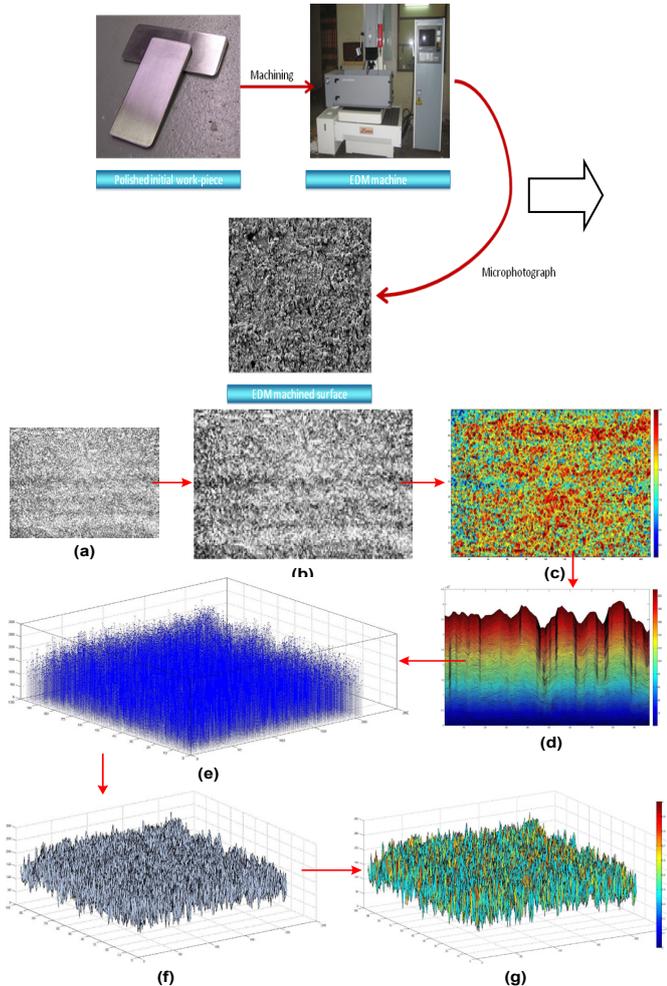


Figure 6: DIP results (a) microphotograph, (b) resized grayscale, (c) 2-D colored contour plot, (d) 2-D profile plot, (e) 3-D plot of datum points, (f) 3-D contour plot, and (g) 3-D colored contour plot

**Surface Roughness Obtained:**

Twelve experiments with different experimental conditions for circular and rectangular copper electrode has been conducted and the surface roughness measured using DIP and surface Profilometer are presented in Table 2.

**Effect of Pulse on time:**

Obtained Surface roughness (measured by DIP) at different Pulse On Time for the two electrode shapes are shown in figure 7. It was observed from that the pattern of surface roughness variation was similar for the two electrode shapes. In both cases the roughness decreased to a minimum and then increased as the Pulse on Time duration was increased.

Table: 2 Surface roughness obtained at different conditions

Process parameter			Circular Electrode		Rectangular Electrode	
On Time $T_{on}$ (s)	Off Time $T_{off}$ (s)	Gap Voltage V (volts)	$R_a$ ( $\mu m$ ) by DIP	$R_s$ ( $\mu m$ ) Profilometer	$R_a$ ( $\mu m$ ) by DIP	$R_s$ ( $\mu m$ ) Profilometer
700	16	55	0.86936	0.93	0.8985	0.9378
700	6	90	1.75418	1.713	2.467	2.3996
120	16	90	1.85893	1.8054	2.5521	2.5020
120	6	55	0.7882	0.842	0.8082	0.8510
300	10	70	1.03149	1.0021	1.0408	1.0012
300	10	70	1.03149	1.0021	1.0408	1.0021
80	10	70	1.62322	1.5452	2.026	1.9789
1000	10	70	1.40124	1.37	1.7051	1.6534
300	5	70	0.69486	0.7412	0.7488	0.7898
300	20	70	0.77588	0.8245	0.8267	0.8612
300	10	50	1.20866	1.165	1.2311	1.1878
300	10	100	1.60369	1.51	1.8813	1.8210

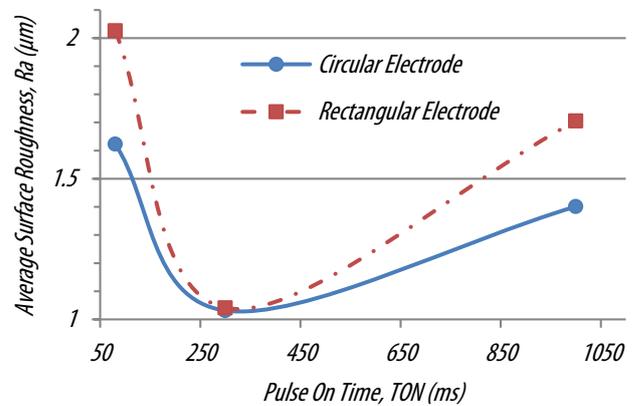


Figure 7: Average Surface Roughness, 'Ra' vs. Pulse On Time, 'TON' Plots for Circular and Rectangular Electrodes

It was also apparent that the resultant surface roughness was higher when rectangular electrode was used. To standardize the comparison and to study the influence of only  $T_{ON}$  on  $R_a$  the other two machining parameters' values ( $T_{OFF}$  and  $V$ ) were set to constant.

**Effect of Pulse off time:**

Obtained average surface roughness (measured by DIP) is plotted against different Pulse Off Time for the two electrode shapes are displayed in figure 8.

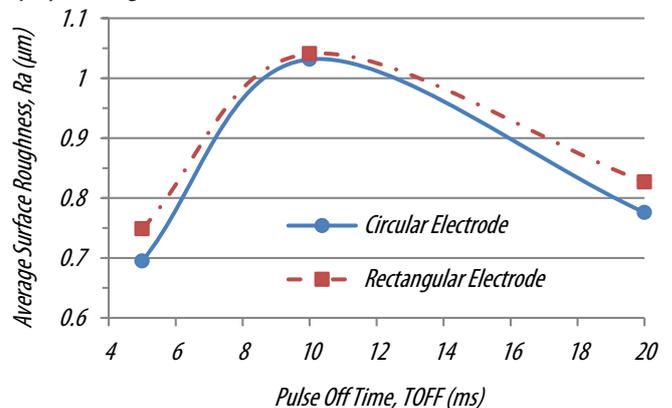
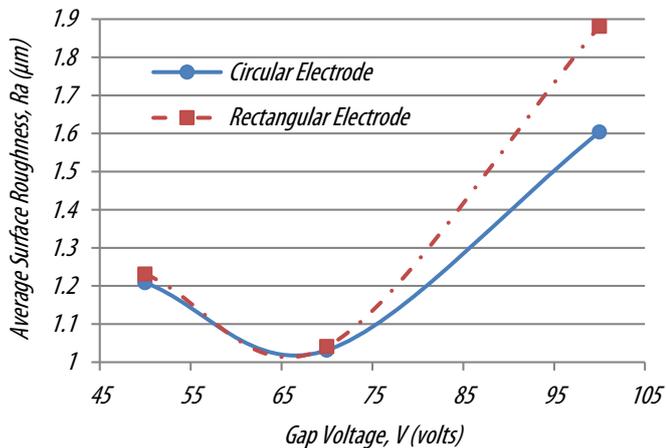


Figure 8: Average Surface Roughness, 'Ra' vs. Pulse Off Time, 'TOFF' Plots for Circular and Rectangular Electrodes

It was observed from the above graph that the pattern of surface roughness variation was similar for the two electrode shapes. In both cases the roughness increased to a maximum and then decreased as the Pulse Off Time duration was increased. It was also apparent that the resultant surface roughness was higher when rectangular electrode was used. To standardize the comparison and to study the influence of only  $T_{OFF}$  on  $R_a$  the other two machining parameters' values ( $T_{ON}$  and  $V$ ) were set to Constant.

**Effect of Gap voltage:**

The one factor plots of resultant surface roughness (measured by DIP) vs. Gap Voltage for the two electrode shapes are displayed in figure 9 below: This time, it was observed in the graph, below, that the pattern of surface roughness variation was again similar for the two electrode shapes. In both cases the roughness decreased to a minimum and then increased as the Gap Voltage was increased. It was also apparent that the resultant surface roughness was higher when rectangular electrode was used. To standardize the comparison and to study the influence of only  $V$  on  $R_a$  the other two machining parameters' values ( $T_{ON}$  and  $T_{OFF}$ ) were set to Constant.



**Figure 9:** Average Surface Roughness, 'Ra' vs. Gap Voltage, 'V' (One Factor) Plots for Circular and Rectangular Electrodes

It has been observed from the surface roughness plots for the two electrode shapes, that roughness was usually higher in the case of the rectangular electrode but the trends of the two graphs were similar.

**CONCLUSIONS**

The findings, of this research, suggest that the average surface roughness is greater when the rectangular electrode is used. This could be due to the concentration of electric field at the sharp edges of the rectangular electrode. The similarity of shape of the two electrodes, however, implies that the effect of the three machining parameters, investigated, is similar in case of both electrode shapes.

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## IMPROVEMENT OF THE JACKET SIDE HEAT TRANSFER IN STIRRED VESSELS

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**Abstract:** This paper presents several different jacket constructions. These were compared with each other's to find the best jacket side heat transfer coefficient (HTC) in case of same input technological data. Another goal of the paper is to find the effect of the simple modification of the construction. This paper presents several different types of jacket constructions for example a simple jacket, a channeled jacket and a divided jacket. To determine the heat transfer coefficients on the jacket side is fairly difficult; the results calculated by various methods differ significantly. If the jacket construction would modify it causes heat transfer coefficient changing. Previously was developed a construction and a calculation method for heat transfer coefficient (HTC). Based on the transferred heat the different type of jacket construction were compared with each other's to find the best jacket side HTC in case of same input technological data. Another goal of this paper is to find the effect of the simple modification of the construction.

**Keywords:** jacketed vessel, heat transfer, rectangular flow channel

### INTRODUCTION

Many industrial sectors use reactor tanks (vessels), which are fitted from outside with jackets to heat or cool the contents of the vessels. Usually, the flow geometry in this annular space between the outer surface of the vessel and the inner surface of the jacket is relatively simple. Nevertheless, to determine the heat transfer coefficients on the jacket side is fairly difficult; the results calculated by various methods differ significantly.

If the jacket construction would modify it causes heat transfer coefficient changing. Previously was developed a construction and a calculation method for HTC. Based on this construction this paper would like to point out how to improve the heat transfer.

### HEAT TRANSFER FROM A JACKET

The inner surface heat transfer coefficient is relatively constant, because jacketed vessel is equipped from inside with an impeller, which can have – according to the requirements of the process – different shapes.

A limited number of publications are available about heat transfer on the jacket side of a stirred vessel. Heat transfer from the outer wall surface of a vessel and a liquid inside the jacket can be described by dimensionless equations of the following form:

$$Nu = C Re^a Pr^b \left( \frac{\eta}{\eta_w} \right)^e \quad (1)$$

with

» Nusselt number  $Nu = \frac{\alpha d}{\lambda}$  where  $d$  is a characteristic dimension

» Reynolds number  $Re = \frac{ud\rho}{\eta}$  where  $u$  is a characteristic velocity in space of a jacket

» Prandtl number  $Pr = \frac{c\eta}{\lambda}$

The exponents of the Reynolds number, the Prandtl number and the viscosity ratio in Eq. (1) have a numerical values depends on the calculation methods. The constant  $C$  takes into account all the geometrical effects. The physical properties ( $c$ ,  $\rho$ ,  $\eta$  and  $\lambda$ ) are to be evaluated at mean liquid temperature and  $\eta_w$  at mean wall temperature.

### A simple jacket

Heat transfer calculation methods in a simple jacket are known. In this case, the flow geometry is a simple annular space in the jacket. Lehrer [1] used the Prandtl analogy between momentum and heat transfer and derived the following equation:

$$Nu = \frac{0,03 Re^{0,75} Pr \left( \frac{\eta}{\eta_w} \right)^{0,14}}{1 + \frac{1,74 (Pr-1)}{Re^{0,125}}} \quad (2)$$

The characteristic length  $d$  in the Nusselt number and in the Reynolds number is given by

$$d = 1,63\delta \quad (3)$$

where  $\delta$  is the width of the annular space.

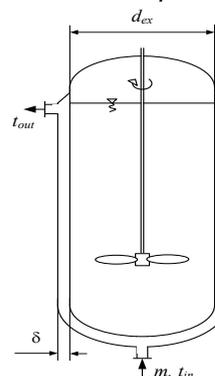


Figure 1. Simple jacket

Stein and Schmidt [2] presented different models and carried out own experimental measurements. They recommended the following procedure to determine the jacket side heat transfer coefficient:

A characteristic length  $l$  is calculated from

$$l = \sqrt{\left(\frac{\pi}{2}\right)^2 d_{ex}^2 + h_s^2}$$

where  $d_{ex}$  is the external vessel diameter and the  $h_s$  is the height of jacket.

A characteristic diameter  $d$  is calculated from

$$d = 2\delta$$

The Nusselt number is given from the following equation:

$$Nu = \left( Nu_A^3 + Nu_B^3 + Nu_C^3 + Nu_D^3 \right)^{\frac{1}{3}} \left( \frac{\eta}{\eta_w} \right)^{0,14}$$

where

$$Nu_A^3 = 3,66^3$$

$$Nu_B^3 = 1,62^3 Re Pr \left( \frac{d}{l} \right)$$

$$Nu_C^3 = 0,664^3 Pr \left( Re \left( \frac{d}{l} \right) \right)^{1,5}$$

$$Nu_D^3 = 0,0115^3 Re^{2,7} Pr \left( 1 - \left( \frac{2300}{Re} \right)^{2,5} \right)^3 \left( 1 + \left( \frac{d}{l} \right)^{\frac{2}{3}} \right)^3$$

**Channeled jacket**

It this case some baffles was built in the jacket. Let to inspect the effect of the baffles. At this case the flow geometry section is rectangular and the fluid flow as in the helical coil. A HTC calculation method was developed previously [3] for this type of jacket side geometry. Based on this, the Nusselt number is given from the following equation:

$$Nu = 0,23 Re^{0,633} Pr^{0,326}$$

The characteristic dimension  $d$  in the Nusselt number and in the Reynolds number is thermal equivalent diameter, which is given by

$$d = 4 \frac{A}{K} = 4 \frac{\delta h_c}{h_c} = 4\delta$$

where  $A = \delta \times h_c$  is the flow section,  $K$  is normally the wetted perimeter, but in this case, the heat transfer occur only on one side of the rectangle, so  $K = h_c$ .

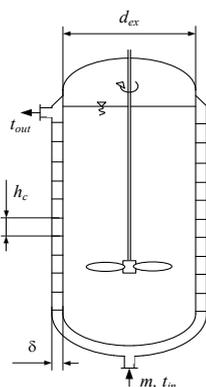


Figure 2. Channeled jacket

This equation can be improved if consider the viscosity of the laminar film next to the wall:

$$Nu = 0,23 Re^{0,633} Pr^{0,326} \left( \frac{\eta}{\eta_w} \right)^{0,14}$$

- (4) Let us examine in this specific case the heat transfer coefficient  $\alpha$  on the jacket side of a stirred vessel. The jacket is equipped with radial inlet tube placed at the bottom of the jacket. The contents of the vessel are cooled by mean of water flowing through the annular space or the rectangular section of the jacket. The data given below are available:

- (6) Outside vessel diameter  $d_{ex} = 4\text{ m}$
- (6) Width of annular space  $\delta = 40\text{ mm}$
- (6) Height of jacket  $h_s = 4\text{ m}$
- (7) Height of rectangular channel  $h_c = 500\text{ mm}$
- (7) Jacket side mass flow rate  $m = 150\text{ kg/s}$
- (8) Inlet water temperature  $t_{in} = 14^\circ\text{C}$
- (8) Mean water temperature  $t_m = \sim 20^\circ\text{C}$
- (9) Prandtl number  $Pr = 7$
- (9) Mean jacket wall temperature  $t_w = \sim 40^\circ\text{C}$

Table 1. Calculation results

	Re	Nu	$\alpha, W m^{-2} K^{-1}$
Annular space Lehrer	$23 \times 10^8$	106	644
Annular space Stein and Schmidt	$19 \times 10^8$	174	1292
Rectangular section	$12 \times 10^8$	3242	9785

The results shows that a quite big difference between the first and second rows in Table 1. However, the HTC for rectangular channel is greater than the others because of the velocity. Obviously, the higher velocity causes higher pressure drop for rectangular channel.

**Divided jacket**

Another possibility for modifying the jacket construction is to divide the jacket side for several parts. In this case the total mass flow is also divided, so the mass flow for one part will be smaller than the original construction. If the jacket would divided into two parts, the flow velocity would be halved, the pressure drop decrease by four times. In case of three parts, the velocity decreasing 1/3, the pressure drop decrease 1/9 of the original.

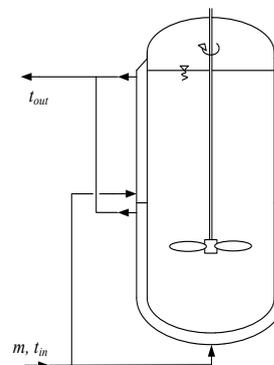


Figure 3. Divided jacket for two parts

The velocity decreasing effect of Reynolds number, which is also effect the Nusselt number. The previous equation can be used to calculate the HTC (eq. 2, eq. 6, eq. 11 and eq. 13).

Table 2. Divided jacket calculation results

Rectangular section	Re	Nu	$\alpha, W m^{-2} K^{-1}$
Jacket without divide	$12 \times 10^6$	3242	9785
Jacket divided two parts	$6 \times 10^6$	2090	6310
Jacket divided three parts	$4 \times 10^6$	1617	4881

**SUMMARY AND CONCLUSIONS**

This research investigated several different jacket constructions which are used for heat transfer. The paper pointed out baffled jacket more efficient than the simple jacket in the view heat transfer. The increased pressure drop caused by the baffled jacket would be decreased by divided jacket.

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## QUALITY ASSURANCE IN HIGHER SCHOOL OF APPLIED PROFESSIONAL STUDIES IN VRANJE, SERBIA

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**Abstract:** The quality assurance system in the higher school of Applied Professional Studies in Vranje defines the strategy for quality assurance, quality assurance measures, and subjects and areas for quality assurance. Higher School of Applied Professional Studies in Vranje is subject to external quality control carried out by the Commission for Accreditation and Quality and the National Council for Higher Education, and internal controls by the Commission for self-evaluation and assessment of the quality of academic programs, teaching and working conditions in the school as the highest authority in the process of quality assurance, which is responsible for monitoring, securing and improving quality in all areas. School pays special attention to the systematic monitoring and improving the quality of academic programs, teaching process, scientific and professional work, evaluation of students, textbooks and literature, resources, non-teaching support and management.

**Keywords:** Quality assurance, school, standards, mission, vision, SWOT analysis, action plan

### INTRODUCTION - STRATEGY FOR QUALITY ASSURANCE

Higher School of Applied Professional Studies in Vranje adopted the Strategy for Quality Assurance. In these primary and general development document in the area of quality assurance is defined mission, vision, objectives, goals and principles of the institutional system security and improve quality, also are determined the area of quality assurance and quality assurance system operators, quality assurance measures and mechanisms of implementation quality assurance system and action plan.



Figure 1. Location of the municipality of Vranje within Serbia

The aim of the quality management system, which establishes by this specified document is to provide high quality standards of education, scientific research and professional work in order to create the conditions for the inclusion of schools in European Higher Education Area and to contribute to the development of the community in terms of the general transformation of society.



Figure 2. Serbia – map of districts

The goal of providing quality systems in the higher school of Applied Professional Studies in Vranje is optimally meet the demand for

quality higher education in Serbia in the long term, particularly for education-specific profiles for the education system, then the community's needs for the development of competence and skills of human resources, at the same time with satisfaction of employed in schools. Guaranteeing and continuous improvement of quality will be achieved the highest level of quality study programs, teaching process, scientific research and professional work, continuous improvement of the overall business and developing a culture of quality, which will allow Higher School of Applied Professional Studies to become a modern and attractive multi-disciplinary school.

The Strategy emphasizes the responsibility of schools to monitor, improve and develop the quality of work. The strategy expresses willingness of teachers to schools teaching activities performed while maintaining high quality standards, to be included in the process of European integration in higher education and the quality of our services provide the confidence of students, employers, and the founder of the society in general. The school is strategically committed to their work permanently associated educational activities (transfer of knowledge), research activity (production of knowledge) and professional activity (application of knowledge). The main task of the school is to disseminate and promote knowledge and learning in the context of lifelong learning in the knowledge society, to stimulate creativity, to contribute to the sustainable development of communities, and to promote universal values and goals of the modern university education. School strives to maintain a high level of basic, vocational studies by international standards. Higher School of Applied Professional Studies is a complex institution that brings together different areas of technological fields, as well as the natural and social sciences relevant to the education profile who studied at the school.

By adopting the Strategy for Quality Assurance High School of Applied Professional Studies is committed to a comprehensive, stable, functional, flexible and transparent system of quality control to guarantee the compliance of quality of teaching and scientific research. The strategy of quality assurance is publicly available on the website [www.visokaskola.edu.rs](http://www.visokaskola.edu.rs).

#### QUALITY ASSURANCE MEASURES

The steps to ensure quality include the external control and internal steps to ensure the quality.

External control means:

- » External Quality Assurance, based on the standards of the National Council for Higher Education, by the Commission for Accreditation and Quality Assurance;
- » Accreditation of Schools, by the National Council for Higher Education, within the prescribed period.

The internal steps to ensure quality includes:

- » Compliance with standards adopted by the National Council for Higher Education:
  - Standards for accreditation of higher education institutions and study programs;

- Standards for self-evaluation and quality assessment;
- » Fostering a culture of quality;
- » The security quality by providing to the activities of the Commission and the Commission for the quality of self-evaluation;
- » Determining the factors that affect to the provision of quality teaching and support processes (management) related to the field at next:
  - the quality of the teaching process (programs, classes, teachers, a scientific and professional work, evaluation of students, textbooks and literature, libraries, information resources, facilities and equipment, non-teaching staff);
  - quality of management;
- » The examination of existing and potential students and the inclusion of these requirements in education;
- » The security interaction of education, the vocational and the Science paper;
- » Development and implementation of different mechanisms, tools and techniques in order to improve the quality system;
- » Ensuring that top management supports security system quality and that is to ensure that all develop skills necessary to ensure the quality system;
- » The detection, analysis and implementation experience of the leading institutions of higher education;
- » Cooperation with companies;
- » The security of the active participation of students (Student Council);
- » Conducting regular internal audits and review of the quality management system by the management;
- » Self-evaluation at intervals up to three years;
- » The security of the public in the work.

#### QUALITY ASSURANCE SUBJECTS

Provision of quality subjects are the all school employees. In addition to these important subjects providing to the quality of the students involved in school activities through studenstskog Parliament and their representative bodies in other schools. Their rights and obligations in the provision of quality of these subjects through participation in the work of schools (school council, faculty council, the Committee for Quality Assurance, Committee for Publishing, Student Parliament and its committees, etc.), and through everyday use and improvement of the management process quality. The rights and obligations of all entities providing quality schools are regulated by the statute and relevant regulations (Regulations for Publishing, Rules for self-evaluation and quality assessment, etc.). All subjects have the right and obligation to participate in quality assurance in their workplace, and through participation in the body to ensure quality.

In addition to human subjects important quality assurance are space, laboratories, equipment, library holdings and information support to all work processes.

– Bulletin of Engineering

For the implementation of quality improvement measures, the Commission is responsible for self-evaluation and quality assessment.

