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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AIMS, MISSION & SCOPE

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:

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- ✓ *Scientific Papers - concise, high impact original theoretical articles,*
- ✓ *Perspectives - commissioned commentaries highlighting the impact and wider implications of research appearing in the journal.*

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

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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.

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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**.*

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ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering *is dedicated to publishing material of the highest engineering interest, and to this end we have assembled a distinguished Editorial Board and Scientific Committee of academics, professors and researchers.* ***ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering*** *publishes invited review papers covering the full spectrum of engineering. The reviews, both experimental and theoretical, provide general background information as well as a critical assessment on topics in a state of flux. We are primarily interested in those contributions which bring new insights, and papers will be selected on the basis of the importance of the new knowledge they provide.*

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Abstract: *With invent of new technologies and devices, Intrusion has become an area of concern because of security issues, in the ever growing area of cyber-attack. An intrusion detection system (IDS) is defined as a device or software application which monitors system or network activities for malicious activities or policy violations. It produces reports to a management station. In this paper we are mainly focused on different IDS concepts based on Host and Network systems.*

Abstract: *This paper presents a calculation model the thermal elastic behavior ofthe cylindrical roller bearing for bearings towed vehicle in railways. The present mathematical model allows to definethe value ofthe moment friction due to lubrication, the friction moment due to the radial and axial loads. Heat generated in the bearing calculated based on the value of previously defined moments. Also, it shows the method of calculating the coefficients of conduction and convection of heat in bearing. Using programming system general purpose analyzed ther mal elastic behavior of the cylindrical roller bearing for bearings axle to wed vehicle in railways. Finite element method determined by temperature values in the characteristic points of the bearing depending on the speed wheel for different time periods. Also, it determined of displacement in characteristic points of bearing due to the heat load in the steady temperature state, maximal stress and bearing life.*

Abstract: *The article discusses the state of transformer insulation. For a more accurate determination of the transformer insulation state are used three methods. The measurement of insulation resistance is the basic method and is set in the standard, value demonstrates the state of total insulation of transformer. Because the determination of moisture content of the paper insulation of transformer is very difficult process and it is necessary take a sample of paper, in this case is used method of return voltage. Return voltage measurement is more complex method and in many cases is determine a clear result very difficult. For evaluation of results have mainly impact moisture content and degree of aging of paper insulation and of course, content of conductive impurities in oil. Because the moisture content in oil is much lower than in the paper, return voltage measurement is used to determine the moisture content in paper insulation only. To confirm the results of return voltage measurement is used frequency domain spectroscopy, which clearly, according computational model, calculates the moisture content in the paper insulation.*

Abstract: *Light emitting diodes (LEDs) can be used for many lightning applications in offices, in homes, and in streets. A special converter with limited duty cycle for driving LEDs is treated. The basic analysis is done resulting in dimensioning equations of the converter. The basic analyses have to be done with idealized components (that means no parasitic resistors, no switching losses) and for the continuous mode in steady (stationary) state. A mathematical model based on state-space description is derived. Some experimental results are shown. The converter is useful for street, home, and automotive lightning applications.*

Abstract: *In this article, the presence of inhomogeneities in solid electrically conducting plate is inspected by non-destructive way with use of eddy current testing method where the perturbed electromagnetic field caused by the defect is detected. We perform three-dimensional finite element simulations of this structure with pre-defined material inhomogeneities and they are evaluated by an induction coil. This study is motivated by the novel eddy current testing technique which is based on sensing of all the three components of the perturbed field. Basically we performed parametric study to quantify the impact of various parameters – depth and electrical conductivity of the inhomogeneity. The analyses provide reference results to understand the effectiveness, feasibility and capability of this approach.*

Abstract: *One of the most important purposes of each logistics system functioning is to define the desired security state. It should be noted that the various elements that refer to the security of the logistics system are related to a number of both external and internal conditions of the company. There is also a number of security areas dependent and independent from the company. On this basis, one can make a statement that the product itself, having specified characteristics and properties can affect the security of the logistics system. The article is an attempt to identify and describe the impact of logistics security conditions on vulnerability of product design, and consequently on the logistical efficiency of the product.*

Abstract: *The paper deals with an idea of informing the car drivers on problem of road degradation via sending of warning messages from road side units. The initial part of the paper summarized the up–to–now realized concept of the mobile measurement platform (MMS) and its mathematical principles showing how detailed data on road surface may be obtained. The main part of the paper is aimed at design of integration of data from MMS into the VANET application. Practical realisation is based on the warning message generation with GPS coordinates which is assuring by digital signature ECDSA cryptography algorithm via OpenSSL tool.*

Abstract: *Forecasting in Supply Chain Management (SCM) is an important yet underestimated research topic. Over the past years numerous methods and concepts have been developed, tested and deployed. In this paper we present a classification framework for the SC Forecasting literature using eight criteria, namely focus, approach, method triangulation, data generation, range, timeline, theoretical background, and target group. Additionally, we present examples for the respective criteria and summarize the major findings. This state-of-the-art review paper is targeted toward both researchers and industry experts who want to get an overview of the goals of contemporary SC Forecasting research.*

Abstract: *Engaging in Lean construction efforts could prove to be highly rewarding for building firms in Libya. However, lean construction is risky and can be disastrous if not properly managed. Lean production efforts in some other countries have not been successful due to the many barriers to its successful implementation. This study sets out intends to explore identify the barriers that affecting the prioritizing of lean construction with the objective of determining the barriers that affects the use of lean construction in construction industry in Libya. Forty six (46) questionnaires were distributed to various construction firms in Libya. This study presents nine (9) barriers and investigates their influence (strength) on the success of lean construction initiatives. This study indicates that extra efforts still needed to be done on the awareness and use of lean construction in the Libyan construction industry.*

Abstract: *Processes with specification limits (tolerance) are typical in industrial practice, for example in the control of the manufacturing process. Often these tools are be used in all engineering processes, here is shown an application in the control of the logistics process. To ensure theeffectiveness of the process and to meet customer expectations it is necessary to ensurestrict compliance with the tolerances. Classic control methods base on variables that require monitoring related to the limits set by the natural process tolerance. In this work considerations expressed for estimating values of the dispersion and the permissible central tendency of the variables from the specification limits, the purpose is to obtain acceptable process capability for the specific case. Considerations are be done in the reverse order, dispersion values and the central tendency is not executed after he process determines in this case the maximum permissible values of dispersion andcentral tendency referred to tolerance specification are estimated to guarantee the required quality before you start the process, so this method can be considered as a preventive tool quality.*

Abstract: *Optimal coordination of direction overcurrent relays in the power systems in the presence of GTO Controlled Series Capacitor (GCSC) installed on meshed power system is studied in this paper. The coordination problem is formulated as a non-linear constrained mono-objective optimization problem. The objective function of this optimization problem is the minimization of the operation time of the associated relays in the systems, and the decision variables are: the time dial setting and the pickup current setting of each overcurrent relay. To solve this complex non linear optimization problem, a variant of evolutionary optimization algorithms named Krill Herd Algorithm (KHA) is used. The proposed algorithm is validated on IEEE 14-bus transmission network test system considering various scenarios. The obtained results show a high efficiency of the proposed method to solve such complex optimization problem, in such a way the relays coordination is guaranteed for all simulation scenarios with minimum operating time for each relays. The results of objective function are compared to other optimization algorithms.*

Abstract: *Measurements of temperature have a great importance in wide range of industrial applications. As temperature affects the quality, safety and effectives of many of these applications, a great effort has been made to enhance the precision and reliability of temperature measuring sensors. One of the main types of temperature sensors that are used in industry are thermoelectric sensors, more commonly known as thermocouples. These sensors play a irreplaceable role in high temperature industrial measurements. Their robust construction, the ability to withstand high temperatures and harsh conditions had made them popular among many users. As thermocouples are active sensors, they work on the principle of the Seebeck effect. This effect is dependant from wire material purity and composition thus any change in these properties will result in change of their voltage output thus temperature. These changes of Seebeck coefficient can be caused by many factors, like chemical impurities, changes in metal lattice of the wire material, reaction between the materials of which the thermocouple consist of etc. This work deals with the analysis of various factors that can effect the Seebeck coefficient of the thermocouple wire material. Influences that affect the long term stability of the thermocouple voltage output have been analysed and a measuring procedure to determine the level of contribution to the Seebeck coefficient is presented. Furthermore the paper deals with the time stability of base metal Type N thermocouples in the MIMS (Mineral Insulated Metal Sheathed) configuration. The presented results determine the level of Seebeck coefficient change during a long time exposure to temperatures from 1200°C to 1250°C.*

Abstract: *The current high requirements for quality, accuracy and durability of produced parts lead to a permanent improvement of the production process. For reasons of efficiency and competitiveness have become increasingly to the forefront of non-conventional machining methods. Non-conventional technology is characterized by the use, physical, chemical or a combination of these processes. Currently, the most commonly used for industrial cutting continuous CO2 laser with an average power. Because of the high requirements for the quality of the cutting edge is necessary to choose the optimal method of cutting either melting laser cutting or oxidizing laser cutting. The main parameters that we can significantly affect the quality of the cutting edges are: laser power, length of focal optics, cutting speed, gas pressure, gap between the nozzle and plate, shaped nozzles etc. If the cutting edge after laser cutting does not reach the required quality, it may negatively affect the price of the product, due to add additional operations, as may be chamfering, grinding, etc. For this reason, high demands are made to the professional knowledge on operator of laser equipment.*

Abstract: *Electrical power is often used as a source of power to operate electrical appliances. However, inconsistent of electricity supply leads to obliviousness of the users to switch off their home appliances; thereby, resulting in energy wastage or eventual damage to appliances when power is restored. Meanwhile, developments in information technology could be used to eliminate this problem. Consequently, a GSM based remote control system has been developed to control and monitor electrical devices that required constant attention using mobile phone. This system is very handy when users forget to turn ON/OFF the electrical appliances at their home or office after they have set out. They can now control or monitor such appliances remotely by sending a text message from their mobile phone. This development ultimately saves a lot of time and effort. Likewise, daily electrical energy savings is made more efficient and effective. In constructing this system, basic components like mobile phones, SIM card, Liquid Crystal Display, relays and microcontroller were used to develop a cost-effective and adaptable system.*

Abstract: *This paper reports on the use of carbon paste electrode modified with clay (Clay-CPE) and cyclic voltammetry (CV) for analytical detection of trace copper (II) in Na_2SO_4 0.1M. The electroanalytical procedure for determination of the Cu(II) comprises two steps: the chemical accumulation of the analyze under open-circuit conditions followed by the electrochemical detection of the preconcentrated species using cyclic voltammetry. The electrochemical responses obtained by CV at Clay-CPE were found to be analytically suitable to develop a method for the determination of copper at low concentration levels.*

Abstract: *Nowadays most commonly used materials in power engineering are stainless steels. Temperatures and pressures in systems are currently increased to achieve higher efficiency. In some plants are applied even supercritical values. This paper is focused on improvement of corrosion protection possibilities. Except new materials (titanium, nickel superalloys), different types of surface treatments or layers are used to reduce problems caused by corrosion. If passive film is formed on treated surface, e.g. nitrided, there can appear differences in its properties. The oxidic layers are common, however in operation of water-steam cycles in power plants arise problems like exfoliation, bigger porosity or disparity of passive layer. Consequence is larger corrosion rate, which leads up to degradation of the material and failure of equipment. In experimental section were created oxidic layers in laboratory conditions and was monitored the behavior of materials used in power industry. Thereafter were evaluated their properties and composition, which permits to analyze what terms are for given materials most suitable. Samples were exposed in autoclave in terms of different cycle chemistry and then analyzed by method of ESCA, X-ray diffraction and metallography.*

Abstract: The early stages of the new product development process are most often defined as idea generation, idea screening, concept development, and concept testing. These stages represent the development of an idea prior to its taking any physical form. In most industries it is from this point onwards that costs will rise significantly. It is clearly far easier to change a concept than a physical product. The innovative approach has become an important aspect in the design and implementation of the organizational strategy. The multi-criteria (MC) model allows for the systematic planning of successful investments.

Abstract: In contemporary solutions for surface asperities measurements some concepts appear where different sensors, basing on different physical principles are used. It is an idea from one side to measure various surfaces impossible to inspect with a standard tactile inductive probe, and from another to measure the same surface with several sensors. Thus it is possible to get more information and draw more complex and versatile conclusions. In the paper a concept of such a multisensor device was shown with a construction and some applications. Here, confocal probes as well as interferometric one and tactile sensors were used.

Abstract: PLCs produced at present have incomparably wider range of application options than PLCs produced in the past. One of the options where the using of PLC has not yet been common is the safety-critical processes control. PLCs used for this purpose form a special category of PLCs and are known as safety PLCs. Safety PLCs (Programmable Logic Controller) are one of the appropriate tools for implementation of safety-related control system (SRCS). Their modular construction allows implementation not only control systems of defined safety integrity level (SIL), but even redundant control systems with defined availability. The contribution considers influence of redundant architectures on safety integrity of SRCS with safety PLC.

Abstract: Natural gas has been the most popular fossil fuel in recent years, and the demand for it has been dramatic. In fact, natural gas possesses several useful features: it has a high heating value, it can be utilised as a raw material in several petrochemical industries and it is a cheap fuel source. However, raw natural gas usually contains a variety of non-hydrocarbon components, e.g., acid gases, helium, nitrogen and mercury. Raw natural gas sources with large amounts of acid gases are known as sour gas. Sour gases should be treated and sweetened to meet natural gas pipeline specifications and sale contracts. The amine gas sweetening process is widely utilised in the gas industry, eitherto reduce or to remove acid gases from sour natural gas streams. Indeed, amine gas sweetening has several advantages over other sweetening processes; it is more economical than other processes, and it operates continuously. Indeed, the global hydrocarbon emissions from the oil and gas industries have been dramatic. Moreover, methane, ethane and propane may be the most obvious gases that are emitted by the natural gas industry. In many cases, these emissions occur from gas processing units, e.g., gas sweetening and gas dehydration processes. In fact, these hydrocarbon gas emissions contribute to global warming and environmental pollution. Moreover, hydrocarbon emissions lead to huge losses of precious hydrocarbons every hour. Therefore, this study aims to study the effects of the solvent circulation rate on the hydrocarbon carryover from the amine gas sweetening using Aspen HYSYS software. The study also used a Murban gas stream in the simulation process because it is loaded with a high concentration of acid gases. The study determined that the amine circulation rate may have significant effects on the hydrocarbon losses during the sweetening process. Moreover, the study also recommended several methods to reduce this effect and the emission, e.g., balancing the amine circulation rate with both the sweetening efficiency and the hydrocarbon emissions.

Abstract: Quenching is being described as one of the most common heat treatment processes used to impart the desire mechanical properties such as high strength, hardness and near resistance to metal parts using quenchants such as air, water and polymer solution. The quenching process parameters such as time, radial distance and immersion speed played a major role in deciding the heat treatment quality of the steel sample. In this research, response surface methodology was used to study the effect of process parameters on temperature distribution during the quenching process of AISI1020 steel sample. A total of seventeen experimental runs were designed using the three variables adopting Box-Behnken design with full replication technique and mathematical model was developed. Sensitivity analysis was carried out to identify critical parameters. Time was found to be the most influencing parameter on the temperature distribution, followed by immersion speed and the least effect was given by radial distance. The quadratic model developed was evaluated at p-value greater than 95% confidence level, having correlation coefficient R-squared of 0.9997, adjusted R-squared of 0.9993 and predicted R-squared of 0.9953.

Abstract: *Pakistan by the grace of Almighty Allah is having huge energy positional but this capability has not been explored fully but with exception of some large hydel works. An endeavor has been put-in by the Govt now to incorporate renewable energy in the development strategy. The strategy will be implemented in three phases. Exploring different energy resources and their use can help Pakistan to come out from this quagmire. Hosts of allied problems like extra costs and dangers of fuel stocking, carriage, and alternative arrangements will be minimized. Global warming, green house gasses, environmental degradation and other related problems will be reduced using alternative energy resources. This will also reduce the energy related hazards.*

Abstract: *Study the application of microelectromechanical system (MEMS) devices especially the electrically actuated MEMS devices which require few mechanical components and small voltage levels for actuation is continuously growing. The MEMS devices are widely used as capacitive accelerometer, capacitive sensor, switches and so on. In this paper, the energy balance method has been successfully used to study a nonlinear oscillator arising in the microbeam-based microelectromechanical system (MEMS). The nonlinear ODE equation is solved by a powerful mathematical tool, the amplitude-frequency formulation. The good agreement of results got from amplitude-frequency formulation with results from fourth-order RungeeKutta method indicates that the obtained period is of high accuracy.*

Abstract: *Mono-symmetric plate girders are often used in simply supported composite bridges to eliminate local plate buckling in the compression flange during construction. This causes the neutral axis of the plate girder to shift downwards subjecting more of the web to compressive stresses due to bending. In slender webs this increases the possibility of local buckling in the compression part of the web during construction. However, depending on the slenderness (width-to-thickness ratio) of the web, the post-buckling reserve capacity may accommodate this local buckling within the elastic limit of the web for during construction loads. Hence, this would allow for the use of more slender webs in composite plate girder construction without the need for longitudinal web stiffeners or the reduction of the overall composite section due to local plate buckling in the web. Recommended values of stress level are given for mono-symmetric plate girders in the non-composite stage based on the results of a non-linear finite element analysis.*

*The **ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering, Tome VIII/2015, Fascicule 1 [January–March/2015]** includes scientific papers presented in the sections of:*

- ***The 10th International Conference – ELEKTRO 2014**, organized by the Faculty of Electrical Engineering, University of Žilina, in Rajecke Teplice, SLOVAKIA (May 19th–20th, 2014). The current identification numbers of the papers are **# 3–5, 7, 21** and **25**, according to the present contents list.*
- ***The 8th International Conference for Young Researchers and PhD Students – ERIN 2014**, organized by the Brno University of Technology, in Blansko - Češkovice, CZECH REPUBLIC (April 23rd–25th, 2014). The current identification numbers of the selected papers are **# 12–13** and **# 16–18**, according to the present contents list.*
- ***The International Conference on Industrial Logistics – ICIL 2014**, hosted by the Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb and International Centre for Innovation and Industrial Logistics (ICIIL), in Bol on island Brač, CROATIA (June 11th–13rd, 2014). The current identification numbers of the papers are **# 6** and **# 8**, according to the present contents list.*
- ***The 6th International Scientific Conference on Management of Technology Step to Sustainable Production – MOTSP 2014**, placed in Bol, Brač, CROATIA as a joint project organized by the Faculty of Mechanical Engineering and Naval Architecture and Faculty of Graphical Arts both from the University of Zagreb, CROATIA, Faculty of Management, University of Primorska, Koper and Faculty of Mechanical Engineering, University of Maribor, SLOVENIA, Faculty of Mechanical Engineering, Ss. Cyril and Methodius University, Skopje, MACEDONIA, and Politecnico di Torino, ITALY (June 11th–13rd, 2014). The current identification numbers of the papers are **# 22–24**, according to the present contents list.*

*Also, the **ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering, Tome VIII/2015, Fascicule 1 [January–March/2015]**, includes original papers submitted to the Editorial Board, directly by authors or by the regional collaborators of the Journal.*

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[1.] Sugata SANYAL, [2.] Niva DAS, [3.] Tanmoy SARKAR

SURVEY ON HOST AND NETWORK BASED INTRUSION DETECTION SYSTEM

[1.] Corporate Technology Office, Tata Consultancy Services, Mumbai, INDIA
[2.] University of Calcutta, Kolkata, INDIA
[3.] Neudesic India Pvt. Limited, Hyderabad, INDIA

Abstract: *With invent of new technologies and devices, Intrusion has become an area of concern because of security issues, in the ever growing area of cyber-attack. An intrusion detection system (IDS) is defined as a device or software application which monitors system or network activities for malicious activities or policy violations. It produces reports to a management station. In this paper we are mainly focused on different IDS concepts based on Host and Network systems.*
Keywords: *Intrusion, Intrusion Detection System (IDS), Host based Intrusion Detection System (HIDS); Network based Intrusion Detection System (NIDS)*

INTRODUCTION

With the recent advances in technology, people are sharing more and more information among each other. Some organizations like medicine, military etc. are sharing data which is highly sensitive and important. For secure communication, people are using cryptography, using secret key, so that only authenticated receiver can decrypt the message and authenticity of message remains intact. But intruders are not interested to decrypt message. They can use sophisticated tools to attack the host on the network and get access to the sensitive data. Here, IDS comes as a savior. IDS provide three important security functions of monitoring, detecting and responding to unauthorized activities [2]. It usually provides three services: Observing and analyzing the host and the network activities, audit system configurations and evaluating of integrity of critical information by estimating abnormal activities. IDS are generally classified as follows:

1. Host-Based (HIDS): Host based intrusion detection systems run on individual hosts / devices on the network. It monitors the incoming and outgoing packets from the device and alerts the administrator on detection of suspicious activity.
2. Network-Based (NIDS): Network based intrusion detection systems monitor traffic between all devices on the network. On performing an analysis for a passing traffic on the entire subnet (in a promiscuous mode), it subsequently matches the traffic on the subnets to the collection of known attacks. On finding a match, alert is sent to the administrator. Today, IDS becomes necessary for every organization to secure their sensitive data from intruders. In the next sections, we will discuss about various tools and techniques used in Host based and Network based Intrusion detection systems.

HOST BASED IDS

Host based IDS is aimed at collection and analysis of information on a particular host or system [3]. This Host agent monitors and prevents intruders to compromise system security policy. HIDS plays different role from Anti-virus. Anti-virus is supposed to monitor all the activities inside the system but not concerned with buffer overflow attacks on system memory nor malicious behavior of operating system process but HIDS checks and collect system data including File System, Network Events, System Calls to verify whether any inconsistency has occurred or not. HIDS system relies heavily on audit trail and system logs to detect unusual activities inside the system. Host-based systems can monitor access to user specific information which is a major advantage [3], [4]. HIDS can identify an improper user of company resources. On detection of similar pattern (similar to past attacks or suggestive of an attack); activity with that workstation can be stopped, thus blocking the attack. This is greatly useful in systems where system resources are accessed remotely in a routine manner. Some major disadvantages as follows:

(1) they cannot see the network traffic [3];
(2) HIDS rely heavily on audit trails which can exhaust a lot of resource and space in server, and
(3) lack of cross-platform interoperability.

Inspection of system configuration files to check for failure-prone setting and of other system objects for security policy violations are the basic job of a HIDS host-based mechanism [3]. If intruders succeed in modifying the HIDS itself then there is no way to detect intrusion – unless security administrators take appropriate precautions.

ELM Enterprise Manager [6], an enterprise class event log management solution, collects event logs from different devices in *real-time. On detection of critical events, immediate email alerts are helpful in activating more stringent security policies.*

[8] has proposed an Intrusion Detection System where they compare the performance of their fuzzy rule based classifiers for IDS with similar performance obtained from the decision tree, support vector mechanisms and linear genetic programming. Toosi et al. [9] presented a method to classify the normal and abnormal behavior in network, proposing Adaptive Neuro Fuzzy Inference system to categorize normal and suspicious behavior and detect intrusion.

Abraham et al. [10] have proposed an Intrusion Detection System which uses Distributed IDS to detect intrusion in a network. The approach makes use of three fuzzy rule based classifiers in a distributed environment to detect intrusion detection.

David et al [28] introduce concept of mimicry attack which allows an advanced intruder to hide their identification to avoid IDS detection. The authors then propose theoretical concept to detect and prevent mimicry attacks.

Yeung et al [29] adopt an anomaly detection approach. They detect possible intrusions, based on program or user profiles, built from normal usage data. Here the dynamic modeling approach, based on Hidden Markov Models (HMM) and the static modeling approach, based on event occurrence frequency distribution have been extensively used.

STATL is a state/transition based attack description language, which is extensible. This is developed by Eckmann et al [30]. It is intended to describe intrusion detection type activity. A STATL helps describe both domain-independent attacks and for providing constructs to help extending the language. This is for taking care of attacks to particular domain and environments.

NETWORK BASED IDS

Network Based Intrusion Detection Systems (NIDS) are active systems. These are deployed on networks to primarily monitor the network traffic. NIDS are operated under promiscuous mode without exposing itself to the potential attackers. NIDS systems generally work by identifying attacking signature within the networks. NIDS are OS independent and also compromising one NIDS will not affect the system if multiple NIDS are deployed to monitor the traffic flow. Sometimes network people raise a question like what can NIDS do that Firewall can't? The firewall is the equivalent of a security fence around a property and the guard post at the front gate. But Firewall is not able to detect what is happing inside [3]. Firewalls are subject to many attacks, tunneling attacks and application-based attacks are most prominent. On the other hand a NIDS system works like a body guard which is monitoring both inside and outside of a property. It monitors packets, matches pattern; find attacking signature from already existing attacks done in the past and sometime statistical analysis of the information to detect abnormal behavior. However NIDS system cannot scan the content if network traffic is encrypted, it cannot efficiently handle high speed networks.

Snort [5], an open source network intrusion prevention system, is capable of performing real-time traffic analysis and packet logging on IP networks. It can handle various intrusion detection techniques like buffer overflow, protocol analysis, CGI attack and many more.

Trivedi et al. [7] proposed an Intrusion Detection System which defines a term called "Reputation" that is assigned to every node in the network. Every node monitors the behavior of its next-hop neighbor through promiscuous mode. A reputation manager keeps track of all the "Reputation" values from all the nodes, for updating the reputation value. A node is declared as malicious whenever it crosses a predefined threshold. A warning message is sent only to the immediate neighbors. Each node also contains an Avoid list. It contains a list of malicious nodes and no further communication is done through these already identified malicious nodes.

Toosi et al. [11] presented a method to classify the normal and the intrusive behavior in a network. They used a combination of neuro-fuzzy networks, fuzzy interference and genetic algorithm to classify the network. Parallel neuro-fuzzy classifiers did the initial classification and its output was the basis of the fuzzy inference system. Finally, the genetic algorithm approach was used to optimize the decision.

Faysel and Haque [12] surveyed various methods of cyber-attack detection and classification technique. These are based on neural networks and data mining. They have also discussed IDS evaluation criteria and dataset for IDS validation. Trivedi et al. [13] suggested a Semi Distributed Reputation-based IDS method for Mobile Ad Hoc Networks (MANETs) proposing a unique concept of redemption and fading with path manager and monitor system, making the system invulnerable to many MANET attacks. An Ant Colony based IDS was proposed by Banerjee et al. [14] which keeps track of the intruder trails and works in conjunction with the machine learning system to make sensor networks less vulnerable to intrusion attacks. Saravanakumar et al. [15] tackle the issue of complexity and throughput, prime important points in the current Intrusion Detection Systems (IDS). They compare various IDS systems that use different algorithms to detect the intrusions. They proposed a scheme that uses a combination of Artificial Neural Network algorithms to design IDS. This enables faster convergence and delivers better performance.

Shun and Malki [16] have a scheme which uses feed forward neural networks with back propagation training to predict and detect the attacks on network. With appropriate training the proposed IDS system greatly enhances the performance of the IDS system and detects the known and unknown attacks with higher probability. Intrusion Detection System (IDS), developed by Chavan et al. [17], uses Fuzzy Inference System and Artificial Neural Networks and it is trained by creating a signature pattern database, using Protocol Analysis and Neuro-fuzzy learning method.

Dal et al. [18] proposed an Intrusion Detection System method which applies Genetic Algorithm with Artificial Immune System (AIS). They have evolved a Primary Response following the concept of memory cells which is dominant in Natural Immune System, enabling faster *detection of already encountered attacks. These cells are random in nature, dependent on the evolution of the detectors, thus granting greater immunity from anomalies and attacks.*

Dasgupta et al. [19] focuses on the recent improvements in Artificial Immune System [AIS]. Yang et al. [20] use a related method in AIS to enhance the performance of IDS, using antibody concentration to evaluate the damaging power of the intrusion in the network.

Hosseinpour et al. [21] suggested a method to improve the detection performance and accuracy of IDS system, proposing a distributed multilayered framework to improve the detection and efficiency of IDS. The genetic algorithm proposed by them enhances the secondary immune response of the system.

Jie et al. [22] devised a method for signal detection using Artificial Immune System [AIS] for anomalistic signal detection in an electromagnetic environment. Saboori et al. [23] proposed an Apriori Algorithm to detect an anomaly in the system. It predicts a novel attack and generates a set of real-time rules for the firewall, and functions by extracting the correlation relationships among large data sets.

Nikolova and Jecheva [24] suggested an anomaly based Intrusion Detection System (IDS) using data mining techniques like classification trees to describe the normal activity of the system. Similarity coefficients are used to detect the intrusion in the system, which compare the similarity between the normal behavior and the observed behavior. Depending on the measured degree of similarity, a decision is reached about the system being under attack or not.

Karim [25] described application of Computer Intelligence in the Network Intrusion Detection, explaining the usage of clustering, feature selection, and anomaly detection.

Jianhua et al. [26] describes detection and exclusion of misbehaving nodes by dropping packets forwarded through them. A reputation-based scheme for efficiently solving the problem has been suggested where nodes with bad comprehensive reputation will be excluded from the network.

Thakur et al [27] described a multi-dimensional approach towards intrusion detection. Network and system usage parameters like source and destination IP addresses, ports; incoming and outgoing network traffic data rate and number of CPU cycles per request are divided into multiple dimensions. Authors established a conditional function during the training phase for each dimension.

CONCLUSION

Network-based and host-based IDS prevent both insider as well as outsider attacks. There are ever evolving methods of intrusion detection but most systems utilize signatures to search for patterns of misuse and either automatically respond to the misuse or intimates system administrator to take appropriate action. Some intrusion detection systems even sense misappropriation by using behavioral data forensics. Due to inherent risk of some automated responses, there is still need for human intervention that can supervise and ensure the state of the system.

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[1.] Vladimir BLANUŠA, [2.] Milan ZELJKOVIĆ, [3.] Aleksandar ŽIVKOVIĆ

PREDICTION THERMAL ELASTIC BEHAVIOR OF THE CYLINDRICAL ROLLER BEARING FOR RAILWAY VEHICLES AND CALCULATING BEARING LIFE

[1-3] Faculty of Technical Sciences, University of Novi Sad, SERBIA

Abstract: This paper presents a calculation model the thermal elastic behavior of the cylindrical roller bearing for bearings towed vehicle in railways. The present mathematical model allows to define the value of the moment friction due to lubrication, the friction moment due to the radial and axial loads. Heat generated in the bearing calculated based on the value of previously defined moments. Also, it shows the method of calculating the coefficients of conduction and convection of heat in bearing. Using programming system general purpose analyzed thermal elastic behavior of the cylindrical roller bearing for bearings axle towed vehicle in railways. Finite element method determined by temperature values in the characteristic points of the bearing depending on the speed wheel for different time periods. Also, it determined of displacement in characteristic points of bearing due to the heat load in the steady temperature state, maximal stress and bearing life.
Keywords: Thermal elastic behaviour, cylindrical roller bearing for railway vehicles, finite element method

INTRODUCTION

The advent of railway in the mid-nineteenth century certainly represents a significant technological innovation as it is no doubt possible to play a revolutionary role and enormous contribution to the industrial development and economic progress of society. The rapid development of the construction and exploitation railways has made a significant impact on the development of strength science and theory construction, [16], because it appeared a series of new problems (particularly in relationship with the design and construction of railways, bridges, locomotives, vagon and etc..) that should be solved.

Although in comparison with other types of transport railway has a number of advantages in terms of economic viability (lower power energy and especially environmental sustainability), inefficiencies created by the railway regulations have placed restrictions on the industry that have prevented effective competition. Stoppages in innovation railway technology and inadequate answer to significant increase in the quantity goods of small packaging, reducing the goods suitable for carriage by rail (such as ore and coal), have primary explanation because of for example the share railways in freight traffic SAD that is after the Second World War was nearly 70% of intercity ton miles, up in 1975. years dropped to 37% [17].

The European Union treated rail as a transporter of the future and seeks to reaffirm rail transport, with requirement of a competitive, secure and high-quality transport all kinds of goods. Achieving these goals among other things requires the construction of modern wagons customized market challenges, specific technological requirements and systems which to quickly perform the loading / unloading operations [2].

Cylindrical roller bearings for railway are key components of wheel towed vehicles and their cancellation can have disastrous consequences. Bearing temperature is one of the most important parameters bearing whose by monitoring the can be determined state of bearing in exploitation. For this reason were performed tests using different lubricants (grease) and based on the test results it can be concluded that the lubricant has a significant influence on the bearing temperature in exploitation. Roller bearings for railways usually lubricated with grease that are accommodated in a closed housing with bearings so as to ensure proper lubrication. During the rotation of grease comes into contact with rollers and the rings and after the certain period of time leads to the mechanical the degradation of grease. For this reason is very important replace the grease before it has loses her mechanical properties. In paper [11] were performed tests in winter and summer period (in winter temperature was -15 °C and in the summer 20 °C) and led to the values of temperature in the steady state temperature in depending on the type of grease which is used for lubrication. The temperature in winter period was between 15 ÷ 51 °C and in the summer of 33 ÷ 59 °C.

The heat generated due to the rolling wheel on the rails transferred to the entire assembly wheel for railway vehicles. One part of this heat transferred to the bearings. Cole and others [3] examined this influence of experimental and computer modeling. For value generated amount of heat due to the movement of the wheel on rail ($Q = 1834$ W) in steady temperature state were determined by the *temperature in characteristic points wheel and rings bearing. In this paper is not considered the fact that due to the rotation of bearing in him generates heat which has great influence on his temperature.*

In addition to the heat generated due to the motion of the wheel on rail on heating assembly wheel significantly affected have the heat that is generated due to the braking locomotives and railway freight wagons (at the contact between the brake block and wheel) [4]. The value of the heat generated between the brake block and wheels, as well as the value of the mechanisms heat transfer on wheel calculated mathematically, and using the finite element method were determined by the temperature on wheel. The value of heat generated due to the contact of brake block and wheel was Q = 446 W. Verification of mathematical calculations and finite element methods performed on a laboratory plant on one side brake block of the shaft.

Mohan [12] by applying the finite element method performed prediction of thermal and static behavior wheel locomotive and railway freight wagons. The value of the temperature on the flange wheel was 70 °C. Static analysis determined the value of Von Mises's stress depending on the deformations caused by the static load. The maximum displacement was on wheel and amounted to 0.2196 mm, and the maximum stress on wheel 46,34 N/mm². Integrated thermal and static behavior in one model were determined by values of displacements and stresses on wheel. The maximum displacement on the flange wheel amounted to 1.084 mm and maximum stress on wheel amounted to 148.98 N/mm².

Preventive maintenance and remont bearing in the exact prescribed intervals is essential on bearing life. In case when remont bearing don't make in prescribed time intervals may lead to disastrous consequences such as damage axle wheels, damaged parts rail and popping train for rails. Because of this reason it is very important change the inner ring bearing before it reaches his damage due to material fatigue that have disastrous consequences [6]. In this paper analyzes the influencing parameters that lead to damage railway line. Bearing was completely damaged due to the material fatigue that led to the cracking of the inner ring. Slipping of the inner ring on the axle has led to the generation of large of heat generated which led to the change in structure of the material in the bearing and on surface axle.

MECHANISM OF HEAT GENERATION

Introdiction

Bearings assembly wheel railway freight wagons can make different types of bearings (cylindrical roller bearing, spherical roller and taper roller). In this paper discusses the bearing assembly wheel with cylindrical roller bearings (mark of the bearing 324 NJ EC.M1C4 VA301). On Figure 1 shows assembly wheel as well as details bearings mounted on the axle.

This paper considers only the heat generated in the bearing (without heat generated by the movement of wheel on railway line). The heat generated determined on the basis of the friction torque due to lubrication and friction torque due to the load (axial and radial) [1].