**Areas of quality assurance**

In order to achieve the set of basic tasks and goals, the school pays special attention to the systematic monitoring and quality improvement in the following areas:

- » the study programs,
- » teaching process,
- » a scientific and professional work,
- » evaluation of the students,
- » textbooks and literature,
- » resources,
- » non-teaching support
- » management.

**SWOT analysis**

» **S (STRENGTH)**

1. Excellent geographical location. ++
2. Excellent structure and content of the study programs (some of them are unique in Serbia: Wood technology and production economics). +++
3. Excellent spatial conditions. +++
4. Quality assessment and self-assessment in all areas of quality assurance. ++
5. Good professional staff. ++
6. Incentives for young teachers and staff in the further development of the country and abroad. ++

» **W (WEAKNESSES)**

1. Inadequate research. ++
2. Low participation in development and professional projects. ++
3. Inadequate nurturing the spirit of inquiry and critical thinking of students. +
4. The level of quality of students enrolled in certain programs of study. +++

» **O (OPTIONS)**

1. The economy is still doing relatively well („Alfa Plam“, „Simpo“, „Bi water“, „Zivinoprodukt“ etc.) provides opportunities for the quality of professional practice. +++
2. Wide geographical area covered by the Higher School of Applied Professional Studies provides an opportunity to introduce new study programs. +++
3. The favorable geographical position provides an opportunity for cooperation with similar institutions of higher education in Macedonia, Greece and Bulgaria. ++

» **T (THREATS)**

1. The difficult economic situation that may endanger the structure of vocational studies. +++
2. Lack of funds may result in a reduction of quality in all aspects that define quality. +
3. Low participation in professional projects may affect the weaker development of teachers and staff, and therefore the quality of

their work with students, as well as the downgrade of the School. ++

Quantification of the previous estimates of the categories defined in the following way:

- +++ - Highly significant
- ++ - Medium significantly
- + - Little significant
- 0 - No significance

**Proposed measures and activities to improve the quality**

In accordance with the orientation defined in the Strategy of "quality assurance measures", need the following:

- » the competent authority of a Higher School of Applied Professional Studies conducted periodic review and improvement strategies, based on the acquired insight into the results of operation of the quality management system (monitoring and measurement provided for in the Rules of self-evaluation and includes the following standards (Annex 1.4.).
- » strategy to ensure continuous quality is operationalized appropriate action plans, according to the baseline defined in the Strategy for Schools.

**STANDARDS AND PROCEDURES OF QUALITY ASSURANCE**

Higher School of Applied Professional Studies Vranje with a specific document adopted standards and procedures to ensure a minimum level of quality for each area to provide standards for self-evaluation and quality assessment of higher education institutions. Baseline Higher School of Applied Professional Studies in Vranje in the field of providing quality management are the following documents:

1. Law on Higher Education (The Republic of Serbia official messenger, No. 76/05)
  2. The Bologna Declaration which our country signed in 2003.,
  3. Ordinance on standards for self-evaluation and quality assessment of higher education institutions (The Republic of Serbia official messenger, No. 106/2006)
  4. Ordinance on standards and procedures for the accreditation of higher education institutions and study programs (The Republic of Serbia official messenger, No. 106/2006)
  5. Statute Higher School of Applied Professional Studies in Vranje.
- Development of standards and procedures for quality assurance based on the above-mentioned documents, which the school defines the following acts:
1. Strategy for Quality Assurance,
  2. Regulation of self-evaluation and quality assessment study programs, teaching and working conditions, which is adopted by the Governing Board Higher School of Applied Professional Studies in Vranje), and in which certain specific procedures for monitoring and measuring the quality of schools as institutions of higher education;
  3. Ordinance on the books and the publishing industry, which was adopted by the Governing Board of the High School of Applied Professional Studies in Vranje

4. *Statute of Higher School of Applied Professional Studies in Vranje. Implementation of the adopted documents of the school precisely defined standards and procedures for ensuring the quality of study programs, teaching process, scientific research, monitoring and evaluation of students, textbooks and other literature, resources, non-teaching support and management processes. To maintain the quality of all aspects of the work Higher School of Applied Professional Studies in Vranje Commission are responsible for self-evaluation and assessment of the quality of study programs, teaching and working conditions in schools, as well as of management/leadership in the school. Commission for self-evaluation and assessment of the quality of study programs, teaching and working environment in the proposed legislation which operationalize the activities of quality assurance in all aspects of quality assurance.*

*Strategy and mentioned rules are publicly available on the school website [www.visokaskola.edu.rs](http://www.visokaskola.edu.rs)*

**SWOT analysis**

» **S (STRENGTH)**

1. *Mainstay of the economy - a direct application of study programs . + + +*
2. *Uniqueness of individual study programs ( Wood technology and production economics) . + +*
3. *Quality implementation of programs of study and professional practice in particular. + + +*

» **W (WEAKNESSES)**

1. *Low participation of industry experts in the implementation of professional practice. + +*
2. *Low participation of industry experts as guest lecturers in teaching curricula. + + +*

» **O (OPTIONAL)**

1. *The involvement of industry experts in the implementation of professional practice with the prior provision of financial resources. + + +*
2. *Communication with related scientific and educational institutions in order to improve academic programs. + +*
3. *Donations for the purchase of equipment. + +*

» **T (THREATS)**

1. *The instability of the economic environment due to the economic crisis. + +*
2. *Lack of involvement of experts from the industry to engage in professional practice. + + +*

*Quantification of the previous estimates of the categories defined in the following way :*

- + + + - Highly significant
- + + - Medium significantly
- + - Little significant
- 0 - No significance

**Proposed measures and activities to improve the quality of standards and procedures for quality assurance**

*The adoption of the Strategy for Quality Assurance, then the standards and procedures for quality assurance, self-evaluation of the Rules, the Rules of textbooks and other books of rules, and their publication, met the starting level of quality assurance.*

*In accordance with the commitment in the Strategy and Regulations self-evaluation, the following is needed:*

- » *the Commission for self continuously monitors implementation of all tasks within the improvement and quality assurance, as well as evaluating the implementation of action plans for quality assurance;*
- » *proposes to operationalize procedures for quality assurance and adaptation in specific areas of the School as a higher education institution;*
- » *stated that the Commission proposes to periodically measure the improvement and development of new standards and measures for ensuring and improving the quality and quality management system;*
- » *to all school employees, in accordance with its obligations and business functions, contribute to meeting this standard;*
- » *comparison and analysis study programs with similar schools and institutions.*

**QUALITY ASSURANCE SYSTEM**

*Institutional quality assurance system has been established and governed by the Statute Schools, The Strategy Quality Assurance and Regulations on self-evaluation.*

*Monitoring and ensuring the quality of schools is based on providing a new system that provides transparency, internal and external quality assessment, interpersonal, and time comparison of the quality of work, the development of a quality culture, raising awareness of the importance of achieving quality standards, undertaking academic and administrative measures in order to overcome perceived weaknesses and problems, and based on that the integrity and uniqueness of the system.*

*The basic preconditions Quality Assurance System were established by forming the competent authorities and the Commission, as well as supporting documents and determining the roles, tasks and responsibilities of each entity in the system of quality assurance. In order to maintain and further improve the quality of work in certain areas of activity Higher School of Applied Professional Studies Vranje, in accordance with the Regulations on self-evaluation, the school the established a body responsible for quality assurance: Commission for self-evaluation and assessment of the quality of study programs, teaching and working conditions in school.*

*Commission for self-evaluation and assessment of the quality of study programs, teaching and the conditions of work in schools is the highest body in the process of quality assurance, which is responsible for monitoring, securing and improving quality in all areas. The Commission has five members: three members from the ranks of*

teachers, one from the group of students, one member from the non-teaching staff. Decision of the Academic Council, is determined by the composition of the Commission for self-evaluation and assessment of the quality of study programs, teaching and working conditions in school.

By Statute of the Schools, Strategy for quality assurance and the Ordinance on self-evaluation, provided the student participation in decision making and implementation of strategies, standards and procedures for quality assurance.

Students are involved and play an active role both in the process of self-evaluation, and in the process of defining quality policies in the school. The active role of students in the process of quality assurance is carried out: the work of student organizations and student representatives in the bodies of schools, student representatives participate in the work of quality assurance, periodic evaluation of the quality study programs, all elements of the teaching process, the literature of library and information resources, educational activities teaching staff and services through surveys, opinion on all general school acts which establish strategies for quality assurance and regulating standards and procedures for quality assurance.

Standards for quality assurance include a minimum level of quality of schools, to ensure the achievement of the mission and goals of the Schools. The strategy is determined by the quality of the methods for quality assurance, which include standard procedures for monitoring and quality control, and a system of incentives and corrective measures whose application ensures the achievement standards that guarantee a satisfactory level of quality of all segments of the educational, research and professional work of the school.

#### SWOT analysis

##### » S (STRENGTH)

1. The continuing work of the Commission for self-evaluation and quality assessment throughout the year. + + +
2. Maximum involvement of all the members of the self-evaluation. + +

##### » W (WEAKNESSES)

1. A relatively small number of the members of the self-evaluation and quality assessment. + + +

##### » O (OPTIONAL)

1. The inclusion of new members from the teaching staff in the composition of the Commission for self-evaluation. + + +

##### » T (THREATS)

1. Lack of financial resources. + +

Quantification of the previous estimates of the categories defined in the following way:

- + + + - Highly significant
- + + - Medium significantly
- + - Little significant
- 0 - No significance

#### **Proposed measures and activities to improve the quality of quality assurance system**

Establishment of institutional quality assurance system, the adoption of appropriate by-laws and constitution of the appropriate Commission as a body of quality assurance, achieved as a starting point for meeting the demands of a third standard.

In accordance with the commitment in the Strategy of quality assurance and adopted regulations, that the application of this standard continues to grow, you need the following:

- » Consistently implement planned procedures and measures for ensuring quality;
- » Systematically monitor the implementation and evaluate the effectiveness of implementation;
- » Systematically measure the effects of these measures;
- » Monitor the effectiveness of structural and organization model applied to quality assurance and the need to propose new solutions,
- » Establish institution cyclical self-evaluation and action planning to establish a system that encompasses a continuum of the following activities: planning quality assurance, implementation of quality assurance procedures, checking quality and quality improvement;
- » Provide institutional support to individuals and organizational units to improve the quality of activities.
- » Implement corrective measures to improve freshmen

#### **CONCLUSIONS**

Higher School of Applied Professional Studies Vranje is a serious public higher education institution with a tradition of thirty-nine years. As such it defines the mission, vision, goals, commitment and principles of institutional security systems and improving the quality, determine the area of quality assurance and the subjects of the quality assurance system, quality assurance measures and mechanisms of implementation quality assurance system, and an action plan. The foundation of Higher School of Applied Professional Studies in Vranje in providing and managing quality are the Law on Higher Education, and the Bologna Declaration which our country signed in 2003., the Regulation on standards for self-evaluation and quality assessment of higher education institutions, Regulation on standards and procedures for the accreditation of higher education institutions and study programs and the Statute Higher School of Applied Professional Studies in Vranje.

Guaranteeing and continuous improvement of quality will be achieved the highest level of quality study programs, teaching process, scientific research and professional work, continuous improvement of the overall business and developing a culture of quality, which will allow to Higher School of Applied Professional Studies become a modern and attractive multi-disciplinary school.

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## ***PARTIAL REPLACEMENTS OF FINE AGGREGATE WITH POLYPROPYLENE FIBRES IN REINFORCED CONCRETE SLABS***

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**Abstract:** Package water nylon (Polypropylene) waste seems uncontrollable in some parts of the world, where they cause harm to the environment and living organisms. Disposal of this waste has been a major problem especially in most third world countries. This paper researched into the effective use of recycled polypropylene as partial replacement of fine aggregate in concrete. Tests such as specific gravity and sieve analysis were carried out on the recycled polypropylene waste. Concrete slabs (600mm x 400mm x 50mm) and cubes (150mm x 150mm x 150mm) were made from the mixture of the recycled material at different percentages of 0%, 4%, 8%, 12% and 16%. The slabs were subjected to flexural test while the cubes were subjected to compressive strength test. Results revealed that 56.29% of polypropylene fibres were retained on the 4.75 mm sieve, the specific gravity of the material was 0.73. The compressive strength of the 4% mixture was 16.28 N/mm<sup>2</sup> while the control was 19.07 N/mm<sup>2</sup>. The flexural test showed the crack width for the control as 1.79 mm, while that of 4% mixture was 2.73 mm, the 12% mixture gave the largest crack width of 6.08 mm. Deflection in the polypropylene mixes are generally higher than the control. The work concluded that at a maximum 4% mixture, the recycled waste can be used as partial replacement of fine aggregate in concrete.

**Keywords:** Polypropylene fibres, Fine aggregate, Concrete slabs, crack width, Deflection

### **INTRODUCTION**

Environmental pollution is the outcome of improper waste management in highly populated countries such as Nigeria, India, Brazil, etc, where polypropylene materials are used in packaging. In these countries waste generation is high and management is somewhat poor. One of the ways to manage this waste is the re-use of waste materials itself. According to Dynaab (2014), Nylon (Polypropylene), invented in 1928 by Wallace Carothers (DuPont) is considered to be the first engineering thermoplastic, and it is a non-biodegradable material.

The production of conventional concrete is achieved by the use of natural materials which has been the practice for so many years and thereby leading to the reduction in the readily available construction materials on the earth surface.

Sachin et al. (2012) expressed the fact that, to meet the requirements of globalization, in the construction of buildings and other structures, concrete plays the rightful role and a large quantum of concrete is being utilized. River sand, which is one of the constituents used in the production of conventional concrete, has become highly expensive and also scarce. In the backdrop of such a bleak atmosphere, there is large demand for alternative materials from industrial waste. Aitcin (2003) also emphasized this, stating that although High Performance Concrete (HPC) has found widespread application, its production is still limited in many countries because suitable concrete aggregate

such as river sand, gravel or hard crushed aggregate are either not available or are available only in little quantity. Murali et al. (2012) also said the high consumption of raw materials by the construction sector, results in chronic shortage of building materials and the associated environmental damage.

According to Kamkam and Odum-Ewuakye (2006), most developing countries where more than 70% of the population lives in improvised villages, are often confronted with acute housing shortage due to their over-dependence on rather expensive imported materials. It is imperative therefore for researchers in such countries to fully exploit locally available materials to meet their housing needs.

Several researches are based on the use of recycled waste material in the production of concrete. Gautam et al. (2012) replaced fine aggregate with glass waste and concluded that the presence of 10% glass waste in place of fine aggregate, the compressive strength at 7 days is found to increase by about 47.75% on average. Seeni et al. (2012) in a research on the studies of partial replacement of fine aggregate with waste material from China clay industries also concluded that the waste material from china clay industries can be used as a replacement for fine aggregate. It is found that 30% replacement of fine aggregate by industrial waste give maximum result in strength and quality aspects than the conventional concrete.

The results proved that the replacement of 30% of fine aggregate by

the industrial waste induced higher compressive strength, higher split tensile strength and higher flexural strength.

Aggregates are the important constituents in the concrete composite that help in reducing shrinkage and impart economy to concrete production. Most of the aggregates used are naturally occurring aggregates, such as crush rock, gravel and sand which are usually chemically interactive or inert when bonded together with cement (Keerthinarayana and Srinivasan, 2010).

Several waste materials have been channelled into replacing fine aggregate in concrete, majority of which are to reduce the waste of used polymer materials and to solve the problem of material shortage.

The abundance of water packaging nylon (polypropylene) in third world countries which are disposed off indiscriminately after use is an eye sore; this material generates irritation to the environment by polluting it because of its non-degradable property.

Several approaches have been thought of and put into practice on how to manage/control this particular type of waste. In that case, after use, where does it go? Where is it supposed to go? How has it been managed? What is the outcome of the on-going methods of management? Are the questions to be asked?

Adetunji and Ilias (2010) while carrying out research on waste generated from polypropylene sachets gave the report that almost every nook and cranny in Nigeria is littered with sachet water nylon, popularly called "pure water", the large volume of which in ordinary parlance, constitutes pollution and termed negative externality or economic 'bad' in economics. This is as a result of millions of used sachets being thrown on daily basis onto the streets of virtually every city, town, and village in Nigeria. This is a fact as majority of the populace rely on the consumption of water packaged in this form because it is associated with ease of access and cost of purchase is somewhat affordable by the majority. The most beneficial way of managing this waste is the recycling which is still at the verge of development in some countries of the world. Poor waste management such as burning is practised in some countries and one of the most effective ways of controlling waste is the reduction of waste. Burning of waste particularly inorganic waste leads to the emission of harmful substances into the atmosphere which is highly detrimental to the life of living things. This is similar to the explanation made by Adetunji and Ilias (2010) that, in the case of sachet water, it is not only the litterbugs (or the pure water consumers) that are affected but also the non-consumers and the entire environment. This is because burning the packaging lowers the quality of the air that both the consumers and non-consumers breathe in, gives off stench, and causes harm through the release of toxic gases and smoke. It also causes environmental problems such as acidification, eutrophication, the greenhouse effect (or global warming), smog, and ozone loss.

Waste products of polymers are made from inorganic compounds which makes them vary in characteristics. This was also confirmed by

Veera (2010), who stated that "Each waste product has its specific effect on properties of fresh and hardened concrete". Waste materials of polymer are lightweight materials; this limits their application to some extent depending on the technique of use, for this reason, structures constructed to carry loads should also not be light to the degree at which it will not serve its function.

Due to rapid industrialization and urbanization in most third world countries, lots of infrastructure developments are taking place. This process has in turn led to the question of how mankind will solve the problem of population growth. The problems defined are acute shortage of constructional materials, increased dumping of waste products (Suganthi et al. 2013). Hence in order to overcome the above said problems waste products should be employed as construction material.

Replacing fine aggregate in the concrete with waste materials such as water packaging nylon could be an alternative to the materials used as fine aggregate in concrete. Since up to approximately 80 percent of the total volume of concrete consists of aggregate, aggregate characteristics significantly affect the performance of fresh and hardened concrete and have an impact on the cost effectiveness of concrete, (Hudson 1999).

River sand, which is one of the constituents used in the production of conventional concrete, has its price increasing with time due to several factors such as distance and location, cost of dredging, and so on, thereby making it a scarce commodity, (Shetty 2009) also stated that, in years to come, natural sand will be exhausted or costly, hence there is the need for manufactured or artificial sand. As a result of this, there is large demand for alternative materials from industrial waste. The focus of this research is based on the addition of recycled polypropylene as fine aggregate in concrete mixes and to examine the properties and performance of reinforced concrete slab under axial loads.

## METHODOLOGY

### Sieve analysis

The polypropylene fibres were obtained from shredded water pack made from nylon, the sieve analysis of the shredded waste material was also carried out.



Figure 1: Recycled Polypropylene fibres

The sieve used was that of AASHTO specified. 500g of the recycled nylon material was measured on the digital scale and poured into the sieve no 1 (top sieve). It was shaken for about 5- 7 minute, the shaken continued until there are no more particles passing through the sieves. The mass of samples retained in each sieve was measured and results were recorded. Figure 1 showed the shredded polypropylene fibres.

**Specific gravity**

The specific gravity of the recycled nylon following the standard of ASTM D 854-00 standard test for specific gravity of soil solids by water pycnometer was carried out. The specific gravity was calculated using the equation below.

$$\text{Specific gravity, } G_s = \frac{W_0}{W_0 + (W_A - W_B)}$$

where:  $W_0$  = weight of sample of oven-dry soil,  $W_A$ = weight of pycnometer filled with water + sample,  $W_B$ = weight of pycnometer filled with water

**Preparation of test specimen**

The concrete specimens were made from the combination of different percentages of the polypropylene material. The different proportions are 0%, 4%, 8%, 12% and 16%. Each percentage of polypropylene is represented with two samples of slabs of size 600 x 400 x 50 mm. The casting of the slabs was carried out with thorough mixing of the concrete using concrete mixer. The mixed concrete was placed into the corresponding formwork and compacted; the formwork was removed after 24 hours of setting. The concrete slabs from each sample mix were cured by wetting daily and test was carried out on them after 28 days of curing.

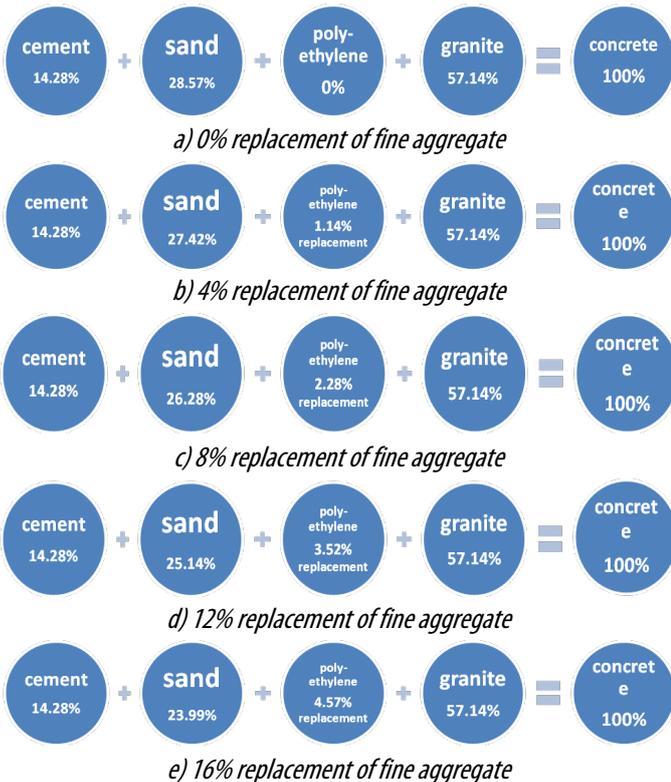


Figure 2: The detail mix ratios

A mix ratio of 1:2:4 was used with water cement ratio of 0.75. The water cement ratio was used due to the high absorption of water by the polypropylene mixture in concrete. The first mix was with 0% of the polypropylene material. The batching by weight process was used. The size of granite used was ½ inch (12mm) and the local fine aggregate popularly called sharp sand was used. Measurements of individual materials were carried out for each mix before pouring into the concrete mixer. The mass of the fine aggregate was measured for and the percentage of polypropylene to be used was subtracted from the mass of fine aggregate for all corresponding percentages. The detail mix ratios are shown in Figure 2.

**Compressive strength test**

Concrete cubes for each mix ratio were cast and subjected to compressive forces to determine the compressive strength of the concrete after 28days. This is done by applying compressive axial load to the moulded cubes at a rate which is mild and continuous until failure occurred.

**Flexural strength test**

Flexural strength test was carried out on the concrete slabs after 28days. This test determines the bending strength of the concrete.



Figure 3: Slab specimen undergoing 3 points loading

The slabs were placed under the universal testing machine and subjected to a third point loading (Figure 3). It was subjected to continuous loading until failure occurred. Crack lengths and widths were measured and the deflection with increasing loads was determined.

**RESULTS AND DISCUSSION**

**Sieve analysis results**

The test was carried out on the recycled polypropylene material and the result is shown in Figure 4. From the result obtained, 56.29%, 20.28%, 16.48%, 5.83%, 0.88%, 0.23% of the recycled material was retained in 4.75 mm, 2.36 mm, 1.18 mm, 600 µm, 300 µm, 150 µm

diameter sieves, respectively. Greater percentage of the polypropylene grain was retained in the 4.75 mm sieve; this showed that the material can be used as partial replacement for fine aggregate in concrete since the standard size for fine aggregate in concrete is 4.75 mm or less.

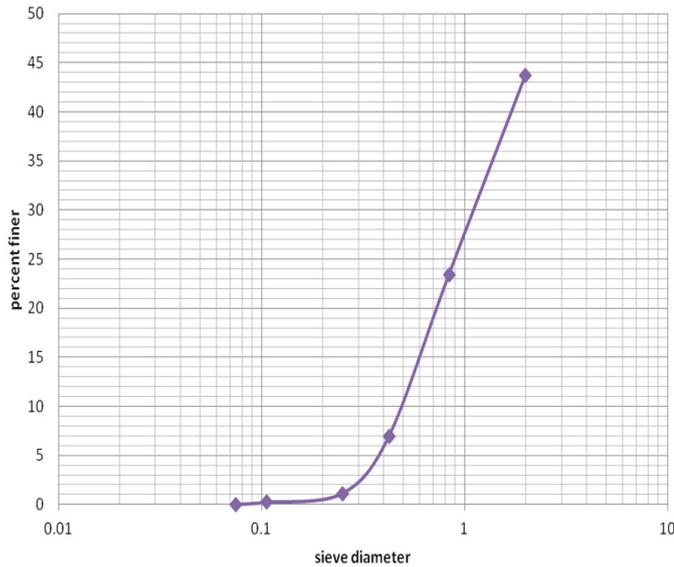


Figure 4: Grain size distribution for polypropylene materials

**Specific gravity**

Result of specific gravity of the substance shows 0.73 as calculated. This indicates that the density of the material is 730kg/m<sup>3</sup>. The result of the specific gravity test shows that, the material has a low density compared to the density of the natural sand. While carrying out the test, the recycled nylon floats on water unlike the natural sand which settles under its own weight. The average specific gravity for rocks that are commonly used as fine aggregate vary from 2.6 to 2.8, the 0.73 obtained for the polypropylene fibre is low, this is because the material is a product of hydrocarbon, which naturally have low density, but using it as a partial replacement for sand in concrete is a technology that must be well researched into.

**Compressive strength test**

Compressive strength being the failure load of a concrete cube or cylinder per unit area indicates the mechanical and durability properties of the concrete mix. After 28days of curing, the cubes were subjected to crushing under the Universal Testing Machine. The result revealed that control concrete cubes have a compressive strength of 19.07 N/mm<sup>2</sup> this low strength was obtained because of the high water cement ratio used in the experiment, the 4% mix gave a compressive strength of 16.28 N/mm<sup>2</sup>. Although there was a general reduction in compressive strength when polypropylene fibres were added to the concrete, this is because concrete is like a chain in which aggregates are the links bonded together by cement paste, the strength of concrete is depended on the bond strength occurring within the concrete cement paste, the introduction of polypropylene fibre which is fluffy, water repellent and insoluble in the cement matrix reduces the bond strength, hence the low compressive strength obtained from all the specimen that contained the fibres.

Any mix less than 4% can be used for partial replacement in concrete, especially in light weight concrete. Figure 5 showed the detail results.

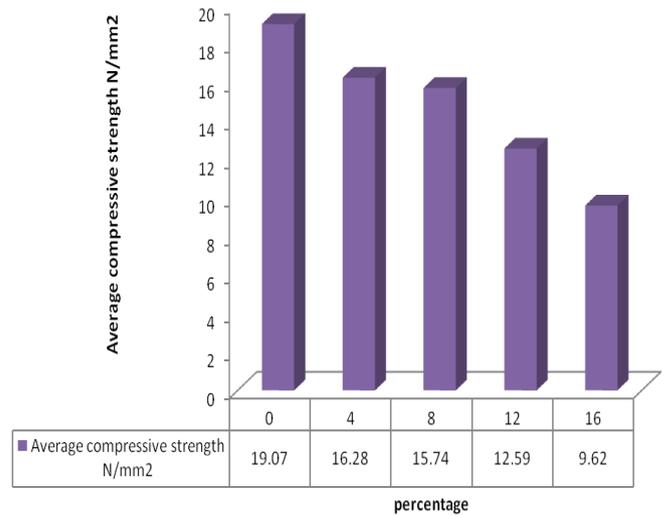


Figure 5: Compressive strength test result

**Flexural test**

Reinforced concrete is very unique in its behaviour, and this has made it popular as construction material. In solid slabs; at flexural failure, concrete slabs develop hinge lines. A hinge line causes much of the reinforcement passing through it to resist the moment along its length, contributing to the safety of the slab. The largest flexural strains therefore occur at the point of load application, consequently, cracking initiates at the soffit of the region, from where the cracks then spread rapidly to the edges of the slab with increasing load to collapse (Kankam and Odum-Ewuakye 2006).

In addition as reported by Kankam and Odum-Ewuakye (2006), collapse of slabs may occur either through flexural failure caused by the crushing of concrete and/or fracture of the tension bars. The modes of collapse therefore depend on the amount of reinforcement, concrete strength and the effective depth of the slab (Aalamin 2005). From the test carried out on the entire specimen (slabs), gradual increase in load showed corresponding deflection in all the specimen. With the continuous application of loads, the slabs started showing cracks gradually until the specimens can no longer resist the applied load. The control mix failed at 48 kN load with a final deflection of 3.75 mm, the 4% and 8% mix failed at 40 kN and 36 kN, final deflections were 5.8 mm and 7.5 mm respectively, while the 12% and 16% replacement failed at 34kN and 22 kN load respectively. Deflection and the extent of cracking of a reinforced concrete slab are highly dependent on its support conditions, nonlinear and inelastic properties of concrete and the surrounding structure (Gilbert 2005). The initial load at which deflection was observed; failure load and final deflection are shown in Figure 6. However, increase in percentage of recycled nylon waste led to the slab showing significant deflection at reduced load and within increased time. There was no significant recovery of the slab at complete failure because the elastic limit was exceeded.

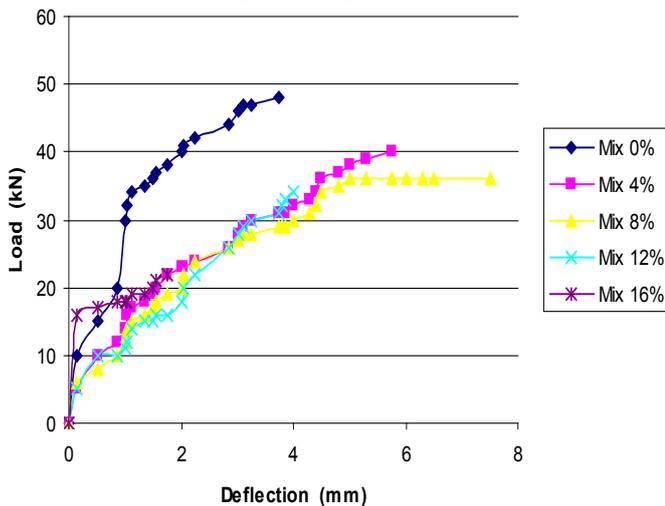


Figure 6: Deflection of samples under load

**Cracking and failure loads**

The crack width at the middle and the two edges were measured, and the average crack width was obtained. From Table 1, crack width was minimal and gradually increased with increase in the percentage of polypropylene fibres in the concrete, but 0% mix showed the lowest crack width of 1.79 mm, while the 12% mix gave the highest crack width of 6.08 mm. Further increments in load on the reinforced concrete slab led to disintegration between polypropylene material and other concrete materials like coarse and fine aggregates with cement. This must have been as a result of poor or loose bond between the concrete matrix, iron reinforcement and the polypropylene fibres. Ductile properties such as cracks and deformation before failure is an important stage regarding the load bearing capacity of reinforced concrete members, the unique ductile behaviour observed in the slab specimens especially the partially replaced samples was evidence by the large crack width observed.

Table 1. Cracks at failure loads

Replacement Ratio %	Crack Length (cm)	Crack width (mm)			Average Crack Width (mm)
		Right Edge	Mid-way Left Edge	1.575	
0.	45.25	1.725	2.06	1.575	1.79
4.	43.25	2.52	2.805	1.995	2.73
8.	30.85	6.255	5.515	4.60	5.45
12.	45.50	6.39	5.28	6.575	6.08
16.	42.00	6.13	5.63	5.575	5.775

**CONCLUSIONS**

Laboratory test were performed on all slabs and cubes that were made from the replacement of fine aggregate in varying percentage in concrete. The result showed that there is a good possibility of utilizing partially replaced aggregate in concrete for Civil engineering construction with careful consideration given to the percentage of recycled waste. The water demand for proper mix of the concrete increases as the percentage of the recycled waste increases. The weight of the cubes and slabs decreases gradually with increase in recycled waste in the mix. The difference between concrete slab and cube at 0% replacement and slabs and cubes with 4% replacement is

not more. The gradual increase in parentage of recycled waste in concrete, led to drastic reduction in strength. The positive response of the concrete with 4% replacement of fine aggregate should encourage the use of such concrete in construction to aid waste management around the world. Waste commonly generated apart from polypropylene waste should be examined for their usefulness in civil engineering materials and deep study should be carried out on polypropylene use in concrete mix with more tests carried out such as response to heat, seismic activities and so on.

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## DISASTER MANAGEMENT SYSTEM OF PAKISTAN

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**Abstract:** Disasters, natural or manmade, are part of challenges faced by human beings while they are living on the earth in any community. One thing common with all the disasters is that they cannot be averted. For the nations, the task is to deal with circumstances emerging sequel to any disaster. This paper is focused on the analysis of Disaster Management (DM) system in place in Pakistan. It initiates with an insight into the challenges faced by the country while focusing only on major natural disasters like earthquakes and floods that are perpetually causing damage to life and property over the years. Nevertheless, other significant challenges have also been enlisted. This is followed by a review of the system that has been put in place by the government to deal with the situation created consequent to any disaster. In this part, a detailed analysis of the organization and functioning of various bodies has been discussed; highlighting the shortfalls in resources and the methodology employed to apply these resources. At the end, pertinent recommendations have been proffered to address the observed shortfalls. Mainly, the paper is a summary of a host of writings available on the issue, prepared with a focused approach towards core issues prevalent in our country with regards to disaster management. Apart from studying the articles and analyses available on the issue, direct consultation has also been made to official documents of concerned government bodies.

**Keywords:** Disaster management, challenges, natural disaster, Pakistan

### INTRODUCTION

Pakistan is a 3<sup>rd</sup> World, underdeveloped country and is densely populated. A review of DM policies and System states "Situated between latitudes 24 and 37 degrees north and longitudes 62 and 75 degrees east, it covers a total land area of 796,095 sq km". Pakistan is prone to various forms of disasters due to diverse land and climatic conditions. Provinces of Gilgit-Baltistan (GB), Balochistan and AJK are highly susceptible to disasters being vulnerable seismic regions. Punjab and Sindh, especially the low lying areas, perpetually suffer from floods. Each year, colossal damage to life and property is experienced by the populace as a result of one or the other form of natural disasters.

Disasters cannot be averted; nevertheless, consequent damage can be significantly controlled with a planned approach towards DM. After years of unfortunate experiences, some actions have been initiated by the government to meet these continual challenges. Governing bodies for DM have been put in place, however, it is evident from the latest disasters faced by the nation that there is a lot left to be done to mitigate losses and alleviate the sufferings of people in affected areas. Disasters are perceived to be a result of insufficiently and incompetently managed risks [1]. These risks arouse consequently by a combination of hazards and vulnerabilities. Hazards striking the areas with low vulnerability will never become disasters, as is the case in less populated regions. Natural disasters can set back years of urban development by destroying infrastructure with colossal human and material losses. A report suggests "Approximately, over 90% victims of disasters in the world are habitants of developing countries", and the consequent losses and damages are about twenty times more in developing nations as compared to developed countries [2].

In addition to natural disasters like floods and earthquakes, incidents like outbreak of fires, train accidents and industrial accidents are also experienced in Pakistan, with consequent damages. Magnitude of destruction caused by such disasters can be significantly lowered if proper procedures are in place. Generally, however, it has been observed that there is a lack of planning and coordination between various agencies/ setups responsible to deal with such situations. Moreover, critical deficiencies in resources also come to limelight when any disaster of this kind occurs in the country. In addition to the deficiencies pointed out above, which by and large fall in the domain of government, a general lack of awareness in the public is also a major factor contributing towards an incident or accident getting into the realm of Disaster. Knowledge of DM is the only effective step in which one can ensure participation of the general public wholeheartedly [3]. Therefore, any DM Regime is of use only when some degree of awareness to the general public about the disaster is imparted. DM is all about applying adroit ways and methods of controlling a disaster. While the occurrences of disasters in Pakistan are many, only the salient ones have been short listed and will be subsequently discussed. These have been categorized according to their scope and gravity, which either require an effort of all relief agencies, including armed forces or those which only require intervention of one or few concerned agencies. Likewise, the ones on broader scale are being classified as disasters, while the others are termed as crisis.

### CHALLENGES FACED BY PAKISTAN

#### Natural and Manmade Disasters

As highlighted above, Pakistan being an under developed and densely populated country is prone to a large spectrum of disasters;

both natural and manmade. Salient ones are discussed in subsequent paragraphs [4].

- **Earthquakes.** Pakistan lies in an earthquake prone seismic area and therefore it is likely to suffer frequent earthquakes. Mountainous ranges of Himalaya, Hindu Kush and Karakoram are significantly vulnerable. The earthquake hazard is also derived from Pakistan’s position on the eastern margin of the collision between Indian and the Eurasian Plates. The result is the potential for major earthquakes in the north, where the Indian Plate thrusts under the Himalayas and along the western edge of the country, while transverse motion of the Indian Plate relative to the Iranian and Afghan micro-plates results into Chaman fault. The Arabian Plate sub ducts beneath the Iranian Plate along Makran Coast, where the 1945 earthquake of 7.9 magnitudes resulted in a tsunami with 12 meters high waves. Karachi has significant seismic risk due to several nearby faults. Chronology of the major earthquakes of the area constituting Pakistan is appended in Table 1.0.

**Table 1: Major Earthquakes of the Pakistan**

Year	Area	Magnitude	Casualties
1909	Loralai-Sibi	7.0	100
1929	Buner-Hazara	8.0	Data not available
1935	Quetta	7.7	35,000
1939	Badakhshan	6.9	Data not available
1945	99 km SE of Gwadar (at sea)	8.2	Plus of 4,000
1974	Swat & Hazara	6.2	5,300
1981	GB	6.1	220
1997	Harnai	7.3	50
2001	Kutch (Bhuj)	7.7	20,023
2002 (3)	GB-Astor	5.5, 5.3, 6.3	11,723
2005	Muzaffarabad & Balakot	7.6	80,361

- **Floods.** Generally floods occur due to high to moderate intensity rainfall over sufficiently longer duration. S. Sreekesh states “Flood can also occur due to dam or reservoir failure or improper management of high water level conditions in reservoirs and consequent sudden release of the water especially during the period of high intensity rainfall”. Pakistan is prone to floods as a result of heavy downpour during monsoons and its province of Punjab is most vulnerable to floods from its rivers. Katcha area of Sindh Province is also affected by these floods significantly. Recently, flash floods have occurred in Khyber Pakhtun Khawa (KPK), Balochistan and Sindh. Coastal floods in Sindh and Balochistan are rare; however the one in 2004 caused lot of damage including washing away of coastal highway [5,6]. Though Indus River System Authority (IRSA) has installed a telemetric system at each barrage and other flow control points providing useful flood forecast yet there are no worthwhile arrangements to manage floods. Irrigation and Planning departments work in isolation with little focus on managing a disaster jointly. Inadequate means at the disposal of provincial

governments, i.e. power boats, life saving equipment, relief rations, epidemic control medical etc., eventually leaves the entire responsibility on the shoulders of Armed Forces. Major floods with their effects are given in Table 2.0.

**Table 2: Major Floods of Pakistan**

Year	Financial Losses (Billion Rs)	Lives Lost	Villages/districts Affected	Area (sq miles)
1950	9.1	2,910	10,000	7,000
1959	5.9	160	11,609	29,065
1973	5.5	474	9,719	16,200
1975	12.7	126	8,628	13,645
1978	41.4	393	9,199	11,952
1992	56.0	1,008	13,208	15,140
1995	7.0	591	6,852	6,518
1996	3.5	307	3,769	3,852
1997	Data not available	607	3,245	2,300
2003	450,000 acres crops 20,000 cattles, 100,000 houses	215	10,000	400
2005		424		400
2010		1802	79	1,54,000
2011	8.9 million affected, million acres land damaged, 1.52 million homes damaged	434	16	1.7 million acres

- **Accidents in Nuclear Facilities.** Pakistan operates some nuclear fuel conversion, research and weapon grade enrichment facilities that could be prone to nuclear accidents. Fortunately, no major accident has occurred on any of these sites, primarily as a result of adherence to procedures and cognizance of nuclear safeguards.

**Various Crisis Situations**

- » **Tropical Cyclones.** Cyclones usually occur between April & May and from October to December. According to a research “Cyclonic storms cannot be prevented; only the loss of lives and damage to the properties can be mitigated if prompt action is taken after receiving timely warnings”. Cyclones can cause huge damage to the coastal belts of Balochistan and Sindh. 14 Cyclones were recorded from 1971 to 2001.
- » **Droughts.** Generally, these occur when a region receives consistently below average precipitation. Very little rainfall occurs in Balochistan, parts of Sindh and south-eastern parts of Punjab. These areas are hence most susceptible to drought. Annual wastage of 27 MAF of water into sea could be controlled and storage dams constructed to facilitate water availability for cultivation. Intense drought in 2000-02 was devastating for the affected populace of 2.2 million people.
- » **Locust Attack on Crops.** Locust attack is a sort of pest plague that can damage crops, fruits and trees. Medium sized swarms came to Pakistan from across the Indian border in late 2010, which settled and bred in Ghotki and Bahawalpur desert areas, sparking fears that the total cotton production may fall further after the floods which had “damaged two million bales earlier”.

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- » **Major Fires in Oil and Gas Wells.** Natural as well as human induced fires are common in Pakistan. Apart from causing human and wildlife loss, they have disastrous effects on the environment and economy. Forest fires are common in AJK, KPK, Murree and Margalla. Fires in urban commercial and residential centres as well as rural areas are also frequent as exemplified by recent factory fires in Karachi causing tragic loss of life. Gas and oil fields, transmission lines and oil depots are particularly vulnerable to this hazard.
- » **Health Epidemics.** Cholera is a serious health issue in Pakistan, with a large number of cases every year. Between May and Aug the disease becomes intense, due to monsoon rainfall combined with poor sewerage system and inadequate water supply. The disease involves comparatively older population and majority of the patients are poor, refugees or immigrants, living in crowded refugee camps under humble living conditions.

**SUMMARISED CHALLENGES**

Pakistan has a serious vulnerability to both natural and manmade disasters. Major natural disasters like earthquakes, tsunamis and cyclones cannot be avoided or altered but deliberately planned risk management can minimize the resulting damages both to life and property. Industrial accidents can be averted through failsafe procedures and better oversight. Disasters like floods, cyclones, drought and epidemics can be predicted well before occurrence thus allowing planning and mobilization. KPK, Northern Areas, AJK, Karachi, and Balochistan are extremely vulnerable to earthquakes. Gwadar and other big cities are also exposed to this hazard. A major earthquake has occurred once in every 8 years in the last century. Floods in Pakistan are frequent phenomena and cause extensive damage. A major flood has struck Pakistan once in every six years. Drought is also a serious disaster in Pakistan. If not addressed, it is likely to cause huge human, economic and social loss in the future. Disasters like earthquake, traffic accidents, industrial / fire hazards, etc. can occur at any time and without any warning.

Statistics show that lack of resource management and awareness in developing and under developed countries causes much more damage than developed countries. No nuclear accident has occurred in the country but there is no room for complacency. Construction of dams and barrages is becoming call of the day.

**ANALYSIS OF DM REGIME**

Pakistan's DM policies were limited to flood disasters with primary focus on rescue and relief operations. Resource constraints and neglect of departments and organizations meant to deal with disasters resulted in an inefficient DM Policy. Disasters require huge finances to cope with, however, no fund for disaster relief/management used to be placed in government's planning. In addition, the response activities have not been properly institutionalized to ensure all inclusive and coherent response e.g. Emergency Relief Cell (ERC) had only been responsible to deal with post disaster situations alone. Conventional national emergency

services such as Police, ERC, Crises Management Cell, Fire Services, Civil Defence Agency, Federal Flood Commission and Meteorological Department were the key agencies for DM in Pakistan. In case of larger emergencies Armed Forces were invariably assigned the role of DM.

According to NDM Act 2010 "The National Disaster Management Act 2010 provides National DM Commission (NDMC) as the apex body for managing disasters, with National DM Authority (NDMA) as its administrative arm". The Act also establishes DM commission and authorities at provincial as well as district tiers. A brief review of these institutions is as under [7]:

- » **National DM Commission (NDMC).** Led and chaired by the Prime Minister, its members include key Federal ministers, leaders of opposition in both the Houses, Chief Ministers of all the provinces, Prime Minister AJK, Governor KPK (also represents FATA), Chief Executive GB, Chairman Joint Chiefs of Staff Committee or his nominee, and representatives of civil society. It is mandated to formulate policies and develop guidelines for national Disaster Relief Management (DRM).
- » **National DM Authority (NDMA).** The NDMA is an executive limb of the NDMC to coordinate DRM activities at the national, provincial and district levels. The authority is responsible for preparing national disaster risk management plan, developing policy guidelines and providing technical assistance.
- » **Provincial DM Commissions.** PDMCs are the apex bodies at the provincial tier, headed by Chief Minister (CM) of the Province as ex officio Chairperson.
- » **Provincial DM Authorities (PDMAs).** PDMAs are primarily responsible for implementation of DRM plans and related activities. PDMAs have been established in Sindh, Balochistan, KPK and Punjab, whereas State DM Authorities (SDMAs) are working in AJK and GB.
- » **District DM Authorities (DDMAs).** National DM Ordinance provides for the establishment of DDMAs in all the districts of Pakistan including AJK, GB and FATA.

**RESPONSE AGENCIES**

» **Institutional Perspective.** Prior to establishment of NDMC and NDMA in 2010, there were four key agencies for DM at national level, i.e., The Civil Defence Department, Emergency Relief Cell (ERC), Federal Flood Commission (FFC) and National Crises Management Cell (NCMC).

» **National/Provincial DM Authorities (DMAs).** DMAs' vision entails achieving sustainable social, economic and environmental development in Pakistan through reducing risks and vulnerabilities with a mission to manage complete spectrum of disasters by adopting a DRR perspective in development planning at all levels and enhancing institutional capacities. NDMA is the principal coordinating body to facilitate implementation of DM with all stakeholders, including ministries, divisions, departments, and humanitarian organizations at respective

- levels for emergency response. Its functions are very generic, holistic and at macro level, mainly addressing policy formulation, coordination and monitoring, since implementation of DM has been passed on to the provinces under the Devolution Plan 2010.
- » **Civil Defence.** Civil Defence undertakes various measures for suitable response against natural or manmade disasters.
  - » **Pakistan Red Crescent Society (PRCS).** Relief & recovery besides reconstruction and capacity enhancement are the areas of main focus for PRCS.
  - » **Punjab Emergency Services (Rescue 1122).** Being the most efficient and largest emergency service in Pakistan, Punjab Rescue 1122 has a well laid out infrastructure in all districts of Punjab and is rendering good assistance to other provinces befittingly. It has very successfully rescued over 1.7 million victims while maintaining its response aptly below 7 minutes to reach incident sites. It has Rescue & Fire services and Community Emergency Response Teams in all districts of Punjab. The service is successfully placed in KPK also”
  - » **Merger of ERC and 6<sup>th</sup> Aviation Squadron into NDMA.** In keeping with the spirit of National DM Ordinance (NDMO), it has recently been proposed that the 6<sup>th</sup> Disaster Aviation Squadron, as well as ERC of the Cabinet Division be merged with NDMA, amending Rules of Business accordingly. The proposal has been concurred by NDMC.
  - » **Integration of Civil Defence Department into DMAs.** In order to streamline DM capacities at the provincial and district levels, the NDMC decided that Civil Defence Department at district and provincial levels be integrated into DDMA and PDMA, respectively. However, despite consistent pursuance by NDMA, no provincial government reported any substantial progress on the issue.
  - » **Role of Pakistan Army.** The Army’s role has always given a clear evidence of careful planning, optimal utilization of resources and sharp focus. It involved itself in every aspect of the challenges, and rendered full support in terms of resources and rescue efforts. It helped in controlling the damage to a large extent thereby saving not only lives, but also the means of livelihood.