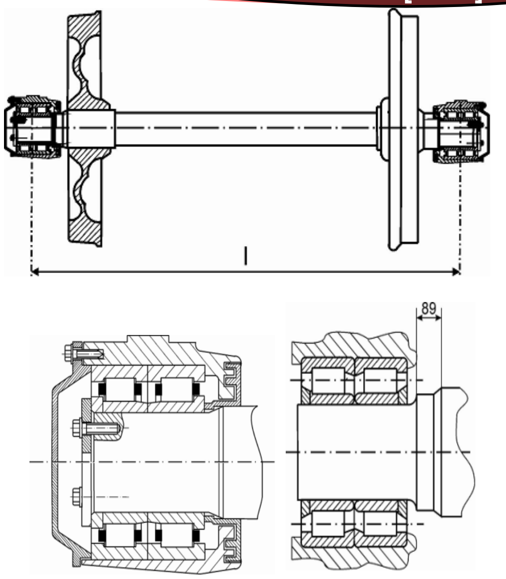


Figure 1. *Assembly wheel with details bearings*

Determination of the friction torque

$$M = M_0 + M_1 + M_2 \ Nmm \qquad (1)$$

M_0- friction torque due to lubrication,
M_1- friction torque due to the radial load,
M_2- friction torque due to axial load.

$$M_0 = 10^{-7} \cdot f_0 (\nu \cdot n)^{\frac{2}{3}} \cdot d_m^3 \ \ Nmm \qquad (2)$$

f_0 – coefficient depended of the bearing type and lubrication type (for cylindrical roller bearing it value is 3),
ν- kinematic viscosity of the lubrication ν=18,
n- bearing speed [rev/min],
d_m - middle bearing diameter (d_m=190 mm).

$$M_1 = f_1 \cdot F_r \cdot d_m \ \ Nmm \qquad (3)$$

$$F_r = \frac{G_1}{4} \qquad (4)$$

$$G_1 = \frac{G}{n_t} \qquad (5)$$

f_1 - coefficient which depends of the bearing type (for cylindrical roller bearing it value is between 0,0003-0,0004),
F_r - radial static load acting on one bearing (F_r= 55181 N),
G_1- radial static load acting on one wheel set (G_1=220725 N),
G- weight of the vehicle,
n_t- number of wheel sets.

$$M_2 = f_2 \cdot F_a \cdot d_m \ \ Nmm \qquad (6)$$

f_2- based n d_m ν i F_a/A,

$$A = k_B \cdot 10^{-3} \cdot d_m^{2,1} \qquad (7)$$

A-surface,
F_a -axial load bearing.

The axial load bearing occurs when the train move a curve. For a radius curvature R = 500 m and height superelevation on one side stripes h = 110 mm can be defined by the maximum permitted speed move of the train in a curve, and it is v = 68 km/h. The value of axial load calculated for the speed of move the train in a curve of v = 50 km/h.

Permissible speed of movement of the train in a curve calculated from the following equation:

$$h = \frac{11{,}8 \cdot v^2}{R} \qquad (8)$$

for 50 km/h axial load is F_a=16479 N, and coefficient f_2=0,008.

Table 1 shows the values of the friction torque due to lubrication, radial and axial load, and the total value of the friction torque M for the different speed movement of the train.

***Table 1**. The values of the friction torque*

n rev /min	M_0 Nmm	M_1 Nmm	M_2 Nmm	M Nmm
300	629	4193	25080	29902
450	991	4193	25080	30264
700	1107	4193	25080	30380

Determination of the heat generated heat in the bearing

Heat generated in the bearing determined by the equation (9):

$$Q_{uku} = 1{,}05 \cdot 10^{-4} \cdot d_m \cdot n \left[f_0 (\nu \cdot n)^{\frac{2}{3}} \cdot d_m^2 \cdot 10^{-7} + f_1 \cdot F_R + f_2 \cdot F_a \cdot 0{,}1 \right] \quad W \qquad (9)$$

In table 2 shows the values of heat generated during movement of the train at speed of 50, 80 and 120 km / h (operational speed bearing). Accepted that the vagon has such a path in exploitation to move 90% straight and 10% in the curve (5 % left and 5 % right curves and the speed of movement in curve v = 50 km/h, this values have been adopted on the basis of recommendations for calculation bearing wheel car).

***Table 2**. Value of the generated heat*

n rev /min	Q_{uku} W
300	231
450	364
700	573

THE HEAT TRANSFER MECHANISMS IN THE BEARING

Heat transfer mechanism at bearing (embedded as shown in Figure 1) are convection due to the rotation, conduction between the inner ring and the axle and the outer ring and housing [1].

Convection due to rotation the bearing

Heat transfer through the bearing is realized only between bearings and surroundings air. Absorbed heat from the grease, in this paper is not discussed. Because of the small difference in temperature radiation could be neglected, coefficient of the heat transfer is calculated according to condition of the flow air through bearing which belong to the turbulent motion. At this transfer, total air flow velocity, caused by the bearing rotation, is calculated from the axial and tangential component.

Surfaces for the axial flow air between the inner and outer track rolling:

$$A_{ax} = \frac{\pi}{4} \cdot (D^2 - d^2) \quad m \qquad (10)$$

Axial flow velocity could be calculated as a velocity between two cylinders, from the relation:

$$u_{ax} = \frac{V}{A_{ax}} = \frac{4 \cdot V}{\pi \cdot (D+d)} \quad m^2/s \qquad (11)$$

where V-volume air flow obtained from the continuity equation:

$$V = u_{sr} \cdot A_S = \frac{u}{2} \cdot B \cdot s = \frac{1}{2} \cdot d_m \cdot \omega \cdot s \cdot B \quad \frac{m^3}{s} \qquad (12)$$

In previous equation is considered medium velocity air through the cross-sectional area $A_S = B \cdot s$.

Tangential velocity component, on the midlle diameter, could be calculated from relation for air flow between movable and immobile cylinder:

$$u_{at} = \frac{\omega \cdot d_m}{2} = \frac{\pi \cdot f \cdot (D+d)}{4} \quad m^2/s \qquad (13)$$

where are:

f-frequency bearing Hz,

D- diameter outer ring m,

d- diameter inner ring m.

The resulting air velocity during rotation bearing is obtained from axial and tangential components according to [1].

$$U = \sqrt{u_{ax}^2 + u_{at}^2} \quad m^2/s \qquad (14)$$

Coefficient convection is calculate according to [1]:

$$\alpha = (c_0 + c_1 \cdot U^2) \quad \frac{W}{m^2 K} \qquad (15)$$

c_0 i c_1 are constants obtained experimentally (c_0=10 a c_1=5).

In table 3 shows the values of the coefficient of convection during rotation bearing, depending on the speed.

***Table 3** . Values of the coefficient of convection*

Speed bearing rev /min	Coefficient convection $\frac{W}{m^2 \cdot K}$
250	10,5
450	35,3
700	71,2

Heat convection between ring and housing and ring and axle

The coefficient of thermal conductivity depends on the gap between the outer ring and the housing and the inner ring and axle. Thermal conductivity between the two elements can be determined on the basis of equation [8]:

$$\lambda_{ij} = \frac{ln\left(\frac{r_j}{r_i}\right)}{\frac{ln\left(\frac{r_j}{r_1}\right)}{\lambda_j} + \frac{R_W}{r_1} + \frac{ln\left(\frac{r_1}{r_i}\right)}{\lambda_i}} \qquad (16)$$

where are λ_i i λ_j thermal conductivity of ring and housing. Other marks are shown in Figure 2.

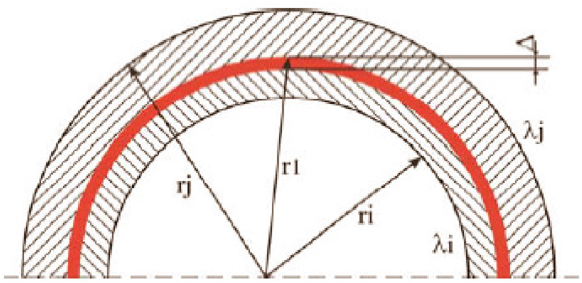


***Figure 2**: Schematic representation the contact between the outer ring and housing [16]*

In the previous equation R_w represents the thermal contact resistance on place of contact of the ring with housing, and according to [8] can be calculated as follows:

$$R_w = \frac{r_1}{\lambda_{ij}} ln\left(\frac{r_1+\Delta}{r_1}\right) \qquad (17)$$

where is Δ - clearance between outer ring and housing.

On similar method are determine conduction at contact between the inner ring and axle.

In Table 4 shows the values coefficient thermal conductivity of certain based on the previous equation.

***Table 4** . The values of coefficient thermal conductivity between the ring and the housing and ring and axle*

Place contact	*Coefficient conduction λ W/m²K*
Inner ring/axle	*60,5*
Outer ring/ housing	*90,9*

MODELING THERMAL ELASTIC BEHAVIOR

Figure 3 shows a model of a cylindrical roller bearing modeled using the program system PTC Creo Parametric. This bearing used for the bearing assembly wheel in railways.

Setting the coordinate system, the choice of contact pairs (CONTA 174, 53 contact pairs), defining of heat generated in the bearing, the choice of the type of finite element (SOLID 87, mesh than 8021 elements and 31720 nodes) and defining the elements between which there is conduction and convection heat transfer has been done in the framework of preprocessing. As a result of the previous on Figure 4 shown discretized model considered bearing.

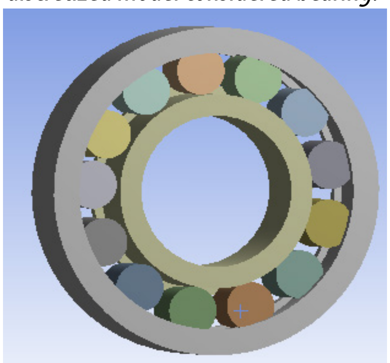


***Figure 3**. Appearance a cylindrical roller bearing for the bearing assembly wheel for railway*

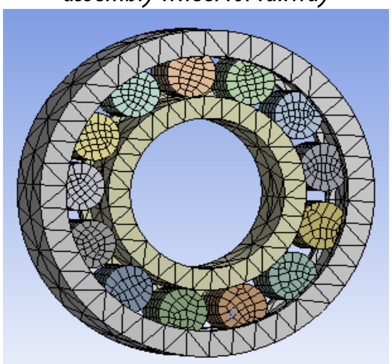


***Figure 4**. Appearance discretized model bearing*

After the calculation and after post processing obtained is graph showing the temperature distribution on elements bearing for speed n = 450 rev/min, respectively with speed moving a train of 80 km/h (Figure 5). The maximum temperature is marked with red color and equals to 54 °C and minimal with blue and equals to 53 °C in the steady temperature state bearing.

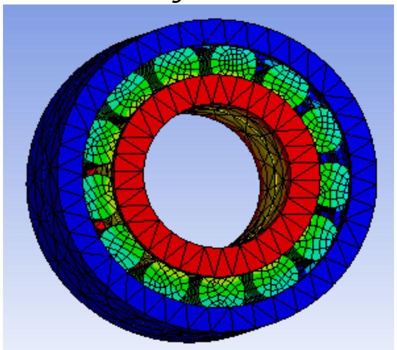


***Figure 5**. Graphical representation temperature on elements bearing*

Based on results of modeling in Figure 5 show temperature changes on rings bearing in depending from time for three different speeds movement of the train (v=50, v=80 i v=120 km/h). On diagram maximum temperature represents temperature of the inner ring and the minimum temperature is the temperature of the outer ring. Observation diagrams shows in Figure 6 can see that the steady temperature state bearing with highest speed motion (n = 700 rev/min, v = 120 km/h]) reached in shortest period of time.

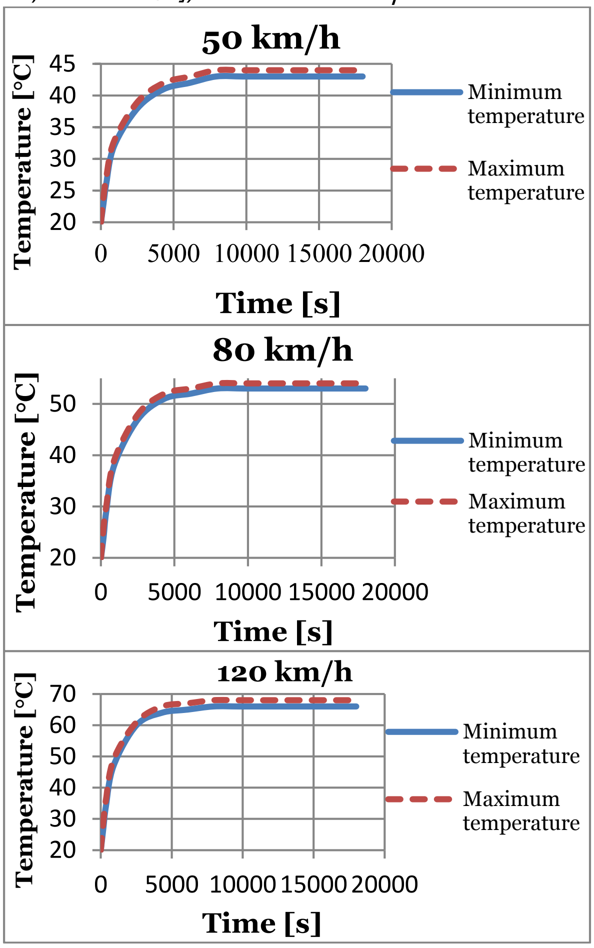


***Figure 6**. Change of the temperature on rings bearing depending on the time and speed of movement*

Based on the previously defined thermal model (temperature fields) can be determined by displacement in nodes bearing. The thermal load is defined on basis of the results of thermal analysis, and it represents the temperature of in nodes of the bearing. On elastic model is necessary to define limits displacement and it is shown in Figure 7.

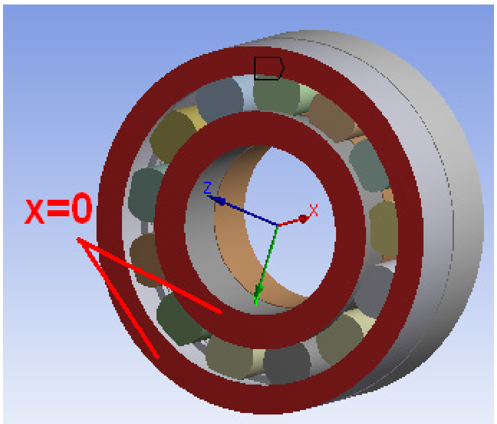
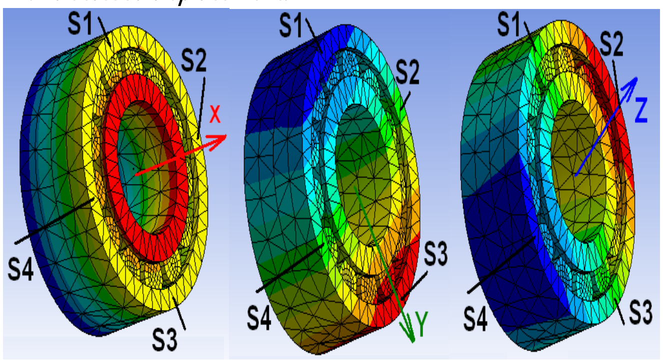


***Figure 7**. Constraints displacement*

In Figures 8 a. (displacement in the direction of x-axis), 8 b. (displacement in the direction of y-axis) and 8 c. (displacement in the direction of z-axis) shows the computer models of cylindrical rolling bearing for railway after heat load for speed n = 700 rev/min in the direction x, y and z axes. In figures shown characteristic points in which discussed displacement.



a. b. c.

***Figure 8**. The results of computer modeling of elastic behavior of the bearing after effects of heat load*

The obtained results can be seen that maximum displacement in the axial direction (direction x-axis) was 51 [μm], and in the radial direction displacement was 55 [μm]. Displacement values in characteristic points S1, S2, S3 and S4 are shown in Table 5.

***Table 5**. Values displacement in characteristic points*

Axis	Values displacement characteristic points μm			
	S1	S2	S3	S4
x	51	51	51	51
y	-55	0	55	0
z	0	55	0	-55

Stress (Von Misses's) appearing in bearing have a maximum value at the place of contact rollers and outer ring bearing and the amount 58 N/mm^2. In Figure 9 shows the distribution of stress on the bearing.

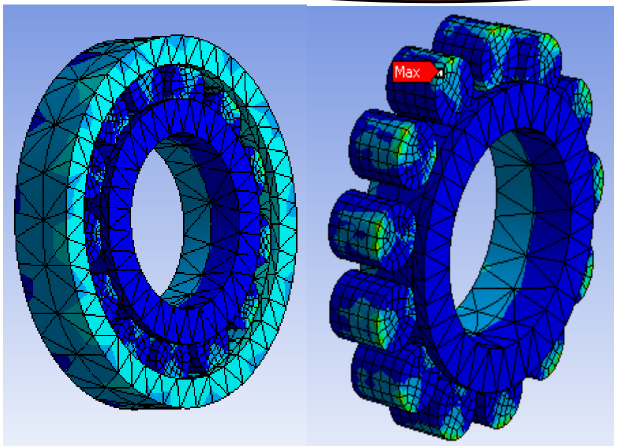


***Figure 9**. Distribution of stress on the bearing*

Bearing life for towed vehicles on railways determined following equation:

$$L_{10} = \left(\frac{C_r}{P_r}\right)^{\frac{10}{3}} \cdot \pi \cdot D_k \cdot 10^{-3} \qquad (18)$$

where are:
C_r-basic radial dynamic load rating (C_r=465 KN)
P_r-radial equivalent dynamic load acting on one bearing

$$P_r = F_r \cdot f_d \qquad (19)$$

f_d-factors of additional forces (f_d=1,2÷1,4)
D_k-diameter of the vehicle wheel (D_k=0,92 m)
On basis equation (18) and previously shown calculations obtained bearing life, which is 1 million kilometers.

CONCLUSION

In this paper were analyzed thermal elastic behavior cylindrical roller bearings for railway. Mathematical modeling of cylindrical roller bearing defined by the finite element method.
Based on the results of thermal behavior can be seen that the maximum temperature bearing was 68 °C which is considerably less than the maximum permissible temperature of 120 °C.
Maximum stress in bearing is 58 N/mm^2 which is much lower than the permissible stress in bearing.
The calculated bearing life corresponds to the required recommendations EN C (2006) 3345.

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[1.] Richard JANURA, [2.] Jozef JURČÍK, [3.] Miroslav GUTTEN, [4.] Daniel KORENČIAK

TRANSFORMER INSULATION ANALYSIS BY TIME DOMAIN METHOD

[1-4.] Department of Measurement & Applied Electrical Engineering, Faculty of Electrical Engineering, University of Žilina, Žilina, SLOVAKIA

Abstract: The article discusses the state of transformer insulation. For a more accurate determination of the transformer insulation state are used three methods. The measurement of insulation resistance is the basic method and is set in the standard, value demonstrates the state of total insulation of transformer. Because the determination of moisture content of the paper insulation of transformer is very difficult process and it is necessary take a sample of paper, in this case is used method of return voltage. Return voltage measurement is more complex method and in many cases is determine a clear result very difficult. For evaluation of results have mainly impact moisture content and degree of aging of paper insulation and of course, content of conductive impurities in oil. Because the moisture content in oil is much lower than in the paper, return voltage measurement is used to determine the moisture content in paper insulation only. To confirm the results of return voltage measurement is used frequency domain spectroscopy, which clearly, according computational model, calculates the moisture content in the paper insulation.
Keywords: transformer; return voltage; insulation resistance; polarization index; time domain; paper; oil

INTRODUCTION

Operating conditions has a major impact on aging of individual parts of transformer and also affect the change of the major electrical and mechanical properties. To the check of the condition greatly contributes electro-technical diagnosis, whose main task is to find a clear relation between the change in functional characteristics of the machine and some measurable values. The assessment of these measured values must be visible not only the level of change, but also whether it is a permanent or reversible state. The aim of diagnostics of transformers is to verify that the machine complies with the determined conditions in accordance with standards [1].

Economically reliable and effective power delivery always is the primary concern to utilities all over the world. Insulation diagnostics is one of the requirements for safe operation of transformers. Conventional methods to assessment of insulation condition are its loss factor, insulation resistance and partial discharge measurement, etc. These methods, however, provide only partial picture about the polarization processes in insulating material.

Deregulation of power market has increased the competition and also emphasized on the search for the new, efficient and effective methods for diagnosing the insulating system. The use of the return voltage method is significant way to detect ageing of the insulation of operating power transformer in a non-destructive manner [2].

MEASUREMENT THEORY

A. Insulation resistance of winding

Insulation resistance usually responds to the weakest point of the transformer insulation system and its decline is often coupled with the influence of conductive impurities and moisture. In measuring of the insulation resistance are read two values of the absorption current in 15 and 60 seconds after the applied of voltage. Absolute size of the insulation resistance is value measured in 60 seconds after the applied of voltage. Both values of the absorption current are necessary for the determination of polarization index p_i from the equation:

$$p_i = \frac{i_{15}}{i_{60}}, \qquad (1)$$

where i_{15} is the absorption current to 15 seconds and i_{60} is the absorption current in 60 seconds after the applied of voltage to the transformer [1].

Additional variable characterizing the transformer insulation system is the time constant τ, whose absolute value is independent of the geometric dimensions of the winding. Time constant is calculated from measured values of insulation resistance and capacitance of the transformer.

$$\tau = R_{60} C_{50} \qquad (2)$$

where R_{60} is insulating resistance in 60 seconds after the applied of voltage and C_{50} is capacitance of insulation measured at 50 Hz.

The value of the polarization index for new and transformers after revision should be at least 1.7 [1].

B. Return voltage

When a direct voltage is applied to a dielectric for a long period of time, and is then short circuited for a short period, after opening the short circuit, the charge bounded by the polarization will turn into free charges i.e., a voltage will build up between the electrodes on the dielectric. This phenomenon is called the return voltage. Now, the process of polarization and the equations to describe this process will be described in [3], [4].

When a dielectric material is charged with an electric field the material become polarized. The total current density is the summation of the displacement current density and the conduction current density, which is given by

$$j(t)=\sigma E(t)+\frac{dD}{dt}, \quad (3)$$

where σ is the direct conductivity, and is the electric displacement given by (4).

$$D(t)=\varepsilon E(t)+\Delta P(t)=\varepsilon_0\varepsilon_r E(t)+\Delta P(t) \quad (4)$$

where ε_0 is the vacuum permittivity, and ε_r is the relative permittivity at power frequency. The ΔP(t) term is related to the response function f (t) by the convolution integral shown in (5).

$$\Delta P(t)=\varepsilon_0\int_0^t f(t-\tau)E(\tau)d\tau\,. \quad (5)$$

If we expose the insulation to a step voltage at time t = 0 the charging current density is given by

$$j_p=E(\sigma+\varepsilon_0 f(t)). \quad (6)$$

If we consider the case where an insulation system with geometrical capacitance C_0 is exposed to a step voltage, U_a, the polarization current can be given by

$$i_p=C_0U_a\left(\frac{\sigma}{\varepsilon_0}+f(t)\right). \quad (7)$$

If the step voltage is now disconnected from the insulation

$$i_d=-C_0U_a[f(t)-f(t+t_{ch})] \quad (8)$$

gives the depolarization current. The charging time normally should be at least ten times larger than the time for which the response function is calculated then the second term in (8) can be neglected. Therefore, the response function becomes proportional to the depolarization current. Hence, the response function and conductivity can be calculated simultaneously by using polarization and depolarization currents. Very often, the response function needs to be expressed in a parameterized form. The response function can be written in the general form:

$$f(t)=\frac{A}{\left(\frac{t}{t_0}\right)^n+\left(\frac{t}{t_0}\right)^m}\,. \quad (9)$$

The response function describes the fundamental memory property of any dielectric system and can provide significant information about the insulation material. After opening the short circuit, the charge bounded by the polarization will turn into free charges i.e., a voltage will build up between the electrodes on the dielectric. This phenomenon is the return voltage. The return voltage arises from the relaxation processes inside the dielectric material. The current density during the return voltage measurement is zero and

$$j(t)=\sigma E(t)+\varepsilon_0\varepsilon_r\frac{d}{dt}E(t)+\varepsilon_0\frac{d}{dt}\left[\int_0^t f(t-\tau)E(\tau)d\tau\right] \quad (10)$$

gives the expression of current density, where E(t) is the electric field resulting from the return voltage build up across the open circuited dielectric. Equation (10) shows that the return voltage depends on the conductivity σ, relative permittivity ε_r and dielectric response function f(t). These parameters are all affected by aging and moisture in the insulation. The response function can be obtained from the polarization and depolarization currents. These currents depend on the geometric capacitance and on the applied step excitation. The response function and conductivity can be calculated from equations (7) and (8) if the geometric capacitance of the transformer composite insulation is known. If the proper geometry of the transformer oilpaper insulation is known then by solving (10), return voltage for a transformer can be estimated. The return voltage also depends on the applied electric field and if the dielectric material is assumed to be linear this problem is resolved easily for the interpretation of results [5]. A modeling tool can be very useful to investigate the impact of geometry on return voltage results [6].

TRANSFORMER MEASUREMENT

A. Insulation resistance and polarization index

The measurement was performer in the laboratory of the Department of measurement and applied electrical engineering on the transformer, which parameters are given in table 1.

Table 1. Tested transformer parameters

Connection	Yz1
Power	30 kVA
Voltage transfer	22 / 0.4 kV
Current ratio	0.787 / 43.3 A
Year of production	1958
Manufacturer	BEZ

The transformer wasn't before this measurement in operation for over two years and the oil state was deliberately under the operation level. Firstly the insulation resistance and polarization index was measured by MEGGER series 1-5000. The low and high voltage terminals were connected to test voltage 2500 V in measuring the insulation resistance of the windings. Results of the measurement are shown in table 2.

Table 2. Insulation resistance measured values

Test voltage	2500 V	
Insulation resistance	After 1 min	3.85 GΩ
	After 5 min	5.8 GΩ
	After 10 min	6.33 GΩ
Polarization index	1.64	

According to (1), the absolute size of the insulation resistance is equal to 3.85 GΩ. As was expected, the value of polarization index is below 1.7, but the measured value 1.64 is above the assumptions and says that the insulation is in very good condition. The value of the polarization index in such transformers is approximately 1.4.

B. Measurement and evaluation of return voltage

To measure of return voltage can be used, for example, device RVM 5462. Because we used two separated devices – DC source and switch panel, which consists of electromechanical switching relays, the disadvantage is theimpossibility to perform measurements at charging times below 1 second. Return voltage measurement consists of four steps (figure1 and figure 2):

1. Charging (during the time t_c the voltage is connected to LV and HV terminals),
2. Discharging (during the time $t_d = t_c / 2$ LV and HV are short-circuited),
3. Measurement U_{max} and t_{max} (measured voltage between LV and HV terminals),
4. Recovery before the next cycle (during the time $t = t_c$ LV and HV terminals are short-circuited).

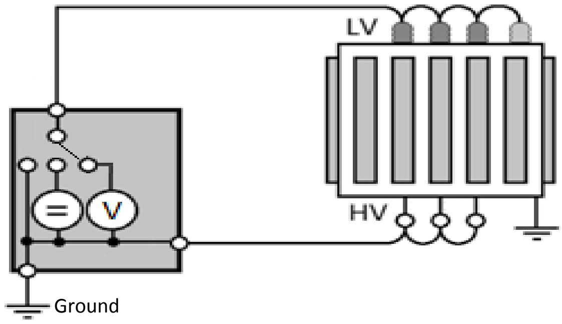

Figure 1. Return voltage measurement connection

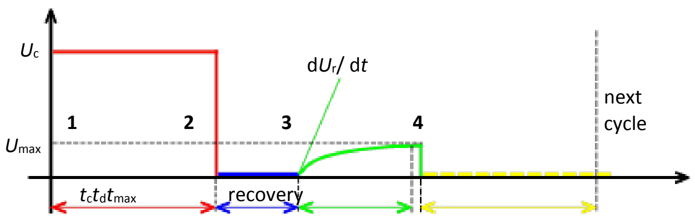

Figure 2. The test voltage shape

Table 3 shows the measured and calculated values from return voltage measurement. The time constant is equal to the time, at which the value of voltage $0.63U_{ss}$ is reached: $t(U_\tau) \cong t(0.63U_{ss})$. The voltage U_{ss} is steady-state value at different times of charging.

Table 3. Measured and calculated values of return voltage

t_c (s)	U_{max} (mV)	t_{max} (ms)	U_{ss} (mV)	U_τ (mV)	τ (ms)
2	587.50	12.5	542.41	341.72	2.3034
4	493.75	14.5	481.69	303.46	2.4547
6	443.75	16.7	386.16	243.28	2.5621
12	437.50	16.9	390.35	239.62	2.6224
24	362.50	19.1	312.05	196.59	2.3956
48	212.50	13.1	208.48	131.34	2.3016
96	162.50	10.9	147.77	93.09	2.2839

From the measured values were compiled curves (fig. 3-fig. 6). Figure 3 shows the measured voltage values at time for different times of charging. From this curves it is obvious that the maximum voltage response was reached at the time of charging $t_c = 2$ s.According to [7] and [8] could be stated that the maximum size of voltage response was reached at the point 2 s, which implies that the moisture content is approximately 3.5%.

Figure 5 shows time in which the maximum voltageis reached for different charging times. As the curve shows, the longest time to achieve the maximum voltage response was for charging time $t_c = 24$ s.

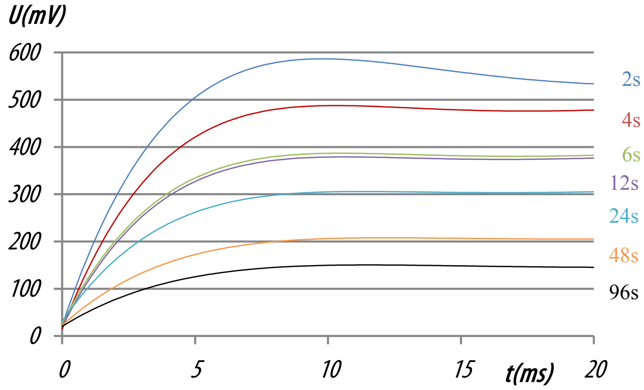

Figure 3. Dependence of voltage in time at different times of charging

Figure 4 shows the dependence of the maximum voltage response by charging time, from which is apparent that at lower charging times $t_c < 2$ s, the curve took the opposite, thus decreasing tendency. This phenomenon shows that the transformer insulation is on the border of operable condition and before the full load of transformer is necessary to carry out oil filtration andthen slowly increase the transformer load by reason of residual moisture content in paper insulation.

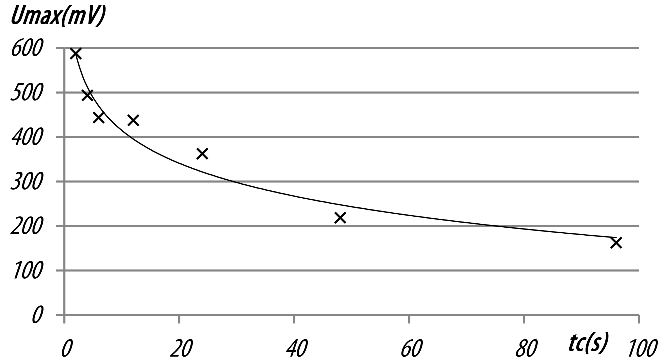

Figure 4. Maximum voltage response at different times of charging

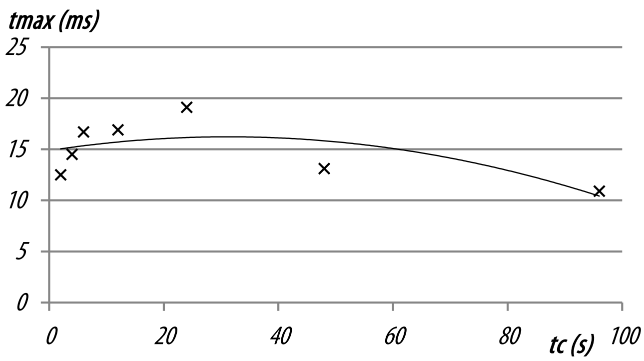

Figure 5. Time in which the voltage peak was achieved at different times of charging

From the measured values,the time constant at different charging times was calculated.The curve is depicted on fig. 6. It shows that the values at different charging times are not much uneven, so could be declared that the dependence of the time constant of the equivalent circuit of the insulation system is independent on time of operation of DC voltage in the range of measured times. The average value was $\tau_A = 2.417$ ms.

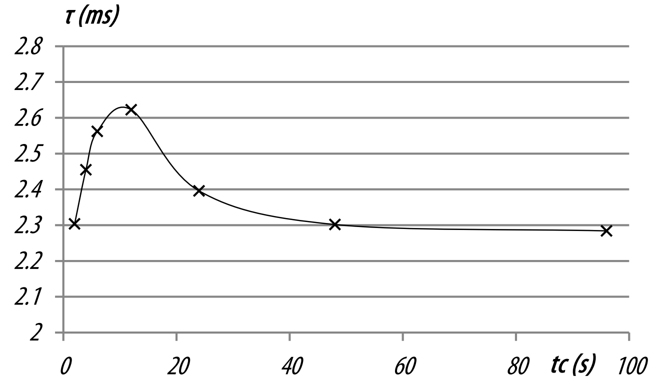

Figure 6. *Time constant at different times of charging*

CONCLUSION

Return voltage measurement was designed for cable insulation state investigation. The most of measuring devices for cable investigations don't allow measurement at different times of charging or discharging. Whereas the cable insulation like transformer windings insulation could this measuring method use also for transformers. It doesn't matter whether the insulation is dry or oleic. Due to the large use of oil transformers was this measurement aimed right at them. We could obtain moisture level content in oil transformers with using the RVM method too. An attempt has been made in order to use the initial slope of the decay voltage and the initial slope of the return voltage (single cycle) to separately investigate the moisture and ageing in the oil impregnated paper insulation. From the results, it could be seen that in some situations the initial slope of the decay voltage could provide a good indication of the moisture level. The initial slope of the single cycle RVM reflects the combined effect of ageing and moisture. As in many other methods also in RVM is difficult to evaluate the results but in combination with PDC method a more accurate evaluation of the measurement results could be achieved. Moisture content in paper and oil insulation of transformer could be more reliably determined using FDS method. The final moisture contents of the paper insulation by RVM and FDS methods are almost identical. Moisture content determined by RVM is approximately 3.5 % and by the FDS method is 3.3%. The advantage of using both methods is their similarity and accurate determination of moisture content in paper insulation of transformer is therefore simpler.

Acknowledgment

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[1.] Daniel R. WEISZ, [2.] Felix A. HIMMELSTOSS

LED CONVERTER WITH LIMITED DUTYCYCLE

[1-2.] Department of Energy and Industrial Electronics,
University of Applied Science Technikum Wien, Vienna, AUSTRIA

Abstract: *Light emitting diodes (LEDs) can be used for many lightning applications in offices, in homes, and in streets. A special converter with limited duty cycle for driving LEDs is treated. The basic analysis is done resulting in dimensioning equations of the converter. The basic analyses have to be done with idealized components (that means no parasitic resistors, no switching losses) and for the continuous mode in steady (stationary) state. A mathematical model based on state-space description is derived. Some experimental results are shown. The converter is useful for street, home, and automotive lightning applications.*
Keywords: *LED converter; limited duty cycle; peak-current-control; high-power LED*

INTRODUCTION

Light emitting diodes (LEDs) can be used for many lightning applications in offices, in homes, and in streets. There exists a rich literature about converter topologies and control. The [1] shows a classical boost converter used to drive a series connection of LEDs. In [2] a good overview about possible converter topologies is given. Buck, boost, buck-boost, flyback and a resonant converter are treated. Peak current control is used. The control concepts of peak and hysteresis control are discussed in [3]. The voltage controlled non-inverting buck-boost and the Sepic converter are explained in [4] and [5], respectively. A system analysis and a control description for a boost converter are given in [6]. A combined power factor corrector and LED driver based on a flyback converter is explained in [7]. An interesting concept based on a kind of three-level converter is shown in [8]. Deep insight views on power electronics are given in [9, 10].

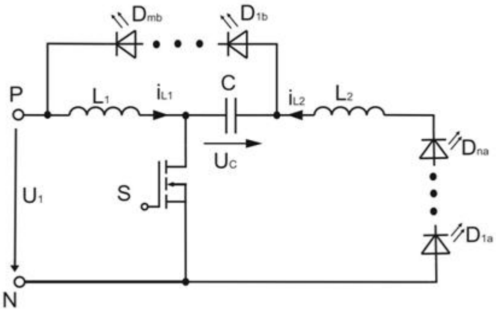

Figure 1 . *Converter schematic*

The here described converter was first published in the patent literature [12] and is shown in Figure 1. The converter consists of an active switch (S), two inductors (L_1, L_2), one capacitor (C), and two strings of LEDs. The upper one has m diodes (D_{1b} till D_{mb}) and can be replaced by only one diode, working as a freewheel path. The other string has n diodes connected in series (D_{1a} till D_{na}) which is in series to the second inductor and is the main light source. The current through this series connection can be easily controlled by a bang-bang controller. The special feature of the converter is that a duty cycle greater than 0.5 is necessary as will be shown in the following section.

BASIC ANALYSIS

The basic analyses have to be done with idealized components (that means no parasitic resistors, no switching losses) and for the continuous mode in steady (stationary) state. A good way to start is to consider the voltage across the inductors. The duty cycle d is the ratio of the on-time of the active switch related to the switching period.

Since for the stationary case the absolute values of the voltage-time-areas of the inductors have to be equal (the voltage across the inductor has to be zero in the average), we can easily draw the shapes according to Figures 2 and 3. (Here the capacitor is assumed to be so large that the voltage can be regarded constant during a pulse period). The shapes are drawn with a duty cycle of 70%. The forward voltage of an LED is symbolized by V_D.