Relief efforts are handled by NDMA, Army, Provincial Governments and international and local humanitarian organizations. Planned interface mechanism at National/Strategic level is NDMA and MO Directorate. At Provincial and Operational level is joint Coordination Group of PDMA, Provincial Government, Corps Headquarters, national NGOs and international donors. And at District level is the District management with local Brigade/ Unit Commanders.

The principal responsibility of Army is its involvement in damage control stage and revolves around rescue and relief operations to assist the civil administration as and when required. Major tasks assigned to the Armed Forces include, relief, rescue and evacuation of casualties in aid to civil power, provision of aviation and medical support besides relief and recovery utilizing available national assets,

provision of required assistance to the civil administration for camp setting, organization of medical camps, establishing tent villages and preparation of flood relief plans, and if needed the provision of requisite security during DM operations.

The Army DM Cell functions at General Headquarters to act as focal point for NDMA and nerve centre for Army DM operations. This cell is responsible for implementation, monitoring and coordination of Army policies, strategies and plans.

» **Earthquake Reconstruction and Rehabilitation Authority (ERRA)**

It was created after the earthquake of 2005 for planning coordinating and regulating the reconstruction and rehabilitation work in the affected areas. It is an umbrella organization which provides platform to all stakeholders in their post damage efforts and activities. ERRA Ordinance came in 2009 and finally ERRA Act was passed in 2011, making it a permanent post DM authority nationwide under the Prime Minister Secretariat.

ERRA has worked in 12 priority sectors which are at various phases of implementation. These sectors are broadly categorized into three clusters, with environment falling under the cross-cutting themes of Direct Outreach to rural housing, livelihoods and cash grants, and social protection. These sectors assist the affected population directly through housing design, cash, loans and training, Social Services to education, health, water and sanitation. Services provided under these sectors, focus not only on physical facilities, but also on the quality of service delivery and public infrastructure of governance, transport, power, and telecommunication. These aim to put in place high-quality, seismically-safe public infrastructure to facilitate resumption of government departments and reinstatement of power, transportation and communication in the affected areas.

**ISSUES REQUIRING ATTENTION**

The NDMA’s Legislated Authority is the main issue. Implications arising from the 18<sup>th</sup> constitutional amendment and NFC Award pose momentous challenge to the existing DM system in the country. NDMA does not have authority to control PDMA that result in considerable difficulties in mounting centrally organized and cohesive national response to the disasters. The ERRA is an autonomous body which does not work directly under Ministry of Climate Change. Existence of parallel tiers affects national DM capacity and prohibits synergy of national effort. NDMA, PDMA and DDMA are facing serious challenges of capacity building. Shortage of trained manpower and specialized equipment remain crucial in managing the entire flood relief activities. Clear policy on resource management needs to be spelled out. The Lack of disaster hazard mapping and poor EW system prevent preparing contingency plans and contingencies for responding to disasters. Lack of coordination amongst NDMA, PDMA and the Armed Forces has been observed during last two floods of 2010 and 2011. Furthermore, very limited or no coordination amongst DDMA, DCO, Development Authorities and Irrigation & Power (I&P) Department has also been noticed during

same floods. Although every agency has documented its role, responsibilities and mandate in some form but the information is not accessible to the public. For example list of key appointment holders, their duties and contact numbers are not publically available; hence people face difficulty in contacting the responsible individuals when needed. DM plans for various contingencies down to tehsil level, which should have been the basis for preparation of master plans by NDMA/ PDMA, mostly do not exist. No database for disaster prone areas is prepared at national or provincial levels that can be used to ensure delivery of relief goods and award of compensation to the affected people. Though some measures have been taken for institutional level training but a huge void exists in preparing a disaster resilient society. Lack of DM education results in poor response by the departments.

Our electronic media plays negative role on occurrence of any disaster. Sensational reporting creates unrest amongst the masses. No standard mechanism exists to share lessons learnt with each other for education of all concerned. Although NDMA has started documenting the disasters yet there is a need to improve on this aspect for future reference.

#### **SUMMARY OF ANALYSIS**

DM in Pakistan is centrally controlled and national DM authority works under the federal government. Provincial management is done under provincial government and chairmanship of chief minister of the province. District DM Organizations (DDMOs) are established at district level under the district administration. Armed forces can be called upon by federal government in any eventuality. No concrete/practical plans at national and provincial levels are made/ rehearsed in the realm of DM. There is no worthwhile task force for DM exists at national/ provincial levels except the armed forces for post disaster efforts. There is no system of community teams is established to work at the grass root level. And unfortunately no pre-disaster organizations/ institutions are established in Pakistan for early warning and preparedness. Pakistan is primarily working on the Post disaster issues and rescue efforts. Most of the casualties occur because of lack of knowledge and awareness amongst the common people which has not been addressed so far. Pakistan Medical Association (PMA) is not brought into the DM system of Pakistan which is a serious shortfall in the system. Lack of planning in urbanization is clearly visible in Pakistan which may exacerbate impact of any disaster in Pakistan. No media campaign is observed in the DRM system of Pakistan. Due to lack of funds, organizations like Civil Defence and Relief Commissioners that are important component of DM are activated on required basis. In the wake of a disaster most of the responsibilities rest with Army. In devolution plan, district governments were empowered to deal with disasters but in a bid to devolve authority, the plan to articulate disaster response has become weak. Having faced the brunt in 2005, Pakistan has gone a long way in institutionalizing DRM framework by enacting National DM Act 2010 and National DM Authority in 2007. It was hoped that with the

raising of these authorities and working bodies the damages to human life and property will decrease, yet the devastation caused by floods in 2010 and 2011 resulted in alarming surge in deaths.

#### **RECOMMENDATIONS**

Important aspects needing special attention include sound policy formulation and legislation, capacity building of various institutions, infusion of responsiveness through efficient interface between various tiers and effective employment of various elements of the national power. Subsequent paragraphs contain various steps to nudge our nascent DM system towards greater maturity.

Formulation of strategy at national level should be led by political/civilian leadership and must have legislative approval. It should give out broad guidelines to Civil Governments at Federal, Provincial & District levels and other components visualized to be involved in DM. It should focus on lasting, inclusive and coherent institutional arrangements to address disaster issues with a long-term vision. Pakistan needs strong federal institutions to handle large scale disasters. A clear and unambiguous legislation needs to be put in place at priority to retain the strong centralized character of the DM Regime. DM institutions cannot become effective without guaranteed budgets. Legislation to this effect is necessary. A percentage of budget to be decided by an expert panel must be allocated to DM Regime. Involvement of local and grass root mechanisms need legislative authorization. Community teams if incorporated will cover the extant gap in our response mechanism.

Necessary linkages may be established between PMA and the DM Regime through legislative process. Strict punishments for criminal activities like looting and fraud during national emergencies need to be legislated to deter their perpetration. A transparent and speedy trial through special courts is suggested to enhance the impact. Legislative measures need to be taken to ensure proper planning for housing/ construction in disaster prone areas with special emphasis on safety issues, for restrictions on construction in areas with potential risk, and to avoiding concentration of population in hazard prone areas.

A commission to be set up to undertake detailed study of major disasters and vulnerability profile in order to categorize the areas as per disaster vulnerabilities down to district level. Basing on this risk profile, contingencies may be worked out to minimize the disaster effects. Necessary amendments may be made in NDMA 2010 to incorporate ERRAs as part of DM Regime. If deemed suitable its name may be changed without changes to organizational structure and core capabilities. It should either be amalgamated under NDMA or be taken as an organization parallel to NDMA for handling the post disaster rehabilitation works under ministry of DM. Predictable disasters like floods and epidemics need timely coordination between various organs of state to help mitigate scale of destruction. An effective interface between global, regional and domestic early warning and response mechanisms must be established to minimize impact. Effective pre-disaster coordination between various DM

agencies is essential to deal with sudden disasters so as to save as many lives as possible. Coordination between and within various ministries, executives and agencies must be done during peace times so as to waste minimum time to operationalize requisite response. Currently, no concrete plans at national and provincial levels exist in the realm of DM. Small scale Earthquake and Flood Rescue Exercises are suggested to help formulate the standing operating procedures and infuse interoperability between various DM tiers.

It is suggested to have better legislation for town and infrastructure planning in coordination with DM Regime. To avoid information scarcity which leads to sensationalism and negative reporting, proactive coordination mechanism between media and DM Regime must be established. A greater degree of transparency in fund utilization through coordinated media involvement will convince the public to remain sensitive to community needs in stressful situations. Greater public support and donations can be gathered if people trust the government. DM exercises, if conducted among the nations of region like Afghanistan, Iran, China and Gulf countries, will enhance skills and regional cooperation. A better interface with International community and NGOs who have helped in disaster relief in the past will prove instrumental in future DM tasks. An effective liaison with them will result in timely infusion of foreign assistance in the disaster zones.

Ministerial Committee recommendations to resolve various institutional issues pertaining to NDMA including merging of ERC and Aviation Squadron into NDMA needs to be implemented on priority to ensure organizational strengthening and functional autonomy of NDMA. A well-funded institute may be established with mandate to study and recommend measures for legislation and capacity building. It should also have institutional linkages with global and regional centres for early warning and disaster mitigation.

Construction of new dams and water storage facilities may be pursued earnestly to fight floods. Such projects will also have an indirect contribution towards capacity building due to their positive effects on energy sector and economy. Requisite wherewithal for flood relief and urban disasters needs to be procured, after necessary evaluation. All civil and military teams should have interchangeable equipment and communication. Wireless, line and data links should exist between civil agencies and military. Data maintained by National Database and Registration Authority (NADRA) and other departments must be available to all.

Assessment is essential for rescue, evacuation and subsequently for a viable second phase response. Sources like UAVs and satellite streams should be made available for this purpose. There is an acute shortage of military and civil aviation assets especially helicopters for transportation of personnel and logistics. This needs to be addressed as dependence on helicopter transport is high in any disaster related scenario. NDMA is mandated to address all DM operations which essentially revolve around preparedness, mitigation, prevention, response, recovery and rehabilitation and reconstruction. In order to

deliver, the organization needs to have professional expertise with required financial, logistics and human resource. Major areas of capacity building are creation and training of National Disaster Response Force (NDRF), formulation of National DM Fund (NDMF), DM equipment, machinery and means of communication and logistic support storage including essential food and other relief items.

It is suggested that requisite capacity building be undertaken for Civil Armed Forces and other Law Enforcing Agencies for interoperability with regular armed forces. Armed Forces will have to develop a coordinating headquarters, preferably at Joint Staff level which will should able to harness all the services capacities. Within this the services will have to define their individual areas of responsibility. Training of military personnel does not match the one imparted to professionals all over the world.

The Military Training Directorate to appropriately train senior and junior leadership for DM. As an interim measure, an introductory DM Module may be included in the training curricula of courses at schools of instructions. Simulated exercises at formation level to refine the drills and procedures in the perceived threat environment and interaction with foreign institutions to gain training for 'rescue teams' and other specialized DM skills.

Hazard risk profiles of the country till district level be made public through print and electronic media. DM must be introduced in syllabi of education institutions. First aid, casualty evacuation and survival training be imparted in the school/colleges. Identification of the disaster prone areas and taking measures in advance can minimize the impact of potential calamities. Pre-positioning of stocks of food and non-food items is proposed to be adjusted in relation to the degree of disaster risk. During the earthquake 2005 and floods of 2010/11 it was observed that the relief support could not be managed appropriately at national level. This causes a serious setback with political ramifications. A credible and transparent body having interface with national and foreign donors needs to be established to oversee the entire process of camp management and relief distribution.

In order to enhance local capacities, there is a need to establish 'Rapid Reaction Teams' at city, district and region level. These teams should be trained to undertake independent and immediate search and rescue operations in their affected zones. In Pakistan this form of participation is not yet common as against a common practice in other countries. Leaders at various political, religious and youth level should strive for a change in the attitude of the people in this regard through motivation and campaigning. The idea was practiced during Earthquake - 2005, which proved to be quite useful especially during reconstruction and rehabilitation phase of the disaster.

#### CONCLUSIONS

Disasters are sudden, adverse and extreme events which cause great damage to human beings as well as plants and animals. Disasters occur rapidly, instantaneously and indiscriminately. These have always coexisted with civilizations. Human beings have learned to

live with these catastrophes and effort has always been made to mitigate the impact of disasters with the available tools in a particular era. DM has become a precise and useful branch of knowledge in the present times. A brief mention of recent major calamities indicates the growing role of technological prowess in risk mitigation as well as increasing severity of the natural disasters. The increased frequency of floods, cyclones, tsunamis, vicious disease and the industrial disasters reflects impact of changed global environment, partly as a result of human actions. Industrial disasters are especially painful as greater foresight and procedural efficiency can render many a catastrophe avoidable.

Various regional and international protocols exist in the realm of DM. However, the world seems least able to coordinate the response to natural disasters which cause such acute suffering on so great a scale. Pakistan's DM institutions have evolved over time as necessitated by the need for effective measures. However, lack of resources, bad planning and lack of focus render the whole process weak, ineffective and unresponsive. Pakistan like other poor countries relies heavily on its armed forces to act as first responders in almost all crisis situations. The comparison of floods / earthquakes in Pakistan and recent hurricanes in United States of America are illuminating in terms of response. Although, huge gap in resources and technology exists between the two nations, some common features are discernible. The unpredictability of nature, limitations of technology, poor coordination and lack of preparations to meet the challenges plague the post disaster phase. While developed countries can easily make up for initial mistakes through pouring of huge resources, poor countries like Pakistan have to bear greater pain and sufferings. Although natural phenomena can hardly be altered by human ingenuity, yet a determined effort at the right time and place can always mitigate risks to manageable limits.

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## EVALUATING THE UNDERSTANDING OF INDUSTRY TOWARDS BUILDING INFORMATION MODELLING TECHNOLOGY IN MALAYSIA

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**Abstract:** Building Information Modelling (BIM) has gained the attention in the construction industry especially within the Malaysian construction context. This paper generally aims to investigating the understanding of industry towards building information modelling technology in Malaysia. Study was carried out through a random questionnaire survey among the registered professional architects and graduate architects. Overall from this research, it was indicated that the level of BIM technology adoption in Malaysia is still low with percentage of 70 although it has been applicable in Asia. Therefore, it is suggested that government should take initiative to promote BIM in order to make more professional in the industry aware of this technology.

**Keywords:** Building Information Modelling, Understanding, Industry, Malaysia

### INTRODUCTION

BIM is a data-rich, object oriented, intelligent digital representation of software, and are much more than just three dimensional representations of two dimensional drawings. Users are able to add cost, systematic schedule, sustainability issue and other useful data to the model. The BIM manager can analyse, review and suggest changes at the research, informational databases, plans, and scope of the project (Anantatmula, 2008). It uses coordination, consistency, computable information that will results in a reliable and digital representation of the building project. This tool is able to synthesize the results from assessments, identifying and structuring problems and conflicts among the evaluated results, and finally produce a set of suggestions and options to assist the decision making process (Fu et al., 2006). Globally, BIM is most commonly used on complicated projects such as high-rise buildings, bridges, arts centres, stadiums, educational buildings, office projects and medical facilities. Mostly, it is applied for planning, design, construction and management of buildings. However, its capabilities can and is being extended to challenging and complex civil engineering projects (Sah and Cory, 2009). Previous literatures indicate that research done by Farhana (2011) is aimed to determine the level of awareness on BIM among the engineers in Malaysia. Thus, the research is carried out by distributing to the Engineers in Johor, Selangor and Kuala Lumpur. The result shows that the level of awareness on BIM among the engineers in Malaysia is still at initial stage. Hence, the effort to promote BIM need to be increased so that the BIM benefit can be applied by professionals in the construction industry. In addition,

another research finding by Tan (2011) reveals the objective to determine the level of awareness towards the technology of BIM among Quantity Surveyors (QS) in Malaysia. The results showed that the level of awareness towards the technology of BIM among QS in Malaysia is relatively still at early stage even in pre-contract or post-contract stages (Tan, 2011). Therefore, this study is to evaluate the understanding of industry towards Building Information Modelling technology in Malaysia.

### RESEARCH METHODOLOGY

The study was carried out within states in Malaysia and the technique used for the data collection in this research was questionnaire. The process involved is the questionnaires will be distributed to the respondents through email and by hand. The survey was administered randomly among architect respondents. The total number of registered professional architects is 1836 and graduate architects are 1654, which both make up the total of 3490 members according to Board of Architects Malaysia (BAM) in 2012. Tables (1 and 2) breakdown the location of registered professional architects and graduated architects. The data was gathered through reliable source from the Board of Architects Malaysia's website (LAM).

Most of the research will use a table which is provided by Krejcie and Morgan (1970). However, there are difficulties in getting architects who have the knowledge in BIM technology. For this survey, the method used is by convenient simple random sampling which the questionnaire is distributed to all respective registered architects in states of Malaysia (see Tables 1 and 2).

Table 1. Number of Registered Professional Architects in Malaysia

State	No.
Sarawak	136
Sabah	95
Johor	73
Pahang	17
Negeri Sembilan	10
Melaka	29
Perak	28
Kuala Lumpur	613
Kelantan	16
Terengganu	13
Pulau Pinang	137
Kedah	40
Perlis	3
Selangor	622
Putrajaya	3
Labuan	1
<b>Total</b>	<b>1836</b>

Source: Board of Architects Malaysia (2012)

Table 2. Number of Registered Graduate Architects in Malaysia

State	No.
Sarawak	97
Sabah	63
Johor	84
Pahang	27
Negeri Sembilan	25
Melaka	20
Perak	70
Kuala Lumpur	406
Kelantan	20
Terengganu	34
Pulau Pinang	96
Kedah	43
Perlis	4
Selangor	634
Putrajaya	28
Labuan	3
<b>Total</b>	<b>1654</b>

Source: Board of Architects Malaysia (2012)

Eight five questionnaires were sent out and from these only 30 questionnaires were returned and analysed using SPSS software (v.17.0). This software will compute the data into result by means of percentage, mean and standard deviation (Mo, 2011).

**RESULT ANALYSIS**

**Level of BIM adoption in local construction industry**

Figure (1) shows the level of BIM adoption in Malaysia is still very low with (70%) of majority respondents agreed on the low level (0- 20%). This indicates that the adoption is relatively low although it has been applicable in some Asian countries.

**Sector that has been Adopting BIM in the tasks**

The respondents indicated that the private sector in Malaysia has the highest BIM adoption in their works, which is 60%, while the public sector has shown 36.7% (See Figure 2).

**Current Project that used BIM Technology**

Concerning the current projects using BIM technology, it was found from the analysis that architecture and landscape work has the highest percentage (53.3%) of BIM used, especially in the design part.

While, the civil engineering and housing and building project both shows result of same percentage, which is 20% each.

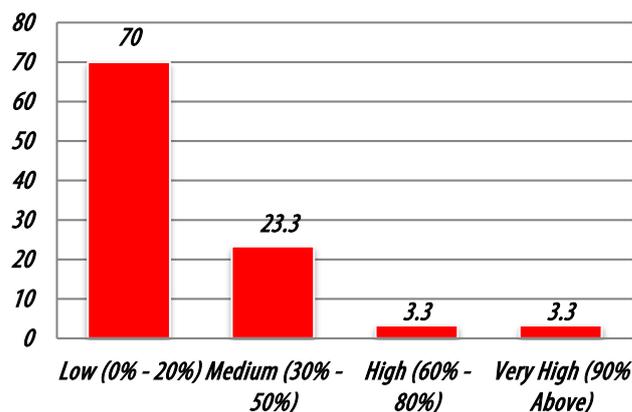


Figure 1. Level of BIM Adoption in Malaysia

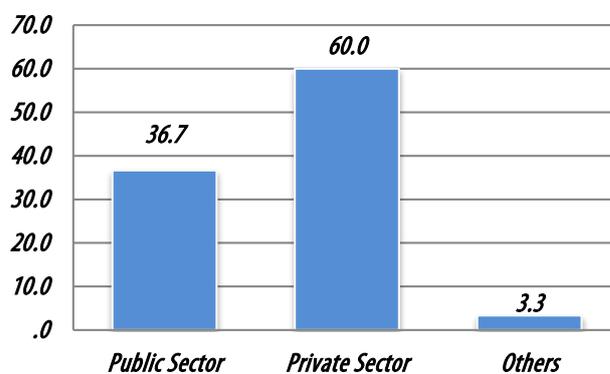


Figure 2. Sector that been Adopting BIM

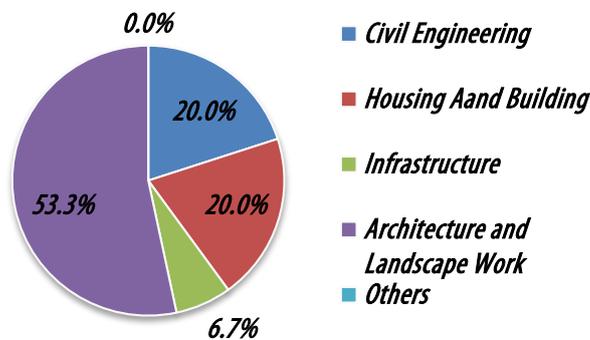


Figure 3. Project Currently Used BIM Software

**Comparison of BIM technology to other Software**

The respondents were asked to rate the benefit of BIM technology comparing to other softwares such as Billsoft, AutoCad, Revit, Autopipe, Primavera and many others when implement projects in local construction industry. However, based on the obtained results, it can be observed that most of them rated that BIM is actually good in implementing project (43.3%) comparing to the other softwares (Figure 4).

**Readiness of Acceptance and Adoption of BIM in tasks**

Based on the Figure (5) below, it indicates that most respondents are not ready yet to accept and adopt BIM in their professional tasks. This can be seen with 56.7% which is the highest percentages. However, there are still 26.7% of respondents who are ready to accept and adopt this technology in their work.

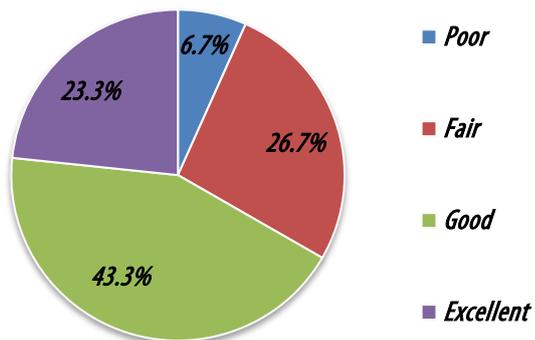


Figure 4. Benefit of BIM compare to other Software

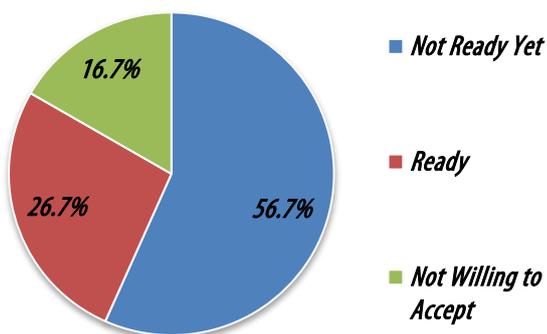


Figure 5. Readiness of Acceptance and Adoption

#### Way to solve BIM Problem

There is several ways suggested that can overcome the challenges in BIM. However, Based on the results presented in Table (3), it can be seen that most respondents agree that setting a training plan by the company is the most effective and efficient way, which rank the highest percentage 34.3 and frequency of 12, followed by the second ranking which is both giving subsidy by the government and personnel management by the government which both shows the same 25.7%.