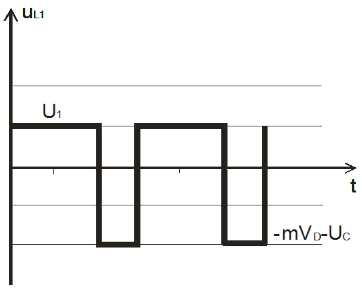

Figure 2. *Voltage across inductor L1*

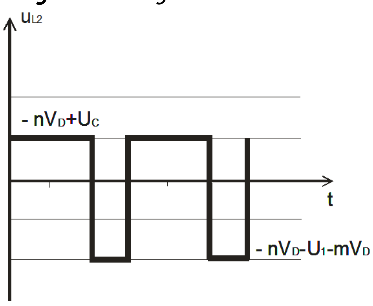

Figure 3. *Voltage across inductor L_2*

The equal voltage-time-areas of inductor L_1 are

$$U_1 \cdot d \cdot T = (U_C + mV_D)\cdot(1-d)\cdot T \quad (1)$$

and therefore the capacitor mean voltage in steady-state is

$$U_C = \frac{U_1 \cdot d - mV_D \cdot (1-d)}{(1-d)} \quad (2)$$

The equal voltage-time-areas of inductor L_2 are

$$(-nV_D + U_C)\cdot d \cdot T = (nV_D + U_1 + mV_D)\cdot(1-d)\cdot T \quad (3)$$

and therefore the mean voltage across the series connection D_{1a} till D_{na}(output voltage of the converter U_2) in steady-state is

$$U_2 = \frac{U_1 \cdot (1-2d) - mV_D \cdot (1-d)}{(d-1)} \quad (4)$$

When only one free-wheeling diode is used instead of the series connection D_{1b} till D_{mb}, the idealized voltage transformation rate of the converter is

$$M = \frac{U_2}{U_1} = \frac{1-2d}{(d-1)} \quad (5)$$

The duty cycle must be greater equal than 0.5 and smaller than one. If the duty cycle is smaller than a half, the output voltage would change its sign. That is impossible due to the used semiconductors. The converter is a step-up-down converter, useful for step-up rates of up to about four. Figure 4 shows the voltage transformation rate of the converter.

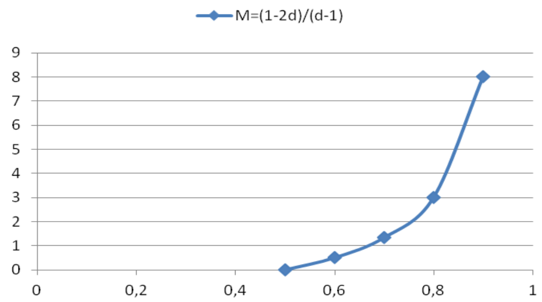

Figure 4 . Voltage transformation rate in dependence of the dutycycle

In steady-state the mean-value of the current through a capacitor must be zero. Therefore, the positive and the negative current-time-areas must be equal. With the mean values of the inductor currents, one can write

$$d \cdot \bar{I}_{L2} = (1-d)\cdot \bar{I}_{L1} \quad (6)$$

The mean value of the current through inductor L_2 is equal to the mean value of the current through the LED string (D_{1a} till D_{na})

$$\bar{I}_{LED} = \bar{I}_{L2} \quad (7)$$

The current through the inductors has a pronounced current ripple (shown in Figure 5) depending on the voltage and the inductor value.

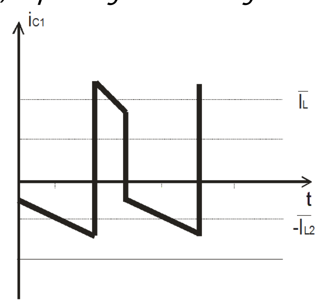

Figure 5 . Current through the capacitor

The current through the first inductor depends on the load (LED) current and the duty cycle. The mean value of i_{L1}i s always larger than the current through the load.

DIMENSIONING OF THE COMPONENTS

Capacitor

The change of the capacitor voltage during one period can be described by

$$\Delta u_{C1} = \frac{1}{C}\cdot\int_0^{dT} i_{C1} dt \quad (8)$$

With $M = \frac{U_2}{U_1} = \frac{1-2d}{(d-1)}$ the duty cycle can be calculated to

$$d = \frac{U_2 + U_1}{U_2 + 2U_1} \quad (9)$$

The capacitor can now be dimensioned by

$$C = \frac{1}{\Delta u_C}\cdot\frac{U_1 + U_2}{2U_1 + U_2}\cdot I_{LED}\cdot\frac{1}{f} \quad (10)$$

The higher the switching frequency f the lower is the capacitor value.

Inductors

With the chosen current ripple ΔI_{L1} and ΔI_{L2} of the inductors, the inductor values can be calculated out of the basic equation of the inductor to

$$L_1 = \frac{U_1}{\Delta I_{L1}}\cdot\frac{U_1 + U_2}{2U_1 + U_2}\cdot\frac{1}{f} \quad (11)$$

$$L_2 = \frac{U_1}{\Delta I_{L1}}\cdot\frac{U_1 + U_2}{2U_1 + U_2}\cdot\frac{1}{f} \quad (12)$$

Voltage stress of the semiconductors

The highest voltage stress of the active switch is during the free-wheeling stage and is

$$U_S = U_C + U_1 + mV_D \quad (13)$$

which can be converted to

$$U_S = 2U_1 + U_2 + mV_D \quad (14)$$

Using a free-wheeling diode and ideal devices one gets

$$U_S = 2U_1 + U_2 \quad (15)$$

The maximum stress across the free-wheeling diode or the LED string D_{1b} till D_{mb} occurs during the on-time of the active switch and its absolute value is the same as in (15).

Current stress of the semiconductors

When the active switch is on, the sum of the inductor currents is flowing through it. Using the mean values one can calculate the mean value of the current through the active switch according to

$$\bar{I}_S = (\bar{I}_1 + \bar{I}_2)\cdot d \quad (16)$$

The maximum value of the current through the active switch is

$$I_{\max,S} = \bar{I}_1 + \bar{I}_2 + \frac{\Delta I_{L1} + \Delta I_{L2}}{2} \quad (17)$$

Using the mean values (assuming that the inductor current ripple is low) one can approximately calculate the rms value to

$$I_{rms,S} = (\bar{I}_1 + \bar{I}_2)\cdot\sqrt{d} \quad (18)$$

When the active switch is off, the sum of the inductor currents is flowing to the freewheeling diode or the LED string D_{1b} till D_{mb}. Using *the mean values one can calculate the mean value of the current through the passive switch or the diode string acting as the free-wheeling path according to*

$$\bar{I}_S = (\bar{I}_1 + \bar{I}_2)\cdot(1-d) \quad (19)$$

The maximum value of the current through the passive switch is equal to the active switch and can be again calculated by (17).

Using the mean values (assuming that the inductor current ripple is low) one can approximately calculate the rms value to

$$I_{rms,S} = (\bar{I}_1 + \bar{I}_2)\cdot\sqrt{(1-d)} \quad (20)$$

STATE SPACE MODEL

The state variables are the inductor currents i_{L1}, i_{L2}, and the capacitor voltage u_C. The input variables are the input voltage u_1 and the fixed forward voltage of the LED strings mV_D and nV_D. The LEDs are modeled as a fixed forward voltage V_D and an additional voltage drop depending on the differential resistor of the LED diodes R_D). The other parasitic resistances are the on-resistance of the active switch R_S, the series resistance of the converter coils R_{L1}, R_{L2}, and the series resistor of the capacitor R_C.

In continuous inductor current mode there are two states. In state one the active switch is turned on and the passive switch or the LED string D_{1b} till D_{mb} is turned off. Figure 6 shows switching state one.

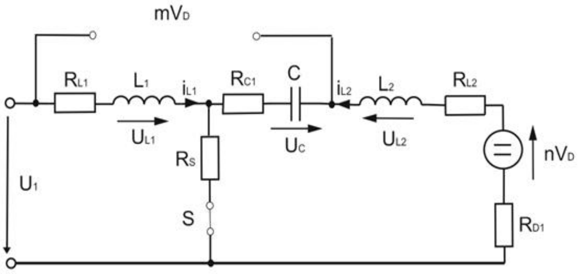

Figure 6 . *Equivalent circuit for state 1*

The state space equations are now

$$\frac{d_{iL1}}{dt} = \frac{-i_{L1}\cdot(R_{L1}+R_S) - i_{L2}\cdot R_S + u_1}{L_1} \quad (21)$$

$$\frac{d_{iL2}}{dt} = \frac{-i_{L1}\cdot R_S - i_{L2}\cdot(R_{L2}+R_{D1}+R_S+R_{C1}) - nV_D + u_C}{L_2} \quad (22)$$

$$\frac{du_C}{dt} = \frac{-i_{L2}}{C} \quad (23)$$

leading to the state-space matrix description according to

$$\frac{d}{dt}\begin{pmatrix} i_{L1} \\ i_{L2} \\ u_C \end{pmatrix} = \begin{bmatrix} -\frac{(R_{L1}+R_S)}{L_1} & -\frac{R_S}{L_1} & 0 \\ -\frac{R_S}{L_2} & -\frac{(R_{L2}+R_{D1}+R_S+R_{C1})}{L_2} & \frac{1}{L_2} \\ 0 & -\frac{1}{C} & 0 \end{bmatrix}\cdot\begin{pmatrix} i_{L1} \\ i_{L2} \\ u_C \end{pmatrix} + \quad (24)$$

$$+\begin{bmatrix} \frac{1}{L_1} \\ 0 \\ 0 \end{bmatrix}\cdot(U_1) + \begin{bmatrix} 0 \\ -\frac{1}{L_2} \\ 0 \end{bmatrix}\cdot(nV_D) + \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}\cdot(mV_D).$$

In state two the active switch is turned off and the passive switch or the LED string D_{1b} till D_{mb} is turned on. Figure 7 shows this switching state two.

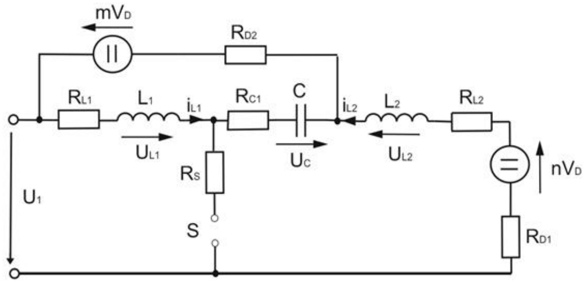

Figure 7*. Equivalent circuit for state 2*

The describing equations are

$$\frac{d_{iL1}}{dt} = \frac{-i_{L1}\cdot(R_{L1}+R_{D2}+R_{C1}) - i_{L2}\cdot R_{D2} - mV_D - u_{C1}}{L_1} \quad (25)$$

$$\frac{d_{iL2}}{dt} = \frac{-i_{L1}\cdot R_{D2} - i_{L2}\cdot(R_{L2}+R_{D1}+R_{D2}) - mV_D - nV_D - u_1}{L_2} \quad (26)$$

$$\frac{du_c}{dt} = \frac{i_{L1}}{C_1} \quad (27)$$

leading to the state-space matrix description according to

$$\frac{d}{dt}\begin{pmatrix} i_{L1} \\ i_{L2} \\ u_C \end{pmatrix} = \begin{bmatrix} -\frac{(R_{L1}+R_{D2}+R_{C1})}{L_1} & -\frac{R_{D2}}{L_1} & -\frac{1}{L_1} \\ -\frac{R_{D2}}{L_2} & -\frac{(R_{L2}+R_{D1}+R_{D2})}{L_2} & 0 \\ \frac{1}{C} & 0 & 0 \end{bmatrix}\cdot\begin{pmatrix} i_{L1} \\ i_{L2} \\ u_C \end{pmatrix} + \quad (28)$$

$$+\begin{bmatrix} 0 \\ -\frac{1}{L_2} \\ 0 \end{bmatrix}\cdot(U_1) + \begin{bmatrix} 0 \\ -\frac{1}{L_2} \\ 0 \end{bmatrix}\cdot(nV_D) + \begin{bmatrix} -\frac{1}{L_1} \\ -\frac{1}{L_2} \\ 0 \end{bmatrix}\cdot(mV_D).$$

Under the condition that the system time constants are large compared to the switching period, we can combine these two sets of equations (24, 28) to the state-space model

$$\frac{d}{dt}\begin{pmatrix} i_{L1} \\ i_{L2} \\ u_C \end{pmatrix} =$$

$$\begin{bmatrix} -\frac{[d\cdot R_S+(1-d)\cdot(R_{D2}+R_{C1})+R_{L1})]}{L_1} & -\frac{[d\cdot R_S+(1-d)\cdot R_{D2}]}{L_1} & \frac{(d-1)}{L_1} \\ -\frac{[d\cdot R_S+(1-d)\cdot R_{D2}]}{L_2} & -\frac{[d\cdot(R_S+R_{C1})+(1-d)\cdot R_{D2}+R_{L2}+R_{D1})]}{L_2} & \frac{d}{L_2} \\ \frac{(1-d)}{C} & -\frac{d}{C} & 0 \end{bmatrix}\cdot\begin{pmatrix} i_{L1} \\ i_{L2} \\ u_C \end{pmatrix} +$$

$$+\begin{bmatrix} \frac{d}{L_1} \\ \frac{(d-1)}{L_2} \\ 0 \end{bmatrix}\cdot(U_1) + \begin{bmatrix} 0 \\ -\frac{1}{L_2} \\ 0 \end{bmatrix}\cdot(nV_D) + \begin{bmatrix} \frac{(d-1)}{L_1} \\ \frac{(d-1)}{L_2} \\ 0 \end{bmatrix}\cdot(mV_D). \quad (29)$$

By this equation the dynamic behavior of the converter is described correctly in the average. The superimposed ripple (which appears very pronounced in the coils) is of no importance for qualifying the dynamic behavior. This model is also appropriate as large-signal model, because no limitations with respect to the signal values have been made.

EXPERIMENTAL MODEL OF THE CONVERTER

In Figure 8 a picture of the experimental converter is shown. The values of the devices are included. Five LUXEON Altilon LED were used. The typical of the forward voltage of one chip is about 6.4 V.

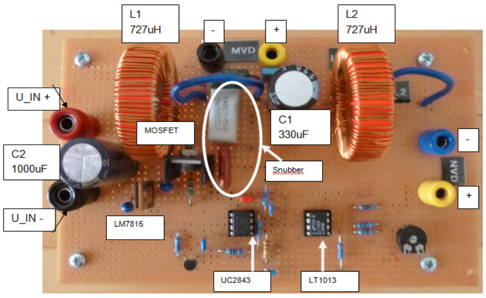

***Figure 8** . Experimental Converter*

In Figure 9 the voltage across the capacitor, the current through the load, and the drain voltage of the active switch are shown. Due to an RCD snubber the spikes at switch-off are minimized.

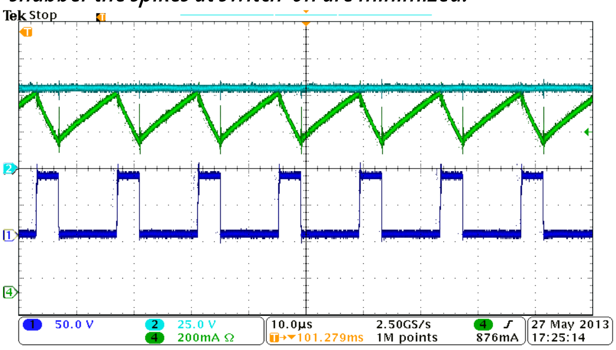

***Figure 9** . Voltage across the capacitor (turquois), the current through the load (green), and the drain voltage of the active switch (blue)*

Figure 10 shows the converter with a series connection of five LED in action.

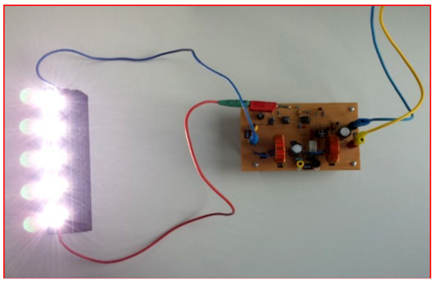

***Figure 10** . Converter in action*

CONCLUSION

A novel LED converter with limited duty cycle was analyzed. The advantage of this converter is its continuous output current and a duty cycle which is always greater than 0.5. If loss-less snubbers are used, more than the half switching period is available to discharge the snubber capacitor. The input and the output have the same reference point (ground) so avoiding common mode disturbance. The current can be controlled with a standard current control IC. The freewheeling path can also be used to drive further LED in series. The converter is easily dimmable.

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[1.] Vladimir CHUDACIK, [2.] Ladislav JANOUSEK, [3.] Milan SMETANA

EVALUATION OF SPATIAL COMPONENTS ON EDDY CURRENT TESTING RESPONSE SIGNALS OF SELECTED DEFECT PARAMETERS

[1-3.] Department of Electromagnetic and Biomedical Engineering, Faculty of Electrical Engineering, University of Zilina, SLOVAKIA

Abstract: In this article, the presence of inhomogeneities in solid electrically conducting plate is inspected by non-destructive way with use of eddy current testing method where the perturbed electromagnetic field caused by the defect is detected. We perform three-dimensional finite element simulations of this structure with pre-defined material inhomogeneities and they are evaluated by an induction coil. This study is motivated by the novel eddy current testing technique which is based on sensing of all the three components of the perturbed field. Basically we performed parametric study to quantify the impact of various parameters - depth and electrical conductivity of the inhomogeneity. The analyses provide reference results to understand the effectiveness, feasibility and capability of this approach.

Keywords: spatial components, three-axes sensing, eddy current testing coil, material inhomogeneities

INTRODUCTION

The importance of non-destructive testing (NDT) and evaluation (NDE) of the materials increase along with industrial development and the need of optimal and cost-efficient material consumption. The continuous assessment of material characteristics during the production process is used to increase the quality of the end product but also to avoid additional production costs. Controlling during the operation is valuable information. It can help to increase the overall reliability and maintain the required safety of the product. These requirements are followed by a strong demand on development of new NDT techniques which can overcome some of the limitations of already available techniques, [1].

Development of new testing techniques, which allow preventing functional losses, is still continuing and their number went up to over a hundred. Especially the electromagnetic methods are widely spread due to their simplicity and flexibility of application. Among these methods the eddy current testing (ECT) is predominant for examination of non (fero-) magnetic materials. It can be applied for detection of close-to-surface defect anomalies which lead to a change in electrical conductivity. The principle of this method lies in electromagnetic induction phenomena. When an alternating current is used to excite a coil, an alternating magnetic field is produced and magnetic lines of flux are concentrated at the center of the coil. Then, as the coil is brought near an electrically conductive material, the alternating magnetic field penetrates the material and generates continuous, circular eddy currents as shown Figure1.

As the penetration of the induced field increases, the eddy currents become weaker, therefore larger eddy currents are produced near the test surface.

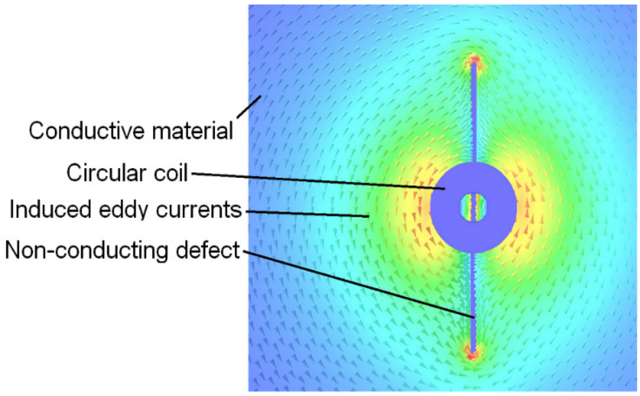

Figure 1. Distribution of the current field in a conductive material sample with non-conducting defect

The induced eddy currents produce an opposing (secondary) magnetic field, Figure1. This opposing magnetic field, coming from the material, has a weakening effect on the primary magnetic field and the test coil can sense this change. In effect, the impedance of the test coil is reduced proportionally as eddy currents are increased in the test piece. Changes in the coil impedance (self inductance sensor) or in the induced voltage (mutual inductance sensor) due to a presence of discontinuity are sensed during mechanical movement of a sensor over an inspected region of a material. The main purpose is the detection and reliable characterization of defects or inhomogeneities.

Eddy current probe is the main link between an eddy current instrument and a component under the test. Success of eddy current testing for a specific inspection application depends on sensor, instrument and on selection of test parameters. The probe plays two important roles: it induces the eddy currents and it senses the distortion of their flow caused by the defects.

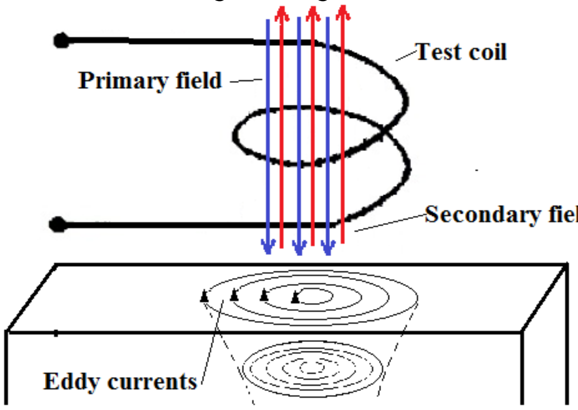

Figure 2. Basic principle of the ECT method

The design and development of eddy current probes is very important as it is the probe that dictates the probability of detection, sensitivity, resolution and the reliability of characterization. Traditional eddy current testing methods based on excitation-detection coils is fundamentally limited by the lower sensitivity of the detection coils at low frequencies. Nowadays, different types of magnetic detection elements such as Hall sensors, SQUID, GMR, Fluxgate, AMR and others have been employed in order to increase the detection probability and the sensitivity. The main focus in these research areas nowadays is to increase the information value of the detected response signal to get more information about the dimensions of the material defect. For this purpose was used new approach where all the three (X, Y, Z) axes of electromagnetic field are sensed. These components are evaluated and analyzed by numerical simulations and their influence to different inhomogeneities parameters (depth, electrical conductivity) of all electromagnetic components is presented.

NUMERICAL MODELING

Definition of the problem

The model of the simulated problem was investigated by numerical way. Commercially available software for numerical analyses of electromagnetic fields OPERA 3D, based on the finite element method, is employed for the above-mentioned purposes.

The eddy currents are driven by a circular coil standard self-inductance probe, shown Figure3. The probe is positioned normally in a view of the plate surface with lift-off 1 mm. The coil is driven by the harmonic current with a frequency of $f = 10$ kHz and current density $J = 2$ A/mm^2.

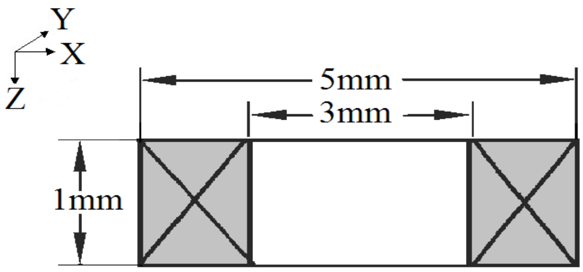

Figure 3. Dimensions of the coil

Conductive plate specimen with a thickness of $h = 10$ mm and having the electromagnetic parameters of the stainless steel SUS316L is inspected in this study, shown Figure 4. The material has the conductivity of $\sigma = 1.35$ MS/m and the relative permeability of $\mu_r = 1$.

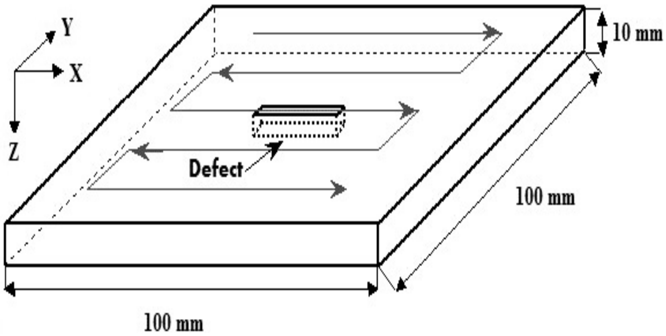

Figure 4. Dimensions of the inspected material

The non-conductive defects with rectangular shape are modeled and positioned in the middle of the plate. The defects have a width of $w_c = 0.2$ mm, a length of $l_c = 10$ mm and their depth d_c and electrical conductivity are varied according to Table1. The electrical conductivity is changing from $\sigma_d = 0\%$ to 10% of the base material conductivity. These interpretations are used for modeling of the stress corrosion cracks. Only one parameter is varied in numerical simulations for one case, while other parameters are kept constant.

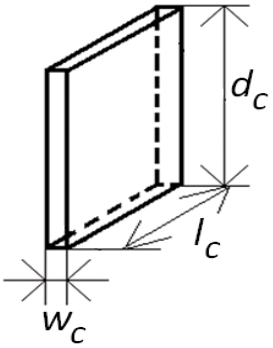

Figure 5. Dimensions of the simulated imhomogeneity

Table 1. Change in parameters of the Defects

Depth (d_c) [mm]	0	1	2	3	4	5	6	7	8	9
Conductivity [%]	0		1		2		5		10	

The inspection of the material is realized as a 2D scan. In order to assure a thorough inspection of the sample, the coil moves over the material surface in both X and Y axes as shown Figure 4. The three spatial components of the magnetic flux density vector B_x, B_y, B_z with respect to coordinate system are considered as response signals.

NUMERICAL SIMULATIONS RESULTS

Eddy current method does not provide a direct measure of the size or severity of the defects. The response signal is usually found by subtracting the reference signal from the one gained over a defect. A reference signal is collected over a defect-free region. Any flaws, defects, or conductivity and dimensional changes produce the changes in the response signal.

The peak value of gained differential response signals for all three spatial components of the magnetic flux density vector has been identified as an important characteristic of the response signals.

Figures 6-8 show the surface distribution of the maximum values of the differential response signals for all the three spatial components of magnetic flux density vector B. The surface distribution is different for different defect dimension and properties and it also influence the maximum value of each spatial component. The position of the maximum value depends on the analyzed defect parameter.

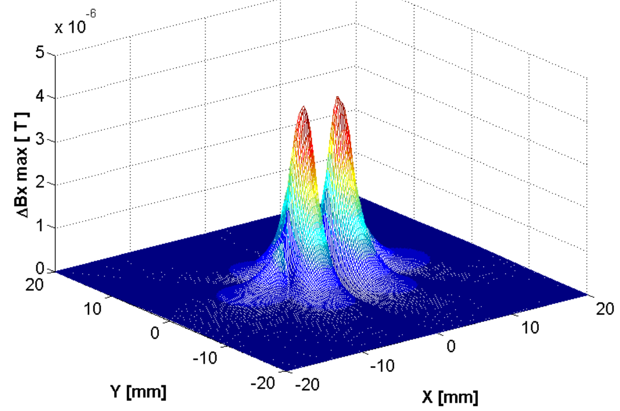

Figure 6. *Surface distribution of the differential signal Bx; defect 0.2x10x3mm, probe position x,y=[0,0]mm above a middle of defect*

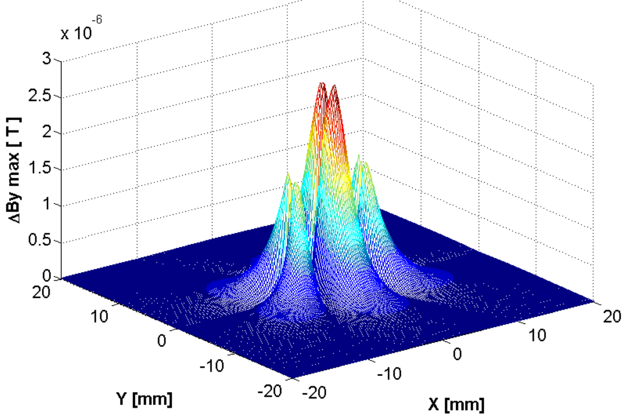

Figure 7. *Surface distribution of the differential signal By; defect 0.2x10x3mm, probe position x,y=[0,0]mm above a middle of defect*

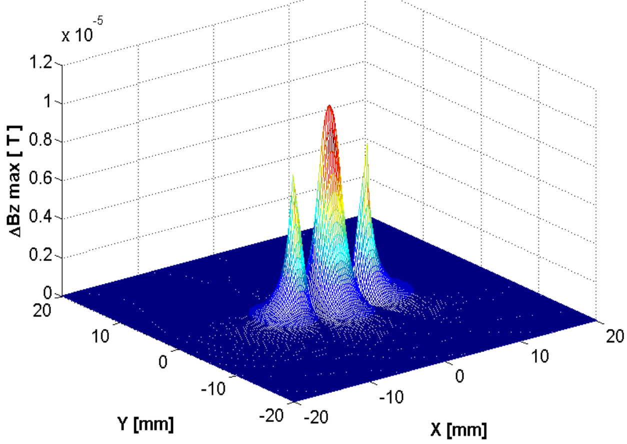

Figure 8. *Surface distribution of the differential signal Bz; defect 0.2x10x3mm, probe position x,y=[0,0]mm above a middle of defect*

Impact of defect parameters on response signals

The impact of defect parameters on responses is analyzed in this section. Real defects are mostly represented by fatigue cracks or stress corrosion ones. The area of fatigue crack is narrow and non-conductive, while the stress corrosion crack has more complicated structure, which is wider and particularly conductive. Hence, in numerical simulation the defect depth and electrical conductivity has been changed according to Table1.

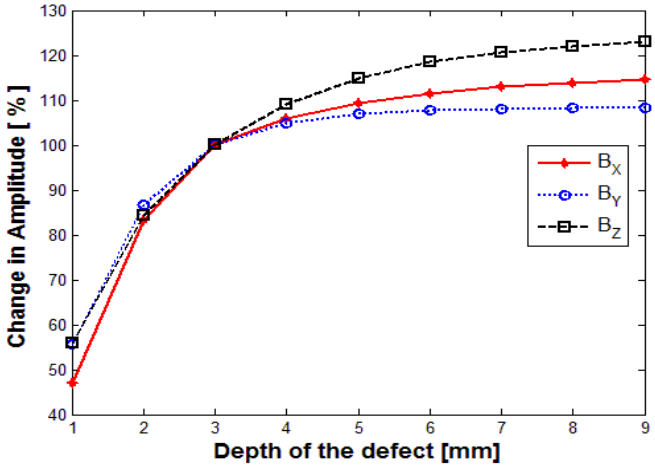

Figure 9. *The dependence of amplitude changes on depth of defect for each **B** component*

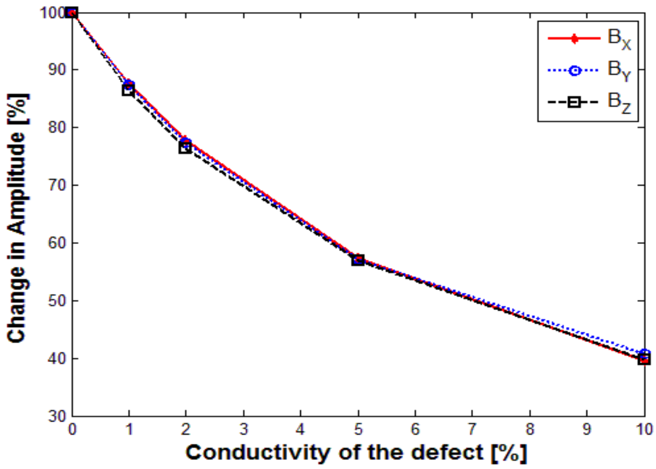

Figure 10. *The dependence of amplitude changes on conductivity changes for each B component*

Figure 9 and 10 demonstrate the parameters influence of real defects on each spatial component of the vector B. It can be clearly seen that these waveform varies for each component differently. With increasing depth of the defect the value of each component increasing, shown Figure 9. On the other hand with increasing the crack's partial conductivity the values for each component are decreasing and slowly settle down, Figure10.

Presented results clearly showed that each change in the defect parameters affect the distribution of eddy current density near defect, resulting in different values and different spatial components of the vector B. Spatial components of the vector B are not linearly dependent on each other and they reflect the specific parameter of the defect in slightly different way. These results confirm the expectation that in the investigation and identification of real defects *it would be beneficial to consider all three spatial components of the magnetic flux density vector.*

CONCLUSION

In the article the eddy current method of non-destructive evaluation was discussed. The exciting coil was used to perform simulated 2D scan above the inspected structure and surface distribution of all three spatial components of B vector was sensed and analyzed. The impact of various crack parameters on response signals was investigated by numerical way. From the presented results it is clearly obvious that all the three spatial components of the magnetic flux density vector significantly modify their distribution depending on the dimensions and electromagnetic properties of the crack and on the position of the excitation coil towards to defect. The obtained knowledge are of great asset to this work and it confirm the expected conclusion that for the investigation and identification of the real defects, it is necessary to take into account the spatial distribution of the sensed values of the field, because this significantly increases the information value of detected signals. Further work of the authors will be concentrated on realization of the simulation where the other parameters as width, length will change too. The unique response signal database from parametric analysis could be used in the future as a source of information for inverse problems solutions, where the geometry of the defect will be reconstructed.

ACKNOWLEDGEMENT

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[1.] Maciej BIELECKI, [2.] Andrzej SZYMONIK

THE IMPACT OF LOGISTICS SECURITY CONDITIONS ON THE LOGISTICAL EFFICIENCY OF THE PRODUCT

[1-2.] Lodz University of Technology, Faculty of Organization and Management, Department of Production Management and Logistics, Wolczanska 215, 90-924 Lodz, POLAND

Abstract: One of the most important purposes of each logistics system functioning is to define the desired security state. It should be noted that the various elements that refer to the security of the logistics system are related to a number of both external and internal conditions of the company. There is also a number of security areas dependent and independent from the company. On this basis, one can make a statement that the product itself, having specified characteristics and properties can affect the security of the logistics system. The article is an attempt to identify and describe the impact of logistics security conditions on vulnerability of product design, and consequently on the logistical efficiency of the product.
Keywords: security, vulnerability, efficiency, product, logistics

INTRODUCTION

The challenges faced by manufacturing companies of the 21st century increasingly more often concentrate around the problems related to the flow of goods and information which in a natural way associates itself with logistics, defined as the process of efficient and cost-effective flow of goods and information from the point of their origin to the place of consumption. This forces enterprises to re-think their functional and global strategies, into such that would account for the primacy of logistics problems. This leads to the necessity of introducing new concepts and ideas, which include the concept of Total Logistics Management (TLM) formulated by the authors.

The concept of TLM should become a strategic declaration of the enterprise, with its foundation considering the complexity of problems and organizational challenges of the 21st century. One of the key elements of the TLM concept is the need to compose some part of the logistical conditioning into the product itself, which is dependent on multiple factors and elements. Another challenge of TLM is the problem of logistic security. The below article is an attempt to interconnect both fields and define the conditions of logistic security that are possible to be composed into an item within the concept of the logistical efficiency of the product.

THE CONCEPT OF LOGISTICAL EFFICIENCY OF THE PRODUCT IN THE CONTEXT OF TOTAL LOGISTIC MANAGEMENT

For many companies the vision of managing through logistics – TLM, is strongly dependent on the product itself and the information connected to it. Both the product and the information should be subject to successful and efficient flow. The concept of TLM itself is connected with a certain group of concepts that are usually placed before logistics, such as:

- ✓ the comprehensive implementation of the "7R" rule (right product, right quantity, right condition, right place, right time, right customer, right price) [9],
- ✓ cost rationalization in management of entire supply chain [13],
- ✓ comprehensive managing of the product in the context of logistics – the concept of a logistically efficient product.
- ✓ Provision of logistics security,
- ✓ ensuring logistic security,
- ✓ accounting for goods identification and IT support for the flow of goods and information.

One of the elements mentioned above is connected with the idea of comprehensive product management in logistic context. Thus, the idea of a logistically efficient product arises.

The concept of logistical efficiency of the product is based on the notion that the features and characteristics of the product itself have a fundamental influence on logistic management in the enterprise. We may therefore attempt a general statement that the correct product assessment in terms of logistical efficiency should be the starting point for any actions related to shaping the functional or global strategy of the company based on logistics (whether conceptual or adjustive [2]). However, in order to be able to implement this rule in the economic life reality on should first define the basic criteria of the discussed concept, including any conditioning that might be crucial here from the logistic perspective

Analysing every product of the market exchange, one may state that it has some features and characteristics. Features are defined as elements distinguishing or characterizing the objects in some way, as an ingredient that does not function autonomously and may be differentiated only by means of thought analysis. Characteristics are defined as whatever is typical of the given item (the dominant features) [3]. Both features and characteristics of the product can either be natural of acquired. From the logistics perspective, this notion is extremely important as it allows to use a particular chosen logistic strategy and thus, directly or indirectly, influence the product itself.

The analysis and assessment in terms of natural and added features that foster logistic processes, is bound with the concept of logistical design vulnerability. Every product may be viewed as a set of natural features and characteristics, some of which can be modified and other that cannot undergo any transformation process. All those features and characteristics which are purposely designed create the set of acquired properties. The logistical design vulnerability of the product [4], [12] (composed of the transport, storage and organizational aspects) diagnoses the scope of possible changes that can positively influence logistic management. The key question here would be whether the analysis of the logistic security issues would make it easier to extract a group of factors that can be considered in the logistically efficient product design.

SELECTED NOTIONS OF LOGISTIC SECURITY

The rapid technological development and increasing range of economic globalization, along with the disappearance of traditional boundaries, are some of the many factors causing an increase in security threats within logistics systems. The number of factors generating risk is constantly growing along with the development of civilization. Among these we might include: rising energy and transport costs, the unexpected bankruptcy of strategic logistics providers, difficulty in maintaining regular cash flow, the need to adapt to the new requirements (including eco-logistics) of the local and international law, shortage of skilled employees among the shippers performing the loading of the goods or those providing transport services and logistics, rising insurance, road and credit fees.

The optimistic thing is that when new types of threats appear people are able to combat them by creating new methods, or by improving the older ways to organize prevention. The logistic systems, which are vulnerable to all changes and threats, both close and remote ones, due to the global length and width of the supply chain, must adapt to new technological, technical and legal conditions both in on the national and international scale.

The safety status of every system unstable and thus it cannot be seen as an item that is granted to the economic system once and for all. In the real world there are constant threats, caused both by the forces of nature as well as unintentional and intentional effects of human activities. Therefore every logistic system must put effort to assure itself a stable security status and, as a link in the supply chain, should include the possibility to react quickly to all changes, both internal and external, including the possibility of cooperation with other entities within the scope of the security system. This statement is nothing new as in the middle of the previous century, the father of contemporary management Drucker while proposing the criteria of choosing and designing an organization stated that every enterprise should have an end stability to survive in the time of confusion and the ability to adjust to new conditions [10]. The adopted strategy of logistic functioning should not be targeted only on implementing logistic processes and lowering costs but also should take into account the issues of contemporary threats along the whole supply chain.

Every action in logistics both in the planning and real phase is burdened with uncertainty that may be caused by the arising threat (threats) or disruption(s). By threats to logistic security we mean all actions (events, incidents) that disrupt the realization of logistic processes, the flow of goods and information (along with the logistics processes associated with them, such as the processes of transport, warehousing, packaging, order handling and inventory management). One also needs to note that logistic security is hugely influenced by the logistics management areas that are indirectly or directly connected with the above-mentioned processes: the infrastructure of logistics stream and logistic costs. These kinds of events may occur individually or jointly, creating a situation that is hazardous from the business perspective for the economic system and all participants of the supply chains. These threats may be directed inwards or outwards, and the measures taken to reduce them should go in the same direction. Threats can be destructive to the logistic system disrupting the flow of the goods and information. These disruptions can be divided based on [6]:

- ✓ *the place where the threat occurs;*
- ✓ *subsystem (according to the phase or functional approach to logistics [8]);*
- ✓ *duration;*
- ✓ *physical properties;*
- ✓ *range.*

The short description of disruptions according to the duration or range criteria may not be included here as it is difficult to distinguish particular categories within these issues that can be used in the concept of logistical efficiency of the product. The remaining threats should be presented so that they might be referred to in the following chapter. The disruptions depicted within the place criterion will mainly apply to: routes of all transport modes (i.e. road, rail, air, inland-waterway and marine); the modal points of the logistic network often called transport points [11] (e.g. a warehouse, independent container points, airports, marine ports, logistics centers; auxiliary devices facilitating service on roads and at transport points, management (i.e. lack of full identification of threat effects, overestimation of capabilities, inaccurate interpretation of results, lack of tools for optimization and simulation of activities, growing prices of energy and transport, sudden bankruptcy of logistic service providers).

The disruptions depicted under the criterion of the functional subsystem refer to: transport (e.g. a fire, an explosion, an accident of the transport means, washing off the deck, lack of possibility to move due to weather conditions, defective transport means, unadjusted internal transportation, change in regulations of the transport management, thefts, catastrophes), related to inventory storage and shaping (e.g. thefts, losses due to oversized inventories, fires, floods, construction disasters, grid and IT network downtime, damage of the automatic identification system), packaging services (e.g. environment contamination, damage of the goods while *transportation resulting from bad weather conditions), handling customer's orders (e.g. shortage of inventories, incorrect order or invoice, late delivery, damaged goods delivered to the customer, lack of response to complaints and delays, fire, theft, destruction of goods). Information-related (e.g. loss of confidentiality, integrity and possibility to dispose, natural threats such as fire, climate disruptions, electrostatic disruptions, passive and active attacks, random errors);*

The disruptions depicted within the subsystem that accounts for the phase division of logistics are related to supply (e.g. lack of timeliness, bad quality, price or quantity, bad assortment, bribery, corruption, lack of possibility to obtain components for manufacturing, information system corruption, lack of buffer stock), production (e.g. inefficient manufacturing system, damage, losses, thefts of resources, availability of professional staff, production interruptions, technical failures, floods, fires, disasters), distribution (e.g. new products, new producers, thefts, economic crisis, neglecting customer relationship management, neglecting flow of goods management within the supply chain).

The disruptions classification that considers the materiality criterion is divided into: material ones (e.g. transport-related) information-based ones (e.g. damage of information system, damage of automated identification system), energy-related ones (e.g. concerning gas or fuel), assets-related (e.g. financial crisis);

Disruptions and threats have a direct influence on logistic security. However to be able to describe this notion, one needs to predefine what characterizes the safety of actions in logistic networks and channels. By definition, it can be said that it is a state that gives the feeling of certainty and a guarantee for:

- ✓ *the flow of material goods and services;*
- ✓ *the flow of information for planning and management of logistics processes;*
- ✓ *protection and survival during dangerous situations (threats);*
- ✓ *adaption to new conditions (flexibility in unplanned situations).*

The security level of logistics processes is dependent on the condition of the hazards of cooperating participants in the channels and networks at local and global levels.

The security of a logistics system is associated with:

- ✓ *preparation and resistance level of the system to combat emergency situations (the majority of the attention is concentrated on recognition, monitoring, analysing data and correct decision-making within the scope of logistic operation along the entire supply chain);*
- ✓ *the quality of the created and functioning security system - understood as a set of forces and means of ensuring a security status acceptable by the participants of the international logistics network.*

A certain degree of safety of international logistics can be achieved in various ways - not only by providing a predetermined efficiency of direct countermeasures towards occurred events. The people managing the company have the opportunity to shape the security level of international logistics services through thier management, which can be defined as a set of coordinated actions taken at the time of the emergence of threats (interference), aimed at the logistical resources of all members of the supply chain, with a view to achieve the objective, which may be the security of supply, reduce risks, to realize the conditions set by the owner of the cargo and the protection of market position and brand. Controllable values in this case are the parameters characterizing the factors affecting the level of security of the system, which is associated with[1]:

- ✓ *prevention of possible threats to the security processes implemented within the framework of international logistics.*
- ✓ *preparation of the logistics systems for the event of activation of these risks;*
- ✓ *resources countering these threats;*
- ✓ *removal of the consequences of the event.*

Referring the presented notions to the logistic efficiency of the product it can be noticed that in fact the biggest influence on the product itself should be the prevention of possible threats to the security of the international logistics which includes:

- ✓ *formulation of security policies by all members of supply chain;*
- ✓ *risk assessment [7][8] during the implementation of processes in the supply chain;*
- ✓ *developing a plan for managing and reducing the identified threats;*
- ✓ *detection, identification, recording and control the possible risks;*
- ✓ *foreseeing the possibility of crisis (e.g. with the use of data warehouses or computerized systems);*
- ✓ *examination of the acceptance level of risks in the supply chain among its members;*
- ✓ *determination of the type and scope of activities to prevent risks in the area such as road transport, warehousing, distribution, logistics costs – increased fuel costs;*
- ✓ *providing training to the people involved in logistics on both micro-level (individual economic system) and macro-level, with particular attention to:*
  - » *the institutionalization of logistic relations*
  - » *standardization of logistics processes,*
  - » *standardization of processes (e.g. according to GS1)*
  - » *increasing the requirements of the economic system transparency in business and logistics contacts,*
  - » *tightening the criteria for risk-taking and the professionalization of activities within the supply chain*
  - » *need to broaden international cooperation of science and industry in the field of improvement of logistics processes,*
  - » *reconstruction of destroyed ecosystems and wider use of renewable energy sources,*
  - » *trust management, risk and security in logistics operations*

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[1] *See. E. Kołodziński, Istota inżynierii systemów zarządzania bezpieczeństwem, http://www.uwm.edu.pl, 10.04.2012.*

The tools that help to manage the security of logistic systems at the micro and macro scale are the solutions that arise from the norms provided by national and international organizations as well as from various technical and technological aspects.

As for the normalization, it should be noted that in most cases it relates to the establishment of standards that systemically solve issues such as risk management in a supply chain (ISO 28000 2007), or ensure the continuity of the action (BS 25999:2007).

The group of technical and technological solutions includes among others: traceability (comprehensive traceability or origin - identification of the batch of the product, raw materials used for its manufacture, followed by individual identification of each product comprising the batch during production and/or distribution to the direct consumer), GS1 standard (bar codes and electronic product codes), Business Intelligence - BI (business intelligence) or the monitoring network.

THE IMPACT OF LOGISTIC SECURITY ON THE LOGISTIC EFFICIENCY OF THE PRODUCT

The above-presented logistics and security issues should be the basis of the considerations related to the design of the product itself as seen in the light of hereby discussed issues. The logistical efficiency of the product should allow for incorporation of certain solutions in the product itself to make it possible to provide more efficient and effective management across the entire supply chain. The presented overview of selected topics on logistics management clearly shows that there is a group of logistic security issues, which cannot be included in the logistical efficiency of the product. However, to attempt a discussion as to which safety features can be included in the product, one needs first to look closer at the issues that might possibly generate threats to logistics and analyse their impact on the product itself.

The division of disruptions presented in the article allows us to notice, that the factors categorized within the groups associated with the place, subsystem and physical attributes should have an impact on the concept of logistical efficiency of the product. The question of where disturbances occur, i.e. all modes of transport routes, modal points, auxiliary equipment to facilitate road maintenance and transport points, is in fact related to the concepts of transport, storage and organization vulnerability. The combination of the three together creates the logistic vulnerability of the product, which in turn is a key element of the logistics efficiency of the product. The same applies to the interference generated by the subsystems in terms of the functional and phase approach. The same might be said, to an even greater degree, of disruptions associated with physical properties, where the division to material and information-related interference, allows to decide which of the basic vulnerability analyses might include particular disturbances from this group. In the context of logistics system security, the level of preparedness and resilience of the system to the prevention of emergency situations, as well as the quality of the functioning security solutions, is inextricably linked to the organizational vulnerability of the product. Another, separate matter would be to investigate which of the elements associated with the preparation, resistance and quality of such a system can be integrated into the widely understood product, or, more precisely, into the its organizational vulnerability aspect. In case of both preventive measures and tools that assist safety management, one may see that, as regards the latter, that the impact of particular standards widely associated with logistics security, usually applies to the organizational sphere of company activity, forgetting the product itself. In most cases, no one analyses the possible changes in the product just adapt it to some specific standard unless this standard is enforced by law. The situation is different with technical and technological solutions. The implementation of identification systems based on the GS1standard barcode or RFID or comprehensive Tracing, often forces the producers to incorporate specific sets of characters either directly into the product or its packaging, thus allowing to identify individual elements in each dimension. The described preventive actions range shows that the available range of processes affects product modification only indirectly. That so happens because they are mostly related only to the way the system is organized or managed, i.e. to its organizational vulnerability.

SUMMARY

The concept of logistic efficiency of the product implies the possibility of incorporating the optimum number of features and characteristics that would facilitate the flow of this product along with related information. To be able to discuss the issue further, one need to distinguish the design vulnerability of the product, which consists of transportability, storage and organization and describe the circumstances that may impact all of these vulnerabilities. The sphere of logistics security is one of the groups of conditions described here, which similarly to the customer service subsystem is mainly related to organization and management of logistic system. Organizational vulnerability clearly provides framework to the debated issue, at the same time affecting the logistical efficiency of the product.

The further scientific research intended by the authors will involve the identification of these factors of organizational susceptibility (including logistics security), which may already be intentionally designed at the stage of product design, thus increasing the subsequent efficiency of the entire logistic chain. Moreover, the above presentation of logistic security issues and logistical efficiency of the product allows the reader to notice that specific analytical tools allowing to diagnose the scale of threats and uncertainties of logistic operations in terms of security and the product itself, are yet missing; this matter will also become a focus of the further conducted research.

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[1.] Ján ĎURECH, [2.] Marián HRUBOŠ, [3.] Mária FRANEKOVÁ, [4.] Aleš JANOTA

IMPLEMENTATION OF DATA FROM THE MOBILE MEASUREMENT PLATFORM TO VANET APPLICATION

[1–4.] Department of Control and Information Systems, University of Žilina, 010 26 Žilina, SLOVAKIA

Abstract: The paper deals with an idea of informing the car drivers on problem of road degradation via sending of warning messages from road side units. The initial part of the paper summarized the up–to–now realized concept of the mobile measurement platform (MMS) and its mathematical principles showing how detailed data on road surface may be obtained. The main part of the paper is aimed at design of integration of data from MMS into the VANET application. Practical realisation is based on the warning message generation with GPS coordinates which is assuring by digital signature ECDSA cryptography algorithm via OpenSSL tool.
Keywords: point cloud; 3D model; data fusion; VANET; C2C; C2I, vehicular communications; cryptography; OpenSSL

INTRODUCTION

In the field of road transport currently many countries are facing the problem of degradation especially of older roads. Constantly raising intensity of road traffic has negative effect on quality of road communications. Various sorts of defects of road surfaces such as cracks, potholes, longitudinal and transverse bumps, ripples of surface, local falls or beaten tracks have negative effects on driving comfort and cause greater wear of some parts of motor cars.

For measurement of deformations which can occur on the road surface several measurement methods and devices have been created. Generally, manual methods for measurement of surface attributes are being replaced with methods based on electronic measuring devices. One big group of measuring devices used for measurement of road deformations is based on utilization of the laser measurement systems. They measure flight of time of laser impulses to find out what is a distance between the laser scanner and road surface.

For detection of road texture there have been many methods developed so far, resulting in a number of various coefficients and attributes proposed to define surface roughness in an optimal way.

In the Slovak Republic devices of VIDEOCAR and Profilograph GE are currently being used for measurement of surface roughness. The Progilografh GE (see Figure 1) measures the texture and gives data on an average depth of texture. At the same time it is also used as a volumetric method for determining of an average texture depth. VIDEOCAR is a device which is used for fast visual inspection of the road surface. Data are collected using the VW Caravelle vehicle type. Basic task of fast visual survey is to collect data about state of road surface and determine defects attributes for the following purposes:

- ✓ Data collection and filling databases of the Road databank for consecutive rating of individual sections of selected roads further utilized in the Road management system.
- ✓ Search engine, which serves for processing of detailed visual inspection if needed.
- ✓ Solutions of the research projects and projects of scientific–technological development.

Figure 1. Mobile measurement platform (MMP)

Basic conditions required for data collection are good optical conditions and dry unpolluted surface of the road. However, these methods do not provide all necessary information about the measured road and its surrounding area.

In the context of ITS (Intelligent Transport Systems) development integration of other offered services into one complex service package seems to be one of actual tasks. Some of those services may require communication connections based on C2C and/or C2I communication using wireless communication standards, through VANET (Vehicular Ad Hoc Networks) [1], which additionally requires authentication of services provided.

For measuring of attributes of road surface and surrounding areas the authors proposed the solution shown in Figure2 consisting of the MMP (Mobile Measuring Platform), It should be capable of storing scanned data about potholes positions into server connected to the

RSU (Road Side Unit) and thought VANET networks transmitting warning messages to all vehicles finding themselves in a communication range. To ensure authenticity and integrity of such messages a cryptography method is used to generate digital signature on the base of elliptic curve mechanism.

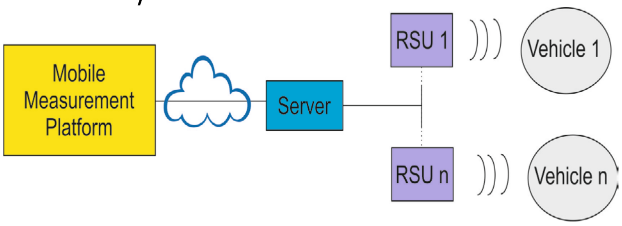

***Figure 2**. Interconnection of MMP with VANET application*

MATHEMATICAL PRINCIPLE USED IN THE MOBILE MEASUREMENT PLATFORM

The MMP is primary dedicated for measuring of geometric changes of road surface. The secondary assignment of this platform is measuring surrounding areas around the road itself.

The conception of the MMP is based on gathering of data characterizing a measured road and its surrounding areas and on its fast processing and graphical interpretation appropriate for next analysis. Processing of data obtained from the laser scanner is principally performed by off–line methods. It means that all measured data are first saved to the hard disk and after surveying the whole intended road section the computing algorithm is being initiated to calculate and get coordinates of all measured points [2].

The MMP illustrated in Fig1 can be used in generally for creation of the 3D model of real objects within road infrastructure such as roads, buildings, bridges or tunnels. By fusion of data coming from multiple sensors integrated in the MMP we are able to generate the 3D model of the real environment with its texture. Thus we are able to merge for example data from the laser scanner and a GPS receiver and generate the 3D model consisting of cloud of points.

Subsequently the algorithm for creation of surfaces in the points cloud may be applied to obtained data as a precondition of the following step – application of texture itself. Textures data are obtained from a set of cameras integrated in the MMP and monitoring the whole space around.

To calculate cloud of points the equations (1) may be used, designed on the base of analysis of data gathered from the following data sources: laser scanner, GPS receiver and INS (Inertial Navigation System) [3].

Thanks to data from the laser scanner we can obtain the following quantities [4]:

- ✓ *Starting angle α_{0n},*
- ✓ *Sequence number of a current point i,*
- ✓ *Angle increment $\Delta\alpha_n$,*
- ✓ *Measured distance between an object and the laser scanner d_{in}.*

After re–calculations of GPS receiver data we get position of the MMP in the form of coordinates x_{0n}, y_{0n} and z_{0n}.

The INS helps us to get data on rotation of the MMP in each axis α_{rn}, β_{rn} and γ_{rn}.

$$x'_{in} = d_{in} * \sin\left[\frac{(\alpha_{0n} + i*\Delta\alpha_n + \alpha_{rn} + 90)*\pi}{180}\right] * \cos\left[\frac{\beta_{rn}*\pi}{180}\right] + x_{0n}$$

$$y'_{in} = d_{in} * \cos\left[\frac{(\alpha_{0n} + i*\Delta\alpha_n + \alpha_{rn} + 90)*\pi}{180}\right] + y_{0n}$$

$$z'_{in} = d_{in} * \sin\left[\frac{(\alpha_{0n} + i*\Delta\alpha_n + \alpha_{rn} + 90)*\pi}{180}\right] * \sin\left[\frac{\beta_{rn}*\pi}{180}\right]$$

$$r'_{in} = \sqrt{y'^2_{in} + z'^2_{in}}$$

$$\gamma'_{in} = \arccos\left[\frac{y'_{in}*180}{r'_{in}*\pi}\right]$$

$$x_{in} = x'_{in} \qquad (1)$$

$$y_{in} = r'_{in} * \cos\left[\frac{(\gamma_{rn} + \gamma'_{in})*\pi}{180}\right]$$

$$z_{in} = r'_{in} * \sin\left[\frac{(\gamma_{rn} + \gamma'_{in})*\pi}{180}\right] + z_{0n}$$

The problem of calculations and needed data conversions is discussed in more details in [5]. Trajectory of the MMP can be also calculated by tracking the center line as the main road surface marking. Such an idea can also be found implemented in e.g. the LDWS (Lane Departure Warning System) where different methods of image processing based on computer vision are used to detect the line– for more details see e.g. [6].

For searching of defects on the road surface one must know the height of the laser scanner head situated at the MMP. In our case the laser scanner is located in the height of 108 cm above the road surface. Defects are searched in a programmable way by systematic searching of points whose distances from the laser scanner are greater than 108 cm. The algorithm provides an output in the form of output file which contains data on GPS position of identified defect, its length and depth. The 3D model may be used to create a visualized model of road surface that can make the process of subsequent road maintenance easier.

DESIGN OF INTEGRATION OF DATA FROM THE MMP INTO THE VANET APPLICATION

The authors have extended the concept of the MMP and the idea of recording defects in road surface in this paper for application of the warning system RHCN (Road Hazard Control Notification), In case of detection of potentially dangerous situations (pothole, ice, ...) this system can send through the VANET all nearby vehicle warning message, informing drivers about dangerous situation or dangerous spot on road communication / infrastructure. The principal scheme of this idea is shown in Figure3.

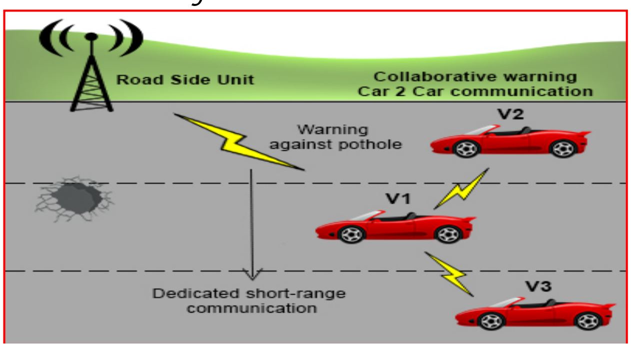

***Figure 3**. Warning system in VANET network*

```
Message: $GPRMC,152811.2,A,4912.73250,N,01845.30582,E,000.01,204.4,070513,003.3,
E,D*36 s=25,3;h=5;d=10,2;
Private key: 64AAAFDDCEAE0F548216789CE171477B8484D241E7EAB4D0E94F919722DC7B6FF40
0BFB5BAE8543C9327C82FE5D462BB
Public key: 0642A6BC867F22883E267C2FD290BF8F5B0B57E8506C95331EA05B7F8567446026A4
114910077893243942ED8385061FC33EFBCD7A3B7DCB436405CB980CD75D623A07769E5E5BB3647A
3AF86AA26AF6759B3F4F556C42B7C7A0A3DDD20361FF78
Digital signature: (3A393C8C08EA8401B8847B63B5D26AB9FE10643DFF2B3C0E3CAC32930837
1618074B9F65D22ED25F75A70F573AA04BB1,414603BBEE77635A04DA226800ED8F595934A6BF87D
B65D53029CA85A30B555903CCE1E5DF13E39E0AA1EE83466E1E)
Verifed EC Signature
```

***Figure 4**. Example of signed message with using ECDSA algorithm realised via OpenSSL*

As explained in the previous chapter, the MMP after computing all sensed data evaluates which data represent defects in road surface and record data about their positions to the server connected to the roadside unit RSU. The RSU through short range communication DSRC (Dedicated Short Range Communication) sends warning message to vehicles available in range of the relevant RSU. The proposed concept can be used also for warning drivers about blind spots and other dangerous situations. This is a modified method of C2C communication, respectively C2I where in the case of the proposed application the road infrastructure (relevant RSU) communicates with vehicles.

Considerations of wireless communication bring higher possibility for abuse and potential existence of attacks to the communication system. If a vehicle (respectively RSU unit) doesn't have security features implemented in the control unit, other vehicles may not consider and mark received warning messages as secured, it means there is no warranty about authentication of sent messages. Security solutions of C2C and C2I communication are actually solved by the C2C–CC organization [7]. The use of IPv6 (Internet Protocol v6) protocol is being advocated actually there. IPv6 according to the set configuration solves the following security requirements for the communication in the VANET:

- ✓ *Authentication of message and its integrity – protection of message prior to its modification, the ability to identify the sender.*
- ✓ *Non–repudiation of messages – the sender cannot deny that he sent the message.*
- ✓ *The timeliness of reports – the recipient can be sure that the message is fresh and was generated within the specified interval.*
- ✓ *Access control – a decision which nodes in the network can perform their assigned actions.*
- ✓ *Confidentiality of message – preservation of content messages secret from unauthorized parties.*

In the practical part of the paper, the authors deal only with issues of authentication of message and its integrity.

Currently in modern cryptography cryptographic authentication protocols are based on scheme of digital signature mostly based on asymmetric cryptography. In commercial applications there are currently expanded several types of digital signature schemes:

- ✓ *RSA (Rivest, Shamir, Adleman) digital signature scheme,*
- ✓ *DSA (Digital Signature Algorithm),*
- ✓ *ECDSA (Elliptic Curve Digital Signature Algorithm).*

The most important parameters of digital signatures in the transport system are: the size of the signature, public key size, generation time of signature and time of signature verification.

Matter of choosing an efficient digital signature schemes for authentication purposes in VANET networks is devoted to a number of projects. Project SeVeCom [8] supports the use of a modified version of a digital signature scheme based on ECDSA.

PRACTICAL REALISATION

The authors have chosen the ECDSA digital signature scheme to ensure the credibility of message transmission from MMP which is also supported by the results of testing three schemes of digital signatures: RSA–1024, DSA–1024 and ESDSA–160 from the perspective of time sessions for generating and verifying signatures (see Table 1) which was implemented in the OpenSSL tool.

All three schemes were applied to the message of the same length on one type of PC with Intel Dual Core processor with frequency of 2.3 GHz.

Given the large number of tests performed in several projects with different results always the best and the worst case of available data is given in the table. Additional crucial parameter for choosing an algorithm is the size of the key.

As shown in Table 1 in the case ECDSA scheme compared with other schemes the process of signature generating and certificating is very fast, which predetermines the algorithm used in applications with a focus on performance, which can also include sensor networks.

***Table 1**. Time demands of algorithms RSA, DSA, ECDSA*

	Generating of signature	Verification of signature	Size of signature [Byte]	Size of public key [Byte]
RSA – 1024	15 – 154.5	1	128	128
DSA – 1024	8.7 – 80	9.9 – 97.72	40	128
ECDSA 160	0.9 – 6.94	1.382 – 14.01	40	20

Before sending safety–relevant messages (in our application – "RHCN") a digital signature (Figure5) is generated in the RSU using its private key SK_1 which is function of message M and message header H. The header may contain, for example, information about location of roughness on the road.

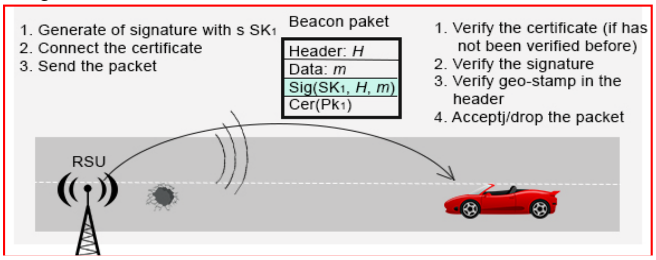

***Figure 5**. Authorized transfer of messages between RSU and vehicle via VANET network*

Thus created cryptographic number is attached to the message simultaneously with a certificate Cert, which is tied to the i–th anonymous public key of the sender VK^i_1, which certifies the corresponding CA (Certification Authority). On the side of the vehicle V the received certificate is validated first (if it was not done before) and the received digital signature is verified using the i–th public key *of the vehicle VK^i_{V1}, that is downloaded by the vehicle V (resp. other vehicles) in regular intervals. At the same time information of geostamp type (about position of place where emergency condition happened) is verified from the header H and after completing these procedures the safety–related message is either accepted or rejected.*

The process of generating a digital signature in RSU can be mathematically expressed:

$$RSU \rightarrow \; : M, H, Sign_{SK^i}[(M,H)|T], Cert_{RSU}. \quad (2)$$

where: M represents sent safety–relevant message,

H represents the message header,

SK^i is a short–term private key RSU in the i–th moment,

VK^i is a short–term public key RSU, in the i–th moment,

T is the time stamp,

Cert is a short–term certificate of the RSU (for the anonymous public key pre VK^i_1), represents the number of receivers (in the case, that message was sent to multiple vehicles in mode „broadcast").

Current certificate of the RSU valid in the i–th point of time for the anonymous public key RSU V_1 (VK^i_1) includes:

$$Cert^i_{V1}\left[VK^i_1\right] = VK^i \,|\, Sign_{SK-CA}\left[VK^i \,|\, ID_{CA}\right] \quad (3)$$

where: $Sign_{SK-CA}$ represents signature of certificate signed by relevant certification authority based on its private key SK–CA, ID_{CA} represents the unique identification number of the certification authority.

When the MMP finds a pothole on the road, respectively other roughness, it generates a message that consists of GPS coordinates and by using the selected cryptographic algorithm (in our case ECDC scheme) sign and send the message to the nearest RSU unit. The experiment has been realized using MMP in the University of Žilina Campus. We walked through the campus with MMP and after recording the potholes, message containing its GPS coordinates has been generated. Subsequently the message was signed. The process of signing the message has been simulated using the OpenSSL in which elliptic curve over a 384 bit prime field has been chosen. We have chosen prime field curve because of more effective implementation in the software implementation. Digital signature is shown in Figure4. Next step would be adding signature and send message with public key to the vehicle. Subsequently vehicle can verify message using public key, and if the vehicle verify the message, warning can be shown.

CONCLUSION

The aim of this paper was to describe integration of the RHCN system into the C2I communication. An initial part of the paper shows the concept of data fusion that helps us reach a 3D model covered with surfaces where surface textures may be applied. One of the tasks potentially covered by the presented concept of the MMP is detection of road surface deformations. Data on these findings may be further used to calculate and send warning messages to passing vehicles, signed by digital signature within the VANETs. Described methods and algorithms of data fusion have been implemented in MATLAB programming environment. Example of the digital signature scheme ECDSA has been realized with the help of the OpenSLL library.

Furthermore, the realized software applications of detecting potholes can be amendment to detection of transverse and longitudinal tracks.

Choosing a digital signature scheme with focus on elliptic curve algorithm ECDSA has been chosen on the basis of comparison of the effectiveness signing scheme e.g. referred to [9] due to the described applications where except security performance of the used digital signature scheme is also an important parameter.

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[1.] Horst TREIBLMAIER

A CLASSIFICATION FRAMEWORK FOR SUPPLY CHAIN FORECASTING LITERATURE

[1.] University of Applied Sciences Upper Austria, Logistikum Wehrgrabengasse 1-3, Steyr, AUSTRIA

Abstract: Forecasting in Supply Chain Management (SCM) is an important yet underestimated research topic. Over the past years numerous methods and concepts have been developed, tested and deployed. In this paper we present a classification framework for the SC Forecasting literature using eight criteria, namely focus, approach, method triangulation, data generation, range, timeline, theoretical background, and target group. Additionally, we present examples for the respective criteria and summarize the major findings. This state-of-the-art review paper is targeted toward both researchers and industry experts who want to get an overview of the goals of contemporary SC Forecasting research.
Keywords: Forecasting, Forecasting Models, Supply Chain Forecasting, Supply Chain Management

INTRODUCTION

Forecasting is an important and well-established research topic in economics as well as in business. Not only exists a plethora of literature which deals with various aspects of forecasting and prediction, but even highly specialized journals (e.g. Long Range Planning, Journal of Forecasting, Journal of Business Forecasting, International Journal of Forecasting, Foresight: The International Journal of Applied Forecasting) and conferences (e.g. Supply Chain Forecasting and Planning Conference, Sales & Operations Planning (S&OP) Conference, Workshop on Industry & Practices for Forecasting) exclusively focus on that area. Notwithstanding the long tradition of this research stream, Datta et al. [1] state that "Forecasting is an underestimated field of research in Supply Chain Management" (SCM) (p.187). At first sight, this seems surprising, given the high importance of forecasting for an effective and efficient supply chain. For instance, one of the most important phenomena in business, the so-called Bullwhip (Forrester) effect, was discovered more than 50 years ago [2]. Today scholarly papers still deal with this highly complex subject [3] [4]. We found four major reasons for the enduring importance of SC Forecasting on which we will elaborate in the following subsections.

Increasing Market Volatility

The financial crisis of 2007/08, which was followed by a global recession that affected the entire world economy, has caused many companies to rethink their overall business strategies. Following the economic downturn, a general awareness now exists that increasingly complex international business networks lead to dependencies on business partners and a greater-than-ever vulnerability to market fluctuations triggered by political crises, natural disasters and economic cycles [5]. Current research and political indicators point towards an ongoing market volatility in the future [6], which tend to make corporate forecasting and planning crucial yet increasingly difficult.

Methodological Developments

New and innovative methods take time to diffuse from formal to applied science and finally to the industry. Frequently, established methods are modified in order to fit a prevalent problem. Datta et al. [7], for example, illustrate how to adapt an advanced forecasting technique, GARCH (i.e. Generalized Autoregressive Conditional Heteroskedasticity) with the goal of improving it into a flexible decision support tool. Those models are based on ARCH models, which were originally developed by Nobel prize laureate Robert Engle [8] decades ago. Datta et al. [7] further refine them by adding vector auto regression (VAR) methodology and model volatility for a vector rather than a single series. They suggest to call the proposed model VAR-MGARCH and conclude that "in one isolated experiment [...] the model provided a forecast that was appreciably closer to the observed or realized value" (p. 1469). However, they also stress the need for further methodological refinement: "This observation is immature. [...] Several more experiments with rigorous controls must be performed before this result may be even considered to offer 'preliminary' evidence that the GARCH type model proposed in this paper may represent an advanced tool" (p. 1469). This is but one of many examples in which existing methods are altered in order to fit the demand of modern SCM.

Big Data

In a current issue of the Journal of Business Logistics (JBL), Waller and Fawcett [9] describe data science, predictive analysis and big data as "a revolution that will transform supply chain design and management" (p. 77). They show that, in spite of being often named a buzzword, big data holds a lot of potential for those companies which understand how to capitalize on it. The opportunities for organizations to gain valuable information from big datasets are simply too attractive to ignore them. Furthermore, as is the case with most hypes, numerous companies are afraid of losing market share to competitors who capitalize on the "first mover advantage". Modern *technology has made it possible to easily gather data in hitherto unimaginable quantities. Quite naturally, in many cases these data contain valuable information which can be used for extracting meaningful forecasting information that helps to generate agile supply chains [10].*

Supply Chain Focus

Although a significant amount of papers exists which exclusively deals with forecasting in the supply chain, the majority of published research either focuses on methodological issues or has a different kind of operational focus. Hence, a huge untapped potential of forecasting knowledge exists, which allows SC researchers to simply transfer existing know-how in order to tackle problems specifically pertaining to supply chains. This is of crucial importance, since the overall importance of SC Forecasting is constantly growing [11]. The remainder of this paper is organized as follows: In section 2 we will briefly elaborate on the methodology we used for this research, followed by the presentation and discussion of our classification framework in section 3. Finally, we summarize our findings, highlight implications and options for further research and also mention several limitations.

METHODOLOGY

In this conceptual research-in-progress paper we followed the procedure suggested by Tranfield et al. [12] for conducting a systematic literature review. We first identified relevant keywords related to SC Forecasting and used the scholarly databases "ProQuest" and "EBSCO" as a starting point. The literature review was carried out from September 2013 until March 2014 and was constantly refined by including articles being cited in the analyzed papers or which we found via Internet search (e.g. by using Google Scholar). We finally ended up with a total of 92 papers which had both a focus on supply chains as well as forecasting and which we deemed relevant for the study at hand. In the first phase we classified each paper according to its main research goal. Next, we created various categories suitable to further categorize the papers. If a paper did not fit into one of our categories, we revised and extended our framework. In line with the qualitative and explorative nature of this research, we did not strive to categorize all papers exhaustively and did not provide any descriptive data pertaining to the absolute number of papers within a specific category, but rather used the publications in order to create a sufficient number of categories in our framework. In the following section we will not only introduce the framework itself, but also briefly discuss various examples of papers in order to illustrate the meaning of the respective categories.

SCM FORECASTING IN THE LITERATURE: A CLASSIFICATION FRAMEWORK

During the classification process a total of 8 different categories emerged. It has to be noticed that this framework is neither fully exhaustive nor mutually exclusive, but its main purpose is rather to highlight the various existing goals of contemporary SC Forecasting research. We will provide one or more examples in each category for illustration purposes.

Focus

A lot of published research in academic literature focuses on developing and refining methods. Apart from the previously mentioned paper from Datta et al. [7], another example stems from Ferbar et al. [13], who utilize the theory of wavelets in order to create a wavelet denoising model which they find to be superior to the commonly used exponential smoothing method. A second stream of research focuses on the classification of existing methods. Armstrong [14], for example, presents a selection tree for various forecasting methods, whose choice depends on criteria such as available data, expected changes, available expertise, similar cases and domain knowledge. This tree may be used to select the best suited method for a given problem with various characteristics. Finally, scholarly papers exist which compare methods and give recommendations on how to choose the most appropriate one. Acar and Gardner [15], for example, select the most appropriate method based on operational performance in a real supply chain. They compare various exponential smoothing methods and base their final choice on tradeoff curves between total costs and customer service.