Table 3. Solution of Problem

Way to solve BIM Problem	Frequency	Percentage (%)
Developed an action plan like technology analysis	8	22.9
Form a professional committee to further explore the benefits	8	22.9
Set training plan	12	34.3
Giving subsidy by the government	9	25.7
Personnel management by the company	9	25.7

#### DISCUSSION OF THE FINDINGS

Based on the obtained results, it was indicates that the level of BIM technology adoption in Malaysia is still low with percentage of 70 although it has been applicable in Asia. Teo (2012) in her studies revealed the study include identifying the level of usage of technology within the construction industry, identifying the barriers for the implementation of BIM, the potential driving factors in accelerating

the BIM adoption and the consequences if BIM has being adopted in the local construction industry. However, the respondents discussed that the private sector in Malaysia had the highest BIM adoption in their task compare to public sector. Moreover, this research show that architecture and landscape work has the highest percentage of BIM used, especially with designing part, followed by civil engineering and housing and building project. From the result collected, it shows that respondent rate that BIM technology had actually the advantages and good in implementing project, compare to other softwares such as Billsoft, AutoCad, Revit, Autopipe, Primavera and many others. However, they had not ready yet to accept and adopt BIM in their professional tasks which shown 56.7%.

Therefore, there were several ways suggested that can overcome challenges in BIM. Based on the study, most respondents agreed that setting training plan for BIM was the most effective and efficient way. According to Arayici (2008), this software tool whom the firm chooses to train can increased productivity in future projects, enhanced greater collaborative and cooperative skills among other employees and participating consultants.

#### CONCLUSION AND RECOMMENDATIONS

Based on the obtained results, it can be concluded that BIM has indeed changed the mind-set industry thinks about how technology, can be applied to the design, construction, completion, maintenance and management of building projects. In the view of many parties, it facilitates the involvement of all designers start from the project earliest stages. Therefore, it is recommended that government should take initiative to promote BIM in order to make more professional in the industry aware of this technology.

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## TRANSITIONAL ECONOMY AND THE NEW ECONOMIC ROLES OF GENDER

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**Abstract:** *The historical experience of communism becomes a heritage difficult to manage not only in the field of political culture, but especially in the sphere of economic relations. Romanian communism was characterized by a violent segregation of economic roles and by isolation of gender labor force inside some closed economic patterns. The dissolution of the totalitarian order did not solve the problem of economic inequalities, and gender discrimination remains an essential feature of transitional societies. Also, the persistence of economic dependence of women stimulated the aggravation of some previous social and economical cleavages such as: apparition of economic encapsulated enclaves, especially in the country side, stimulation of grey economy, due to the discrimination of women on accessing education, the conservation of a negative balance for gender participation in the field of private initiative. The entire phenomenon mentioned below affected the transition of the Romanian society towards a stabile and functional economical environment. This paper aims to explore the new roles of gender in the economy of transitional states, with a special focus on the Romanian post communist experience.*

**Keywords:** *economic relations, transitional states, gender participation, Romania*

### INTRODUCTION

*The unanticipated crisis of communist system in East Europe, in the early 90', generated some tremendous expectations in the subject of gender equality. The sudden collapse of communist archipelago bring to light a space marked my dramatic gender disparities and suffering from an obviously deficit of equality culture. Still, the initial prospects for an accelerating positive evolution were contradicted by a rapid degradation of women's economic, political and cultural status. The fall of communist did not solve the problem of gender inequalities, and in an apparently difficult to explain mode, it compound the gender gap to a worrisome level.*

*In the same time, despite the acute differences of historical, cultural and economical background of the former socialist states, the evolution of gender issues were trapped in a surprisingly homogenous pattern. The post-communist societies were experimenting dramatic changes, and the dissolution of communist order reactivated some influential social and economical cleavages. The transformation of state-controlled economy in a free-market structure was the trigger vector for creating supplementary economic burden. The gender issues in transitional economy raised general attention and there were identified a set of essential problems, that affected the economic and social status in former socialist countries<sup>1</sup>.*

*The key elements that contributed to deterioration of women situation in Eastern Europe, especially in the economic perspective were: the growing unemployment, the increasing economic insecurity, the uncontrolled work force migration and the lack of awareness of rights related to gender equality and work opportunities<sup>2</sup>.*

*The transformations supported by the transitional societies were characterized also by a resurrection of some previous structural problems. The post-communist economies were pressed to solve some internal breeches which were only masked by the communist policies of mass industrialization. Under the communist rule the gender status was protected, at least at a declarative level, trough proportional regulations. The "statist feminist" era was granting gender participant in the economy<sup>3</sup>, maintaining an apparent balance between otherwise very fragmentary spaces such as: urban and rural economy or central and secondary economic layers.*

*The pressure of the communist state against some of these traditional cleavages did not solve the issues of economical and gender gap, but still succeed in imposing an artificial unity of the system. The breakdown of controlled economy revealed these structural differences and pushed the economic status of the women into a dynamic of degradation. This researched is grounded on two major*

<sup>1</sup> Report of Committee of Equal Opportunities for Women and Men, European Commission, *The situation of women in the countries of post-communist transition*, 9 June 2004,

<http://assembly.coe.int/ASP/Doc/XrefViewHTML.asp?FileID=10366&Language=EN>.

<sup>2</sup> Idem.

<sup>3</sup> Idem.

work hypotheses: first one claims the presence of a structural legacy in the subject of gender economic roles, and the second one asserts the essential role of the gender economic gap in obstructing the evolution towards a stable economical environment. The study will use the tools of comparative analysis and conceptual reconstruction and locates its perspective at the conjunction of political philosophy with economic history.

#### **GENDER EQUATION AND TRANSITIONAL ECONOMIES**

In order to obtain a better understanding of gender economic involution of the inner transitional economies it is necessary to identify the main features of post-communist transformation. One of the first aspects that require attention is related to the problem of interdependency between political dimension of a system and economical structures and equilibriums. The transitional economies supported sever loses almost crushed due to the major transformation of production and trade<sup>4</sup>. The process of economic restructuring, including privatization and liquidation of state-own enterprises destroyed the artificial balance of communist economy<sup>5</sup>. The unemployment stroked the peripheries of the communist system and revealed, in a quite traumatic manner, the failure of planned economy. The differences between the various economic layers were increasing, promoting a slow disintegration of the deceitful unity of the communist societies. The economic disparity primarily affected the gender roles. With a highly raising level of unemployment, women economic status was depreciating.

The general phenomenon was at a first sight difficult to explain, mostly in an economic landscape that still conserved a lot of the former economic regulations. The sudden activation of the gender gap and the continuous "feminization of poverty"<sup>6</sup> was a hard process to diagnose the phenomena. In the communist stage, women's participation on labor market used to be extremely high, beyond the democratic countries level. The proportion of women engaged in the labor force decreased rapidly, from 80 percent employment ration to less the 50 percent in some the most affected post-communist economies.<sup>7</sup> The changing pattern of gender balance inside the labor market had some intermediary explanation, but the emerging point of this process still remains cast in shadow.

The migration from the free market to a grey dimension of labor force (informal, unpaid economy) and the resurrection of traditional roles for gender can be used as explanatory elements, but these aspects do not solve the main interrogation over the gender gap<sup>8</sup>. The deconstruction of communist economic system was producing serious

side effects, and the corrective reactions of the transitional societies were inefficient. Also, the lack of improvement in women's situation remains hard to explain, especially when gender segregation and design of occupational picture tend to survive the political regime<sup>9</sup>. The evolution of gender roles in transitional economy was negative, but the source of this democratization error remained uncertain.

Another influential feature experienced by transitional economies is connected with a contradictory cultural evolution. The industrialized society promoted by communism accepted the participation of women in the field of labor, motivated by two decisive arguments: the need for supplementary work force in countries with serious deficit of labor resources and the interest in destroying patriarchal cultural landmarks such as family or religion.

The industrialization movement increased gender participation in economy, but this apparent progressive step was affected in many situations by intrusive gender policies. The Romanian case is a concluding example of this lack of authenticity of communist emancipation of gender roles. The communist economy needed the supplementary force of gender, but was not interested to pay the whole price of this modernization of social and economic roles. The result of this incomplete evolution was a "double burden"<sup>10</sup> for the women's social and economic status. The intrusive practices in the sphere of reproductive policies created some paradoxical results. Women were pressed to assume and perform economical roles very similar with those of the men, and in the same time they remain trapped in traditional sphere, trough the mechanism of forced maternity. The crash of communist designed economy did not solved the way it was expected the problem of gender equity.

In this case, the hidden patriarchal approach of communism imposed some unexpected costs over the transitional era. The participation of women in economy was labeled as a genuine communist practice and it was reject by a very influent transitional culture. The violent shift generated by the collapse of the communist systems enforced the post-communist society to identity new values in the subject of gender. The solution was the reinforcing of the pre-modern gender roles<sup>11</sup>, with a strong focus on glorifying the patriarchal family model. Women were pushed again in the burden of unpaid home work, losing even the negative equality, previous guaranteed by communist economy. The modernization process experimented in most of the post communist societies, was also producing an erosion of gender status. The cultural evolution of women's identity after communism still remains a relevant argument in explaining the economic decline of gender roles. The participant of women in the filed of labor was

<sup>4</sup> Katalin FÀBIÀN, *Issues of Economic and Social Justice in Post-communist Central and Eastern Europe*, p. 4, <http://www.indiana.edu/~reeiweb/newsEvents/pre2006/fabianpaper-all.pdf>.

<sup>5</sup> *Idem*.

<sup>6</sup> *Ibidem*.

<sup>7</sup> *Idem*.

<sup>8</sup> *Idem*.

<sup>9</sup> Susan Gal, Gail Kligman, *The Politics of gender after Socialism*, Princeton University Press: Princeton, 2000, p. 11.

<sup>10</sup> Katherine Verdery, *What Was Socialism and What Comes Next*, Princeton University Press, Princeton, 1996, p. 65.

<sup>11</sup> Ulf Brunnbauer, *From Equality without democracy to democracy without equality? Women and transition in south-east Europe*, in *SEER South-East Europe Review for Labor and Social Affairs*, Issue: 03 / 2002, p. 151.

not limited only through the interventions of traditionalism, but the cultural pattern remains a vector of aggravation<sup>12</sup>.

Besides the general crises experimented by the post-communist economies and the contradictory cultural echoes generated by the modernization process, the evolution of transitional societies was also strongly influenced by the phenomenon of state hybridization. The process of hybridization is defined by the presence of a dual structure inside the former communist states. Some scholars considered the post-communist societies as forms of “flawed democracies”<sup>13</sup>. The term could still be considered as unsatisfactory for some of the cases, in the light of their transitional evolution. Inside the transitional societies, the internal structure of communist state did not disappear. It was only slightly modified and adapted to more suitable economical expression. If the political dimension was pressed to support more acute changes, the economic landscape remains a field engaged in a slow motion evolutionary process. The collapse of communism could not be defined as a historical cut, irreversibly separating the planned economy, fully controlled by the state, from a new free economic paradigm. The transition from the communist structure of economy towards a free market based society was a complicated process. Not fully understood, even in the late stages of post-communist transformations, the transitional phenomenon was strongly influenced by the communist legacy. The forms of development experimented by the transitional societies are connected with the paths that have been taken in the recent past.<sup>14</sup> The history of former socialist democracies in the Eastern Europe reveals a map with multiple contours and shades.

The evolution of transitional societies was engraved by the structural heritage left behind by communist era. The communist archipelago of the East contained a large variety of models and patterns. The clash of the system was produced simultaneous, but over very different landscapes. Some of the communist societies were already engaged on a decisive changing pattern. It is the case of Poland, Yugoslavia and the triggering case of Soviet Union. The state scaffolding was gradually adapted and the economic transition began in an ironic attempt to reform the system. Nevertheless, some of the communist societies did not embrace the Gorbachev doctrine, and remain trapped in a closed, encapsulated and isolated economic model. One of the most relevant examples is the Romanian case. The difference between the transitional formulas experienced by post-communist countries is besides all a difference of communist legacy. The hybridization of the state could be explained as an adaptive reaction. The secluded

economies of conservative communism could not find a way to survive in aftermath of the system. The function of the closed economies, such one of communist Romania, was assured through the artificial support of the state. Those types of communist economies were marked by violent imbalances and the crush of the system pressed in the direction of a forced adaptation.

The unreformed economies did not genuinely evolve after the fall of the system. In most of the cases they engaged themselves on the dysfunctional option of state hybridization. Some of the old structures of the communist economy were conserved, and other branches were simply dissolved. The transitional societies were operating a posthumous reform of the system. The still efficient economic levels remained untouched and the economic bargain of ineffectual industries was abandoned. The transitional societies had no resources to sustain the “edge economy” and chose the adaptive solution. Surface reforms were adopted, but the price of state hybridization was unequally shared. The most affected branches were the ones already marginalized inside the planned economy: the rural space and the light industry and the industry of common goods. Those economic fields had also a strong gender component. The final consequence of state hybridization and peripheries decoupage was the dissolution of the essential levels of gender economy. Gender economic roles were pulverized and the women’s economic status inside most of the transitional societies was rapidly depreciating. The clash of gender economy was a silent strike and the influence of this deficit of equality was very often diminished.<sup>15</sup> The three main phenomena mentioned below affected in an essential perspective the evolutions and features of transitional economies. All the three processes, the fragmentation of the economic environment, the resurrection of traditionalism and the hybridization of the state, triggered a negative dynamic in the subject of gender equity.

From the “double burden” of the communist paradigm, the transitional process pressed the women to accept a “triple burden”<sup>16</sup>. The ineffective help provided by the communist states vanished and the new hybrid democracies had a dominant patriarchal oriented values scale. The previous gender economic roles were destroyed and the women were forced to perform inside the grey dimension of unpaid work. The source of this complex phenomenon remains hard to isolate and as a consequence, difficult to solve. The following section aims to explore the roots of this crisis of gender economic roles and also to formulate some possible answers for the degradation of women’s economic status in the post-communist transitional phase. The Romanian communist experience could be considered as one of the most violent and virulent form of oppressive system from East Europe. Also, the degradations of women economic, social and political status were one of the most dramatic from the

<sup>12</sup> Ronald Inglehart & Pippa Norris, *Rising Tide. Gender Equality and Cultural Change around the World*, Cambridge University Press: Cambridge, 2003, p.11.

<sup>13</sup> Jonas Linde, Joakim Ekman, *Patterns of stability and Performance in Post-communist hybrid regimes*, in *20 Years Since the Fall of the Berlin Wall*, ed., Elisabeth Bake, BWV Verlag, Berlin, 2011, p. 97.

<sup>14</sup> John Pickels, Adrian Smith, *Theorizing Transition: The Political economy of Post-Communist Transformations*, Routledge: London, 2005, p. 15.

<sup>15</sup> *Idem*, p. 292.

<sup>16</sup> Nanette Funk, *Gender politics and post-communism: reflections from Eastern Europe and former Soviet Union*, Routledge, London, p. 349.

whole socialist archipelago. The “politics of duplicity”<sup>17</sup> promoted by the Ceaușescu regime marked the gender identity in a profound manner and left a contradictory picture for the post-communist society. An analysis of the Romanian case could this way serve as a general explanatory model and also could provide some research hypothesis to overcome this complicated historical heritage.

#### **EXPLORING THE GENDER GAP. A STUDY OVER THE ROMANIAN CASE**

As already was mentioned below, the recent history of former communist states exerted a tremendous influence over the transitional mechanism. The important differences raised by the evolution of new born societies could be explained through a comparative exercise. The theory of state hybridization brought in discussion the necessity of adaptive measures, in order to assure the survival of the uncompetitive systems of planned economy. The existing variations between the hybrid societies are generated by the typology of their previous political background. The crisis of the Soviet block was already triggered in the middle of 80'. The several attempts of Gorbachev doctrine to reform the general political and economical disparities inside the socialist sisterhood were materialized in two key concepts: *glasnost* and *perestroika*<sup>18</sup>. This was the emerging point of slow disintegration process, which culminated with the general collapse at the begging of the 90'. The changing process inside the communist system was motivated mostly by the pressure of inefficient economy. The almost imperceptible liberation inside the planned economy pattern could not solve the general pathology of the communist system, but ease down the final resolution with almost a decade. In this dynamic landscape, Romania was making an inconsistent note. Ceaușescu's regime chose to maintain a “frozen” economical model that motivated the etiquette of “late Stalinism”. The lack of permeability of Romanian communism influenced in an essential manner the violent collapse and also its transitional evolutions.

In order to explain the dysfunctional evolutions of the gender issue along the transitional period, it is necessary to analyze some aspects of communist legacy concerning this subject. The integration of communism inside the Romanian society, at the end of 40', cast an influential changing mechanism. The key features of this process are the forced urbanization and the accelerated industrialization. The political, social and cultural status of the gender was profoundly

modified, under the influence of new ideological commandments. Under the communist rule Romanian women were pressed to accept an artificial form of emancipation. The process of industrialization required the extension of the labor force, situation that promoted an apparently economic equality between genders. Women began to manifest actively inside the economy and gain a deceitful independence. Nevertheless, this departure from the traditional economic roles was doubled by an inverted process. In the same time, the communist state began a gender offensive, through its reproductive policies. The gender bargains were increasing, women being forced to accept a dual identity. They were in the same time, reproductive resources and work force<sup>19</sup>, committed to a hybrid identity. The communist state triggered a fragmentary modernization process, and the main costs were paid by women. Through the prohibition of abortion and by imposing gender equal labor standard, communist states created a segmented terror.

The pro-natalist policies were promoting flagrant inequalities, transforming gender in an oppressed faction of the ruling class. The sustained offensive over the private sphere and the increasing economic pressure created a double burden, aggravated also by the common scarcity of goods and insufficient child care facilities<sup>20</sup>. The economic roles of gender were also the subject of multiple negotiations and adaptation. After a debut epoch, when were promoted the soviet cultural gender stereotypes, with a strong emphasis on imitating the “male traditional occupations”<sup>21</sup>, the economic status of women suffered a slow drift to the former traditional professions. The division of labor had a strong gender component, especially over the debut of Ceaușescu regime, at the middle of the 60. The small improvement acquired by gender relations was then destroyed and the gender economic roles remain connected mostly with branches as education, health care or light industry<sup>22</sup>. Another important sphere where gender labor force that was used intensively, was agriculture, process stimulated also by the migration of male force in the industrial layer. This presence of a gender-ized economical map will become an influential aspect in analyzing and explaining the Romanian transition.

The artificial modernization of women economical status quo was accompanied by an elusory improvement of their political relevance. The proportion of women politically active inside the official organisms of the communist state was regulated through quota, but the women tended to cluster to bottom of all hierarchies<sup>23</sup>. This non-authentic tradition of women participation became one of the

<sup>17</sup> Between the official proclaimed equality, Romanian women were the subject of a double oppression, in the labor field and in the private space. Through the prohibition of abortion and by assertion of extensive work obligations, the women were exploited in a double register. Gail Kligman, *The politics of duplicity: Controlling Reproduction in Ceaușescu's Romania*, London: California University Press, 1998, p. 231.

<sup>18</sup> The two often paired term, could be translated as “openness” and “restructuration” and remains the central ideas of Gorbachev economical reforms, started in the 80'. Brian McNair, *Glasnost, Perestroika and the Soviet Media*, Routledge, London, 2006, p. 74.

<sup>19</sup> Barbara Einhorn, *Cinderella goes to market: citizenship, gender and women's movements in East Central Europe*, Verso, 1993, p. 40.

<sup>20</sup> Ulf Brunnbauer, *From Equality without democracy to democracy without equality? Women and transition in south-east Europe*, in *SEER South-East Europe Review for Labor and Social Affairs*, Issue: 03 / 2002, p. 153.

<sup>21</sup> *Idem*, p. 154.

<sup>22</sup> *Idem*, p. 154.

<sup>23</sup> *Idem*, p. 155.

triggering vectors of gender cultural crisis in post-communism. The resurrection of gender traditional culture after the collapse of communism has as its major source, the communist legacy. The deficit of gender culture accumulated through the communist experience and lack of alternative term of reference produced an aggravation of the gender gap, even if the roots of the phenomenon remain too little understood. The first section of the paper identified three major features that engraved the gender subject inside transitional societies: general crisis of the economic system and growing gender unemployment, contradictory cultural trends, state hybridization and clash of “economic peripheries”. This triad of elements stimulated an acute erosion of the gender status. The short enquiry over the communist heritage realized at the begging of this second section could provide at this point some explanatory hypothesis.

First at all, it is important to mention the connection raised by two of the phenomena previously mentioned. The general clash of the post-communism economy and process of state hybridization are sharing some common constitutive condition. The lack of permeability of Romanian communist in the last years of the Ceaușescu regime postponed some of the key processes already activated in other communism states. The main aim of Gorbachev attempt of reformation was to change the gravitation point of communist economy, from the hard industry to the neglected layers of consumption goods and light industry. Perestroika was before all a public acceptance of the failure of classical communist perspective over the economy. The forced industrialization adopted by most of the socialist democracies in the 60 and in the 70 created tremendous economic misbalances. The Gorbachev doctrine tried to correct these structural errors, increasing the role of secondary economy. The typology of transition in the case of adaptive communism was extremely different from the one experienced by Romanian communism. Through the rejection of Gorbachev doctrine, Romanian economy remained trapped in the dysfunctional and anachronistic model of hard industry domination. The light industry, the industry of consumption goods, or other secondary economic layers such as education or healthcare were neglected. By definition, through the presence of a gender design economical map, those spaces used preponderant female work force. So, as a following consequence, the gender economical base was shirking, even before the official clash of the system.

The economy of transitional Romania was confronting simultaneous by the process of state hybridization. The abandon of economic peripheries represents another phenomenon with major implications in the field of gender economic. Roles the crisis of the “edge economy” was strongly influence by the communist approach of the rural problem. The domination of hard industry generated a closed pattern that isolated the Romanian economy. By comparison, the socialist states that engaged themselves on the road to liberalization, their economical structure became very similar with the one of the

states that never experienced the planned economy<sup>24</sup>. In the early 90, Romanian economy was secluded not only from its near abroad evolutions, but even from its internal layers. The rural economy was a neglected part of the communist economic strategy. The forced industrialization exerted in addition a major urbanization movement, leaving the rural space as a secondary economic level. Gender work force active in the country side had low incomes level and also was defined by a strong gender component. The gender economic roles were modified also the ideological pressure. The work migration of male work force to the industrial zone stimulated a “gender-ization” of agriculture, which will become the basis of the future grey economy.

After the clash of communist order, the rural dimension becomes an economical encapsulated enclave. One of the most influential and essential change produce in the transitional economy of post-communist Romania was the abolishing of the communist work cooperatives. Even this association forms were often dysfunctional, and the membership was forced, the general disintegration of this rural economical system produce one major economical break-down. Between 1989 and 2005 Romania was confronting with a declining cooperative sector and the number of members was dropping from more 1 million to the modest level of 30 000<sup>25</sup>. This rural decline triggered major effects on the gender economic roles. As already was mention before, agriculture was using an important reservoir of gender labor force and the dissolution of the former work cooperative erased the rural space from the official economic map. The sudden apparition of an important percent of hidden economic activity could be connected with the process of rural exclusion. In its first year of democratization, Romania was already confronted with a rising level of hidden economy<sup>26</sup>. From the full employment of the communist planned economy, the transitional society was pressed to manage a worrisome level of grey economy (26.2 percent between 1990 / 1991)<sup>27</sup>.

Thereby, one of the major hypotheses that could explain the serious decline of gender participation in the labor field is connected but the unsolved problem of rural economy. In conclusion, the growth of hidden economy in the first stages of transitional processes could be

<sup>24</sup> Grezgorz Ekiert, Jan Kubik, Milada Anna, *Democracy in the Post-communist World: an Unending Quest*, [http://scholar.harvard.edu/files/ekiert/files/ekiert\\_democracy\\_and\\_postcommunist.pdf](http://scholar.harvard.edu/files/ekiert/files/ekiert_democracy_and_postcommunist.pdf), p. 12.