Approach

In academic literature, quantitative approaches are prevalent, as is shown by the meta-study from Fildes et al. [16] who analyzed a total of 558 publications in forecasting research. 27.2% of the papers used univariate methods, 21.5% causal and multivariate methods and 13.4% computer-intensive methods such as non-linear statistical methods and neural nets. Only in 8.2% of the cases judgment, i.e. a qualitative approach, was used. The authors also categorized 879 articles from operational research journals and found a similar dominance of quantitative methods with only 8.5% of the papers under investigation using judgment. This coincides with our findings that the vast majority of the scholarly papers relies on quantitative data. However, we also found examples for papers which combine qualitative and quantitative approaches [17] [18], or which solely rely on a qualitative approach. An example of the latter category comes from McCarty and Golicic [19], who use depth interviews with executives in three firms in order to come up with seven guidelines for implementing interfirm collaborative forecasting. As far as quantitative research is concerned, the majority of publications deals with the development, testing and refinement of forecasting techniques. However, we also found evidence for survey-based research. Nakano [20], for example, administered a survey among 65 Japanese manufacturers and used confirmatory factor analysis in order to examine the perceived impact of internal and external collaborative forecasting and planning on logistics and production performance.

Method Triangulation

The aforementioned study from Fildes et al. [16] also lists the usage of method triangulation, i.e. the combination of various methods in *order to study a situation or phenomenon. 3.8% of the forecasting and 6.1% of the operational research publications actually applied method triangulation, indicating that the vast majority of publications relies on using a single method only. Notable exemptions include Caniato et al. [17] who integrate quantitative and qualitative approaches to improve demand forecasting in the cement industry and who report improved forecasting accuracy as well as increased knowledge within the organization. The second example stems from Forge [18], who uses a qualitative forecast derived from a scenario for a quantitative projection. Although not exclusively focused on SCM, his approach may be used for all studies which need to simultaneously take into account socio-economic, technological and market developments. Third, Goodwin and Fildes [21] report that in the industry statistical forecasts are frequently adjusted using management judgment. They differentiate between large adjustments, which tend to improve accuracy, and small ones, which often turned out to be a waste of time.*

Data Generation

Another distinctive feature which we observed in the literature is the type of data generation. Researchers have a choice between collecting real world data from companies [22] and using some kind of Monte Carlo experiment in order to obtain the required distribution of an unknown probabilistic entity [23]. We observed the latter procedure mainly in the context of testing new methods. In some cases the authors split an existing real world data set in order to create a model and use the remaining data for testing purposes [24].

Range

Collaborative planning, forecasting and replenishment (CPFR), i.e. the joint planning of key supply chain activities, has gained significant attention in recent years. Previous research has shown that CPFR yields numerous positive results, such as the need to innovate and strong relationships between business partners [25]. Several authors therefore consider the potential impact of decisions that go beyond company boundaries. Aviv [26], for example, presents a time-series framework for supply chain inventory management which takes into account the benefits of various types of information-sharing agreements between supply chain members. He presents a methodology which allows for the investigation of the benefits of various types of information-sharing options, such as sharing subsets of demand-related information or sharing information in one direction of the channel. Acar and Gardner [15] discuss the case of a global manufacturer which owns plants in America, Europe and Asia. Their paper is about forecasting method selection in a real supply chain and they conclude that "forecasting must be evaluated at the aggregate level [. . .] for the entire supply chain" (p. 847).

Timeline

We found a large number of publications investigating changes over time, which is common in forecasting research. Although it is possible that these papers are purely conceptual and do not use data, as is the case with Giloni et al. [27] who investigate the problem of demand propagation in multi-stage supply chain and demonstrate the benefits of information sharing, many of the papers we found rely on actual time series data [30].

Theoretical Background

The importance of theory varies between scholarly disciplines, as does its purpose and usage [28]. We found that most research on SC Forecasting focuses on solving specific operational problems and does not refer to a specific underlying theoretical background. Notable exceptions include Stapleton et al. [29] who discuss in their conceptual paper the applicability of chaos theory principles to selected supply chain functions and who conclude that chaos theory bears some potential to help explain unpredictability within nonlinear systems. Ferbar et al. [13] use a mathematical approach when they apply the theory of wavelets in order to denoise signals.

Target Group

We found that the publication outlet mainly determines the respective target group (researchers vs. practitioners), which is usually the case in all kinds of academic and non-academic communities. We were therefore especially interested in publications which might serve as a bridge between these groups, i.e. which might be well-suited to transfer cutting-edge knowledge into the industry. We found several examples, e.g. in the Journal of Business Forecasting Methods & Systems, such as the papers from Peterson [31], who reports on the supply chain integration efforts of the Bayer HealthCare Division and how they improved forecasting by reducing bias, and Picksley and Brentnall [32] who describe how Bayesian modeling might help to enhance supply chain forecasting and planning. A similar outlet is the Journal of Business Forecasting, in which Khadar [33], for example, describes how a vendor inventory management program helped to create visibility in the supply chain and let to improved forecasting. Occasionally, relevant papers were published in high-impact journals such as Harvard Business Review (HBR), as is evidenced by the publication from Fisher et al. [34] who illustrate how companies manage to cope with uncertain demand.

***Table 1** – SCM Forecasting Literature Framework Category*

Focus	Methodology	vs.	Application
Approach	Quantitative	vs.	Qualitative
Method Triangulation	Yes	vs.	No
Data Generation	Real World Data	vs.	Simulation
Range	Single Location	vs.	Chain
Timeline	Cross Sectional	vs.	Time Series
Theoretical Background	Yes	vs.	No
Target Group	Researchers	vs.	Industry

Table 1 summarizes the eight major categories of our framework. Most papers can be classified according to all of the criteria, some of which overlap.

CONCLUSIONS AND LIMITATIONS

Supply Chain Forecasting is a topic which is of utmost importance to both practitioners and academics. Numerous papers in this area have been published over the past decades, and new methods and concepts are constantly being developed, tested and refined. In this review paper we present a framework which may be used for *classifying existing research according to its main goal. We differentiate between eight categories (focus, approach, method triangulation, data generation, range, timeline, theoretical background, target group) and provide several examples in order to illustrate the respective categories. We show that numerous papers exist which shed light on the intricate subject of SC Forecasting from different angles. Authors use a wide variety of methodological approaches, data generation methods and research designs in order to make useful contributions for their respective target groups.*

This paper is research in progress and part of an extensive SC Forecasting project. Therefore, several limitations exist. First, our framework needs to be refined with further categories and a more detailed distinction between them. Rather than having only two options in each category, more choices might be appropriate. Second, we suggest to find categories which are mutually exclusive and collectively exhaustive, and, third, a comprehensive quantitative study is needed which shows the distribution of papers in each category.

Finally, we also want to highlight opportunities for further research. Our preliminary results already suggest potential research gaps, such as the significant time lag of knowledge diffusion into the industry. We found a huge number of cutting-edge research papers, but there is strong indication that the actual application of novel research findings in the industry frequently has a significant delay. Future studies might enhance our framework and use the results in order to systematically identify research gaps in the area of SC Forecasting.

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[1.] Abdelnaser OMRAN, [2.] Abdulsalam ABDULRAHIM

BARRIERS TO PRIORITIZING LEAN CONSTRUCTION IN THE LIBYAN CONSTRUCTION INDUSTRY

[1.] School of Economics, Finance and Banking, College of Business, Universiti Utara Malaysia, 06010, Sintok, Kedah, MALAYSIA
[2.] Engineering Department, Construction Company, Sebha city, LIBYA

Abstract: *Engaging in Lean construction efforts could prove to be highly rewarding for building firms in Libya. However, lean construction is risky and can be disastrous if not properly managed. Lean production efforts in some other countries have not been successful due to the many barriers to its successful implementation. This study sets out intends to explore identify the barriers that affecting the prioritizing of lean construction with the objective of determining the barriers that affects the use of lean construction in construction industry in Libya. Forty six (46) questionnaires were distributed to various construction firms in Libya. This study presents nine (9) barriers and investigates their influence (strength) on the success of lean construction initiatives. The strongest barrier is the provision of inputs exactly when required. Additionally, the barriers were ranked according to the ease of overcoming each. The easiest barrier to overcome is keeping the required items in the right place. This study indicates that extra efforts still needed to be done on the awareness and use of lean construction in the Libyan construction industry. Additionally, a graphical aid is provided to enable decision makers to concentrate their efforts on the influential (strong), yet easy to overcome barriers. A lack of buildable designs and a participative management style for the workforce are the most important barriers to successful waste reduction in terms of strength and ease of overcome. On the other hand, a lack of an organizational culture that supports teamwork, a lack of prefabrication and a lack of knowledgeable and skilled workers are regarded as low in strength, and at the same time difficult to overcome. This therefore shows that efforts still need to be done on the awareness and use of lean construction in the Libyan construction industry.*

Keywords: *Lean construction, Barriers, Construction industry, Efforts, Libya*

INTRODUCTION

The construction industry in Libya faces serious challenges and difficulties due to fast developments and dependence on foreign experts. The current capacity of the Libyan construction industry is unable to meet national housing supply needs. New homes, airports, ports, railway, and roads need to be built and upgraded. Hotels, office building and resorts are required to meet the needs of an expanding tourism industry. The building industry is often described as an industry with many troubles and a lack of efficiency. The solution to all of these evils is said to be in using the concept of lean construction. The word lean was distinct by (Howell, 2001). The lean construction knowledge developed by Toyota is, for many people, regarded as the only path for the building industry. Lean production or manufacturing concept comprises a variety of production systems that share certain principles, including waste minimization, responsiveness to change, effective relationships within the value stream, continuous improvement, and quality from the beginning by (Murman et al., 2002). Lean construction concepts have recently received attention as a modern way to improve construction performance and labor productivity (Abdel-Razek et al., 2007).Lean production is currently a buzzword in many manufacturing industries (Fellows et al., 2002), and some in the construction sector have tried to adapt it. The proponents of lean construction argue that it has the potential of tapping into new and presented production theories committed to minimizing wasteful activities and values adding. Waste includes overproduction, wait time, transportation, assessment, inventories, movement and production of defective parts and products. To improve on craft and mass production, lean production combines the advantages of both (Sowards, 2006; Koskela, 1992). Koskela (1992) stated that construction is exceptional in the sense that it is one-of kind nature of projects, site production and provisional multi organization. However, breakdown of establishing a good management system in the construction project will lead to many problems that would cause cost of project increases, a late conclusion of project and low quality, which finally reduce the profit of the contractor. In order to overcome this problems, lean thinking or lean construction is been introduced in the construction sector. According to Howell, (1999), lean construction is one of the new philosophies that is been implemented by Toyota in their developed process, which now applied to the construction industry in order to smoothen the construction project and increase the contractor's profit by eliminating waste. This is supported by Ballard and Howell, (1998) who also stated the same facts that lean thinking in construction concerned in waste reduction. Lean concepts have been brought to the construction industries of USA, Australia, Brazil, Denmark, Ecuador, Finland and Singapore (Ballard and Howell, 1998). Lean *construction project is very different compared to traditional construction project management where a lean approach aims to maximize performance for the customer at the project level, set well defined objective clearly for deliverance process, design concurrent product and process and applies production control throughout the life of the project (Howell, 1999). This study therefore intends to determine the barriers that are affecting lean construction in the construction industry in Libya. This work will also contribute to knowledge in that there are no case studies or actual documentation of lean construction being implemented in the local construction industry as this will provide a better and concrete result. To the building firms operating in Libya, this study will present the force and ease of overcoming lean production barriers. This study can be useful to the practitioners in diverse ways.*

RESEARCH METHOD

The use of structured questionnaire was employed for data collection and was distributed using a non-probability sampling which is based on the personal judgment of the researchers. The structure of the questionnaire consists of two sections; section "A" is made up of five (5) items which consist of information about the respondent background, while section "B" consist of forty (40) items based on the potential barriers in implementing lean construction, these barriers were listed into nine (9). The aim was to investigate the barriers for prioritizing lean construction in the Libyan construction industry. Data were collected from respondent. The data collection commenced on 1st October 2011 and finished by 15th January 2012. Of the questionnaires that were sent out, only forty six (46) were returned fully filled and therefore used in the analysis.

RESULTS ANALYSIS AND DISCUSSION

On teamwork, inadequate knowledge and skills have the highest mean score of 3.80 (SD= 0.868), while the least problem is the lack of group culture, shared vision and consensus with a mean score of 3.33(SD =1.0). This result agrees with Alinaitwe (2009) where it was identified that inadequate knowledge and skill is a major barrier that strongly influenced worker's productivity. Annie et al. (2003) had also identified ability to measure performance of the team as one of the elements to achieve a more effective approach to managing the resources function within large construction firms which therefore means that inability of measuring performance will affect the firm, this is achieved here with a means score of 3.58 (SD= 0.866), which shows that it is a strong barrier. The total average mean average means score of 3.53 shows that teamwork is a barrier to the prioritizing of lean construction in the Libyan construction industry.

The next item that was measured is based on Total Quality Management (TQM) in Table (2), the most important items for barriers to TQM in Libya are identified as lack of management leadership first ranked with a mean score of 3.60 (SD= 1.136) and it was documented by Venkatraman (2007) that a common barrier to both industry and education in implementing TQM is lack of proper leadership. Another important item that was identified is Poor communication with a mean score of 3.58 (SD of 0.891), This is backed up by Sebastianelli and Tamimi (2003), who pointed out that poor communication between departments, was a real barrier to implementation of TQM.

***Table 1.** Teamwork Barriers to prioritizing of lean construction in the Libyan Construction Industry*

Items	Score	Standard deviation
Inadequate knowledge and skills	3.80	0.868
Lack of organizational culture supporting team work	3.60	0.863
Inability to measure performance of the team and to gauge the team progress	3.58	0.866
Individual needs and personal differences of team members	3.53	0.726
Defined focus	3.47	0.968
Lack of capability of team to maintain alignment with other team	3.42	0.965
Lack of group culture, shared vision and consensus	3.33	1.00
Total	3.53	0.894

***Table 2.** Barriers for Implementing of Total quality Management i n the Libyan Construction Industry*

Total Quality Management	Mean Score	Standard Deviation
Lack of Management Leadership	3.60	1.136
Inadequate Teamwork	3.60	0.836
Poor Communication	3.58	0.891
Lack of understanding customers' needs	3.47	0.842
Lack of continuous improvement	3.40	0.654

Table (3) summarized of all the barriers and their mean scores. Amongst nine barriers provided in the below Table, it was found that "Business Process Review" have the highest mean score of 3.65 (SD= 0.854), this shows that a lack of a defined process at which the construction activities will be reviewed is a strong barrier to the implementation of the concept of lean construction in the Libyan construction industry. This is quite in tandem with Mamish, (2011) where it was identified that under the business review process, inadequate project team skills is one of the factors leading to organizations failing to implement changes. Abdul-Hadi, (2005) also identified organisational culture of the construction firms as being an impediment in Business Process Review. Pull scheduling comes next with a mean score of 3.59 (SD= 0.897), this include inadequate resources and planning. As detailed by Ahlstrom (1998) that organizations need to devote effort and resources to a set of principles in parallel in order to achieve pull scheduling for implementation of lean production, which implies that if the resources are inadequate, it may not be possible to realize lean production. Matthew et al. (2000) on their part in regards to inadequate planning stated that programming and planning on *construction projects are critical to the overall success of the project. Simplification which comprise of incomplete designs and complicated designs have a mean score of 3.58 (SD= 0.775) as it is difficult to use lean construction when the design cannot be understood by the construction workers and in most situations, the design is incomplete leaving room for many variations to come into the design. Alinaitwe (2009) stated that incomplete or complicated designs are barriers to the use of lean construction in the industry. Concurrent engineering consist of four items which are lack of knowledge on how to implement; Lack of management support; Reward system based on individual goals and Lack of client and suppliers involvement in the scheme of events. This have a mean score of 3.55 (SD= 0.852) as where the stakeholders are not carried along and entrenched in the scheme of events, the construction firm may not be able to meet the stakeholders demand, also where the management is not in support of innovation, the project manager cannot achieve much on site, these therefore are barriers that impedes on the implementation of lean construction. Prasad (2000) confirms that lack of management support is a major organizational roadblock in concurrent engineering while Anumba et al. (2000) posited that lack of client and supplier involvement is a barrier to lean construction. Teamwork has a mean score of 3.53 (SD = 0.894) has been previously explained in Table (1). It is made up of seven items. Total Quality Management has a mean score of 3.53 (SD of 0.872) and was explained in Table (2) which included five items. Just in Time have a mean score of 3.48 (SD=0.796), it consists of seven items which are; uncertainty in the supply chain, uncertainty in the production process, high inflation rates, price cuts in case of early purchasing, poor transportation and communication, unavailability of materials in the local markets; and discounts of prices of large amounts of materials. Pheng and Chuan (2001) showed that transportation and communication are an important factor in construction site, and if it not properly managed can become a barrier to JIT, also price cut in case of early purchasing according to Low and Wu (1997) suggested that it was feasible to apply the JIT purchasing system to procure the raw materials, which can significantly reduce the amount of buffer stock on site. Benchmarking consist of five items which are: fragmented nature of the business, cyclic nature of the business, diversity in organizational sizes and structures, ambiguous nature of inputs and outputs; and lack of agreed methodology. These have a mean score of 3.45 (SD=0.796) which portray the issue of benchmarking as a problem in lean construction implementation. Diversity in organizational sizes and structures according to Bergin (2000) is a barrier as small companies will find it difficult to benchmark. While large businesses have taken to benchmarking to gain and maintain the competitive advantage. However, small businesses are slower to adopt benchmarking in their own operations. Lack of agreed methodology as specified by Lee et al. (2005) is to provide the industry with a common set of metric definitions; therefore, if there is no common agreed methodology, then the objectives of the benchmarking will not be realized. The last barrier that was considered is flow reliability which consisted of four items: use of non-standard components, lack of accurate pre-planning, lack of prefabrication and lack of best practices in the procurement process. These have a mean score of 3.37 (SD= 0.941) reflecting that where best practice is not used for procurement, it will be difficult to use lean construction and also since there are no uniform standard of prefabrication of the materials to be used, it will pose a problem of getting the needed materials as at when needed. Alinaitwe (2009) had also identified the use of non-standard components as a barrier while Haas et al. (2000) also identified the lack of prefabrication. Prefabrication can be approached differently, and these may result in change of the flow of the project. In productivity of construction project, onsite reassembly is ranked first followed by on site prefabrication and construction projects using offsite prefabrication are ranked last.*

***Table 3**. List of the Barriers to Prioritizing Lean Construction in Libyan Construction Industry*

Barriers	Mean Score	Standard Deviation	
Business Process Review	3.65	0.854	Accepted
Pull scheduling	3.59	0.897	Accepted
Simplification	3.58	0.775	Accepted
Concurrent engineering	3.55	0.852	Accepted
Teamwork	3.53	0.894	Accepted
TQM	3.53	0.872	Accepted
Just in Time	3.48	0.796	Accepted
Benchmarking	3.45	0.796	Accepted
Flow reliability	3.37	0.941	Accepted

CONCLUSION

In conclusion, this study has been able to identify nine barriers to the prioritization of lean construction in Libya which are; Business process review, pull scheduling, concurrent engineering, team work, total quality management, Just in Time, Benchmarking and Flow Reliability. These are in order of importance to the construction industry in Libya. The findings are in agreement with previous authors who have identified the under listed as barriers to successful implementation of lean construction in the construction industry. The study therefore provides an understanding of the Libyan construction industry such that these problems can be resolved in other to move the industry forward. It is however recommended that training programs about lean construction be provided to industry professionals as these programs will help to upgrade their knowledge, skills, techniques and processes in order to improve on the barriers for prioritizing lean construction in construction industry.

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[1.] Norge Isaías COELLO MACHADO, [2.] Elke GLISTAU, [3.] Béla ILLES

PROCEDURE TO SET VALUES FOR THE STATISTICAL PARAMETERS IN THE PROCESSES WITH SPECIFICATION LIMITS – APPLICATION IN LOGISTICS

[1.] Universidad Central "Marta Abreu" de Las Villas. Faculty of Mechanical Engineering, Santa Clara, CUBA
[2.] Otto-von-Guericke-University Magdeburg. Faculty of Mechanical Engineering, ILM, GERMANY
[3.] Universityof Miskolc.Chair Materials Transportation and Logistics, HUNGARY

Abstract: Processes with specification limits (tolerance) are typical in industrial practice, for example in the control of the manufacturing process. Often these tools are be used in all engineering processes, here is shown an application in the control of the logistics process. To ensure the effectiveness of the process and to meet customer expectations it is necessary to ensure strict compliance with the tolerances [1]. Classic control methods base on variables that require monitoring related to the limits set by the natural process tolerance. In this work considerations expressed for estimating values of the dispersion and the permissible central tendency of the variables from the specification limits, the purpose is to obtain acceptable process capability for the specific case [2], [3]. Considerations are be done in the reverse order, dispersion values and the central tendency is not execute dafter he process determines in this case the maximum permissible valuesof dispersion and central tendency referred to tolerance specification are estimated to guarantee the required quality before you start the process, so this method can be considered as a preventive tool quality.
Keywords: Quality Management, Logistics

INTRODUCTION

The current industry companies have a commercial and technological competence, this competence involves harmonizing measurement systems, and update technologies to obtain satisfactory results with modern control systems quality. Besides the benefits that provide safe and reliable measurements and allows for comparisons with other companies. Current trends in quality control are the key element for continuous improvement; it uses a wide range of engineering tools and techniques, ranging fundamental tools to important development in current manufacturing technologies. It is necessary to find and use new sources of quality improvement, which leads to the use of statistical process control and the use of preventive techniques, i.e., focusing on the control of key input variables of the process, which contributes to creating the output of the desired product in an established quality. Statistical control bases on the application of statistical methods for the analysis, monitoring and control of processes.

Logistics and Quality Management

In logistics appear frequently qualitative parameters, which are measured and whose magnitudes are in turn defined by a maximum and a minimum tolerance limit that is set for that variable. We must have the tolerance as wide as possible and as close as necessary. This is being manifested in various processes and products, which is being treated extensively in the literature mainly with regard to manufacturing processes. An application is being shown in this case to control logistical process. The logistics product is actually a service. These services are essentially sending, collecting or receiving from the client covered by a contract:

- ✓ The correct object= What?
- ✓ The correct amount=How much?
- ✓ In the right place=Where?
- ✓ At the right time=When, how often?
- ✓ With appropriate costs=How many expenses?
- ✓ With the right quality=No damage, incur additional services
- ✓ Environmentally=with less environmental involvement

These aspects lead to a nomenclature to describe a product logistics. Here it refers to "What"(object) to the entire physical world from a needle to a heavy equipment opencast mining, as shown in Figure 1[1].

Each of these terms simplest in turns one or more variables to be controlled, which in turn describe the corresponding quality parameter. Each of these specifications can be expressed by a variable for which the corresponding limits are set and the goal of that variable is within specification limits pursued. A common way to control the behavior of these variables is the control charts, as shown in Figure 2 [1].

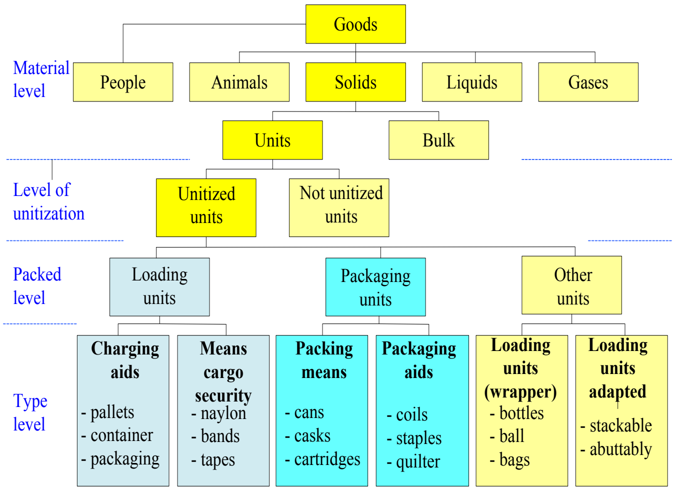

***Figure 1:** Goods classification*

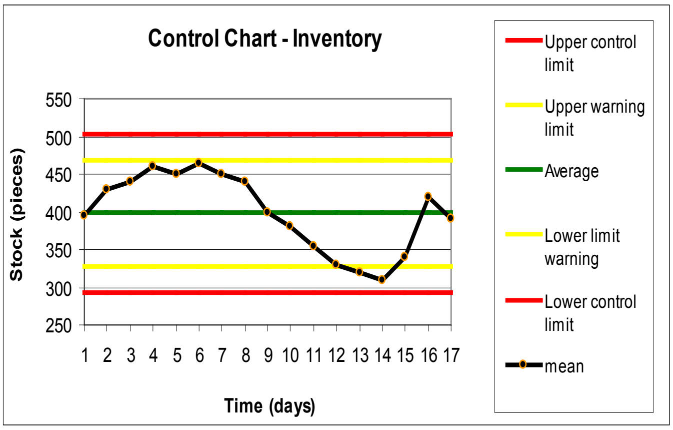

***Figure 2**: Chart control limits applied to a logistic process*

Control charts for regulation of central tendency. Control charts for the mean ($\overline{X}$ -Control Charts).

For the statistical control of the central tendency of processes primarily control charts for the mean ($\overline{X}$ - CC) are used in practice. The main objective of the application of control charts for the mean is to immediately and safety determine the existence of systematic distortions in the process expressed in the form of trend.

Practical experiences in the industry, as well as the mathematics of probability, recognize these control charts as the most efficient means to recognizing systematic process changes and interruptions. Conventional data collection and manual mathematical processing require a relatively long time, which minimizes the applicability of these control charts. Now an automated collection and processing of data significantly increases the benefits of this graph, so that the fundamental criterion for the selection of the type of control chart is its effectiveness.

The calculation of the control limits (CL) and warning limits (WL) for a $\overline{X}$ -GC obtains for the case that the standard deviation (σ) is sufficiently known and it is referred to the central tendency (μ) of the process:

$$UCLM_{\bar{x}} = \mu + km_{\bar{x}} \cdot \sigma \quad (1)$$

$$LCLM_{\bar{x}} = \mu - km_{\bar{x}} \cdot \sigma \quad (2)$$

$$UWLM_{\bar{x}} = \mu + km'_{\bar{x}} \cdot \sigma \quad (3)$$

$$LWLM_{\bar{x}} = \mu - km'_{\bar{x}} \cdot \sigma \quad (4)$$

The coefficients $km_{\bar{x}}$ and $km'_{\bar{x}}$ are calculated as:

$$km_{\bar{x}} = u_{(1-\alpha/2)} / \sqrt{n} \quad (5)$$

$$km_{\bar{x}} = 3/\sqrt{n} \quad \text{for } \alpha = 0{,}27\,\%$$

$$km'_{\bar{x}} = 1{,}96/\sqrt{n} \quad \text{for } \alpha = 5\,\%$$

In case there are predetermined limits or tolerances specification (UL-upper limit, LL-lower limit) calculation of control limits for a process capability indexes $C_p \geq 1$ are performed according:

$$UCLT_{\bar{x}} = LS - kT_{\bar{x}} \cdot \sigma \quad (6)$$

$$LCLT_{\bar{x}} = LI + kT_{\bar{x}} \cdot \sigma \quad (7)$$

The factor $kT_{\bar{x}}$ is calculated as:

$$kT_{\bar{x}} = u_{(1-p/2)} - u_{(1-\alpha/2)} / \sqrt{n} \quad (8)$$

with

$u_{(1-p/2)}$ - Percentile of the distribution of the individual values.

$u_{(1-\alpha/2)}$ - Percentile of the distribution of the mean values.

For the case in which p = 0,27 % and α = 0,27 % obtained:

$$kT_{\bar{x}} = 3\left(1 - 1/\sqrt{n}\right)$$

Control charts for monitoring the standard deviation (s- Control Charts).

The control charts to monitor the dispersion of samples or process (s-GC), are previously seldom used. That is why the mathematical complexity of the calculations is necessary for preparation, this limitation has almost no effect today with the introduction of new computing techniques in manufacturing processes and processes in general, however provides a great advantage from the point of view of its effectiveness to detect changes in the dispersion process. This effectiveness bases on the high information content of the standard deviation and its effectiveness to interpret outliers [1].

The calculation of the control limits (CL) for the control charts for the standard deviation (s-Control Charts) bases on the standard deviation of the process σ in the form:

$$OCL_s = ks_o \cdot \sigma \quad (9)$$

$$LCL_s = ks_u \cdot \sigma \quad (10)$$

Tobe accepted for an error probability $\alpha = 0{,}27\,\%$ obtained:

$$ks_o = c_{2n} + 3\sqrt{1 - c_{2n}^2} \quad (11)$$

$$ks_u = c_{2n} - 3\sqrt{1 - c_{2n}^2} \quad (12)$$

The general procedure for the preparation and implementation of Control Charts for the control variables should be divided in to the following steps:

- ✓ *Determination of the statistical parameters describing the process under control by the process mean (μ) and dispersion process (σ). This determination is made by statistical analysis, in some cases a statistical look ahead is performed or refers to historical data from similar productions.*
- ✓ *For different types of Control Charts for the corresponding statistical parameters (individual values or mean value and*

dispersion for defined volume of the sample) are determined and a proof distribution model is made. There are some exceptions such as non-normal distributions among others; logarithmic distributions and other transformations.

- ✓ *For the process under statistical control are determined μ_o, σ_o and on that basis the boundaries or limits (L) are calculated, into which you can move the corresponding statistical parameters of the sample without the need to intervene in the process.*

Solution for the in determinacy of the sample statically moments

Performing a practical analysis of this problema contradiction occurs in the majority of practical applications. If you have no initial data for the mean and dispersion characterizing the process (μ_o, σ_o) or any estimate there of would be affected by errors, other times the volume of the process does not allow for an initial sample and this forces to establish control of 100% with the known consequences. A possible solution in this case is proposed to proceed as follows:

The fundamental objective is to ensure the quality parameter that expresses the given variable for tolerance (T).

$$T = OL - LL \tag{13}$$

The centre of the tolerance is expressed by:

$$EC = \frac{OL + LL}{2} \tag{14}$$

The potential of a process is known to:

$$c_p = \frac{T}{6\sigma} = \frac{OL - LL}{6\sigma} \tag{15}$$

and:

$$c_{pk} = c_p - \frac{|EC - \mu|}{3\sigma} \tag{16}$$

Given this relationship it can be inferred that the limit values μ_o, σ_o for parameters (central tendency and dispersion) can be set to fulfill the conditions described by the tolerance specification.

It is to assume that the process have to be sufficiently focused, following the techniques of Taguchi, such that the distance from the central tendency to the upper limit is equal to the distance from the central tendency to the lower limit. Mathematically this condition describes the maximum value of c_{pk} (c_{pk}=c_p) which reaches to the condition expressed in equation 17.

$$\mu = EC = \frac{OL - LL}{2} \tag{17}$$

The limits for the parameters μ_o, σ_o may be defined so that that the requirements of the tolerance can be fulfilled.

$$\sigma = \frac{T}{6c_p} \tag{18}$$

By this expression the magnitude of the dispersion refers to the process required potential and its relationship with the tolerance specification.

Using this expression the value of dispersion can be derived from the process capability (necessary process potential) and the correlation to the tolerance of specification. In the case of a process capability of c_p= 1.0, it is neither possible to expound the measurement uncertainty nor the possible displacement of the position, as shown in figure 3. For this general form a minimal value of c_p= 1.33 is required.

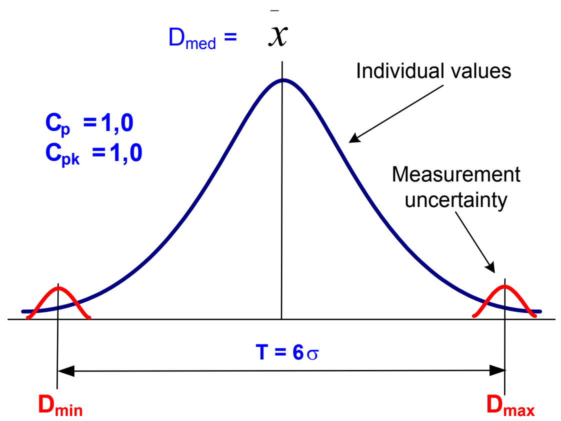

***Figure 3**: Graphical representation of the behavior of the uncertainty in the threshold limit values and considering c_p=1.*

Based on the practical consideration of the characteristic of dispersion and the centering the minimal recommended value of c_p has to be stipulated to 1.33, because this value permits a position displacement. Due to this value there is an equal distance of σ in both directions without increasing the possibility of the variable to exceed the limits of specification.

For the stipulating of adequate values different considerations should exist for every case concerning the economic and technological characteristics.

According to these considerations the measurement uncertainty has to be estimated by using the corresponding, statistical parameters [4]. These displacements exist in every case, even if they can be small. This value can be big for special cases, including the case that the philosophy of 6σ leads to a c_p value of 2.0, as shown in figure 4.

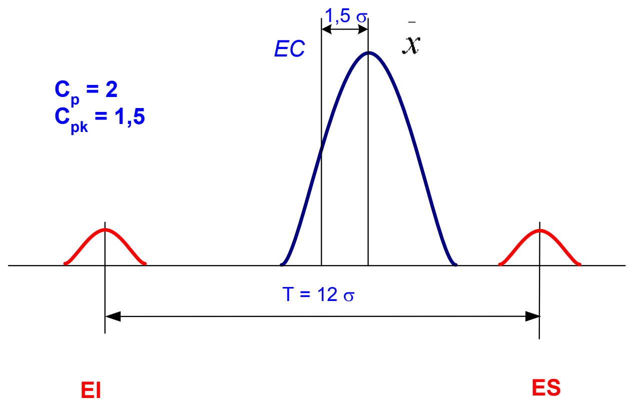

***Figure 4**: Dispersion of process conditions for six sigma (6σ)*

To establish appropriate values for each case other considerations of economic and technological nature [1] should be taken. Alongside these considerations must be assessed the need for the present measurement uncertainty using the corresponding statistical parameters [4]. Also in all cases, even the displacement of the central tendency for these movements to be small is always present. This value may be higher for special cases, even where a philosophy that is valued 6σ, would have a value of c_p= 2.0. This is an example of *employment and improvement of quality tools to prevent potential quality defects and errors, which leads to a conscious action on the rational use of all resources. In general the proposed procedures areas follows figure 5, independence of the values of the average and the dispersion, besides taking into account the capacity of the manufacturing process.*

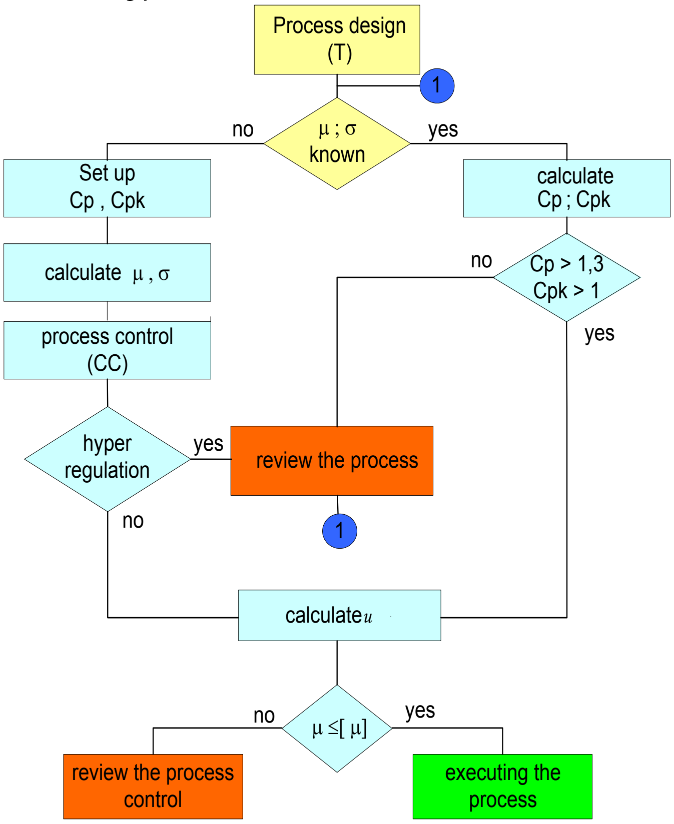

***Figure 5**: Proposed procedures for allocating the actual tolerance*

In consequence of the widespread application of these tools and the awareness of those who must carry it out, it is known that in reference to quality often environmental and sustainability issues are expressed in a close relationship with all aspects relating to quality product. In the development of joint projects in the field of quality management, quality engineering, logistics and the environmental aspect has been sensitizing stake holders on these issues.

CONCLUSIONS

Tools and methods of simple and well-developed assessment can help efficient use of resources for sustainable ecological, economic and social development. The conscious use of preventive quality tools is a potential to be considered in this regard. The possibility of making a prediction oft he values of central tendency and dispersion in the case of control variables allows for a preventive control in the process. Any deviation of the dispersion values and the central tendency established for the process leads to the generation of a signal and thus a required analysis of the causes. That can be supported by using tools of the quality management from a histogram to an experimental design. The solution extends the scope of control charts to those processes in which the valuesof central tendency and dispersion (μ_o, σ_o) are unknown and where it is difficult to carry out a preliminary statistical analysis due to the small volume of production.

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[1.] Mohamed ZELLAGUI, [2.] Abdelaziz CHAGHI

APPLICATION KHA FOR OPTIMAL COORDINATION OF DIRECTIONAL OVERCURRENT RELAYS IN THE PRESENCE MULTI GCSC

[1-2.] LSPIE Laboratory, Faculty of Technology, Department of Electrical Engineering, University of Batna, ALGERIA

Abstract: *Optimal coordination of direction overcurrent relays in the power systems in the presence of GTO Controlled Series Capacitor (GCSC) installed on meshed power system is studied in this paper. The coordination problem is formulated as a non-linear constrained mono-objective optimization problem. The objective function of this optimization problem is the minimization of the operation time of the associated relays in the systems, and the decision variables are: the time dial setting and the pickup current setting of each overcurrent relay. To solve this complex non linear optimization problem, a variant of evolutionary optimization algorithms named Krill Herd Algorithm (KHA) is used. The proposed algorithm is validated on IEEE 14-bus transmission network test system considering various scenarios. The obtained results show a high efficiency of the proposed method to solve such complex optimization problem, in such a way the relays coordination is guaranteed for all simulation scenarios with minimum operating time for each relays. The results of objective function are compared to other optimization algorithms.*
Keywords: *Meshed Power System, GTO Controlled Series Capacitor, Overcurrent Relay, Coordination Time, Krill Herd Algorithm*

INTRODUCTION

System protection is an important part in the power network systems. The most important part in designing the protection needs to consider such as the type of relays, the size of circuit breaker and fuse, the type and size of current transformer, the coordination of relays, and them component to maintain the stability of the system. Then to maintain the stability each relay in the power network must setting in proper technique in term of current and time operation. During the operation of modern interconnected power systems, abnormal conditions can frequently occur. Such conditions cause interruption of the supply, and may damage the equipments connected to the system, arising the importance of designing a reliable protective system. In order to achieve such reliability, a back-up protective scheme is provided to act as a second line of defense in case of any failure in the primary protection. In other words, it should operate after a certain time delay known as Coordination Tine Interval (CTI), giving the chance for the primary protection to operate.

The fore mentioned situation leads to the formulation of the well-known protective relay setting coordination, that consists of the selection of a suitable setting of each relay such that their fundamental protective function is met under the desirable qualities of protective relaying, namely sensitivity, selectivity, reliability, and speed [1]. Overcurrent relaying, which is simple and economic, is commonly used for providing primary protection and as backup protection on power systems [2]. To reduce the power outages, mal-operation of the backup relays should be avoided, and therefore, Overcurrent relay coordination in power transmission and distribution networks is a major concern of protection engineer. A relay must get sufficient chance to protect the zone under its primary protection. Only if the primary protection does not clear the fault, the back-up protection should initiate tripping. Each protection relay in the power system needs to be coordinated with the relays protecting the adjacent equipment [3], the overall protection coordination is thus very complicated. Overcurrent relay have two types of settings: pickup current and dial time settings.

Recently, it is noticeable that the power demand has been increasing substantially worldwide. On the other hand, the expansion of power generation and transmission facilities and equipment has been severely limited due to limited resources and environmental restrictions. As a consequence, some transmission lines are heavily loaded and the system stability becomes a power transfer-limiting factor. Flexible AC Transmission Current (FACTS) controllers offer many benefits to the network and have been mainly used for solving various power system steady state control problems [4, 5].

In recent years, many research efforts have been made to achieve optimum protection coordination (optimum solution for relay settings) without GCSC on power system using different optimization techniques, including Random Search (RS) technique is reported in [6], Evolutionary Algorithms (EA) is presented in [7] while Differential Evolution Algorithm (DEA) in [8], Modified Differential Evolution Algorithm (MDEA) in [9], and Self-Adaptive Differential Evolutionary (SADE) algorithm in [10], application Particle Swarm Optimization (PSO) in [11], and Modified Particle Swarm Optimizer in [12, 13], and Evolutionary Particle Swarm Optimization (EPSO)

Algorithm in [14], Box-Muller Harmony Search (BMHS) in [15], Zero-one Integer Programming (ZOIP) Approach in [16], Seeker Algorithm (SA) is presented in [17], and Teaching Learning-Based Optimization (TLBO) in [18].

This paper presents the solution of the coordination problem of IDMT directional overcurrent relays on meshed power system using KHA approach. The problem is formulated as a non linear constrained mono-objective optimization problem. Our goal behind this optimization is to find an optimal setting of Time Dial Setting (TDS) and Pickup current (I_P) of each relay that minimizes the operating time (T) of overall relays. The new idea presented in this paper, is taking into account the variation of the effective impedance of the line caused by the action of GCSC devices of the transmissions line. Two simulation scenarios with and without multi GCSCs are considered in this paper.

APPARENT RECTANCE INJECTED BY GCSC

The GCSC presented in thefigure1.a is the first that appearsin the family of seriescompensators. It consists ofacapacitance (C)connected in serieswith the transmission line andcontrolled by avalve-type GTOthyristorsmounted in anti-paralleland controlled byafiring angle (γ) variedbetween 0° and180° [19-22].

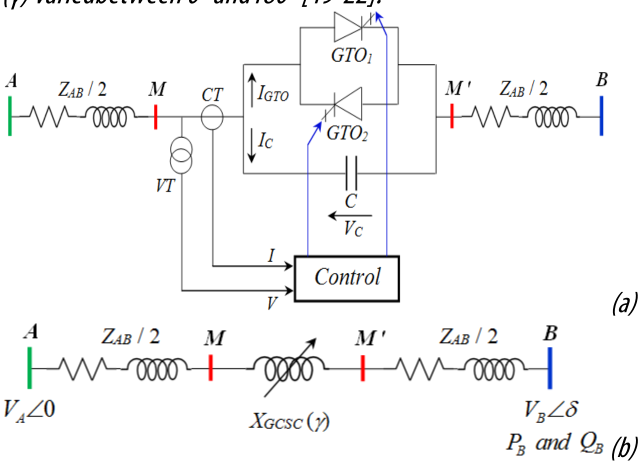

Figure 1. Transmission line in the presence of GCSC device. a). Control principle, b). Apparent reactance.

Thiscompensator is installed in the transmission line AB between bus-bars A (source) and B (load) and modeled as a variablecapacitive reactance(X_{GCSC}). From figure1.b, this capacitive reactance is definedby the equation [21, 22]:

$$X_{GCSC}(\gamma) = X_{C.Max}\left[1-\frac{2}{\pi}\gamma-\frac{1}{\pi}\sin(2\pi)\right] \quad (1)$$

where,

$$X_{C.Max} = {}^{1}\!/_{C_{GCSC}.\omega} \quad (2)$$

The conduction angle (β) which varies between 0 to 90°, is defined by next relation:

$$\beta = \pi - 2\gamma = 2\left(\frac{\pi}{2}-\gamma\right) \quad (3)$$

From equation (3), the equation (2) becomes:

$$X_{GCSC}(\beta) = X_{C.Max}\left[1-\left(\frac{\pi-\beta}{\pi}\right)-\frac{1}{\pi}\sin\left(\pi(\pi-\beta)\right)\right] \quad (4)$$

The relation of injected voltage is calculated by flowing equation:

$$V_{GCSC}(\beta) = V_{Max}\left[1-\left(\frac{\pi-\beta}{\pi}\right)-\frac{1}{\pi}\sin\left(\pi(\pi-\beta)\right)\right] \quad (5)$$

Where, $V_{Max}$is maximum voltage injected and controlled by GCSC. The total transmission line ($Z_{AB\text{-}GCSC}$) impedance with GCSC inserted on midline is given by:

$$Z_{AB-GCSC} = R_{AB} + j\left[X_{AB} - X_{GCSC}(\beta)\right] \quad (6)$$

In the presence three phase fault, the fault current (I_F) is defined by [22]:

$$I_F = \frac{3.(V_A + V_{GCSC})}{Z_{AB.1} + X_{GCSC.1}} \quad (7)$$

Where, $Z_{AB.1}$and $X_{GCSC.1}$is positive component of line impedance compensated and GCSC respectively. From equation (7), the fault current is only related to parameters of transmission line and parameters of GCSC installed (V_{GCSC} and X_{GCSC}).

PROBLEM FORMULATION AND CONSTRAINTS

The coordination of directional overcurrent relays in a multi-loop system is formulated as an optimization problem. The coordination problem, including objective function and constraints, should satisfy three requirements.

Objective Function

The aim of this function (f) is to minimize the total operating time of all overcurrent protection relays in the system with respect to the coordination time constraint between the backup and primary relays.

$$f = Min\left\{\sum_{i=1}^{N} T_i\right\} \quad (8)$$

Where, T_i represents the operating time of the i^{th} relay, N represents the number of relays in the power system. For each protective relay the operating time T is defined by [9-11]:

$$T_i = TDS \times \frac{\alpha}{\left({}^{I_M}\!/_{I_P}\right)^{\beta} + \gamma} \quad (9)$$

Where, T is relay operating time (sec), TDS is time dial setting (sec), I_M is the fault current measured by relay (A), I_P is pickup current (A). The constant α, β, and γ depend on the characteristic curve for IDMT directional overcurrent relay. The current I_M is defined by:

$$I_M = \frac{I_F}{K_{CT}} \quad (10)$$

where, I_F is the fault current, and K_{CT} is ratio of the current transformer.

Constraints

The coordination problem has two types of constraints, including the constraints of the relay characteristic and coordination constraints. Relay constraints include limits of relay operating time and settings. Coordination constraints are related to the coordination of primary and backup relays.

The operating time of a relay is a function of the pickup current setting and the fault current seen by the relay. Based on the type of relay, the operating time is determined via standard characteristic curves or analytic formula. The bounds on operating time are expressed by:

$$T_i^{\min} \le T_i \le T_i^{\max} \quad (11)$$

Where, $T_i^{\min}$ and $T_i^{\max}$ are the minimum and maximum operating times of the i^{th} overcurrent relay.

During the optimization procedure, the coordination between the primary and the backup relays must be verified. In this paper, the chronometric coordination between the primary and the backup relays is used as follows equation:

$$T_{backup} - T_{primary} \ge CTI \quad (12)$$

Where, T_{backup} and $T_{primary}$ are the operating time of the backup relay and the primary relay respectively, CTI is the coordination time interval.

The time dial setting (TDS) adjusts the time delay before the relay operates when the fault current reaches a value equal to, or greater than, the pickup current (I_P) setting [6-12].

$$TDS_i^{\min} \le TDS_i \le TDS_i^{\max} \quad (13)$$

$$I_{Pi}^{\min} \le I_{Pi} \le I_{Pi}^{\max} \quad (14)$$

where, $TDS_i^{\min}$ and $TDS_i^{\max}$ are the minimum and the maximum limits of TDS for the i^{th} relay. $I_{Pi}^{\min}$ and $I_{Pi}^{\max}$ are the minimum and the maximum limits of I_P for the i^{th} relay.

KRILL HERD ALGORITHM (KHA)

KHA is a recently developed heuristic algorithm based on the herding behavior of krill individuals. It has been first proposed by Gandomi and Alavi in 2012 [22-24]. It is a population based method consisting of a large number of krill in which each krill moves through a multi-dimensional search space to look for food. In this algorithm, the positions of krill individuals are considered as different design variables and the distance of the food from the krill individual is analogous to the fitness value of the objective function. In KHA, the individual krill alters its position and moves to the better positions.

Induction

In this process, the velocity of each krill is influenced by the movement of other krill individuals of the multi-dimensional search space and its velocity is dynamically adjusted by the local, target and repulsive vector. The velocity of the i^{th} krill at the m^{th} movements may be formulated as follows [22]:

$$V_i^m = \alpha_i V_i^{\max} + \omega_n V_i^{m-1} \quad (15)$$

and,

$$\alpha_i = \sum_{j=1}^{N_S}\left[\frac{f_i - f_j}{f_w - f_b} \times \frac{Z_i - Z_j}{\left|Z_i - Z_j\right| + rand(0,1)}\right] + 2\left[rand(0,1) + \frac{i}{i_{\max}}\right] f_i^{best} X_i^{best} \quad (16)$$

where, V_i^{max} is the maximum induced motion: V_i^m, V_i^{m-1} are the induced motion of the i^{th} krill at the m^{th} and $(m-1)^{th}$ movement; ω_n is the inertia weight of the motion induced: f_w and f_b are the worst and the best position respectively, among all krill individuals, of the population; f_i, f_j are the fitness value of the i^{th} and j^{th} individuals respectively. N_S is the number of krill individuals surrounding the particular krill; i, i_{max} are the current iteration and the maximum iteration number.

A sensing distance (SD_i) parameter is used to identify the neighboring members of each krill individual. The sensing distance may be represented by [23]:

$$SD_i = \frac{1}{5n_p}\sum_{k=1}^{n_p}\left|Z_i - Z_k\right| \quad (17)$$

where, n_p is the population size, Z_i and Z_k are the position of the i^{th} and K^{th} krill respectively.

Foraging Action

The foraging velocity of the i^{th} krill at the m^{th} movement may be expressed by [22]:

$$V_{f_i}^m = 0.02\left[2\left(1 - \frac{i}{i_{\max}}\right) f_i \frac{\sum_{k=1}^{N_S}\frac{Z_k}{f_k}}{\sum_{k=1}^{N_S}\frac{1}{f_j}} + f_i^{best} X_i^{best}\right] + \omega_x V_{f_i}^{m-1} \quad (18)$$

where, ω_x is the inertia weight of the foraging motion, V_{fi}^{m-1}, V_{fi}^m, are the foraging motion of the i^{th} krill at the $(m-1)^{th}$ and m movement.

Random Diffusion

The diffusion speed of krill individuals may be expressed as follows [22]:

$$V_{D_i}^m = \mu V_D^{\max} \quad (19)$$

where, V_D^{max} is the maximum diffusion speed; μ is a directional vector uniformly.

Position Update

In KHA, the krill individuals fly around in the multi-dimensional space and each krill adjusts its position based on induction motion, foraging motion and diffusion motion. The updated position of the i^{th} krill may be expressed as [24]:

$$Z_i^{m+1} = Z_i^m + \left(V_i^m + V_{fi}^m + V_{Di}^m\right) Pt \sum_{j=1}^{N_d}\left(u_j - l_j\right) \quad (20)$$

where, N_d is the number of control variables u_j, l_j are the maximum and minimum limits of the j^{th} control variable; P_t is the position constant factor.

Crossover

Depending upon the crossover probability, each krill individual interacts with others to update its position. The j^{th} components of the i^{th} krill may be updated by [22-24]:

$$Z_{i,j} = \begin{cases} Z_{k,j} & \text{if, } rand \le C_{R_i} \\ Z_{i,j} & \text{if, } rand > C_{R_i} \end{cases} \quad \text{where, } k = 1, 2, \ldots n_p;\ k \ne 1 \quad (21)$$

where, C_{Ri} is the crossover probability and is given by [22]:

$$C_{R_i} = 0.2 f_i^{best} \quad (22)$$

Mutation

In this process [24], a scalar number F_R scales the difference of tworandomly selected vectors $Z_{m,j}$ and $Z_{n,j}$ and the scaled difference is added to the best vector $Z_{best,j}$ whence the mutant vectors $Z_{i,j}^m$ is obtained.

$$Z_{i,j} = Z_{best,j} + F_R\left(Z_{m,j} - Z_{n,j}\right) \quad (23)$$

Using mutation probability (M_R) the modified value, $Z_{i,j}^{mod}$ is selected from $Z_{i,j}^{m}$ and $Z_{i,j}$ and it may mathematically expressed as [22, 24]:

$$Z_{i,j}^{\text{mod}} = \begin{cases} Z_{i,j}^{m} & \text{if } rand \le M_R \\ Z_{i,j} & \text{if } rand > M_R \end{cases} \quad (24)$$

The proposed optimization algorithm includes steps below:

Step no. 1: Structure definition of data, the limit of scope and parameters,
Step no. 2: Definition of initial population,
Step no. 3: Calculation of the propriety of each Krill according to its location in the search environment,
Step no. 4: Calculation of the movement of each Krill,
Step no. 5: Induced movement of other Krill,
Step no. 6: Movement towards food,
Step no. 7: Physical diffusion based on chaotic portrait,
Step no. 8: Implementation of genetic operators,
Step no. 9: The update process of each krill in the search environment,
Step no. 10: Repetition of step no. 3 to 6 up to the desired accuracy,
Step no. 11: End.

CASE STUDY AND RESULTS

The impact of GCSC on directional relays coordination is performed on the following two scenarios: without and with multi GCSC installed at IEEE 14 bus transmission power systems. As we mentioned above, the relays coordination problem is formulated as constrained mono-objective problem and solved using the KHA optimization algorithm considering 82 decision variables (42 variables represent the I_P and 42 variables represent the TDS).

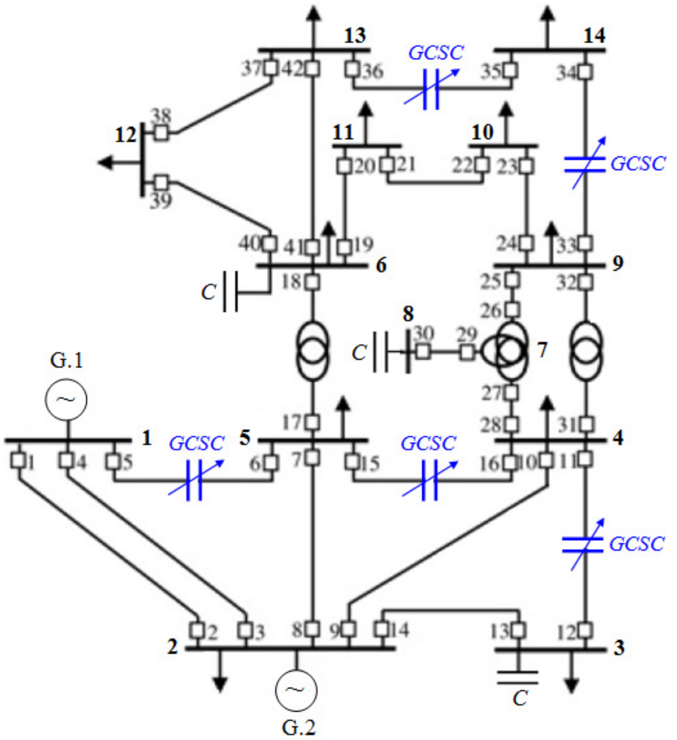

***Figure 2.** IEEE 14-bus power system with multi GCSC*

Figure 2, represents the case study of a network fed by 02 generators and with 14 buses, 20 transmission lines. The power system consists of 42 directional overcurrent relays. The power system study is compensated with five GCSCs located at middle of the transmission lines (1-5, 3-4, 4-5, 9-14, and 13-14), where conduction angle (β) varied between 5°, 45°, and 90° for all installed GCSCs on power system.

Impact of GCSC on CTI

Table 1 presents, the CTI values of the overcurrent relays without and with multi GCSC on three compensation degree.

***Table 1.** Impact of multi GCSC on CTI value*

Primary relay	Backup relay	Without GCSC	With GCSC		
			$\beta = 5°$	$\beta = 45°$	$\beta = 90°$
5	6	0.3400	-0.1124	-1.2366	-0.2507
11	12	0.3600	-0.1462	-1.6086	-0.7261
15	16	0.3200	-0.1123	-1.2352	-0.2504
33	34	0.3893	-0.0778	-0.8553	-0.4734
35	36	0.3321	-0.1061	-1.1666	-0.2365

From this table, it is clear that all relays are coordinated in the case without multi GCSC (superior reference value 0.3 sec), but among of them are not coordinated in the presence multi GCSC for all angle β (CTI value written in bold). Thus, we can conclude that GCSC causes a loss of coordination between the relays protection line. In this situation, we must compute the new settings of the relays to ensure the coordination.

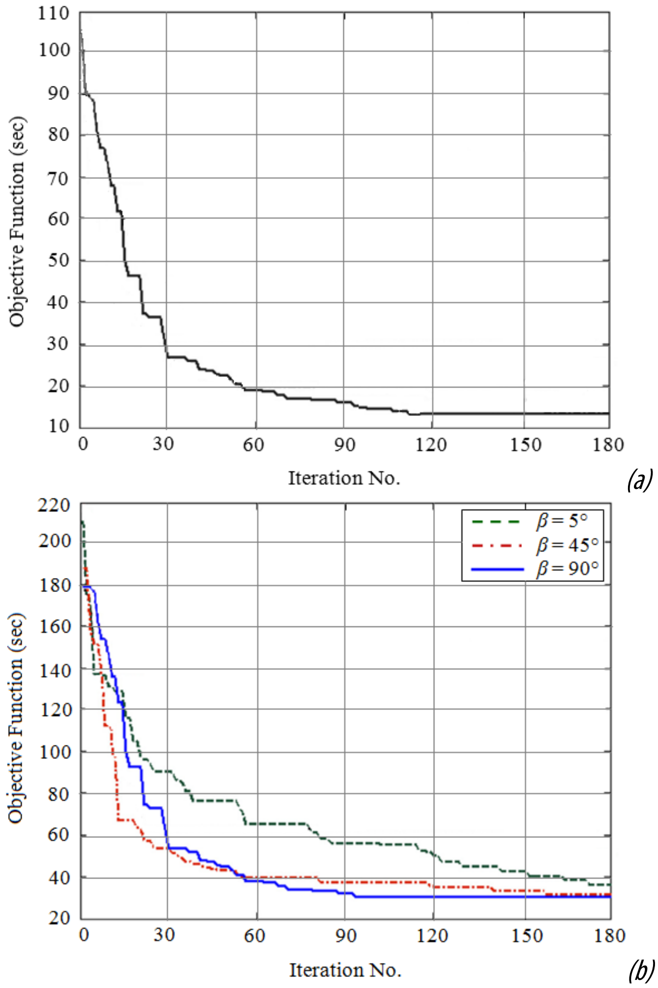

***Figure 3**: Convergence characteristics of KHA for all cases.*
a). Without GCSC, b). With GCSC.

Optimal Settings and Coordination

The optimization constraints for case all study in absence or presence multi GCSCs are:

- ✓ *CTI = 0.3 sec,*
- ✓ $50 \le I_{Pi} \le 1700$ *(A),*
- ✓ $0.02 \le TDS_i \le 0.30$ *(sec),*
- ✓ $0.05 \le T_i \le 1.50$ *(sec),*
- ✓ *Type of curve: very inverse.*

The KHA parameters are:

- ✓ $V_i^{max} = 0.01$,
- ✓ $V_D^{max} = 0.15$,
- ✓ $P_t = 0.20$,
- ✓ $\omega_n = 0.90$,
- ✓ $\omega_x = 0.90$,
- ✓ $G_{max} = 180$.

The convergence characteristics of the KHA without and with multi GCSCs are depicted in Figures 3.a and 3.b respectively.

From Figure 4.a, we can see that the optimization algorithm proposed is convergence within 120 iterations, and the value of objective function is 14.5384 sec. From Figure 4.b, the value of objective function in the presence multi GCSC is 16.4321 sec, 17.0347, and 19.3246 with conduction angle β equal 90°, 45° and 5° respectively. The optimal settings relay (I_P and TDS) for all cases are represented in Tables 2 and 3.

***Table 2:** Optimal relays settings without GCSC*

Relay No.	I_P (A)	TDS (sec)	Relay No.	I_P (A)	TDS (sec)
1	876	0.031	22	526	0.180
2	368	0.042	23	175	0.196
3	368	0.046	24	701	0.226
4	876	0.031	25	421	0.127
5	548	0.072	26	1314	0.143
6	245	0.035	27	245	0.021
7	245	0.053	28	350	0.152
8	329	0.121	29	175	0.044
9	350	0.113	30	788	0.086
10	140	0.099	31	131	0.170
11	350	0.072	32	70	0.046
12	105	0.227	33	701	0.129
13	245	0.064	34	175	0.226
13	548	0.081	35	280	0.131
15	438	0.129	36	526	0.168
16	245	0.168	37	131	0.158
17	394	0.128	38	280	0.136
18	210	0.022	39	105	0.060
19	701	0.193	40	767	0.121
20	280	0.175	41	876	0.162
21	350	0.201	42	280	0.105

***Table 3:** Optimal relays settings with multi GCSC*
a). β = 5°, b). β = 45°, c). β = 90°.

(a)

Relay No.	I_P (A)	TDS (sec)	Relay No.	I_P (A)	TDS (sec)
1	1011	0.036	22	607	0.208
2	425	0.048	23	202	0.227
3	425	0.048	24	809	0.260
4	1011	0.036	25	485	0.147
5	632	0.083	26	1517	0.165
6	283	0.041	27	283	0.022
7	283	0.061	28	404	0.175
8	379	0.140	29	202	0.051
9	404	0.131	30	910	0.100
10	162	0.114	31	152	0.196
11	404	0.083	32	81	0.053
12	121	0.262	33	809	0.148
13	283	0.074	34	202	0.261
13	632	0.094	35	324	0.151
15	506	0.149	36	607	0.193
16	283	0.194	37	152	0.182
17	455	0.148	38	324	0.157
18	243	0.025	39	121	0.069
19	809	0.223	40	885	0.140
20	324	0.202	41	1011	0.187
21	404	0.232	42	324	0.121

(b)

Relay No.	I_P (A)	TDS (sec)	Relay No.	I_P (A)	TDS (sec)
1	974	0.034	22	584	0.201
2	409	0.047	23	195	0.218
3	409	0.049	24	779	0.251
4	974	0.034	25	468	0.141
5	609	0.080	26	1461	0.159
6	273	0.039	27	273	0.021
7	273	0.058	28	390	0.169
8	365	0.135	29	195	0.049
9	390	0.126	30	877	0.096
10	156	0.110	31	146	0.189
11	390	0.080	32	78	0.051
12	117	0.253	33	779	0.143
13	273	0.071	34	195	0.252
13	609	0.090	35	312	0.145
15	487	0.143	36	584	0.186
16	273	0.186	37	146	0.176
17	438	0.142	38	312	0.152
18	234	0.024	39	117	0.066
19	779	0.215	40	852	0.135
20	312	0.194	41	974	0.181
21	390	0.223	42	312	0.116

(c)

Relay No.	I_P (A)	TDS (sec)	Relay No.	I_P (A)	TDS (sec)
1	859	0.030	22	515	0.177
2	361	0.041	23	172	0.192
3	361	0.044	24	687	0.221
4	859	0.030	25	412	0.125
5	537	0.071	26	1288	0.140
6	240	0.035	27	240	0.020
7	240	0.052	28	343	0.149
8	322	0.119	29	172	0.043
9	343	0.111	30	773	0.085
10	137	0.097	31	129	0.166
11	343	0.070	32	69	0.045
12	103	0.223	33	687	0.126
13	240	0.063	34	172	0.222
13	537	0.080	35	275	0.128
15	429	0.126	36	515	0.164
16	240	0.164	37	129	0.155
17	386	0.125	38	275	0.134
18	206	0.023	39	103	0.058
19	687	0.189	40	751	0.119
20	275	0.171	41	859	0.159
21	343	0.197	42	275	0.103

The new optimal value for coordination between primary and backup relays in the presence multi GCSC is presented in Table 4. After this table that all directional overcurrent relays are well coordinated (superior reference value equal 0.3 sec) after optimization using KHA optimization algorithm.

***Table 4**. CTI value in the presence multi GCSC after optimization*

Primary relay	Backup relay	Without GCSC	With GCSC		
			$\beta = 5°$	$\beta = 45°$	$\beta = 90°$
5	6	0.3212	0.3171	0.3321	0.3324
11	12	0.3354	0.4211	0.3034	0.3097
15	16	0.3137	0.3156	0.3166	0.3135
33	34	0.3523	0.3044	0.4371	0.4278
35	36	0.3455	0.3577	0.3105	0.3044

Comparison with Published Results

For comparison purpose Table 5, presents a comparison of the best obtained value of the objective function (OF) for scenario without multi GCSC with other published results.

***Table 5:** Comparison of published results*

	MPSO [25]	LP [26]	NLP [26]	NM [26]	KHA
OF (sec)	61.7200	30.8451	18.0099	16.5948	**14.5384**

From the results of Table 3, it can be also seen that the proposed optimization algorithm KHA has given better performance and provides the best solution compared with other results.

CONCLUSIONS

In this paper we present an optimal relays coordination in the presence of multi GCSCs in the transmission power system for different conduction angle. We propose the formulation of the relays coordination problem as three scenarios. The obtained results show that the multi GCSC has a great impact on the setting and the coordination of the numerical directional overcurrent protections. Furthermore, the proposed optimization algorithm KHA show a high efficiency to solve such complex optimization problem, in such a way the coordination of the relays is guaranteed for all simulation scenarios.

The results showed that the proposed algorithms are able to find superior I_P and TDS and thus minimum operating time of the directional overcurrent relays and minimum CTI.The effectiveness of KHA can be observed from the results in terms of objective function values, which are better in comparison to other optimization algorithms used in the literature.

The continuity of this work will be the coordination of the overcurrent relays in the presence of FACTS devices and renewable energy considering several conflicting objective functions and various power system topologies (transmission and distribution) using new optimization algorithms, and hybrid optimization algorithms.

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[1,2.] Peter PAVLASEK, [1.] Stanislav ĎURIŠ, [1.] Rudolf PALENČAR, [1.] Lukáš ĎURIŠ, [1,2.] Martin KOVAL

TIME INSTABILITY OF BASE METAL THERMOCOUPLES

[1.] Slovak University of Technology, Faculty of Mechanical engineering, Nám. Slobody 17, Bratislava 812 31, SLOVAKIA
[2.] Temperature Department, Slovak Institute of Metrology, Karloveská 63, Bratislava 842 55, SLOVAKIA

Abstract: *Measurements of temperature have a great importance in wide range of industrial applications. As temperature affects the quality, safety and effectives of many of these applications, a great effort has been made to enhance the precision and reliability of temperature measuring sensors. One of the main types of temperature sensors that are used in industry are thermoelectric sensors, more commonly known as thermocouples. These sensors play a irreplaceable role in high temperature industrial measurements. Their robust construction, the ability to withstand high temperatures and harsh conditions had made them popular among many users. As thermocouples are active sensors, they work on the principle of the Seebeck effect. This effect is dependant from wire material purity and composition thus any change in these properties will result in change of their voltage output thus temperature. These changes of Seebeck coefficient can be caused by many factors, like chemical impurities, changes in metal lattice of the wire material, reaction between the materials of which the thermocouple consist of etc. This work deals with the analysis of various factors that can effect the Seebeck coefficient of the thermocouple wire material. Influences that affect the long term stability of the thermocouple voltage output have been analysed and a measuring procedure to determine the level of contribution to the Seebeck coefficient is presented. Furthermore the paper deals with the time stability of base metal Type N thermocouples in the MIMS (Mineral Insulated Metal Sheathed) configuration. The presented results determine the level of Seebeck coefficient change during a long time exposure to temperatures from 1200°C to 1250°C. This work was realized thanks to the support of National Physical Laboratories, Slovak Institute of Metrology, the Slovak University of Technology, grant agency VEGA - grant number 1/0120/12, APVV – grant number 0090-10 and program KEGA grant number 005STU-4/2012.*
Keywords: *thermocouples, time stability, base metal*

INTRODUCTION

Metrological procedures and measuring techniques of temperature affect a wide variety of application that include engineering ,metallurgy, chemical, food, aerospace industry and medical applications. In the field of contact measurement of temperature thermocouples are one of the most used sensors today. This is thanks to their robust construction, reliability and temperature range. As every sensor their precision and reliability directly affect the quality, safety, effectiveness of the manufacturing processes and applications. Due to their wide use and their irreplaceable role in contact high temperature measurements it is of great interest to investigate the behaviour of these sensors in boundary conditions. One of these boundary situations is when a thermocouple in introduced to high temperatures over a long periods of time. This paper is focused on the effect that a long term high temperature exposure has on the thermocouple output. It furthermore deals with the possible relationship between the thermocouple thermoelements (of which the thermocouple consists of) diameter and the drift rate of the voltage output. The thermocouples tested in this study are of type N in a MIMS (Mineral Insulated Metal sheathed) configuration. This work also presents the proposed experimental setup that will be used for the future measurements.

STABILITY PROBLEMATIC IN THERMOCOUPLES

The stability of voltage output of thermocouples is one of the significant issues that occur in each type of thermocouples. This process is caused by many different factors that alter the Seebeck coefficient value. This material constant is unique for each individual material and for its combinations. By changing its value the voltage output of the thermocouple changes as well. These changes are caused by altering the physical and chemical properties of the thermocouple wire material. These changes can be of a temporary or of a permanent nature. There are three cases in which the tested MIMS thermocouples Seebeck coefficient is affected. The first case that occurs is the annealing effect by which the thermocouple is exposed to temperatures above 600°C (changes in the inner material structure occurs). Hysteresis is the second effect that occurs in thermocouples and it can be experienced at temperatures up to 1000°C. In the third case the EMF (Electro Motive Force – the generate voltage by the thermocouple) is altered by chemical contamination. This last mentioned case occurs at temperatures above 1000°C. This study is going to deal with the chemical induced changes thus the permanent change in Seebeck coefficient. These permanent changes arise in nickel based thermocouples (type N and K) at temperatures above 600°C. An increasing voltage output can be seen when thermocouples without a protective sheathing are exposed to these temperatures. This positive drift can be seen in *nickel based thermocouples with metal sheathing and mineral insulation (MIMS) but only at temperatures between 600°C to 900°C. By higher temperatures a significant and constant voltage drop occurs. This behaviour was described in various publication [1, 2, 3] with the same results for type N and type K thermocouples. The mentioned publications describe the process of drift by the migration of particles between the thermocouple thermoelements and the mineral isolation material and the metal sheath. The main source of contamination according to publications [1, 2] is considered manganese (Mn) as the main element that causes drift. This elements can be found in the sheathing material of the thermocouple and at temperatures over 1100°C it contaminates the thermocouple thermoelements affecting the Seebeck coefficient. The publications [1, 2] also points out that the concentration of manganese in the sheathing material also determine the level of the drift. For instance when a Inconel 600 which has a 1% concentration of manganese was used as sheathing material the voltage output drop wasn't so high as when a AISI 310 material with 2% manganese concentration was used. Publications [4, 5] show a decrees of indicated temperature of type N and K MIMS thermocouples with a 3mm outer diameter. At temperature of 1100°C the measured temperature difference form the initial state was 10°C and at temperature of 1200°C the drop was 24°C. These results were obtained after a 1000 hour testing cycle.*

Several publications deals with the thermocouple drift and time stability in which they point out that a considerable degree of long term stability of nickel based thermocouples is an issue that needs further investigation. In this presented paper we are going to deal with this drift problematic but in a relation to the diameter of the thermocouple thermoelements wires.

EXPERIMENTS PROCEDINGS

The drift of the voltage output and diameter relationship was measured on type N thermocouples in MIMS configuration. The sheath material for the tested thermocouples was made of Inconel 600 and with mineral insulation inside the sheath. Eight thermocouples of the highest precision class for the mentioned type were tested. The outer diameters together with the corresponding wire diameter are presented in Tab. 1. One pair of the same thermocouple diameter and type from the same manufacturer was tested to avoid possible error caused by the manufacturing process. Furthermore two runs of the drift testing were planned to proof the repeatable behaviour of drift for individual diameter of sensors.

***Table 1**: Outer and lead diameters of tested type N thermocouples*

Outer diameter of Type N thermocouples (mm)	Thermo element wire diameter (mm)
0.5	0.085
1.0	0.140
1.5	0.280
2.0	0.340

One of the main issues that needed to be deal with was ensuring the temperature stability and homogeneity of the testing furnace. To determine these crucial factors initial furnace homogeneity scans with a calibrated noble metal type R thermocouple was made. After establishing the temperature profile the ideal depth for the thermocouples was determined and was set for 550mm (position of the tip of sensor from the opening of the furnace). Temperature time stability was also determined with the same type R thermocouple. The resulting stability over a 5 hour test was not more than 0.11°C which was considered as sufficient for our study. Furthermore to be confident about the furnaces temperature stability a calibrated type R thermocouple was used to monitor the temperature inside the furnace.

All the initial tests were done at work temperature of 1200°C which was the later used testing temperature as well. The temperature stability of the reference point is also of great importance because it determines the voltage output of the thermocouple and its temperature instability would result in the voltage output instability of the thermocouple which would make the drift detection difficult. This reference point temperature stability was ensured by a dry block cell with a high long term stability of ± 0.005°C.