<sup>25</sup> Ancuta Vamesu, Cristina Barna, *Romania Country Report*, European Commission, <https://webgate.ec.europa.eu/socialinnovationeurope/sites/default/files/sites/default/files/romania%20country%20report%20for%20social%20innovation%20europe.pdf>

<sup>26</sup> Mirjana, Marković-Radović, *Globalization and gender participation in the informal sector in developing and transitional countries*, *E+M, Ekonomie a Management*, no. 4. 2009, p. 21.

<sup>27</sup> *Idem*, p. 21.

accepted as the result of a "disorganization process"<sup>28</sup>. The apparition of a grey zone of informal economy had affected directly the gender economic status. Women are more often engaged in informal activities difficult to capture and measure, and also they remain the essential labor force in the rural area, especially when male work force is the subject of fragmentary migration to the urban professions<sup>29</sup>.

The structural problems of the communist legacy conducted to some posthumous adaptive reactions. The phenomenon of rural grey economy and the clash of secondary industry exert both a cultural pressure. The "domestication of women"<sup>30</sup> was not only a side effect of the cultural politics of Ceaușescu era, but simultaneous a consequence of the economic depreciation of gender. The isolation inside the closed pattern of grey economy and the growing unemployment generated by the generalized economic crisis, determined strong consequences in the field of entrepreneurial culture. The contradictory cultural echoes raised by the resurrection of traditionalism inside the Romanian transitional society marked in an essential manner the participation of women in the space of private initiative. This deficit of the democratization had a dual explanation, its sources being both structural and cultural. The strong gender disparity experienced by Romanian transitional society could be interpreted also as an effect of stagnating economies<sup>31</sup>. The lack of genuine evolutions of Romanian economy after the fall of communist rule determined an aggravation of the economies inequalities. The presence of a gender defined economic map and the clash the gender oriented industries created a disparity in women knowledge capital and interactional opportunities. The transitional neo-traditionalism graft on the dysfunctional evolutions of hybrid economy and delayed the improvement of gender status.

For the female entrepreneurship in the transitional context, formal institutions are essential in creating a positive environment, but the informal level still could affect the entrepreneurial culture<sup>32</sup>. A study over the evolutions of Romanian transitional entrepreneurial culture highlight important gender misbalances. In the first 5 years after the dissolution of communist order, only 29% of small business owners were women, a percent will only slightly increase in the following years.<sup>33</sup> The gender gap was active, but inside this cleavages it could be identified a secondary division line. As most of the transitional

societies, Romania was confronting multiple shades in its evolution. The gender entrepreneurial culture was developing almost in an exclusive urban dimension, and the rural space conserved a great part of the gender informal economy<sup>34</sup>. This inequality between gender urban entrepreneurial culture and the rural space is motivated by the presence of educational and formative limitations. In the great majority on the transitional countries, and Romania is not making exception, the gender entrepreneurship is defined by a restrictive profile. A high percentage of women entrepreneurs posses medium or high levels of education, and they set enterprises especially in sectors like trade or services.

In this manner, the economic exclusion could also be labeled as an unbalance in the educational potential. The lack of entrepreneurial culture in Romanian rural space is demonstrating a deficit of educational equity. Even if the general policies were in favor of gender equality, the post-communist economy remained strongly engraved by an influential gender gap. The general approach to the gender problems created only a surface reform, and the general effects remained insignificant. The evolution of gender issues in the transitional economies shows the necessity for bottom to top approaches in promoting new education policies. Also, one of the main challenges of the in gendering issues is to bridge the gap between official policies and pragmatic practices<sup>35</sup>. The deficit of gender equity in transitional societies is linked with multiple sources, but in the Romanian case, one of the triggering vectors remains the cleavages between rural area and the urban space.

The result of the educational policies is often limited by previous cultural ground<sup>36</sup>, but the rising of the economic potential could be obtained only trough this formative instruments. The motifs for depreciating the women status in the "edge economy" are related with the deficit of information and an acute disparity in the field of professional chances. The achievement of economic equity is limited by structural issues, such as the isolation of the rural sphere, but still there could be operated important steps, trough the tools of educational policies. The dissolution of the rural economy and the general crisis of previous gender oriented industries are pressing for adaptive solutions. One of them could be the rising of a gender entrepreneurial culture. The connection between the presence of women in the sphere of private initiative and the gender access to higher education was already proved, but bridging the educational gap is a difficult task. The polarization of gender economy is not an

<sup>28</sup> *Idem*, p. 23.

<sup>29</sup> *Idem*, p. 23.

<sup>30</sup> Ulf Brunnbauer, *From Equality without democracy to democracy without equality? Women and transition in south-east Europe*, in *SEER South-East Europe Review for Labor and Social Affairs*, Issue: 03 / 2002, p. 157.

<sup>31</sup> Andreea Smith Hunter, *Women Entrepreneurs across Racial Lines*, London: Edward Elgar Publishing, 2006, p. 2.

<sup>32</sup> Ruta Aidis, Friederike Welter Smallbone, David, Nina Isakova, *Female Entrepreneurship in Transition economies: The case of Lithuania and Ukraine*, in *Feminist economics*, no. 13, April 2007, p. 158.

<sup>33</sup> Irina Budrina, *Phenomenon of Women-Leaders in Romania and Russia: Equal Gender Opportunities in Emerging Markets Review of International Comparative Management Volume 13, Issue 5, December 2012*, p. 851.

<sup>34</sup> *Ibidem*, the percent of female entrepreneurs in the agriculture was under 1% in Ukraine, p. 165.

<sup>35</sup> Irina Budrina, *Phenomenon of Women-Leaders in Romania and Russia: Equal Gender Opportunities in Emerging Markets Review of International Comparative Management Volume 13, Issue 5, December 2012*, p. 851.

<sup>36</sup> Shannon Davis, Theodore Greenstein, *Gender Ideology: Components, Predictors, and Consequences*, *Annual Review Sociology*. 2009. 35:87–105, p. 87, [http://socant.chass.ncsu.edu/documents/Greenstein\\_2.pdf](http://socant.chass.ncsu.edu/documents/Greenstein_2.pdf)

overpass phenomenon and this deficit of economic chance tends to become a chronically problem. The evolution of Romanian transitional society to a stabile economic environment is strongly influence by the problem of gender disparities, and without balancing the gender problem, the transition will be difficult, almost impossible to complete.

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## STATIC AND DYNAMIC LOADING TEST OF A RAILWAY BRIDGE

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**Abstract:** A case study for assessing the strength of a recently mal constructed Iraq railway bridge was carried out. The 48.5 m long Reinforced Concrete Bridge shows a Permanent deflection of more than 3 cm at its mid span panel. Responsible Authorities feared of the safety of this bridge and asked for Structural engineering consultancy. The overall bridge elements; piers, bearings, super structure and materials strength have been verified in details, but in this paper the concentration will be focused at a novel method used to perform a loading test. The heaviest available locomotive-weighing 120 tons- was used to conduct the static and dynamic loading test. Surveying team was instructed to tabulate the levels of selected points before and after the passing of the testing locomotive and during its stoppage at certain positions. The bridge showed an acceptable performance under the actual loading of the mentioned locomotive and also it complied with the resisting requirements of the Cooper E-80 standard loading for railway bridges.

**Keywords:** Static, Dynamic, Loading Test, Railway Bridge, Strength Evaluation

### INTRODUCTION

AD'DIWANIYA one way Railway Bridge – 300km south of Baghdad - has a total length of 48.5m and an overall width of 8m. It was constructed in June 2010 across AD'Diwaniya River. It consists of three simply supported spans, the Northern span towards Baghdad has a length of 13.8m and it is supported by seven reinforced concrete girders, the Southern span-towards AS'SAMAWA city has a similar length and supporting girders while the intermediate span has a length of 20.8m supported by nine reinforced concrete girders, as shown in Figure 1.

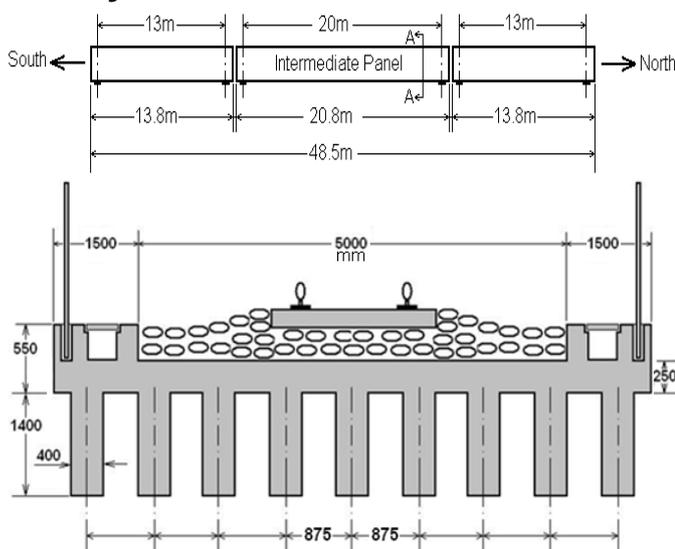


Figure 1. Bridge Profile and its intermediate panel Cross Section

All concrete girders have the same stem outside dimensions of 1400mm x 400mm, but the reinforcing steel varies between the middle panel and the other two panels. All the girders were pre-casted on site, lifted to its final position and connected by shear connectors to a reinforced concrete - cast in-situ - deck slab to ensure the composite action.

The construction of the bridge had started in the year 2004, and then stopped for few years until it was completed in June 2010. During that period, there were some problems due to improper storage of the pre-casted girders on site. A dispute initiated regarding the strength and durability of its concrete, the extent of corrosion in its reinforcing steel which logically will be reflected on the overall structural integrity as well as its effects on the safety to serve as a major structural part of a durable railway bridge sufficient to sustain the repetitive exposure of dynamic loads.

A structural site investigation had been done to verify every part of the bridge to Figure out if it shows any signs of defects or failures. Moreover, a surveying measure for the levels and deflections at 14 selected points along the bridge profile had been recorded to check the, as built, overall geometry perfection of the bridge. An actual static and dynamic live loading tests have been done by passing the heaviest available locomotive (weighing 120 tons) at different speeds and while it was stopping at selected spots on the bridge deck slab. Again by the aid of the accompanying survey team, all the actual deflections under dynamic loading were listed. The measured deflections were compared with the allowable deflections permitted by the standard codes for such type of bridges.

### ANALYSIS OF THE BRIDGE

#### Moment resisting check

To check the bridge initial design adequacy, the following detailed analysis according to AASHTO Specifications has been done<sup>(1)</sup>.

Checking of the girders design:

Dead load per linear foot =

$$\left(\frac{10}{12} \times 2.87 + \frac{55}{12} \times \frac{15.7}{12}\right) \times 150 + \left(\frac{12}{12} \times 2.87 \times 75\right) = 1475 \text{ lb/ft}$$

$$\text{Dead load moment } M_d = \frac{1475 \times 65.5^2}{8} = 790,185 \text{ ft.lb}$$

According to the American Railway Engineering Association (AREMA) Cooper E-80 train load was used to represent live loading<sup>(2)</sup> (Figure 2). With an impact factor of  $I = \frac{50}{65.5+125} = 0.26$  and for a bridge having nine girders, the Cooper Axle loads will be multiplied by  $1.26/9 = 0.14$  for each girder. Then the case shown in Figure 5 represents the most critical live loading for moments.

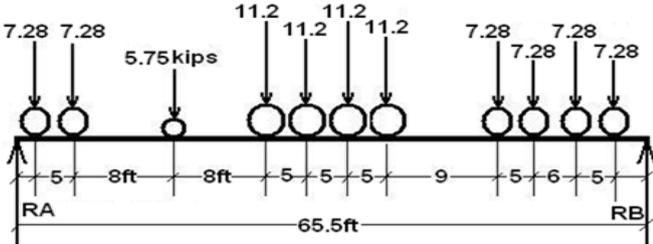


Figure 2. Cooper E-80 Loading Position for Maximum Moment

$RB = 47.27 \text{ kips}$

Maximum live load moment

$$M_{Lmax} = 47.27 \times 32.75 - 11.2 \times 5 - 7.28(14 + 19 + 25 + 30) = 852,000 \text{ ft.lb}$$

According to AASHTO, Sidewalk live load of 85 psf will be applied giving an additional load of  $(7 \times 85)/9 = 66 \text{ lb/ft/girder}$ .

Moment due to sidewalks live loading is  $(66 \times 65.5^2)/8 = 35,454 \text{ ft.lb}$

Total moment for each girder equals:

$$MT = 790,185 + 852,000 + 35,454 = 1,677,638 \text{ ft.lb}$$

Required area of steel is:

$$A_s = \frac{MT}{f_s(d - \frac{t}{2})} = \frac{1,677,638 \times 12}{30,000(58.5 - \frac{10}{2})} = 12.54 \text{ in}^2$$

Required #10 bars are  $= 12.54 / 1.27 = 9.876 \approx 10$  bars

Therefore the original design is perfect regarding the moment resistance of the girders.

**Checking the Concrete Compression Limits:**

By the following equation the maximum actual compression of the concrete can be calculated.

$$f_c = \frac{MT}{(1 - \frac{h_f}{2kd})b_j d \times h_f} = \frac{1,677,638 \times 12}{(1 - \frac{10}{2 \times 0.324 \times 58.5})2.87 \times 12 \times 10 \times 0.89 \times 58.5} = 1525 \text{ psi} < 2000 \text{ psi}$$

(Therefore the original design is perfect regarding the maximum compressive stresses subjected to the concrete of the girders)

The maximum compression of concrete will not exceed 1525psi which is less than the maximum permitted limit of 2000psi. This result will ensure that there will be no overstress at the deck slab and it will also be useful in the process of strengthening of the bridge girders.

**Shear resisting check**

Maximum Dead load shear

$$V_{dmax} = \frac{1475 \times 65.5}{2} = 48,306 \text{ lb}$$

Maximum live load shear according to Cooper E-80 train loading can be calculated when the train position gives the most critical shear as shown in Figure 3.

$$\text{Maximum live load shear at each of the girder supports } V_{Lmax} = RB = \frac{11.2(4.5 + 9.5 + 50.5 + 55.5 + 60.5 + 65.5)}{65.5}$$

$$= \frac{7.28(18.5 + 23.5 + 29.5 + 34.5) + 5.75 \times 42.5}{65.5} = 57.6 \text{ kips} = 57,600 \text{ lb}$$

$$\text{Sidewalks live load shear} = \frac{66 \times 65.5}{2} = 2160 \text{ lb}$$

Total maximum shear at each of each girder supports is:

$$V_T = 48,306 + 57,600 + 2160 = 108,066 \text{ lb}$$

108,066 lb = 48 Tons, this load will be used for the design and check for each bearing pad)

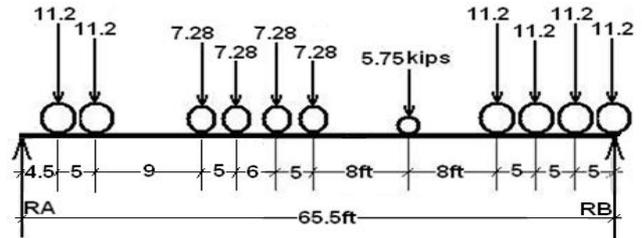


Figure 3. Cooper E-80 Loading Position for Maximum Shear

According to the specifications the most critical shear section is situated at a distance equals to  $d$  from support, so the calculations for shear at  $d$  (58.5 in  $\approx$  4.5 ft) from support will be as follows:

Maximum live load shear at  $d$  from support, according to Cooper E-80 train loading can be calculated when the train position gives the most critical shear as shown in Figure 4.

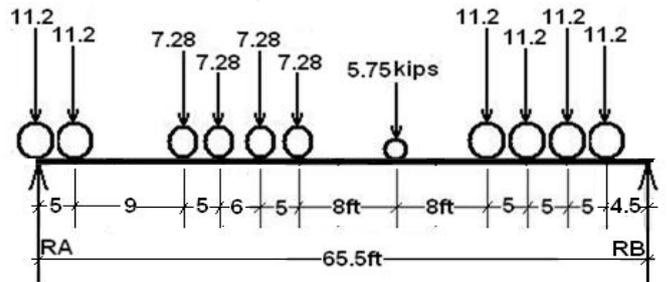


Figure 4. Cooper E-80 Loading for Maximum Shear at  $d$  from support

$$V_{Lmax@d} = \frac{11.2(5 + 61 + 56 + 51 + 46)}{65.5} + \frac{7.28(14 + 19 + 25 + 30) + 5.75 \times 38}{65.5} = 50.5 \text{ kips} = 50,500 \text{ lb}$$

Total maximum shear at  $d$  from each of each girder supports is:

$$V_{Tmax@d} = 48,306 + 50,500 + 2160 = 100,966 \text{ lb}$$

Allowable shear stress of concrete is:

$$0.95\sqrt{f_c'} = 0.95\sqrt{5000} = 67 \text{ psi}$$

Shear stress at  $d$  from support is:

$$\frac{100966}{65 \times 15.7} = 100 \text{ psi}$$

Required spacing of #3 bars is'

$$S = \frac{0.22 \times 24,000}{(100 - 67)15.7} = 10.2 \text{ in}$$

{Again the original shear reinforcement design of #3@6" c/c ( $\Phi 10@150 \text{ mm c/c}$ ) is accepted}

**BRIDGE GIRDERS**

Northern and Southern Panel Girders:

Despite of the moderate construction level of the Northern and Southern panels' girders they show no clear signs of failure.

Intermediate Panel Girders:

The Intermediate panel is supported by nine girders designated as G8, G9, G10, G11, G12, G13, G14, G15 and G16. Each girder spans 20.8 m with a stem of 1.4 m. These girders show visible mid span deflections of more than 3 cm as shown in Figure 5.



Figure 5. Visible mid span deflection at the right side of the intermediate panel

Most of this visible mid span deflections are due to the lack of construction experience. The constructing team did not care about the construction stresses generated during the casting of the concrete of the deck slab process. This fresh concrete weighs more than 100 tons and it was applied only to the rectangular portion of the girders<sup>3)</sup>. An expert construction contractor would not cast such long girders by using flat bottom formworks, but instead they might raise the middle of their formwork by a Cambering process<sup>4)</sup>. The amount of cambering depends upon the span length, loading and experience to avoid this inevitable deflection. In spite of this visible deflection at the bottom face of these girders which exceed 3 cm, leveling measurements at the top of the deck slab of this panel showed no deflections. This essentially means that the construction team had increased the deck slab thickness to produce the required formation level and consequently slightly increased the dead load of the bridge. Nevertheless, this deflection shall only affect the aesthetic appearance of the bridge and may result in some minor cracks.



Figure 6. The Locomotive used in loading Test

LOADING TEST

In order to evaluate the overall structural performance of the intermediate panel girders, a real full scale load testing had been performed. The Iraqi Republic Railways company kindly provided the

heaviest available locomotive shown in Figure 6 which has the following properties: 120 tons of weight, 20 m of length and 6 axles.

Testing Procedure

First of all the locomotive had been stopped at several selected points to check shear and moment resisting strengths of the bridge and to measure deflections under static live loading, see Figures 7, 8, 9, 10, 11 and 12.

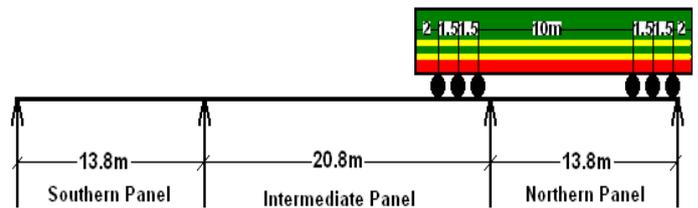


Figure 7. Checking Shear for Northern Panel

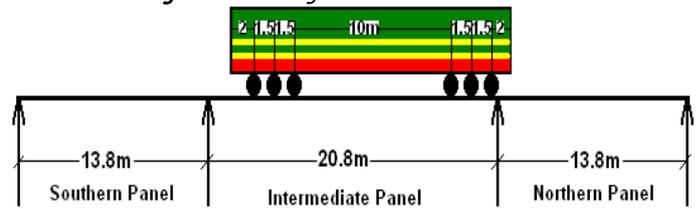


Figure 8. Checking Shear for Intermediate Panel

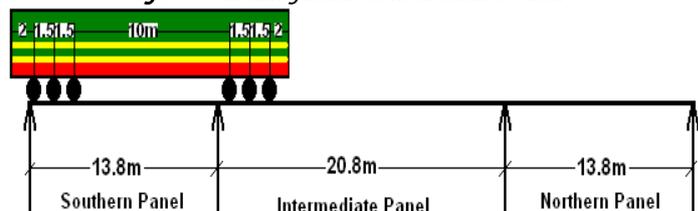


Figure 9. Checking Shear for Southern Panel

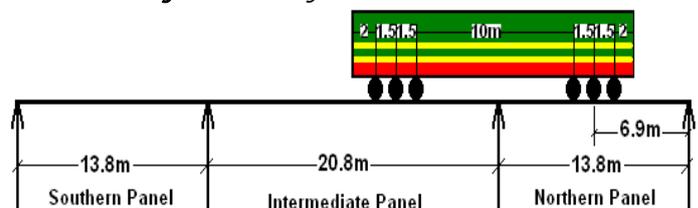


Figure 10. Checking Moment and Deflection for Northern Panel

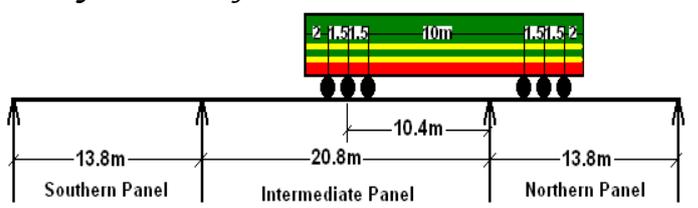


Figure 11. Checking Moment and Deflection for Intermediate Panel

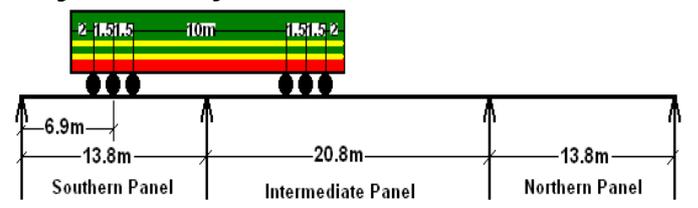


Figure 12. Checking Moment and Deflection for Southern Panel

At this static live loading test there were no signs of Shear or Moment failures, and the recorded deflections were negligible.

The Second phase of the test was the Dynamic Live Loading Test. At this stage the Testing Locomotive was moving at a speed of 40 - 50

km/h while deflections were measured. A new and easy method was adapted by perpendicularly holding the surveying ruler at mid sidewalk point of each tested panel while the level was set in a stable position outside the bridge, see Figure 13. The dynamic stage is considered more severe than the first static stage because the weight of the testing locomotive of 120 tons will be increased according to AASHTO Standards by 26% due to the impact and sudden application of the load. This will make the locomotive apply about 151 tons instead of 120 tons, which results in a single axle load of 25tons.



Figure 13. Method used for measuring deflections under dynamic live loading

Measured deflections under dynamic live loading are shown in Figure 14. Deflections of -1mm were recorded at mid spans (P3, P4, P11 and P12) of both of northern and southern panels. These deflections were less than the permitted maximum deflection by the AREMA'S live load deflection criteria which is equal to L/640;

$$13000/640 = 20\text{mm}$$

The settlements at P6 and P5 might be a normal reduction in the height of the supporting bearings under such heavy loading. While the settlements at both of P9 and P10 were little bit larger due to the torn and worn bearings which were recommended to be replaced.

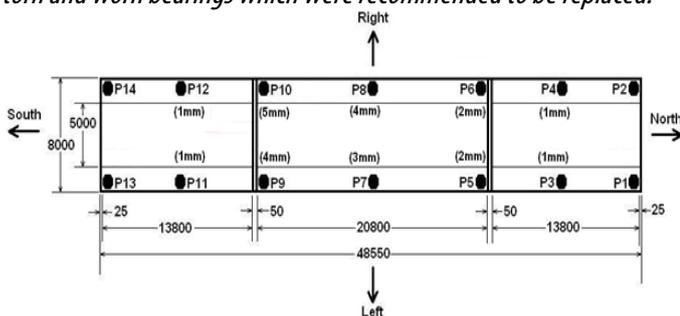


Figure 14. Settlement and Deflection measurements under dynamic live loading

Deflections at P8 (-4mm) and P7 (-3mm) at mid span of the intermediate panel require the following analysis: Figure 15 shows the position and the amount of loading that will produce the maximum moment at mid span of the intermediate panel.

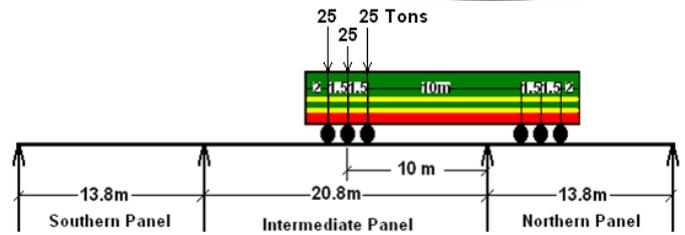


Figure 15. Position and amount of loading that produce maximum dynamic moment at mid span of the intermediate panel

$$\text{Maximum moment/Girder} = (37.5 \times 10 - 25 \times 1.5) / 9 = 37 \text{ t.m}$$

The original design was based on Cooper E-80 Loading of 300 tons for this span. The share of each girder was  $300 \times 1.26 / 9 = 42$  tons. This load will produce a maximum moment of 115 t.m + a maximum moment due to sidewalks live loading of 5 t.m. This means that the deflection of P8 under the maximum design live loading equals:

$$4 \times 120 / 37 = 13 \text{ mm}$$

According to AREMA'S live load deflection criteria which is equal to L/640, the maximum permitted deflection for this panel under live loading is:

$$20000/640 = 31\text{mm}$$

(Therefore, this panel does comply with the permitted deflections)

Finally, although the bridge has passed the deflection live loading test, this bridge was strengthened by the use of Carbon Fiber Reinforced Polymer (CFRP) to enhance its performance and durability due to its cracked concrete.

**CONCLUSIONS:**

The following conclusions can be derived from this case study:

- » Loading Test of an Existing Railway Bridge can be done by applying the heaviest existing Train Locomotive.
- » The recorded test deflections can be modified based upon the difference between the testing and the standard live loading weights.
- » Some deflections of railway bridges can impair its aesthetic appearance but still these bridges can stay in action for a long time.

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## RESEARCHES REGARDING THE MECHANO-PNEUMATIC DISTRIBUTION ON THE STRAW CEREALS SOWING MACHINES

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**Abstract:** This paper presents some theoretical considerations regarding the calculus, design and running of the mechano-pneumatic distribution devices which equip the straw cereals sowing machines. The distribution devices make the seeds measuring and their bleeding to the driven pipes for shovels. This measuring and bleeding process, named the seeds distribution process, affects over the main qualitative index of the sowing machine: flow rate stability, sowing norm, distribution uniformity on the working width, distribution uniformity on row. In paper there are accentuated the advantages of using these distribution devices types in contrast with the classical distribution devices.

**Keywords:** distribution device, measuring, seeds, technical equipment

### INTRODUCTION

Lately, the sowing machines development especially concentrates on the improvement of the seeds distribution uniformity, tendency which much accentuated at present. As a result appeared several distribution device types, which satisfy more and more the sowing agro-technical requests, also the operating and design ones imposed to these machines.

The straw cereals seeds distribution devices are very important for ensure sowing quality and for realize light constructions of a low complexity, also determine the aggregate working speed. In other words the distribution devices determine: the seeds distribution uniformity, the seeds quantity per hectare, the seeds density, the seeds harm, the working speed, the sowing machine weight, adjustment possibilities of the seeds norm per hectare, the shape and sizes of the seeds tank and other characteristics of the sowing technical equipment.

Because of these elements can affirm that the seeds distribution devices are the main working parts of a sowing machine and by the way they works depend the sowing quality and sowing machine type.

### CLASICAL DISTRIBUTION DEVICES

#### Distribution devices with fluted roller

The classical construction of the fluted roller distribution device is represented by a box fixed on the seeds tank bottom, where is the fluted roller. At some sowing machines the distribution device box is fixed laterally bottom, device feed is done by holes at the bottom of the seeds tank wall.

In figure 1 there are presented schematically two design solutions of distribution devices with fluted roller with the box in the lateral side

(fig. 1, a) or in the bottom of the seeds tank. The adjustment of the seeds active layer is obtained with the lappets 1, their driving being in the same time for all machine distribution devices. For make the machine test there is provided the seeds collecting cradle 2.

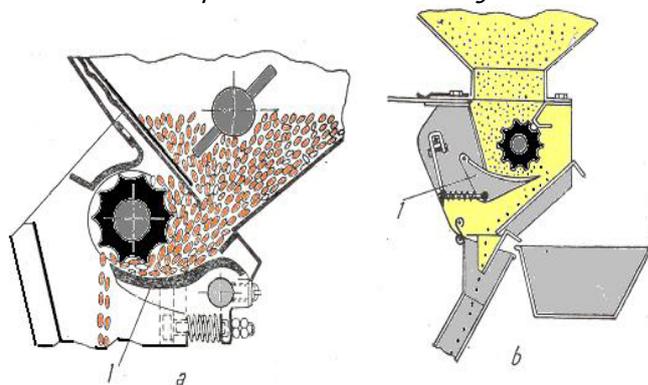


Figure 1 - Distribution devices with fluted roller

#### Distribution devices with spurs roller

The working and design principle of this distribution device is similar with the one of the distribution device with fluted roller.

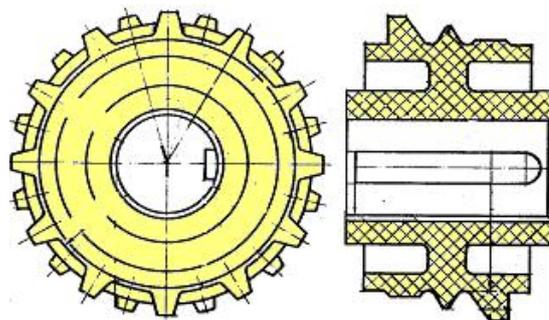


Figure 2 - Spur roller

The main working part is a roller (fig. 2) on whose surface there are disposed two rows of 12 spurs, between the spurs rows being provided a continuous rib, whose role is to direct the seeds to the spurs.

The spurs on the two rows are in zig zag shape, the spurs on a row being disposed in front of the gaps between the spurs from the second row, such a spurs disposal ensuring a better uniformity of the seeds flow, diminishing its pulsations.

The spurs rollers, which equip a sowing machine, are fixed on the same axle, each roller being closed in a box fixed on the lateral wall of the seeds tank, at its bottom (fig. 3).

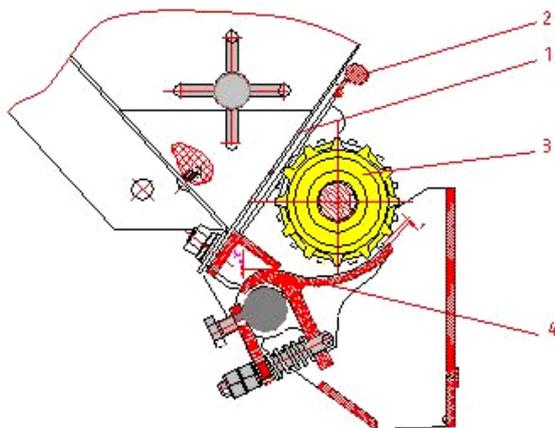


Figure 3 - Spurs roller distribution device schedule

The section of the hole from the seeds tank wall 1, through is ensured seeds feed of the distribution device, can be adjusted by the lappet 2 position modification. The mobile lappet 4 position towards the spurs roller 3 can be adjusted in terms of the seeds dimensions of the crop (the distance between spurs and lappet must be bigger than the seeds maximum size).

By spurs roller 3 rotation, seeds from tank come in the spurs action area where are driven by them and evacuated from the device. Through the spurs way of arrangement, each spur realizes seeds evacuation, ensuring a regular seeds flow.

The two distribution devices presented above are in the classical distribution devices which equip the straw cereals sowing machines, nowadays more and more diminuated. Lately, both on global plane and in our country there are used on a large scale technical equipments for straw cereals setting up with distribution devices with centralized measuring and pneumatic distribution, in other words mechano-pneumatic distribution devices. In contrast with the classical distribution devices, this device type has an advantages range. First, it allows the design simplifies and weight diminution of the sowing technical equipment for seeds tank capacity and efficiency increase. Because of the design characteristics of this device, that means a lots of possibilities to arrange it on the sowing machine, they may have more large working width than the universal sowing machines, in this way being reduced the passes on the field.

**THEORETICAL STUDIES REGARDING THE MECHANO-PNEUMATIC DISTRIBUTION TYPE**

At the mechanical measuring and pneumatic distribution devices the seeds measuring for all shovels are mechanical, with a fluted roller

distributor and their repartition and transport for the shovels is done pneumatically. In figure 4 there is presented the working principle of the device with mechanical measuring and pneumatic distribution: from the tank 1, the seeds measured from the fluted roller 2 are evacuated in the conduct 3, where the air flow made from the fan 4 takes them. From the horizontal conduct 5 for the distribution main head 6, where on make the air and seeds mixture primary distribution for the secondary distribution heads 7, 6-8 in number, which every conduct the seeds mixture for 6-8 shovels. The secondary distribution heads are installed on homogenization vertical pipes (mounted on the machinery frame), like the vertical pipe 5, but with a smaller diameter. The place where the seeds are taken by the air flow must have a Venturi (shape) construction towards obviate of some additional pressures witch upset the seeds back for the distribution device. The vertical conduct walls, on the last region, before the distribution main head, are gofers for the insurance of the air-seeds mixture homogenization.

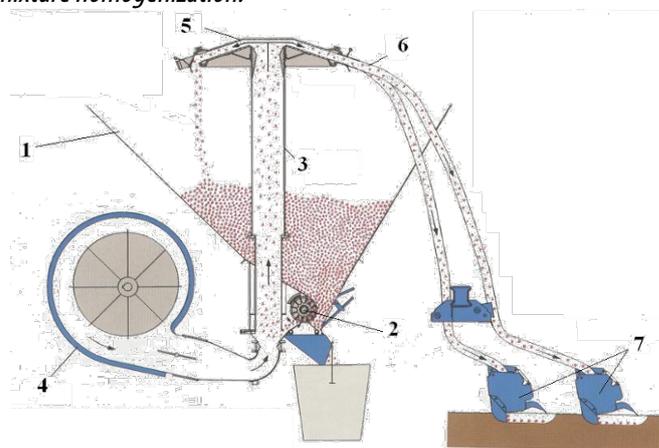


Figure 4 - Device with mechanical measuring and pneumatic distribution

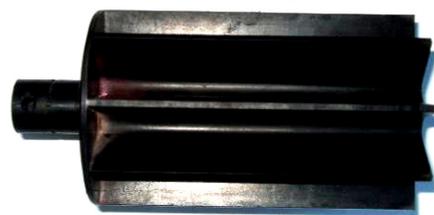


Figure 5 - Mechanical dosimeter as fluted roller type

The main requests imposed to the mechanic fluted roller (fig. 5) which equips the straw cereals sowing machines:

- » can be used to sowing a large crops number; in this aim the fluted roller must be provided with the possibility of the flows rate adjustment corresponding to the sowing norms imposed for each crop, to the distance between rows and to the seeds working depth, in accordance with the setting up technologies for each crop;
- » to ensure an uniform flow rate, respectively the sowing norms, in the limits of the working speeds, corresponding to the sowing machine exploitation conditions;
- » to ensure an uniform seeds distribution both on the machine working width and on row; to this effect they must measuring equal seeds quantities;

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- › the ratio between the seeds dosimeter rotation speed and the sowing machine advance speed must be constantly, at the same adjustment;
- › in the distribution process seeds mustn't be broken.

The main requests imposed to the pneumatic distribution (fig. 6) are:

- › the place where seeds are taken by the air flow must have a Venturi construction (shape), for avoid some overpressures which throw back seeds to the distribution device;
- › the vertical pipe walls, on the last segment, before the main distribution head, must be goffered for ensure the air-seeds mixture uniformity;
- › the seeds flow sent to the shovels must be uniform, respectively on the length unit of each row must be distributed the same seeds quantities;
- › the air flow speed in the transport and distribution process must be bigger than the critical seeds floating; the cereals seeds critical floating speed being generally between 9...14 m/s, result that in the main pipe the air speed must be 20...25 m/s.

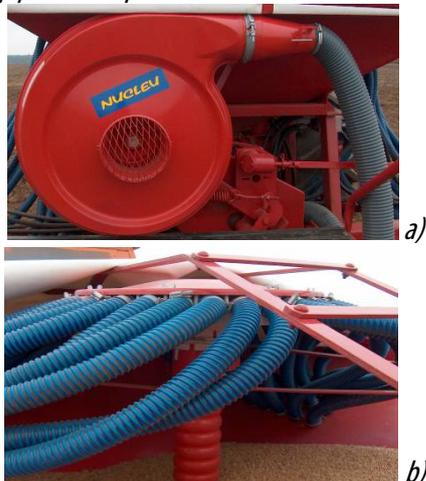


Figure 6 - Pneumatic distribution

a) fan; b) vertical pipe and distribution head

In terms of their destination, the sowing machines equipped with such distribution devices work on 24...90 rows, the distribution device ensuring the norm adjustment between 2...360 kg/ha.

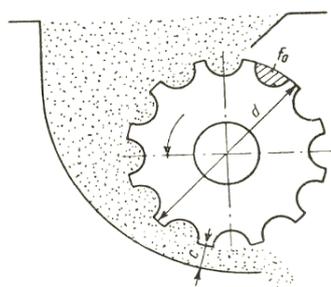


Figure 7 - Working schedule of the fluted roller distribution devices

Calculus elements of the seeds dosimeter as fluted roller type

The distribution device with fluted roller realizes both the seeds constrained distribution (seeds in the flutes) and the seeds free distribution (seeds in the active layer). The thickness *c* (fig. 7) of the active layer depends on the lappet position which limits the bottom size.

Seeds volume evacuated by the fluted roller distribution device

The seeds flow rate is:

$$q = \frac{V_d \cdot n_d \cdot \rho}{60} \left[ \frac{kg}{s} \right] \quad (1)$$

where: *V<sub>d</sub>* is the seeds volume distributed at one fluted roller rotation [m<sup>3</sup>/rot]; *n<sub>d</sub>* – distribution device rotation speed [rot/min]; *ρ* – the seeds volume mass [kg/m<sup>3</sup>].

On determine the seeds volume distributed at one fluted roller rotation with the relation:

$$V_d = V_0 + V_a \quad [m^3/rot] \quad (2)$$

where: *V<sub>0</sub>* is the seeds volume evacuee from the flutes (forced distribution) [m<sup>3</sup>]; *V<sub>a</sub>* – the seeds volume from the active layer [m<sup>3</sup>];

The seeds volume evacuated at one fluted rollers rotation is:

$$V_0 = A \cdot L \cdot z \cdot \psi \quad [m^3/rot] \quad (3)$$

where: *A* is the one flute section area [m<sup>2</sup>]; *L* – the fluted drum active lenght [m]; *z* – number of flutes; *ψ* = 0,93...0,98 for small seeds, *ψ* = 0,60...0,85 for big seeds.

Calculus of the active layer thickness of the fluted roller distribution device

The active layer (fig. 8, a and b) has a roller shape, of *c<sub>0</sub>* depth, concentrical with the fluted roller; this layer seeds are driven in rotating motion because of the friction forces between the fluted roller and the seeds and seeds themselves.

The active roller seeds pass with different speeds, the speed value decrease in the same time with the distance increment till the fluted roller (fig. 8, b).

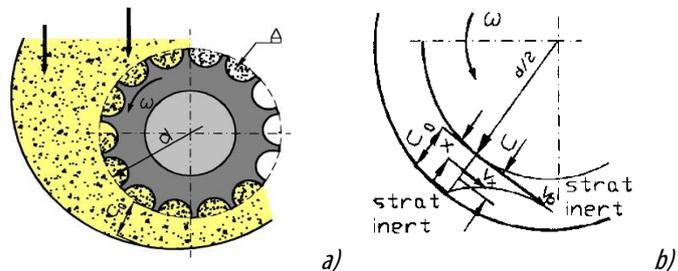


Figure 8 - Calculus of the active layer thickness of the fluted roller distribution device

The speed value in an *x* active layer section is given from a rule as:

$$v_x = v_p \left( 1 - \frac{x}{c_0} \right)^m \quad (4)$$

where: *v<sub>x</sub>* is the seeds speed wich are at *x* distance from the fluted roller; *v<sub>p</sub>* – the fluted drum peripheral speed; *m* – exponent wich value is experimental determined for several crop seeds; *m* = 2,6 for wheat, oat, barley seeds.

Come up the seeds debits which flow through the active layer of *c<sub>0</sub>* depth and through the accepted depth *c<sub>0</sub>* layer on obtain the identity:

$$c \cdot v_p \cdot L = L \cdot v_p \cdot c_0 \int_0^{c_0} \left( 1 - \frac{x}{c_0} \right)^m \cdot dx \quad (5)$$

and by integration on obtain:

$$c = \frac{c_0}{1 + m} \quad (6)$$

The necessary  $Q_a$  air volume debit for the  $q$  seeds debit pneumatic transport is:

$$Q_a = \frac{q}{\mu \rho_a} \left[ \frac{m^3}{s} \right] \quad (7)$$

where:  $\mu$  – the air-seeds mixture gravimetric concentration coefficient;  $\mu = 0.3 \dots 0.5$ ;  $\rho_a$  – the air volume mass [ $kg/m^3$ ].

The  $v_a$  air current speed in the distribution and transport process must be bigger than the floating critical seeds speed:

$$v_a = (1,3 \dots 2,5) \cdot v_{cr} \quad (8)$$

where:  $v_{cr}$  is the floating critical seeds speed.

The  $D_c$  diameter of the main seeds transport and distribution pipe.

On settle the  $D_c$  diameter in terms of  $Q_a$  și  $v_a$  from the equality:

$$\frac{\pi \cdot D_c^2}{4} \cdot v_a = \frac{q}{\mu \cdot \rho_a} \quad (9)$$

and results:

$$D_c = \sqrt{\frac{4 \cdot q}{\pi \cdot v_a \cdot \mu \cdot \rho_a}} \quad (10)$$

### CONCLUSIONS

The seeds measuring and evacuation process determine the qualitative working index of the seeding machines as: the debit stability in the working process, the distribution uniformity on the working width of the seeding machine and the distribution uniformity on the plants row. To this effect the measuring and evacuation devices calculus and dimensioning is very important.

The utilization of these measuring devices present the advantage of a good measure precision at high working speeds (on insurance debits from 0 to 400 kg/ha at working speeds from 7 to 12 km/h) and allows an easy and safety adjustment of the seeds quantity in accordance with the agro-technical norms, for each crop.

At present on observe a tendency for a continuous improvement of the centralized distribution devices, especially because the sowing machines equipped with such distribution devices, in contrast with the ones equipped with individual distribution, have a compact design, large working widths, high maneuverability and a large utilization area.

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Jamiu K. ODUSOTE

## DESIGN AND FABRICATION OF A POLYTHENE/NYLON WASTES RECYCLING MACHINE

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**Abstract:** The traditional methods of disposing polythene/nylon wastes have proved to be relatively expensive and unhealthy. Recycling of these non-biodegradable wastes will be more economical, healthy and safer for the environment. Thus, the objective of this research work is to design and develop a motorized polythene/pure water nylon recycling machine, using locally available materials. The machine is designed to use fixed and rotary blades, which are rotated by high-speed electric motor. Heat is provided for softening of the polythene prior to shredding by the blades. Tests were performed on the recycled machine to determine its possible output, and the results showed that 30-40 kg of recycled flakes was produced per hour at a machine speed of 2880 rpm. The flakes are used with recycled plastic wastes and/or virgin materials for production of colored plastic product.

**Keywords:** polythene/nylon, wastes, recycling machine, mild steel, local materials

### INTRODUCTION

Plastics have become more popular materials for industry and its household uses have also increased tremendously. This has led to increase in the volume of plastic wastes of several types being generated in our society (Wilson, 1981). Most of these wastes are non-biodegradable and thus cannot be broken down by microbial action into simple inorganic forms like most other biodegradable wastes (Andrew and Subramaman, 1992). Most plastics and polythene/pure water nylon wastes are usually thrown in public drains, roads and open places to public view in most parts of the country. These wastes are used at times as a combustion aid for burning other organic refuse, and this liberates toxic vapours or gases that pollute the air and causes inconveniences to residents living near the landfill sights (New, 1986). Their values as reclaimed or recycled waste is considerably higher than their values as energy source (Andrew and Subramaman, 1992). Accordingly, well-known destructive techniques, such as incineration or pyrolysis (Leidner, 1981), seem quite wasteful, and hence, recycling of plastic wastes is the best method for solving both the environmental and economic problems associated with plastic waste disposal.

Recycling of plastic wastes is rapidly developing in almost every society and this is largely based on the environmental awareness, need to conserve materials and energy, and growing demand to increase production economy (La Mantia, 1993 and Chatterjee and Kumar, 2009). Many private industries and few government agencies are now engaging in recycling of plastic and polythene/nylon wastes. Recycling of plastic/nylon wastes could be achieved through chemical or mechanical recycling method. The chemical means involve solvent recycling process (Kampouris et al., 1995), flotation separation (Dilly-

Louis, 1997) and selective dissolution techniques (Herberg et al., 1992). On the other hand, mechanical recycling involves the use of machines in converting the waste into recycle products, which can be re-used in new application (Jost, 1995). However, some of these machines are either non-available or expensive. Thus, the objective of this study is to design and develop a polythene/pure water nylon recycling machine from locally available materials, which will be cheaper and available.

### MATERIALS AND METHODS

#### Machine Components

The polythene/nylon waste recycling machine consists of the following main components/units: the inlet-hopper/drum through which the wastes are fed into the machine, the recycling unit which consists of fixed blades and rotary blades performs the grinding and cutting operations. Three pieces of well sharpen fixed blades are firmly attached to the drum internally at a distance of less than 20 mm from the bottom of the drum. These blades are attached by sturds and bolts for easy removal and maintenance of the machine. Two pieces of rotary blades are welded to the spindle, which is attached to the shaft. The third unit is the driving unit, which consists of belts, bearing and pulleys transmit electric motor power to the drum and driving shaft. Figure 1 shows the assembly drawing (isometric view) of the recycling machine.

The inlet-hopper/drum, which determines the quantity of wastes to be loaded, is made of galvanized sheet based on its ability to withstand working stress, thermal conductivity and good wear resistance. Both the fixed and rotary blades are made of spring steel for good wear and corrosion resistance. A 3 KW electric motor is the power source and mover of the machine by shaft and belt drive. Heat

is generated as the blades are rotating over one another during operation, and thus soften the nylon and then cut it into smaller pieces. The speed of the electric motor also contributes to the cutting rate of the machine.