To be able to determine the level of drift from the thermoelements diameter the thermocouples had to be exposed to an identical temperature conditions. This was ensured by putting all the tested sensors to a narrow ceramic tube which ensured that the temperature conditions would be sufficient for our measurement.

After setting up the measuring equipment and the initial testing phase the first batch of thermocouples was exposed to a temperature of 1200°C for a time period of more than 80 hours. The results of this continuous testing are presented in the following part of the paper.

RESULTS

The data presented was recorded using an automatic recording system which consisted of a switch system, multimeter device and PC with recording software. The recording interval of all the sensors voltage output was set for one minute. By this quick and automatic recording we ensured the comparability of the data from each sensor due to virtually identical data record time. The recorded data has a certain level of noise which was compensated using mathematical filtration methods. After this initial filtration an average value vas calculated for each five hour sections to make the interpretation of the drift level clearer. The results of the measurements that were obtained at temperature of 1200°C are presented in Figure1. The figure shows the voltage output difference of type N thermocouples of different diameters from the initial state of the voltage.

As we can see from the Figure 1 a decrees of the voltage output is visible. The highest level of voltage decrees was noticeable on the smaller thermoelement diameters. This highest level of decrees can be seen on the thermocouple with the smallest outer diameter of 0.5mm. The level of decrees was 5°C from the initial state after 84 hour. Other diameters of thermocouples show a different maximum level of decrees and their values are presented in Table 2. The results have confirmed that the exposure of nickel based thermocouples to high temperatures causes a drop of voltage with time. These results *have also proven that the levels of voltage output decrease and thermocouple thermoelements diameter size are related.*

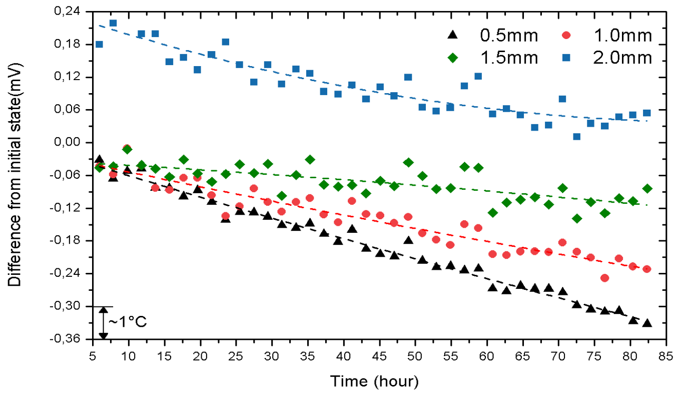

***Figure 1**: Voltage output difference form initial state for type N thermocouples of different diameters*

***Table 2**: Maximum temperature difference from the initial state for various thermoelement diameters at 1200°C.*

Thermo element wire diameter (mm)	*Temperature difference from the initial state after 84 hours (°C)*
0.085	*- 5*
0.140	*- 3*
0.280	*- 2*
0.340	*- 4*

Values of temperature decrees and the corresponding wire diameters have been used to establish a drift function for the type N thermocouples in MIMS configuration. This function that can be seen in Fig. 2 shows the dependence of average temperature decrees by one hour and the thermoelement diameter when thermocouples are exposed to a temperature of 1200°C. As can be seen from the Figure 2 the smaller thermoelement diameters show a higher level of average °C/hour decrease than the higher diameters. This is not the case for the 0.340mm thermoelement where an anomaly occurs that need to be further examined and analysed.

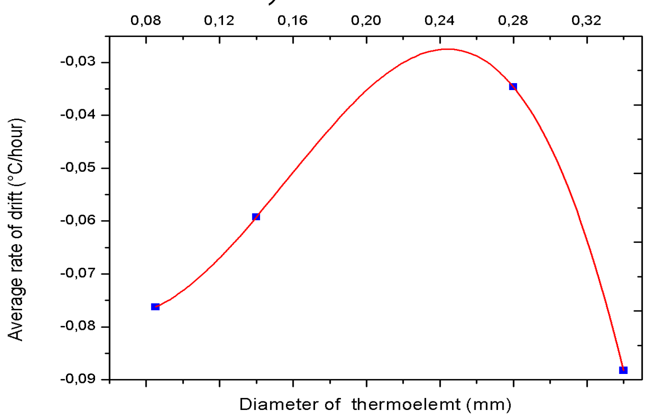

***Figure 2**: Function of type N thermocouple thermoelements diameter and an average temperature decrees in temperature from the initial state after one hour (measured at 1200°C).*

CONCLUSIONS

The measured data show a clear relationship between the level of voltage output decrease and the thermocouple thermoelements diameter. This drift behaviour was observed at temperatures above 1200°C. The sources form which this conclusion was determined can be seen in Fig. 1 and 2. These figures show the different trends of voltage decrease and average °C/hour drop for different thermoelements diameters. This behaviour of nickel based thermocouples in NIMS configuration agrees with the publications [1, 2, 3]. The publications describe the cause of the drift as a chemical contamination of the thermoelement material by manganese (Mn) which can be found in the sheath material of the thermocouple. According to the publications the contamination process starts to occur at temperatures above 1000°C. By analysing the previously made studies in this field we have come to the conclusion that the levels of drift for different thermoelement diameters rely from the amount of material that is contaminated. Smaller diameters are therefore naturally doped faster by the Mn than the larger diameter thermoelements.

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[1.] Marek PAVLICA, [2.] Jana PETRŮ, [3.] Robert ČEP

SELECTION OF THE OPTIMAL PARAMETERS FOR LASER CUTTING

[1-3.] Department of Machining and Assembly, 17. listopadu 15/2172, Ostrava 708 33, CZECH REPUBLIC

Abstract: The current high requirements for quality, accuracy and durability of produced parts lead to a permanent improvement of the production process. For reasons of efficiency and competitiveness have become increasingly to the forefront of non-conventional machining methods. Non-conventional technology is characterized by the use, physical, chemical or a combination of these processes. Currently, the most commonly used for industrial cutting continuous CO2 laser with an average power. Because of the high requirements for the quality of the cutting edge is necessary to choose the optimal method of cutting either melting laser cutting or oxidizing laser cutting. The main parameters that we can significantly affect the quality of the cutting edges are: laser power, length of focal optics, cutting speed, gas pressure, gap between the nozzle and plate, shaped nozzles etc. If the cutting edge after laser cutting does not reach the required quality, it may negatively affect the price of the product, due to add additional operations, as may be chamfering, grinding, etc. For this reason, high demands are made to the professional knowledge on operator of laser equipment.
Keywords: CO_2 Laser, optimal parameters, quality of cutting edge

INTRODUCTION

Separation of materials is still a very important matter of public manufacturing operations. It is used to draw a number of methods, each of which has developed its area of optimum use.

In engineering is nowadays the most advanced laser technology between modes of action on human material in the production process. With their help it is possible significantly improve the quality, technology and productivity. Thermal cutting of materials can be used in within the engineering operations include the preparation of the material. Under this term we mean cutting technology, working on the principle of local melting, combustion, or evaporation, or a combination of these phenomena, the energy required to initiate the process and its process is supplied by various heat sources. Thermal cutting of materials can be used in within the engineering operations include the preparation of the material.

Generally, thermal cutting of materials applied to a wide range of engineering materials: unalloyed and low-alloy steels, high alloy steels and nickel based alloys, non-ferrous metals and their alloys (aluminium, copper) highly reactive materials and their alloys are sensitive to oxygen (magnesium, titanium) non-metallic materials (plastics, composites, wood, paper, glass)

PRINCIPLE OF LASER

Every laser system is comprised of three substantial parts. These parts include active environment (active substance), the excitation (pump) source and a resonant system. A suitable excitation of the active substance is achieved by the phenomenon that is called population inversion. If there are more atoms at higher energy levels than the lower, it is a state of imbalance. Population inversion is inside the active environment necessary condition for that there was a light amplification.

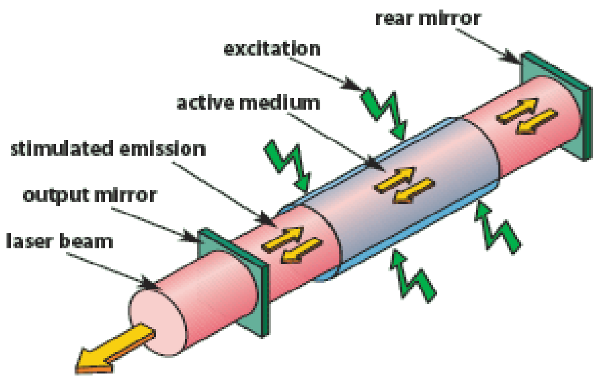

Figure 1: The resonator

Active medium is meant a substance, whether gaseous, solid or liquid, which is saturated with more atoms at higher energy levels. These atoms can also emit twice the light energy. The active medium is the most important part of the laser device because in it there is stimulated emission. The resonator is an optical cavity into which is inserted the active substance. In most cases, a resonator formed by two mirrors, one mirror is reflecting and second semi-permeable and from outside is equipped with a condenser. Due to the large number of photons and their accidental movement, some of them start to move in a direction perpendicular to both mirrors and begin to amplify larger and larger waves. This is enabled due to the metastable levels of electrons that will last for the surface until it hits them in some of the emitted photons. Other photons that are flying in a direction perpendicular to the mirror fly out a space between them, or are pulled down to just photons flying in the perpendicular *direction. When photon will increase to a certain level, a half mirror released out and it results required beam. This is coherent and monochromatic.*

PRINCIPLE OF CO_2 LASER

With gas laser beam is formed in a gaseous environment, which is most commonly argon, helium or neon. The light emission occurs after applying a sufficiently high voltage to electrodes located inside the gas tube. Gas lasers for industrial use can achieve very high performance the disadvantage is the need for a complex cooling the relative expensiveness.

It is the most common gas laser, whose active medium consists of a molecule of dioxide excited by an electric the smoldering discharge. The radiation generated by this type of laser in the far infrared region. CO2 lasers are characterized by a relatively high efficiency of 8-10%. Currently, only CO2 laser reaches the desired range of output power of 1kW to 30 kW and therefore belongs among the most widely used lasers. Except for high performance and high efficiency excels CO2 laser still decent quality the laser beam. Other properties are not desirable. The wavelength is 10.6 μm, despite the fact that it does not pass through optical fibers and laser irradiation is necessary to destination transport system of mirrors, is not well suited for precision machining. Due to the small volumetric power density of the CO2 laser is based on high-performance laser systems and a lot of great material and equipment is not practical mobile. It is also dependent the coolant inlet and the supply of the working gas mixture which, except carbon dioxide also contains nitrogen and expensive helium. Given the complexity and operational performance of such devices requires uninterrupted inspection and maintenance. Despite these shortcomings has achieved maximum performance due to CO2 laser on competition and holds its place particularly in areas such as welding and cutting metal sheets of large thicknesses. The world-famous producer of CO2 lasers is mainly German company Trumpf.

***Figure 2**: CO_2 laser*

METHODS FOR LASER CUTTING

Fusion cutting

Nitrogen or argon is used as the cutting gas here. The gas is blown through the kerf at pressures ranging from 2 to 20 bar. Argon and nitrogen are inert gases. This means that they do not react with the molten metal in the kerf. They simply blow it out toward the bottom. Simultaneously, they shield the cut edge from the air.

The advantage of fusion cutting is the cut edges are oxide-free and do not require additional treatment. The laser beam supplies the energy needed for cutting. This is why cutting speeds as fast as those in flame cutting can only be achieved in thin sheets when fusion cutting. Piercing is also more difficult. Some cutting systems allow you to use oxygen to pierce the material and then switch over to nitrogen for cutting.

Flame cutting

In flame cutting, oxygen is used as the cutting gas. The oxygen is blown into the kerf at pressures of up to 6 bar. There, the heated metal reacts with the oxygen and it begins to burn and oxidize. The chemical reaction releases large amounts of energy – up to five times the laser energy – and assists the laser beam. Flame cutting makes it possible to cut at high speeds and handle jobs involving thick plates such as mild steel.

Sublimation cutting

In this process, the idea is to use the laser to vaporize the material with as little melting as possible. In the kerf, the material vapor creates high pressure that expels the molten material from the top and bottom of the kerf. The process gas – nitrogen, argon, or helium – serves solely to shield the cut surfaces from the environment. It ensures that the edges remain oxide free. For this reason, a gas pressure of 1 to 3 bar is sufficient. More energy is needed to vaporize metal than to melt it. Therefore, sublimation cutting requires high laser power and is slower than other cutting processes. However, it produces high-quality cuts. This process is rarely used in sheet metal fabrication. Its use, however, becomes attractive in applications involving particularly delicate cutting work.

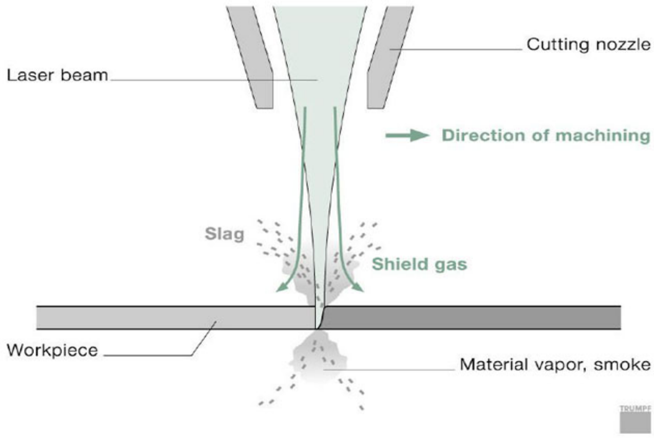

***Figure 3**: Principle of sublimation cutting*

PARAMETERS INFLUENCING THE QUALITY OF CUTTING

The experimental part was carried out at NC Line s.r.o., which deals with the processing of sheet metal components using laser technology for 20 years. Today, the company is a leading supplier of sheet metal parts to companies such as Linde, Still, Pro-Logic, Liebherr and many others. The essence of the experiment is to evaluate the surface roughness depending on the performance parameters of the laser. In the production of test samples in NC Line s.r.o. Company was used material Raex 250 C Laser. Evaluation of the samples was carried out in laboratories VSB-TU Ostrava.

The test material

Raex 250 C Laser is a high-strength and wear-resistant steel with favourable hardness and impact toughness. The plate thicknesses now range from 2 mm up to 80 mm providing a solution to all wear needs. With Raex wear plate you can extend the lifespan of machinery, decrease wear in structural components and save costs. Raex steel grades also enable innovative design and lightweight products improving energy efficiency and lowering fuel costs. Raex is utilised in various applications of mechanical engineering by, for example, the automotive, heavy lifting and transportation, and mining industries. Thickness of the test material was 10 mm.

Applications

- ✓ *Buckets and containers*
- ✓ *Cutting edges for earth moving machina*
- ✓ *Wear parts for mining machina*
- ✓ *Wear parts for concrete mixing plants and wood processing machina*
- ✓ *Platform structures*
- ✓ *Feeders, funnels*
- ✓ *Tipper bodies*

Device for measuring of roughness

For measuring of surface roughness was used Mitutoyo SJ-400. This is a portable device for measuring the roughness of the surface without sliding blocks with touch control panel and an integrated printer. Large 5.7 "color LCD display for easy navigation through the measurement conditions, results and graphs analysis. Possibility of sensor measurements without slip feet for the measurement of unfiltered profile (P), the roughness profile (R), filtered waviness profile (W), and others. This device complies with many standards, industrial DIN EN ISO, VDA, ANSI and JIS. Internal memory can store up to 10 different measurement conditions and up to 500 programs on an optional SD memory card.

***Figure 4**: Portable surface roughness tester Mitutoyo SJ-400*

Selection of optimal parameters

The procedure for selecting the optimal parameters was that the best sample cutted by operator experience and consequently there to modify parameters and evaluation of the sample. During the experiment, there was a change in focal length, power, feed rate, nozzle distance from the material and the gas pressure.

Sample No. 1 was cutted by experience of the staff, which was used parameters viz. table. During the gradual modification of parameters failed to achieve better surface roughness parameters. During the experiment, the different parameters at which the laser ceased to perform its function and scrapes material.

***Table 1**: Machine parameters*

	sample 1	sample 2	sample 3	sample 4	sample 5	sample 6
Length of focal optics [mm]	3,5	3	3.5	3.5	3.5	3.5
Performance [W]	4800	4800	4000	4800	4800	4800
Speed [$m \cdot min^{-1}$]	2,4	2,4	2,4	2.2	2.4	2.4
Distance of the nozzle [mm]	1,2	1.2	1.2	1.2	0.8	1.2
Gas pressure [MPa]	0,8	0.8	0.8	0.8	0.8	0.9

When evaluating the samples in laboratories VSB-TU Ostrava focused on the arithmetic mean deviation of the profile Ra and Rz roughness of the profile. The best value of the sample was No. 1 and the worst value of the sample was No. 4 This showed that the set of parameters that can affect the quality of the cut staff is able to tune themselves according to their experience. Unable to clearly determine the parameters chosen for different materials such as aluminium, copper, stainless steel, because the cut quality is influenced by many other factors.

Generally not say that the reduction or increase of gas pressure there was a worsening of quality of cut as well as in increasing or decreasing the focal length.

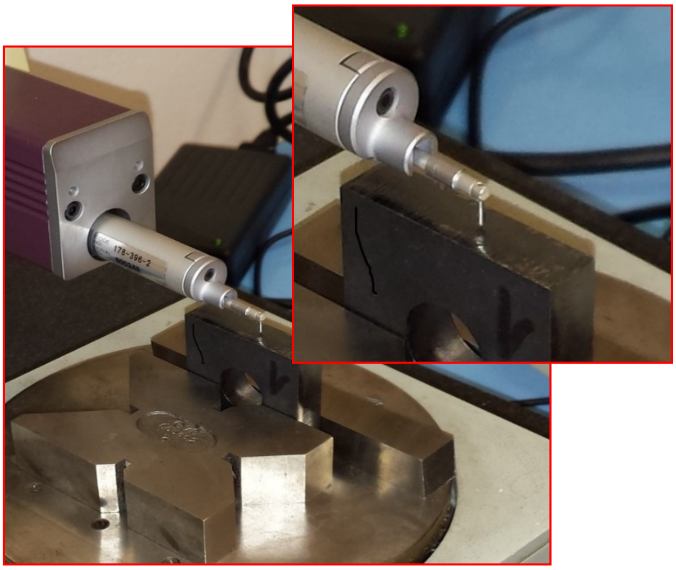

***Figure 5:** Measurement of sample*

***Table 2**: Values of roughness*

	sample 1	sample 2	sample 3	sample 4	sample 5	sample 6
Ra [µm]	2,65	4,12	7,09	25,10	8,83	7,09
Rz [µm]	14,50	22,30	37,40	95,10	43,20	37,40

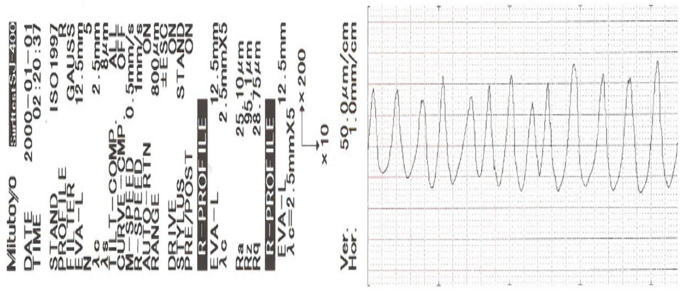

Figure 6: *The worst sample*

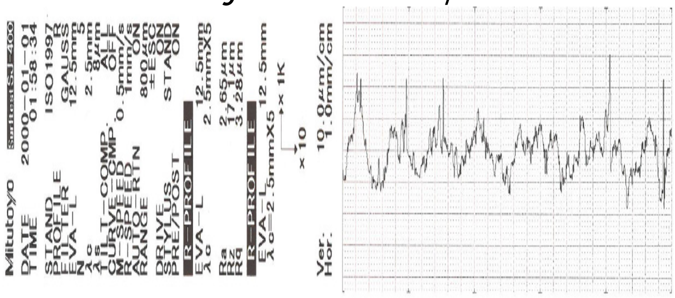

Figure 7*: The best samp*

CONCLUSION

In this article, the possibility was investigated how the operator can affect the laser cutting quality. As the test material was used Raex 250 C Laser thickness of 10 mm. The experiment was conducted on CO2 laser manufacturer Trumpf in cooperation with NC Line s.r.o.

In the actual experiment, the focus was on the main parameters affecting the quality of the cutting area, namely: power of the laser beam focus position to the material being cut, cutting speed and cutting gas pressure and nozzle position on the material from depending on these variables was carved twelve samples which were subjected to measurement of the quality of cut surfaces and the results of these measurements are further processed and evaluated. For best quality results achieved sample cut with the following parameters (the sample number 1) :

- ✓ *Laser power 4800W*
- ✓ *Focal length 3.5 mm*
- ✓ *Cutting speed 2.4 m • min^{-1}*
- ✓ *Gas pressure 0.8 bar*
- ✓ *Distance of the nozzle 1,2 mm*

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[1.] G. ADEDOKUN, [2.] J.A. OLADOSU

DEVELOPMENT OF A GSM-BASED REMOTE CONTROL SYSTEM FOR HOME ELECTRICAL APPLIANCES

[1, 2.] Department of Electrical/Electronic Engineering, Osun State College of Technology, Esa-Oke, NIGERIA

Abstract: Electrical power is often used as a source of power to operate electrical appliances. However, inconsistent of electricity supply leads to obliviousness of the users to switch off their home appliances; thereby, resulting in energy wastage or eventual damage to appliances when power is restored. Meanwhile, developments in information technology could be used to eliminate this problem. Consequently, a GSM based remote control system has been developed to control and monitor electrical devices that required constant attention using mobile phone. This system is very handy when users forget to turn ON/OFF the electrical appliances at their home or office after they have set out. They can now control or monitor such appliances remotely by sending a text message from their mobile phone. This development ultimately saves a lot of time and effort. Likewise, daily electrical energy savings is made more efficient and effective. In constructing this system, basic components like mobile phones, SIM card, Liquid Crystal Display, relays and microcontroller were used to develop a cost-effective and adaptable system.
Keywords: GSM, Microcontroller, Electrical, appliance, hardware, software, relay and Switch

INTRODUCTION

Nowadays, most people have access to mobile phone so that at any given moment, a specific person can be contacted by making voice call or sending a text message. Instant text messaging allows quick transmission of Short Message Services (SMS), and this allows individual to share relevant info. Nonetheless, the applications of mobile phone cannot be restricted to sending text message or making conversations. New innovation can still be derived which can further expand its scope of applications.

Currently, electrical power is regularly used as one of the key source of energy to power electrical appliances. However, erratic power supply leads to forgetfulness of electricity's users to switch off their home appliances when they were set out for their respective work and this always cause a lot of hazard to environ and energy wastage on power restoration. Therefore, there arises a need to develop and implement a system that will allow user to be able to control and monitor their home appliances ubiquitously and also provide security on detection of intrusion via SMS using GSM technology.

Remote management of several household electrical appliances using Global System for Mobile communications (GSM) technology is a subject of growing interest which has found its application in different areas. Tan, Lee, and Mok, 2007 developed an automatic power meter reading system using GSM network. It utilizes the network to send power usage reading to an authorized office to generate the billing cost and send back the cost to the respective consumer through SMS. This concept has been used to develop a GSM-based remote control system which acts as a platform to receive SMS sent from a user mobile phone to control and monitor electrical appliances. The system allows control from a remote area to the desired location so that the need to be physically present in order to control household electrical appliances or office equipment is eliminated.

The approach used in designing this system is implementation of a microcontroller-based control module that will receive command from a user's mobile phone over GSM network and then carry out the issued command and communicate the status of a given device back to the user's handset.

SYSTEM DESCRIPTION

System block diagram of the developed GSM-Based Remote Control System is shown in Figure 1, which is a simple illustration of how the system and the various parts involved had been implemented. The system has two main parts, namely: hardware and software.

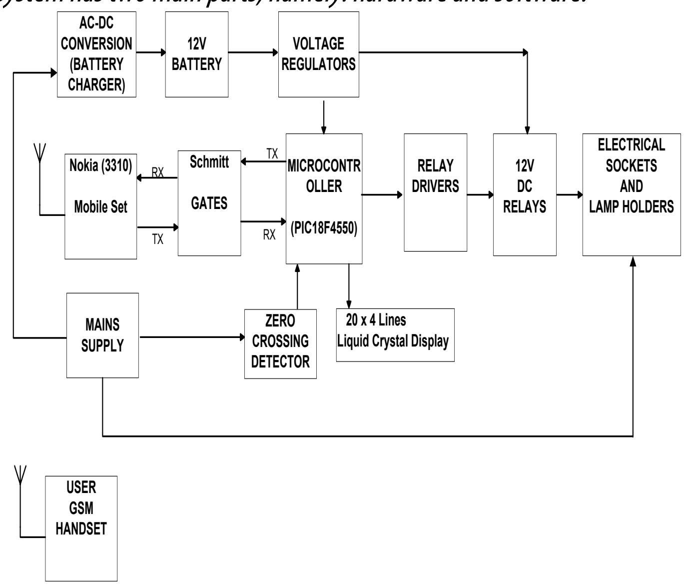

Figure 1. System Block Diagram

The hardware architecture consists of a stand-alone embedded system that is based on 8-bit microcontroller (PIC18F4550), GSM *handsets, driver circuit and DC relays. The GSM handsets provide the communication medium between user and system by means of SMS which consist of command to be executed. The SMS message is sent to the receiver GSM handset via the GSM cellular networks as a text message with a specific predefined format.*

The principle in which the system is based is fairly simple; user GSM handset (Nokia 3310) is used as a transmitting station from which the user sends text messages that contain commands and instructions to receiver GSM handset that is integrated into the developed system. The received SMS is stored in the Subscriber's Identifying Module (SIM) memory of the phone; then, extracted by the microcontroller and processed accordingly to operate appliances via the power switching module. The brief description of individual module in the system is as follows:

- A. ***User GSM Handset***: *Mobile phone through which communication takes place via GSM network. The user sends command through the set to control and monitor electrical appliances in form of SMS. Making call to the system's dedicated line also allows user to make enquiries about the status of the system.*
- B. ***Receiver GSM Handset***: *The mobile phone (Nokia 3310) integrated into the developed system is used to receive calls and the SMS sent by the owner and then to transmit the status of electrical appliance to the user's mobile phone.*
- C. ***Battery Charger***: *This comprises 230V-15V step-down transformer, high-current bridge rectifier, and LM317-based voltage regulator circuit. The regulator's output is designed to have a constant value of 13.8V. This constant voltage keeps a 12V, 7 Ah sealed lead-acid battery on float charge. This is very important to provide power back-up for the system in case of power outage.*
- D. ***Microcontroller***: *This is an 8-bit high-performance RISC microcontroller from Microchip Technology. The microcontroller is selected since it has an enhanced USART which can be configured at baud rate of 115200 bps, large Flash Program and data memory. To read a message, the microcontroller sends the appropriate FBUS command to the Receiver GSM handset (Nokia 3310). The handset then responds with the message and the microcontroller will store the message in the RAM. The microcontroller sends another FBUS command to delete the message, in order to free mobile memory, after which the message is interpreted and the instruction from user is extracted. Based on the received instruction, the appropriate controlling signals are then sent to the relay driver and the system status is updated. Also, the microcontroller sends a command to the Nokia 3310 to query the phone if there is an incoming call. If there is an incoming call, the caller's mobile number will be extracted and the call is subsequently terminated. The mains status (mains utility availability) is then sent via an SMS to the extracted callers' mobile number.*
- E. ***Relay driver***: *The relay driver is controlled by the microcontroller. It allows a low- power circuit to switch a relatively high current on/off according to the command sent through the SMS. The relay driver is basically ULN2003A, which is a monolithic high voltage and high current Darlington transistor arrays. It consists of seven NPN Darlington pairs that feature high-voltage outputs with common-cathode clamp diode for switching inductive loads. It is used to drive the relay circuits which switches different appliances connected to the interface.*
- F. ***Liquid Crystal Display***: *The Liquid Crystal Display (LCD) is used to indicate the last message received from the user, and therefore indicate the cause of the operation performed by the microcontroller and also its inclusion makes the overall system user-friendly.*
- G. ***Zero Crossing Detector***: *This is basically a step-down transformer with a small bridge rectifier. The output of the rectifier is attenuated using a potential dividing network. The scaled rectified mains supply is fed to the microcontroller through an Operational Amplifier that is configured as voltage follower, to determine availability of utility supply. Thus when the users try to call the mobile number integrated into the system, the system send an SMS to indicate mains status automatically.*

The complete circuit diagram of the control system is as shown in Figure 3.

FIRMWARE OVERVIEW

The system operates as depicted in the flowchart of Figure 2.

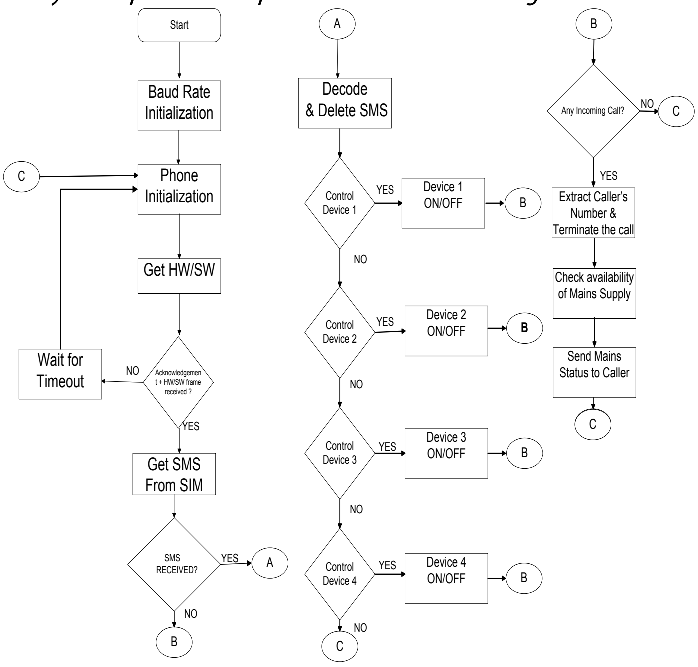

Figure 2 *– Program Flow Chart of the GSM Based Remote Control System NOKIA FBUS INTERFACE*

The firmware for this system was developed using high level language tool in C that is-MPLAB C18. The program is structured to extract the sent message from the Nokia 3310 at a regular interval *and processes it to control the specific appliances connected to the system. The Nokia 3310 has the F Bus connection that can be used to interface a phone to a microcontroller. Hence, the Nokia F-Bus protocol has been used to communicate with the mobile phone. This bus allows exchange of sent and received SMS messages between the microcontroller and the connected mobile phone.*

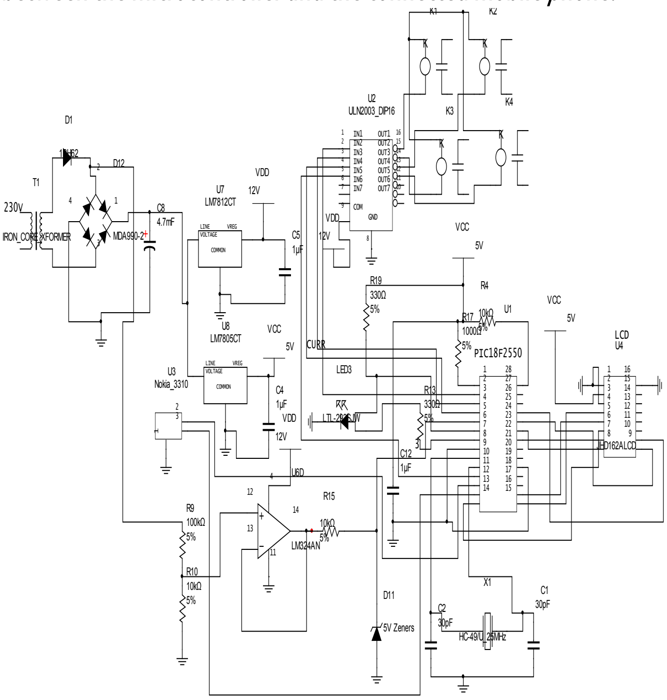

***Figure 3.** Complete Circuit Diagram of a GSM-Based Home Appliances Control System*

FIRMWARE DEVELOPMENT AND CONSTRUCTION

Firmware Development

The Microchip MPLAB Integrated Development Environment (IDE) was used for the firmware development. MPLAB IDE is a Windows Operating System (OS) software program that runs on a PC and contains all the components needed to design and deploy embedded systems applications.

A development system for embedded controllers is a system of programs running on a desktop PC to help write, edit, debug and program code - the intelligence of embedded systems applications - into a microcontroller.

Procedures required for developing an embedded controller application are as follows:

i. Create the high level design. From the features and performance desired, decide which PIC Microcontroller Unit or dsPIC Digital Signal Processor device is best suited to the application, then design the associated hardware circuitry. After determining which peripherals and pins control the hardware, write the firmware that will control the hardware parts of the embedded application. A language tool such as an assembler, which is directly translatable into machine code, or a compiler that allows a more natural language for creating programs, is then used to write and edit code.

ii. Compile, assemble and link the software using the assembler and/or compiler and linker to convert code into binary number - machine code for the PIC MCUs. This machine code will eventually become the firmware (code programmed into the microcontroller).

iii. Test the code. Generally a complex program does not work exactly the way imagined, therefore "bugs" must be removed from the design to get desired results. The debugger allows one to see the program execute, related to the source code written.

iv. "Burn" the code into a microcontroller and verify that it executes correctly in the finished application.

Construction

The programmed microcontroller was tested in a breadboard with its associated sensing/control circuits. Extensive tests were performed on all the components used in each of the subsystems to ensure that they are working reliably.

Having worked satisfactorily, the microcontroller and the associated components were then transferred and soldered on veroboard following light duty soldering techniques; and the entire board was properly connected to accessories. Soldering has been firmly done to reduce loose connection and short circuit. All safety measures are taken to prevent electric hazard.

The whole arrangement was then housed in a plastic enclosure as shown in Figure 4.

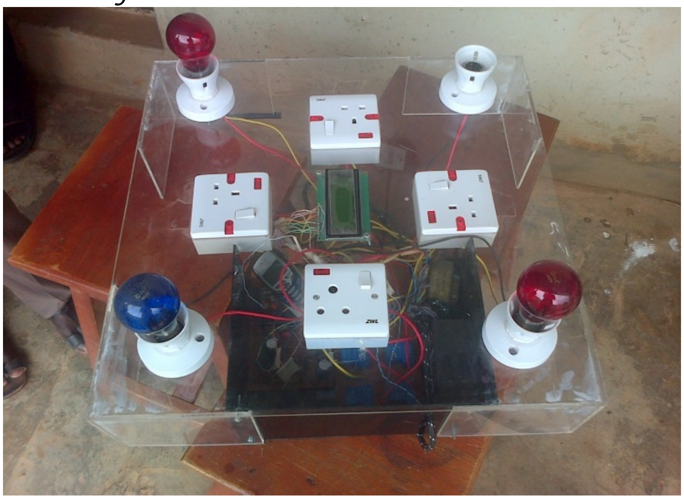

***Figure 4** .GSM-Based remote control system*

RESULT AND DISCUSSION

When the system is powered several tests were carried out to ensure proper accomplishment of the intended result. The system was designed to receive SMS text (commands) from user handset via a receiver handset connected to the microcontroller circuit. These tests were carried out by sending SMS to the receiver handset. The SMS in the receiver are retrieved by the microcontroller and processed to carry out specific task stated in the SMS instruction. The system then replies by sending an SMS to user mobile phone reporting the current status of the appliances. The incoming message is displayed on the LCD by the microcontroller upon completion of the requested task and the message is erased in the connected mobile phone.

Table 1 shows the summary of the typical commands sent by the users and the corresponding responses by the control system. When a command like "Oscotech13 Turn ON Device 1 WOR" is issued, the device(s) corresponding to the number(s) indicated in the command is turned ON. In the commands in Table 1, all messages start with Oscotech13; this is the configured password for this particular system. It is expected that the password is known to only the authorized user. The password can only be changed from the firmware. Then Turn ON or Turn OFF can be issued to respectively turn on or off a specific device. Multiple devices can be controlled by using "&". The last WR or WOR represent WITH REPLY or WITHOUT REPLY respectively. The commands are case-insensitive and spaces between words do not interfere with command interpretation.