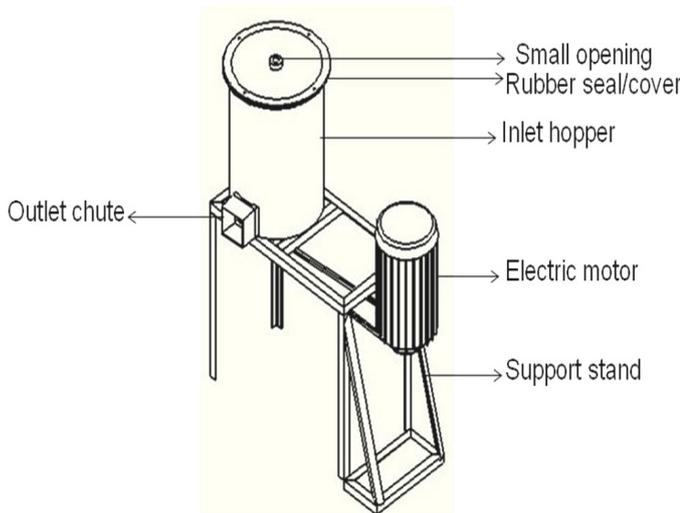


Figure 1. Assembly drawing of the recycling machine (isometric view)

**Design Theory and Calculations**

During the design process of the recycling machine, there are considerations for manufacturability, cost reliability and maintainability of the design product. The primary objective is to design a functioning product within given economic and schedule constraints.

**Drum/Inlet Hopper designs**

The drum is cylindrical in shape and its size can be obtained using the formula for obtaining the volume of cylinder,  $V$ , as given in Eq. 1.

$$V = 2\pi r^2 h \tag{1}$$

where  $r$  is the radius of the drum and  $h$  is the height of the drum. The drum wall thickness,  $t$ , is 6 mm, while the height is 400 mm and the diameter,  $D$ , is 310 mm. The value  $t/D$  for the drum is less than 0.05, which shows that its thinned wall, and thus reinforced with flat bars to increase its ability to withstand any form of pressure.

**Drum Shaft Design**

The shaft is the rotating member having a circular cross section much smaller in diameter than the shaft length. Energy transmitting elements such as pulley, belts and bearings are attached to the shaft. The loading on the shaft can be various combinations of bending (almost always fluctuating), shock or axial, normal, or transverse shear. Thus, shaft design primarily involves the determination of the correct shaft diameter to ensure adequate strength and rigidity when the shaft is transmitting power under various operating and loading conditions. Strength, using yield or fatigue (or both) as a criterion; deflection; or the dynamics established by the critical speed are also considered in designing shaft (Hamrock et al., 1999).

The dimension of the shaft is:

- » Length = 760 mm
- » Diameter = 25 mm

The resultant internal moment,  $M_x$ , at any section along the shaft may be expressed as:

$$M_x = (M_{xy}^2 + M_{xz}^2)^{1/2} \tag{2}$$

where  $M_{xy}$  and  $M_{xz}$  are the bending moments in  $x$ - $y$  and  $x$ - $z$  planes respectively.

The force exerted on a shaft in the transverse direction (perpendicular to the shaft axis) produces a maximum stress of:

$$\sigma_b = \frac{M_b r}{I} \tag{3}$$

$$\tau_{xy} = \frac{M_t r}{J} \tag{4}$$

For a circular cross section, where  $r = d/2$ ,  $I = \pi d^4/64$  and  $J = \pi d^4/32$ , the bending stress according to Hall et al. (1982), will be given as:

$$\sigma_x = \frac{32M_b}{\pi d^3} \tag{5}$$

For torsional stress, the expression is:

$$\tau_{xy} = \frac{16M_t}{\pi d^3} \tag{6}$$

For a solid shaft combining torsion and bending loads by applying the maximum shear equation modified by introducing shock, fatigue and column factors, the ASME code equation is given as:

$$d^3 = \frac{16}{\pi \sigma_s \left[ \sqrt{(K_b M_b)^2 + (K_t M_t)^2} \right]} \tag{7}$$

where,  $\tau_{xy}$  = torsional shear stress ( $N/m^2$ );  $M_t$  = torsional moment (Nm);  $M_b$  = bending moment (Nm);  $K_b$  = combined shock and fatigue factor applied to bending moment;  $K_t$  = combined shock and fatigue factor applied to torsional moment;  $\sigma_b$  = bending stress;  $\sigma_s$  = allowable stress;  $d$  = shaft diameter (m)

If the shaft diameter is known and safety factor,  $n_s$ , is unknown, then,

$$n_s = \frac{\pi d^3 S_y}{32 \left( \sqrt{M^2 + T^2} \right)} \tag{8}$$

where  $S_y$  is yield strength.

**Blades Design**

The recycling machine is designed to use both fixed and rotary blades (Figure 2). These blades are well sharpened for effective cutting of the nylon waste. Two pieces of rotary blades were welded to the spindle, which is attached to the shaft.

The fixed blades are attached firmly to the drum internally with sturds and bolt for easy removal and maintenance. They are attached very close to the bottom of the drum at a distance of about 1.5 mm in between each of them.

The choice of other components such as bearing and belt depends on the diameter of the shaft and or its pulley, while the quantity of waste to be recycled, power required by the machine as well as the required speed rate of the machine will assist in the choice of the electric motor to be used.

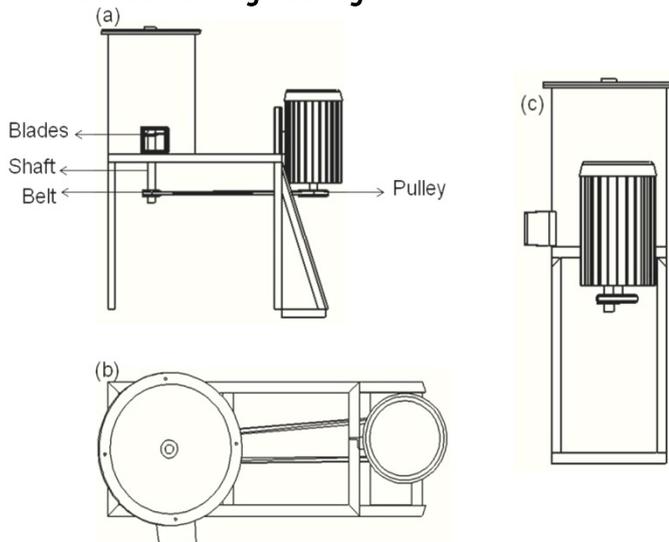


Figure 2. Different views of the machine showing the blades and Pulley  
(a) Front view (b) Top view (c) Side view

**The Fabrication and Testing of the Machine**

Figure 3 shows the diagram of the recycling machine after components design, fabrication and coupling. The processes entailed are listed below:

- » Measuring, marking out and cutting of the various parts of the mild steel
- » Bolts, nuts and stud machining
- » Holes formation
- » Joining of machined parts
- » Finishing and aesthetics

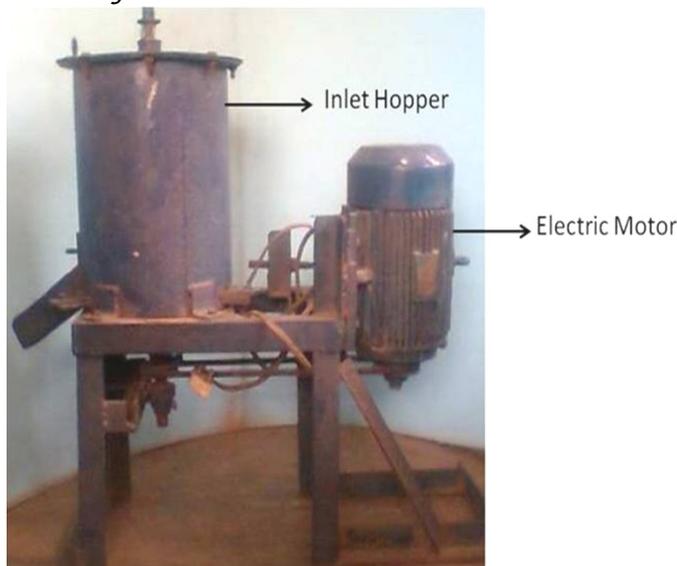


Figure 3: Polythene/Nylon Waste Recycling Machine

**Machine Testing**

Pure water sachets were sorted, cleaned and dried prior to weighing and charging into the machine through the inlet hopper. The charged sachets were pressed close to the fixed blades using the holder inside the hopper. The friction between the fixed and the rotary blades generated heat which help to soften the nylon waste prior to cutting. The flakes from the cut were collected through the outlet chute.

**RESULT AND DISCUSSION**

The product obtained after recycling the waste pure water sachets nylon by the machine is in form of flakes of different sizes. Although, the target is to obtain pellet of recycled waste or small grains similar to result of Kampouris et al, (1988) during recycling of polystyrene (PS) by solvent recycling process. However, the shredded nylon waste can be re-extruded with other plastic waste for production of coloured high density plastic or composite (Sasaki and Tomita, 1993).

**CONCLUSIONS**

The recycling machine designed produced about 20-30 kg of shredded nylon flakes as output per hour. The flakes can be re-extruded for production of colored plastic products and composites. With these results, the primary objective of designing and fabricating a polythene/nylon wastes recycling machine using locally available materials has been achieved. The machine if successfully improved upon will assist in cleaning up our environment of non-biodegradable polythene/nylon wastes, which have constituted a serious health and environmental problems in our society. The following recommendations are suggested to improve on the machine:

- » The properties of the polythene/nylon wastes should be well studied so as to carry our further work on the machine.
- » A heating unit as well as sieving unit should be introduced in the machine in order to be able to produce pellets of relatively same sizes from the machine.
- » Power requirement of the machine equipped with the heating unit must be determined to improve the efficiency of the machine.

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## STOCHASTIC MODELING OF HONING PROCESSES

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**Abstract:** More accurate description of abrasive manufacturing procedures can be done stochastic methods that is why their application are advantageous. The author have elaborated the stochastic mathematical model of abrasive microcutting systems and processes of the tools with undetermined edge-geometry and many edges that makes description of e.g. honing, grinding possible. The system of mathematically formulated relationships corresponds to the experimental observations. The elaborated method is applicable also to describe the abrasive wear processes at grinding or at machining. This method provides the ability to calculate and design the statistical parameters of the machined surface and the process.

**Keywords:** abrasive manufacturing procedures, stochastic methods, honing

### INTRODUCTION

The figure 1 demonstrates schematically the interaction of an optional abrasive tool and a rough workpiece. Validity conditions of the model are in publication [1, 2].

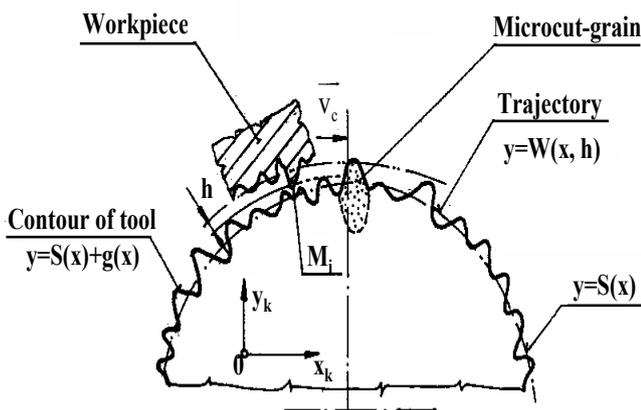


Figure 1. Stochastic model. Interaction of a multi-edge tool and the workpiece ( $\bar{v}_c$  is the cutting speed).

The most important conditions are as follows.

- » The microgeometrical traces formed on the machined surface depending on the shape size, number, distribution of the grains which create them and the technological data (average depth of cut, trajectory, etc.).
- » There are not built up edges on the tool. In most cases the material of the workpiece is cast iron or hardened steel.
- » Wear of the tool is ratherly slow in the case of super hard cutting tools, the process can be pretend to stationary.
- » Examinations are done in the standing coordinate system fixed to the tool.

### INTERACTIONS OF TOOL AND WORKPIECE. STOCHASTIC MODEL

The trajectory of the point  $M_i$  of the workpiece depends on kinematics of the machine, on the applied technological parameters (components of cutting speed), thus on the actual realisation of the forming mechanism. The point  $M_i$  is situated in  $h$  height above a

designated "zero-level". This height will be worked off by the designated cutting grain. Zero-level:  $h=0$ . Other precondition:  $y_0=0$ . The task is to determine the probability of connections of the most protruding cusps on the workpiece with the most protruding grains, thus the expected height of developing roughness. The equation of trajectory of the point  $M_i$  in the orthogonal system of axes taken according to point  $d$  is:

$$y=W(x;h), \quad (1)$$

where the sindow variables are  $x, h$ .

The profile of the tool is:

$$y=S(x)+g(x), \quad (2)$$

where  $S(x)$  is a deterministic function describing the macro-form of the tool,  $g(x)$  is a stochastic stationary formula that characterises the peakness of the grains. The trajectory that belongs to the point  $M_i$  is passing through without any connection over the tool-profile. In this case:

$$W(x;h)>S(x)+g(x). \quad (3)$$

The probability of completion of this relation can be expressed by such a stochastic function that equals to the probability of the skip-free state of the

$$\Psi(x;h)=S(x)+g(x)-W(x;h) \quad (3/a)$$

stochastic function at the given "zero-level". Selection of such a function is a complicated task, however it can be simplified since the tool surface (the height of the protrusion peaks) can correctly be characterised by the Gaussian distribution for honing tools with super-hard grains, according to practical experiences. The probability of the skip-free state is the following [2, 3]:

$$P(h) = \exp \left[ - \int_{x_{min}}^{x_{max}} \int v f_1(y;v) dv dx \right], \quad (4)$$

where  $f_1(y;v)$  is the density function that characterises the peakness of the tool. The relation between the ordinate values  $y$  and variable  $v$  is:

$$v = \frac{dy}{dx}$$

The latter differential quotient expresses the form, running off (incline or direction factor) of the grain-edge. The interval of the skip's examinations:  $x_{max} \cdot x_{min}$ , where the tool-workpiece connections are possible at all;  $f_i(y;v)$  may be expressed by the stochastic characteristics of the  $g(x)$  micro-profile of the abrasive tool given by the  $f(y;v)$  density function.

It is conceivable that if  $y = \Psi(x; h)$ , then  $g(x) = y - S(x) + W(x; h)$ . Similarly:

$$\frac{\partial \Psi(x; h)}{\partial x} = v, \text{ then } \frac{\partial g(x)}{\partial x} = v - \dot{S}(x) + \dot{W}(x; h),$$

where

$$\dot{S}(x) = \frac{\partial |S(x)|}{\partial x} \text{ and } \dot{W}(x; h) = \frac{\partial W(x; y)}{\partial x}.$$

Differentiation at the  $x=0$  spot will lead to the following relation:

$$f_1(0; v) = f[W(x; h) - S(x); v - \dot{S}(x) + \dot{W}(x; h)]. \quad (5)$$

During machining, the cutting tool turns into contact with the workpiece several times. During the previous operation a characteristic micro-topography of the workpiece has already been formed, which depends on the applied machine-tool kinematics, the tool and the set of technological characteristics, thus on the so-called "forming mechanism". The surface after the rough machining is characterised by the  $P_0(h)$  distribution function.

The number of repeated connections of the tool and the workpiece during the machining is  $n$ . At the  $i$ -th touch the  $f_{i1}(0;v)$  density function holds good. Conversely, the depth of cut will be changed due to displacements and elastic deformations. If the point  $M_i$  will contact the tool  $k$  times, then:

$$P(h) = P_0(h) \exp \left[ -k \sum_{i=1}^n \int_{x_{min}}^{x_{max}} \int_0^{\infty} v f_{i1}(0; v) dv dx \right]. \quad (6)$$

The "zero-level" of  $P(h)$  and that of  $P_0(h)$  is equivalent, of course. Consequently, the height-distribution of the workpiece's micro-roughness should be expressed in the plane that is common with the tool-profile, applying the stochastic function that describes the tool-profile. Substituting the stochastic function that designates the tool into the equation (6), we will reach the distribution function that characterises the surface of the workpiece.

Profilograms that describe the workpiece and the tool should be taken at the beginning of calculations. Elementary functions cannot be used when calculating integrals, therefore approximations and numerical methods should be applied.

**STOCHASTIC MODEL OF THE HONING**

After discussing the general case, the honing will be discussed, using the above discussed method. The movement of the workpiece compared to the tool (trajectory) may practically be described by a line with  $\beta$  slope angle, thus (fig. 2.):

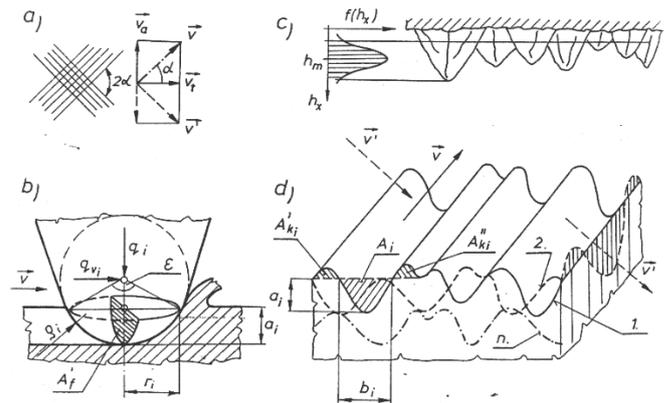
$$tg \beta = \frac{v_{r1} \sin(\pi - \alpha)}{B_s Z_s n_0} = b, \quad (7)$$

where  $v_{r1}$  is the linear radial feeding speed of the tool ( $v_{r1} \cong$  constant),  $\alpha$  is the half of the section angle of surface etching,  $B_s$  is the width of the honing prism,  $Z_s$  is the number of honing prisms on the tool,  $n_0$  is the revolution per minute of the spindle.

The "a" distance between the tool and the workpiece is the allowance to be removed (for one side). The macro-geometrical form of the tool in the longitudinal section is a line (just the axe  $x$ ), thus  $S(x)=0$ , and consequently  $y=g(x)$ . The equation of trajectory:  $y=W(x; y)=a-h-bx$  (the system of axes could be taken for  $y_0=0$ ). The allowance on one side is:  $0,5Z=a$ .

The density function of the cutting grains' peaks is:

$$f_1(0;v)=f(a-h-bx; v-b). \quad (9)$$



**Figure 2.** Stochastic model and interaction of a multi-edge tool with undetermined edge-geometry and the workpiece ( $\vec{v}_c = \vec{v}$  is the cutting speed): a, trajectory; b, model of microcutting; c, height distribution of cutting-grains; d, surface roughness of the workpiece.

The equations of the trajectory and that of the tool:

$$y=W(x;h) \text{ and } y=S(x) + g(x). \quad (8)$$

If the tool meets the workpiece (point  $M_i$ ) once, then  $k=n=1$ . The integration limits by the  $x$  axis expressed as a function of the honing run  $t$  shall be obtained:

$$P(h) = P_0(h) \exp \left[ - \int_0^{\frac{t}{b}} \int_0^{\infty} v f(a - h - bx; v - b) dv dx \right], \quad (10)$$

where  $x_{min} = 0$  and  $x_{max} = v_{r1} (t / b)$ .

The  $f(y;v)$  density-function of the tool should be known for the approximate calculation. Based on experimental data it is supposed that the stochastic component of the abrasive tool can be described by a Gaussian (or normal distribution) function [3]:

$$f(y;v) = \frac{1}{\sqrt{2\pi}\sigma_y} \exp\left(-\frac{y^2}{2\sigma_y^2}\right) \cdot \frac{1}{\sqrt{2\pi}\sigma_v} \exp\left(-\frac{v^2}{2\sigma_v^2}\right) \quad (11)$$

where  $\sigma_y^2$  is the variance of the  $y$  variable of the tool profile  $\sigma_v^2$  is the variance of the introduced  $v$  variable. Interpretation of variances

$$\sigma_y^2 = \sigma_y^2(y) = \frac{1}{n} \sum_{i=1}^n (y_i - \bar{y})^2 \text{ and}$$

$$\sigma_v^2 = \sigma_v^2(v) = \frac{1}{n} \sum_{i=1}^n (v_i - \bar{v})^2,$$

where  $\bar{y}$  and  $\bar{v}$  are the mean values:

$$\bar{y} = \frac{1}{n} \sum_{i=1}^n y_i \text{ and } \bar{v} = \frac{1}{n} \sum_{i=1}^n v_i.$$

Substituting the latest equation into the integral of formula (10), the expression in the exponent is the following:

$$\frac{\sigma_v}{2b\sqrt{2\pi}} \left[ \Phi\left(\frac{a-h}{\sqrt{2}\sigma_y}\right) - \Phi\left(\frac{a-h-v_{r1} \cdot t}{\sqrt{2}\sigma_y}\right) \right], \quad (12)$$

where  $\Phi = \Phi(z) = \frac{2}{\sqrt{\pi}} \int_0^z \exp(-x^2) dx$  error-integral [3].

At the machined surface the relation between average roughness  $R_a$  and smoothness parameter  $R_q$  (previously:  $h_q$ ) is:  $R_a = k_a R_q$ .

According to Linnik and Huszu  $R_a \cong 0,8 R_q$ , where  $k_a=0,8$ , or according to Dyachenko:  $R_a = (0,9 \div 1) R_q$ , then  $k_a = (0,9 \div 1)$ .

Taking also into consideration experimental data, in practice the  $k_a \cong 1$  value is acceptable as well, thus the  $R_a \cong R_q$  approximation holds good.

This method provides the ability to calculate and design the statistical parameters of the machined surface and the process.

Based on the above discussed, we can also describe the distribution of the  $h_1$  penetration depth of the cutting grains into the workpiece (i.e. the width of the chip):

$$P(h_1) = \int_{-\infty}^{\infty} \left\{ P(h_1 - y) \left[ \int_{-\infty}^{\infty} f(y; v) dv \right] \right\} dy. \quad (13)$$

### CONCLUSIONS

It is worth to examine the equation (7) from the technological side. What does this formula explain? Based on experiments and theoretical considerations, the following can be stated.

The radial feeding speed of the tool ( $\mu\text{m}/\text{min}$ ) can be described by the  $v_{r1} = v_{r1}(A_i; S_j; T_k)$  relationship, where  $A_i$  corresponds to the material parameters;  $S_j$  depends on tool parameters, on the  $T_k$  technological factors set by the technologist, on the applied cooling-lubricating liquid, as well as on the rough machining (quality of that). The most important parameters that effect on the speed of removal of stock can be outlined as the hardness of the material among the material parameters, the material, the average grain size and the tool structure among the tool parameters.

Remaining parameters of the equation (7) and their effects have been discussed before.  $B_s$ ,  $Z_s$  and  $n_0$  are in inverse proportion with  $b$ . Increasing of the  $2\alpha$  section angle ( $\bar{v}_t$  increases of  $\bar{v}_a$  decreases) leads to decrease of the value of  $b$ . Consequently the characteristics, causing changes in  $v_{r1}$  shall be increased or decreased by the technologist, depending on the technological task.

The aim of the rough honing is to provide a relatively great productivity. In case of a given material of workpiece and hardness the  $v_{r1}$  radial feeding speed increases if we enhance:

- » the cutting capability of the grains, applying super-hard grains;
- » the average grain size of the tool;

- » the  $p$  tool pressure;
- » the  $\bar{v}_a$  axial speed component, etc.

The aim of the final - or fine - honing is to gain a good surface quality, i.e. small roughness. Different measures to the above mentioned ones are necessary to achieve this, as for example:

- » decrease the cutting capability of the grains, applying smaller, average grain size;
- » decrease the  $p$  tool pressure;
- » decrease the  $\bar{v}_a$  axial speed component,
- » increase the  $\bar{v}_t$  tangential speed component and  $v_c = (v_t^2 + v_a^2)^{0.5}$  the cutting speed.

Applying traditional grain material, the cutting capability of the grains will also decrease. Certainly smaller roughness can be achieved. In this case the production probability of the smaller  $\bar{h}$  and  $R_a$  values will increase. The system of mathematically formulated relationships corresponds to the experimental observations. The elaborated method is applicable also to describe the abrasive wear processes at grinding or at machining [4, 5].

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