***Table 1**: Test result*

Commands from user mobile phone	Operations carried out by the microcontroller	Status report to user mobile phone
Oscotech13 Turn On Device 1 WOR	Device 1 is turned ON	NO REPLY
Oscotech13 Turn OFF Device 1 WR	Device 1 is turned OFF	Device 1 status is OFF
Oscotech13 Turn ON Device 1&2&3 WR	Device 1, 2 and 3 are turned ON	Device 1, 2 and 3 status are ON
Oscotech13 Turn OFF Device 4&5&6 WOR	Device 2, 3 and 5 are turned OFF	Device 2, 3 and 5 status are ON
Oscotech13 Turn OFF Device 2&3&7 WR	Device 2, 3 and 7 are turned OFF	Device 2, 3 and 7 status are OFF
Oscotech13 Turn ON Device 1&4&6&7 WOR	Device 1,4, 6 and 7 are turned ON	NO REPLY
Oscotech13 Turn ON ALL WOR	Device 1,2,3,4,5 6 and 7 are turned ON	NO REPLY
Oscotech13 Turn OFF ALL WR	Device 1,2,3,4,5 6 and 7 are turned OFF	Device 1,2,3,4,5 6 and 7 status are OFF

CONCLUSION

This paper presents a low cost, user- friendly, secured, ubiquitously accessible, auto-configurable, remotely controlled solution for automation of homes. From convenience of a simple handset phone, a user is able to control and monitor nearly any electrical appliances. This allows users to control their home appliances from anywhere in the world; and to be assured that their appliances are not left running when they have left home.

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[1.] Tarik El OUAFY, [2.] Abdelilah CHTAINI,
[3.] Hassan OULFAJRITE, [4.] Rachida NAJIH

CARBON PASTE ELECTRODE MODIFIED WITH CLAY FOR ELECTROCHEMICAL DETECTION OF COPPER (II) USING CYCLIC VOLTAMMETRY

[1-4.] Equipe d'Electrochimie Moléculaire et Matériaux Inorganiques, Faculté des Sciences et Techniques de Beni Mellal, Université Sultan Moulay Slimane. 523, Beni Mellal, MOROCCO

Abstract: This paper reports on the use of carbon paste electrode modified with clay (Clay-CPE) and cyclic voltammetry (CV) for analytical detection of trace copper (II) in Na_2SO_4 0.1M. The electroanalytical procedure for determination of the Cu(II) comprises two steps: the chemical accumulation of the analyze under open-circuit conditions followed by the electrochemical detection of the preconcentrated species using cyclic voltammetry. The electrochemical responses obtained by CV at Clay-CPE were found to be analytically suitable to develop a method for the determination of copper at low concentration levels.
Keywords: Modified electrodes; Cyclic voltammetry; Clay; Cu(II).

INTRODUCTION

Recently, rapid industrialization and urbanization led to the contamination of air, soil and water. The determination of pollution by heavy metals such as copper, mercury, lead, zinc and cadmium is of special concern because of the formation of complexes with proteins [1] and their high toxicity [2-4]. The heavy metal ions are hazardous to ecosystems and can cause serious danger to human population because of their accumulation in organs including liver, heart, brain etc. [5]. For this reason, up to now, several methods including atomic absorption spectrometry, UV-Vis spectroscopy, colorimetric analysis, ion chromatography, inductively coupled plasma mass spectrometry and electroanalytical techniques have been proposed for the determination of heavy metals [6,7]. Among these techniques, electrochemical sensors have great potential for environmental and biological monitoring of toxic metal ions in drinking or waste water and biological samples as blood, urine etc. due to their portability and field-applicability, excellent sensitivity, automation, rapid analysis, low power consumptions and inexpensive equipment [8-11].

Electrochemical determination of copper has been performed with mercury-coated platinum microelectrodes [12], glassy carbon electrode modified with glyoxime [13], polyphenols [14], phenanthroline [15,16] derivatives and poly-4-nitroaniline [17]. In addition to this, the design of electrodes with controllable surface properties can be achieved using self-assembled monolayers (SAMs), which become popular in the formation of well defined functional surfaces [18–20]. The advantages of SAMs include simplicity of preparation, versatility, stability, reproducibility and possibility to introduce different chemical functionalities [21, 22]. As an alternative to environmentally unfriendly mercury- [12] and bismuth- [23] based electrodes several papers related to the detection of metal ions [4, 7, 24, 25,30-31] including Cu(II) ions [26-29] using SAM-modified electrodes have been published recently.

To enhance the preconcentration of metal ions, in this paper, a promising approach to the monitoring of Cu(II) ions was proposed. It was based on clay modified carbon paste electrode. The peak currents of Cu(II) ions were evaluated by cyclic voltammetry within a wide concentration range, with high selectivity, stability and sensitivity suitable for investigation of real samples. It was shown that the proposed sensor has great implications in the determination of Cu(II) ions in tape water even in the presence of some interfering ions.

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 0.1256cm2. 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 Copper ion Cu(II). Standard solution of Copper 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 -0.8 V to 0.7 V. Optimum conditions were established by measuring the peak currents in dependence on all parameters. All experiments were carried out under ambient temperature. In order to insure the inert effect of Clay electrode during the experiment, the potential of 0mV was chosen in presence or in absence of accumulated copper. All other conditions were as described in the Voltammetric part.

RESULTS AND DISCUSSION

Cyclic voltammetry of Cu(II)

Cyclic voltammogram in 0.1 mol L^{-1} Na_2SO_4 (at the pH 7) (Fig. 1) shows cathodic and anodic peaks, which makes it possible to determine this cation. The cyclic voltammograms were obtained for the Clay-CPE in the presence of Cu(II) and without Cu(II). There were no redox peaks in the CV of the Clay-CPE without Cu(II) (Fig. 1a). The Clay-CPE interacting with of Cu(II) showed an anodic peak at -0.05 V and cathodic peak at -0.3V versus calomel reference electrode (Fig. 1b).

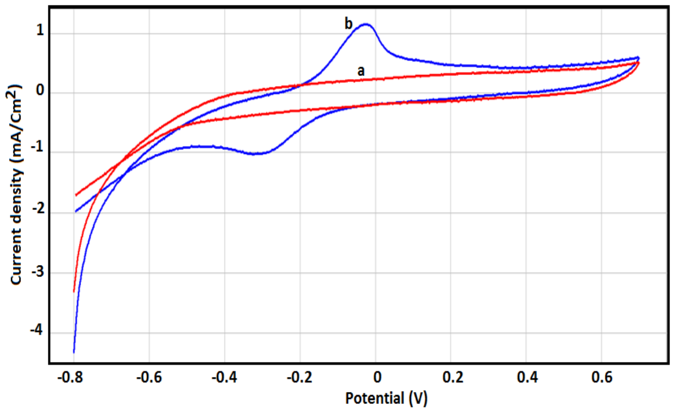

***Figure 1:** CV recorded for 0.31 mM Cu(II) at pH 7 at bare Clay-CPE (a) and Clay-CPE/Cu(II) (b), scan rate 100 mV/s, preconcentration time (tp)=5min.*

Influence of accumulation time

The effect of the accumulation time is investigated (Figure 2), this significantly affects the oxidation peak current of Cu(II). The peak current of 0.31 mmol L^{-1} Cu(II) increases greatly within the first 5min. Further increase in accumulation time does not increase the amount of Cu(II) 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 Cu(II). Maybe this is attributed to the saturated adsorption of Cu(II) on the Clay-CPE surface. Taking account of sensitivity and efficiency, accumulation time was 5 min in the following experiments.

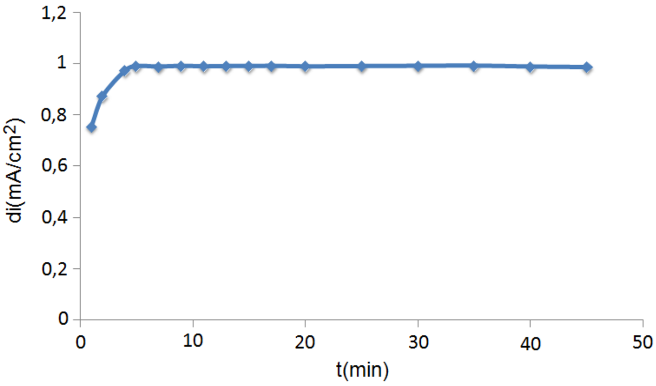

***Figure 2:** Effects of accumulation time on oxidation peak currents of 0.31 mmol L^{-1} Cu(II) (pH 7) at Clay-CPE, supporting electrolyte is Na_2SO_4 0.1M.*

Voltammetric analysis of electrodeposit

As shown in Fig. 1, a voltammetric curve of the Clay-CPE preconcentrated for 5 min in Na_2SO_4 (0.1 M) with a scan rate of 100 mV s^{-1}. It may be noted the presence of a cathodic peak and anodic peak, the peak potentials were attributed to Cu(II) behaviour in Na_2SO_4 0.1 M. An tampon medium was selected as suitable for relegate of Cu(II) according to Eq. (1). Cu(II) species leached out from the clay at the electrode/solution interface can be detected directly by reduction Eq. (2).

Clay-CPE-Cu(II) ⟶ Clay-CPE + Cu(II) (1)

Cu(II) + 2 e^- ⟶ Pb(0) (2)

Effect of scan rate

The influences of scan rate on the oxidation peak potential (Ep) and, peak current (Ip) and the reduction peak potential (Ec) and, peak current (Ic) of copper, (0.1M Na_2SO_4, pH=7) were studied by cyclic voltammetry. The figure 3 shows both the anodic and the cathodic peak currents linearly increase with the scan rate over the range of 40 to 120 mVs^{-1}, suggesting that the electrons transfers for copper at the clay modified CPE is adsorption controlled reaction. The cathodic peak shifted towards negative potential with increased in scan rate, the anodic peak shifted towards positive potential with increased in scan rate. The figure 4 shows the linear relationship between the scan rate anodic peak and cathodic peak currents of copper at Clay-CPE.

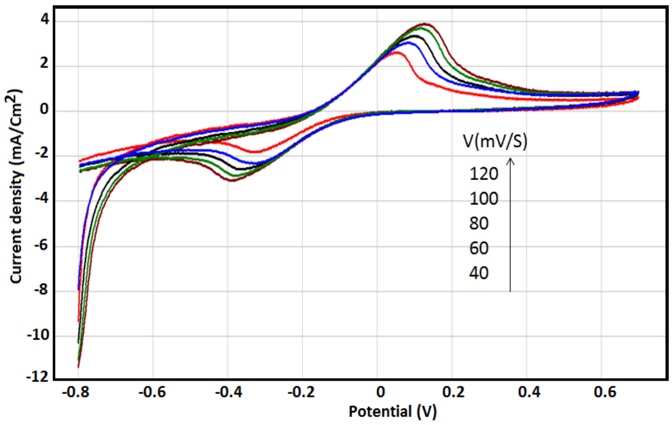

***Figure 3**: CV acquired on Clay-CPE with 1.86 mM Cu(II) in the buffer solution at different scan rates from 40 to 120 mV.s^{-1}.*

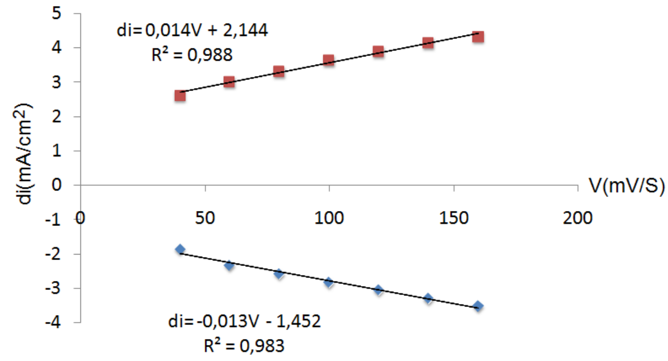

***Figure 4:** Plot of peaks area versus scan rate*

Calibration graph

In order to obtain an analytical curve for the developed sensor, we carried out cyclic voltammograms for oxidation and reduction of Cu(II) at different concentrations in 0.1mol L^{-1} Na_2SO_4 (pH=7) at a sweep rate of 100 mVs^{-1}.

Figure 5 shows the CV curves of different concentration of Cu(II) at Clay/CPE was increased from 0.31 mM to 1.55 mM. Both the anodic and cathodic peak current increases linearly with the concentration of Cu(II). It was also observed that the cathodic peak potential shift towards negative values and anodic peak potential shift towards positive side. This kind of shift in Ep in the cathodic and anodic direction with increasing concentration of the Cu(II) indicates that the product of Cu(II) are adsorbed over the electrode surface.

The figure 6 shows the linear relationship between the concentration anodic peak and cathodic peak currents of copper at Clay-CPE.

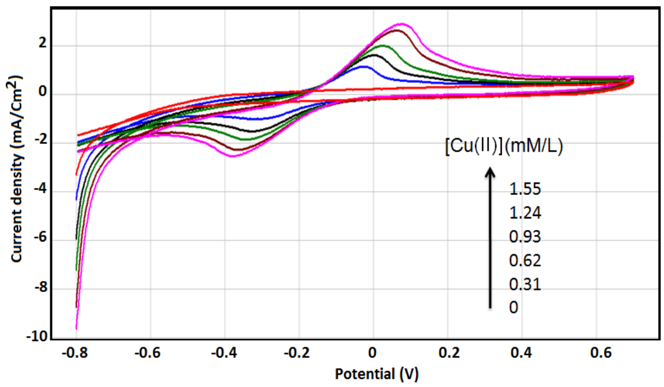

***Figure 5:** Cyclic Voltammograms of different concentration of Cu(II) (0.31mM to 1.55mM) at Clay-CPE in 0.1 M Na_2SO_4, Scan rate 100 mV/s.*

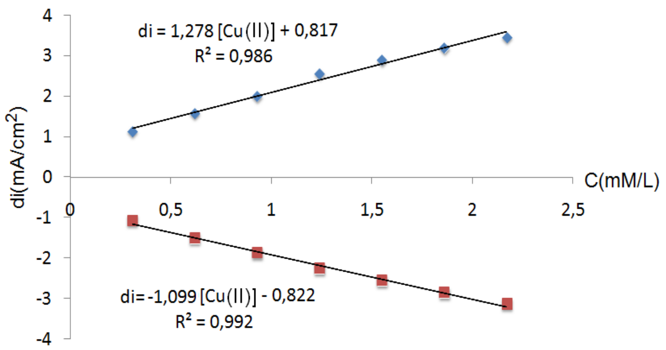

***Figure 6:** Plot of peaks area versus added concentration of Cu(II).*

Influences of pH

In a first step, the effect of pH on electrode response was investigated. In most cases, the solution pH is important to the electrochemical reaction. The Figure 7 a shows the cyclic voltammograms of the Cu(II) at different PH. The current of the peak depend on the solution PH. The anodic peak potential shifted towards negative side and cathodic peak potential Epc shifted towards more positive potential. The figure 8 shows the graph of different pH versus peak current, it could be confirmed that the current density decreases with increased pH.

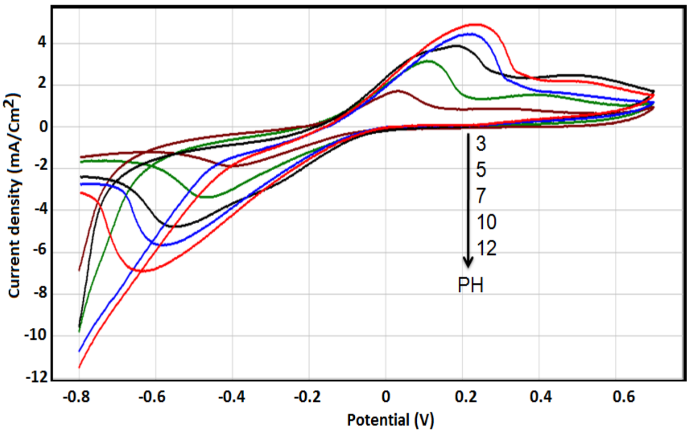

***Figure 7:** Effect of pH on the oxidation and the reduction of Cu(II) at the Clay modified CPE*

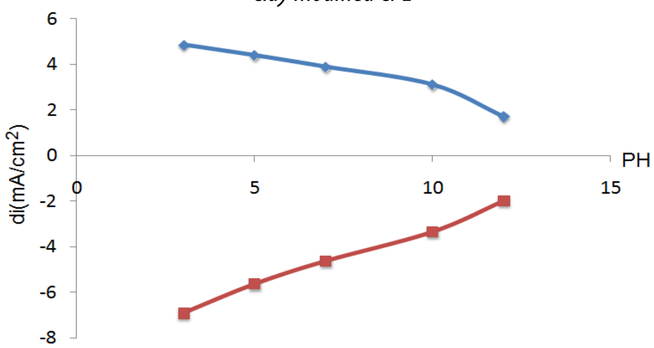

***Figure 8:** Plot of the relationship between solution pH and the oxidation and reduction peak Current*

PRACTICAL APPLICATION

In order to evaluate the performance of Clay-modified carbon paste electrode by practical analytical applications, the determination of Cu(II) was carried out in tap water without any pretreatment. The analytical curves were obtained by CV experiments in supporting electrode (Figure 9). It was founded that the peaks currents increase linearly versus Cu(II) added into the tap water (Figure 10).

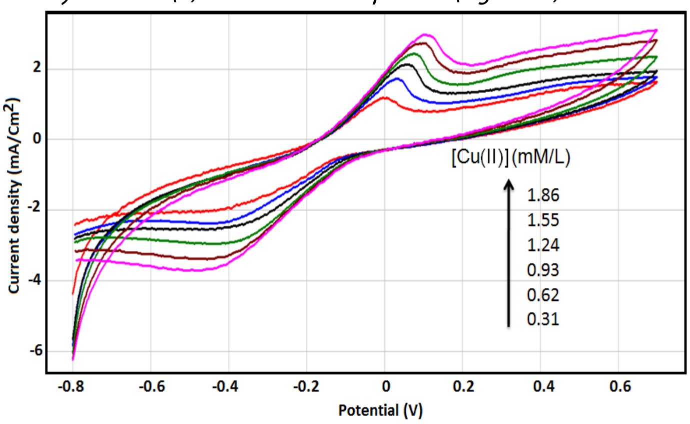

***Figure 9:** Cyclic Voltammograms of different concentration of Cu(II) at Clay/CPE in 100ml tap water, Scan rate 100 mV/s*

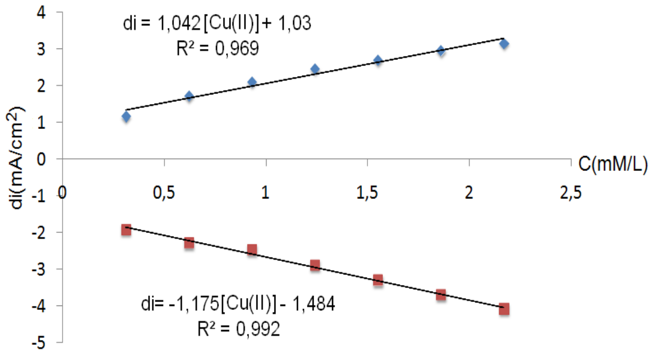

Figure 10: *Plot of peaks area versus added concentration of Cu(II)*

CONCLUSION

Cyclic voltammetry analysis utilizing the clay modified carbon paste electrode for the determination of copper dissolved in aqueous solutions has been demonstrated.

The use of CV is faster and more sensitive than other, conventional, techniques.

Besides, the use of clay modified carbon paste electrode enables direct analysis of tap water sample without treatment of the sample. This extra advantage could reduce the cost of the analysis and the time taken, hence resulting in improvements in analytical sensitivity.

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[1.] Jana POLÁČKOVÁ, [2.] Petr SAJDL, [3.] Jana PETRŮ , [4.] Daniela MARUŠÁKOVÁ

EFFECT OF CHEMICAL REGIMES ON OXIDE LAYERS OF MATERIALS IN POWER ENGINEERING

[1-4] Department of Power Engineering, Institute of Chemical Technology, Technická 5, Praha 6 166 28, CZECH REPUBLIC

Abstract: *Nowadays most commonly used materials in power engineering are stainless steels. Temperatures and pressures in systems are currently increased to achieve higher efficiency. In some plants are applied even supercritical values. This paper is focused on improvement of corrosion protection possibilities. Except new materials (titanium, nickel superalloys), different types of surface treatments or layers are used to reduce problems caused by corrosion. If passive film is formed on treated surface, e.g. nitrided, there can appear differences in its properties. The oxidic layers are common, however in operation of water-steam cycles in power plants arise problems like exfoliation, bigger porosity or disparity of passive layer. Consequence is larger corrosion rate, which leads up to degradation of the material and failure of equipment. In experimental section were created oxidic layers in laboratory conditions and was monitored the behavior of materials used in power industry. Thereafter were evaluated their properties and composition, which permits to analyze what terms are for given materials most suitable. Samples were exposed in autoclave in terms of different cycle chemistry and then analyzed by method of ESCA, X-ray diffraction and metallography.*
Keywords: *corrosion, chemical regimes, oxide layers*

INTRODUCTION

Water treatment in steam-water cycles of power stations especially should ensure functional equipment as long time as possible. Because the construction is made practically only of metallic materials, there is a need to prevent corrosion damage. The choice of suitable chemical regime and its correct regulation are in this issue essential aspect. Appropriately treated environment can considerably reduce material degradation. Dissolved substances increase solution conductivity and promote electrochemical cells formation, which participate at mechanisms of e.g. pitting and crevice corrosion. Species of the reactions taking place on metal surface are thickly affected by pH of environment. This is associated with CO_2 content regulation, which causes solutions acidification and subsequently leads to surface corrosion formation at values pH < 6. Oxygen content has to be controlled as well. It can be cause of pitting corrosion. Moreover is necessary to consider impurities and additives properties, water and steam temperature, velocity and mechanical load of the equipment.

Due to loading turbines construction both tensile and cyclic part of strain, comes up a fatigue corrosion formation risk, frequently initiated by pitting or crevice corrosion. Above that is important to consider blades erosion damage by water droplets cavitation and deposits creation. They can exfoliate from the surface and are dangerous not only for direct parts of the turbine, but can cause also regulation elements failure by clogging them.

Oxidic layers are often used steam turbines corrosion protection type. To be functional, is important to watch their state and prevent undesirable changes, which can be caused by wrong steam quality and inappropriate supply water treatment [1, 2, 3].

RESTRICTION OF STEAM TURBINES CORROSION USING SURFACE TREATMENTS

Surface treatments are effective method to reduce corrosion damage because they constitute solid barrier between the environment and metal. Most commonly are used oxidic layers, organic coatings, electroplating and thermic and vacuum surface treatments.

In this group can be included nitriding as well. However, this technique isn't applied directly as corrosion protection. Metal surface saturation by nitrogen has as a result very tough layer of fine particles alloying elements nitrides. The purpose of nitriding is surface hardness and abrasion resistance increasing while metals original properties remain. This treatment has been carried out on one of tested materials in experimental section [4, 5, 6].

EXPERIMENTAL

To compare corrosion behavior, three types of material for steam turbines construction were tested. The first is martensitic stainless steel X 12 CrNiMoV 12-3 (1.4938) produced by company Böhler. Specimens were taken from a low pressure turbine blade, which was working in Wilson line area. There occurred problems with oxidic layer exfoliation.

Next two samples types are made from nickel superalloy Nimonic 901. Beside nickel (40 – 45 %) it contains approximately 30 % iron and 11 – 14 % chrome. In experiment were tested basic material without surface treatment and nitrided material. Each specimen *except nitrided ones was grinded before testing. Samples designation overview is in Table 1. Numbers are the same as expositions.*

***Table 1**: Designation of samples*

Material	Designation
1.4938 (blade)	L1
	L2
	L3
Nimonic 901 basic	NZ1
	NZ2
	NZ3
Nimonic 901 nitrided	NN1
	NN2
	NN3

All samples were exposed in the autoclave simulating steam turbines operation conditions. Three experiments were performed. Terms were set to locate specimens in the superheated steam environment and their summary is below in tables 2 – 4. Volumetric flow of water was circa 4.6 ml/min. Expositions were implemented due to materials behaviour in terms of different chemical regimes comparison.

***Table 2:** 1st exposition*

T [°C]	570
p [MPa]	6
τ [h]	59
pH	< 10
Degassed water	Yes

***Table 3**: 2nd exposition*

T [°C]	570
p [MPa]	4
τ [h]	66
pH	< 8
Degassed water	No

***Table 4**: 3rd exposition*

T [°C]	610
p [MPa]	3
τ [h]	66
pH	< 8
Degassed water	Yes

METHODS OF EVALUATION

Photoelectron spectroscopy (XPS) was used for chemical constitution evaluation of oxidic layers formed in autoclave. ESCA (Electron Spectroscopy for Chemical Analysis) is a technique enabling qualitative and quantitative surface analyze into depth 50 – 70 Å. Result is XPS spectrum, which displays radiation intensity as a function of binding energy. Survey spectra analyze was performed in range of binding energies 0 – 100 eV. For evaluation was used program Casa XPS [7].

For analyze and photographic documentation of oxidic layers with microscope, were made metallographic samples. Available optical microscope disposed of magnification 25x and 50x.

RESULTS AND DISCUSSION

After all expositions there was dark grey colored oxide layer on each sample surface. On several places occurred in small amount orange corrosion products (hematite Fe_2O_3). The best properties showed samples after third exposition. All layers were unbroken but thin enough.

On steel (designation L) were formed very fine layers. Nimonic 901 nitrided samples (NN1 – NN3) showed in every exposition terms relatively coherent and compact oxidic layers. Only by NN2 occurred exfoliation. Nimonic 901 basic samples (NZ1 – NZ3) were covered with a passive layer but not such undivided as on nitrided set.

On Figure 1 is survey spectrum of sample NZ3 after 15 minutes sputtering with significant iron and oxygen peaks. Figure 2 shows the same samples fitted spectrum.

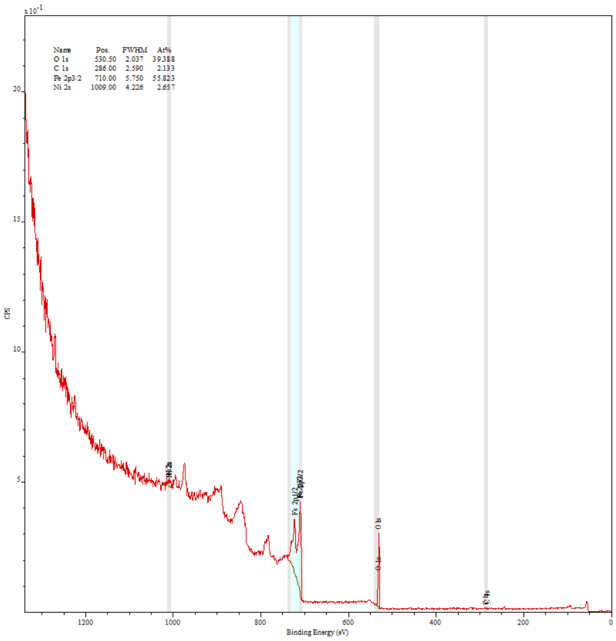

***Figure 1:** Survey spectrum of orbitals of oxidic layer elements, sample NZ3*

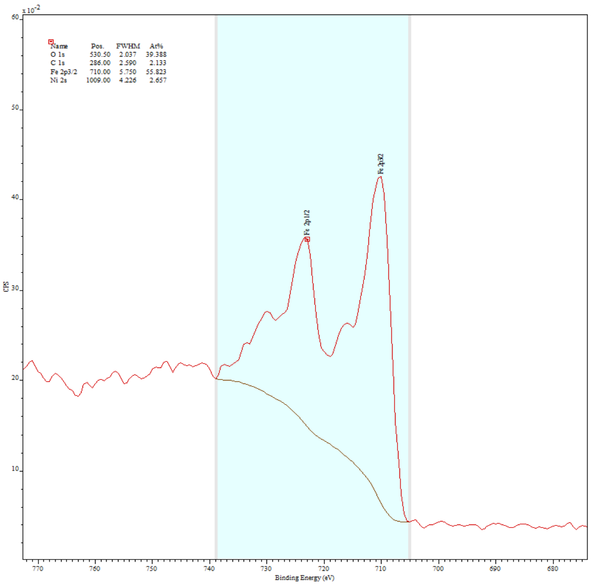

***Figure 2**: Fitted spectrum of Fe 2p1/2 and Fe 2p3/2 orbitals, sample NZ3*

Nimonic 901 basic and nitrided samples have beside original material bigger iron and oxygen content on surface and nickel content is lower as by nitrided samples nitrogen. Next identified in passive layers are chromium, molybdenum and titan, which are alloying elements. However these metals are present only in very small amounts. On surfaces of steel 1.4938 increased iron content and oxygen as well. Before sputtering there was found a low chromium amount on all samples. It is main alloying element for this material. In small amounts were identified also nickel, manganese and other.

On optical microscope is not significant layer on steel. Nimonic 901 nitrided samples have relatively thick oxide layers on surface, on NN1 even 15 µm. But NN3 only has unbroken, compact and slightly thinner layer. By this set of samples was observed one more layer under oxidic (Figure 3). This is probably the result of material structure changes caused by high temperatures influence.

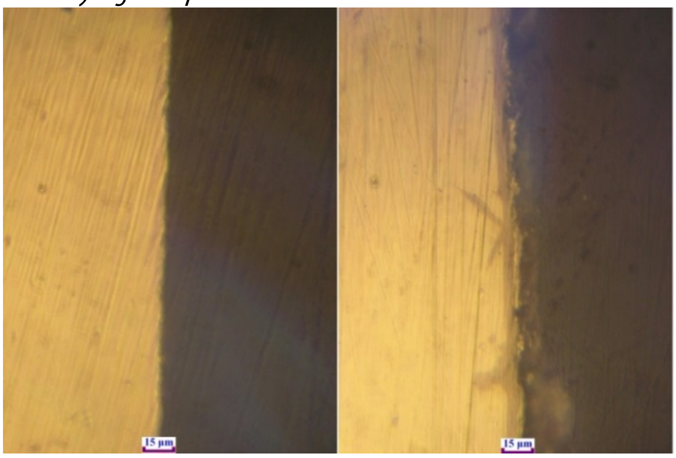

***Figure 3**: Original Nimonic 901 nitrided (left) and NN2 after exposition (right). Magnification 50x*

On Nimonic 901 basic material (NZ1, NZ2, NZ3) are very thin passive layers, visible only with higher magnification.

CONCLUSIONS

Any of samples is not hit by corrosion in a greater degree. The best properties showed oxidic layers formed in the third exposition. They are thin, coherent enough and consisted largely of iron oxides and nickel oxides on Nimonic 901. Terms were in this case set on 610°C, 3 MPa and pH < 8. Water used as medium was degassed with argon.

Each material behavior depends on environment conditions. In general, all samples resisted experiments. Only NN2 has exfoliating layer. This could be dangerous in steam turbines operation, because of mechanical damage and regulation elements blocking. It was probably caused by the water with content of oxygen used in this part of experiment. Structure changes on Nimonic 901 nitrided surface, raised due to extreme terms influence on alloying metals behavior. This phenomenon can cause changes in material properties, for example fragility increase.

Steel 1.4938 samples did not form significant passive layers during any exposition. This material has to resist high temperatures and pressures without hardness and tensile strength changes. In next research is appropriate to study oxidic layers structure and surface material changes as was evident on Nimonic 901 nitrided more in detail.

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ACTA TECHNICA CORVINIENSIS – BULLETIN OF ENGINEERING. Fascicule 2 [APRIL–JUNE]

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[1.] Michal SVÁTEK, [2.] Peter KRIŽAN

MUTUAL INTERACTION OF SELECTED PARAMETERS OF OAK SAWDUST DENSIFICATION PROCESS BY THE DENSITY RESPONSE SURFACE

[1-2.] Institute of Manufacturing Systems, Environmental Technology and Quality Management, Faculty of Mechanical Engineering STU in Bratislava, Nám. Slobody 17, 812 31 Bratislava, SLOVAKIA

Abstract: The aim of this contribution is to present research results - the impact and mutual interaction of selected parameters of the oak sawdust densification process by the response surface. The briquette density represents a measurable indicator of briquette quality. In most cases (analysis) is final density considered with numerical values which are under review by the individual criteria. The response surface creates a separate section and a possibility of its appraisal. A three-dimensional graph creates the response surface of the final briquettes density, whose points are the individual density values in a particular setting of selected parameters of densification process. By an intersection of the individual response surfaces with the selected parameters it´s possible to optimized these parameters with the aim to improve the quality of briquette. Showing the possibility to apply this optimizing method of the technological parameters and to analyse their mutual interaction represents our intention through this article.
Keywords: biomass, briquetting, densification, mutual interaction, briquette density, data evaluation, response surface

INTRODUCTION

Our workplace has been dealing with the research of various parameters impact on the final briquettes density for some time. We have been trying to quantify and define mutual relations of individual influencing parameters to gain complex overview of the parameters behavior present within the densification process. All experiments were conducted in laboratory conditions and an experimental compacting stand was used during the experiments. There are used several methods and procedures for the collected data evaluation and processing considering the type of outcome we would like to reach.

The aim of this article is to present a type of analysis used for the interaction and the selected parameters influence on the final briquette density within the process of densification when the used compacted material is oak.

A mathematical model was used for the purpose of this analysis to calculate the density value. A set of individual density values gained during combining individual settings and iteration steps creates the response surface.

Response surface forms an individual evaluation category of the output value behavior in the individual points. In our case the response surface is formed by the set of density values in the individual settings points represented by a three-dimensional graph. Using this graph and its shape enables monitoring the curving of the surface and analyzing its minimum and maximum values. At the same time the surface analyses the output value increase direction – in our case the briquette density value or the behavior within the range of input values.

EXAMINED PARAMETERS OF DENSIFICATION PROCESS

While selecting the parameters, the following parameters present within the densification process were considered – pressing temperature, compacting pressure, fraction size and the compacted material moisture.

Pressing temperature – during the compression process it is necessary to focus on the effectiveness of the used temperature. One reason is the plastification and volatilizing of lignin, which is the joining material of the individual compacted particles. Consequently the bond between the particles is decreased, which decreases the compactness of the briquette.

Compacting pressure – the amount of the compacting pressure is important not only for the final quality of the briquette itself but also because the type of used compacting equipment depends on the amount of compacting pressure. In the end, this also influences the economic side of the compacting and therefore also the production price of the briquette.

Compacted material moisture – high amount of moisture does not have any significance during compacting as the briquette does not become sufficiently integrated due to the evaporating steam. Similarly, when using compacting material with too low amount of moisture, the briquette can become sintered and too fragile which influences its further use.

Compacted material fraction size – also when considering the compacting material fraction size, higher fraction is practically useless as high fraction size causes low compactness of the briquette due to weak bonds. Due to lower fraction, stronger inter-particle bonds are expected.

DENSITY RESPONSE SURFACE AT VARIOUS VALUES OF MATERIAL MOISTURE

Response surface is a great and useful tool for presenting the process in maximum amplitudes of individual parameters. As presented in functionalities Figure 1 and Figure 2, it is limiting to present the functionality with fixation of several parameters. Using the response surface we can get clear presentation of the process within the given extend by the means of surfaces. These represent set-up levels.

Analysis considering fixation of compacting pressure and fraction size

In this section the analysis of the final briquette density while using the fixation of compacting pressure and compacted material fraction size, is discussed.

In Figure 1 one can see the two-dimensional display of the relation, the influence of the pressing temperature on the briquette density. As the presented graph shows, the influence was monitored by various values of the compacted material moisture, while the fraction size was a fixed parameter –1mm and similarly the compacting pressure – 95 MPa. These parameters were selected upon experience.

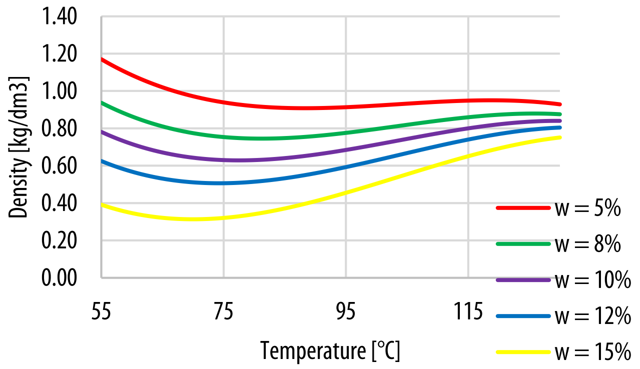


***Figure 1**: The influence of the pressing temperature on the briquette density*

As visible in the graph, at increased moisture of the input compacting material, part of the temperature is used in the first phase for drying out the material to the level of moisture necessary for quality binding of individual particles and then the briquette is compacted to the required density. At higher levels of moisture, the binding of the compacted material structures is not firm that is why the briquette does not reach sufficient density. On the contrary, at the lowest level of moisture, the material becomes hard dried and the quality of particles binding is lowered which causes slight decrease of the briquette density while the pressing temperature is higher. With higher pressing temperature, positive impacts on the briquettes density can be observed. After comparing individual levels of compacting material moisture it is evident that moisture is an important parameter within compacting process.

Analysis considering fixation of pressing temperature and fraction size

The same method was used for analysis of final density using fixation of other two parameters – pressing temperature and compacting material fraction size. Also in this case, the final briquette density was closely analyzed. Figure 2 presents two-dimensional display of the relation and the impact of compacting pressure on the briquette density. The graph shows that the impact was monitored at various values of compacted material moisture while the fraction size was the fixed parameter – 1mm and similarly the pressing temperature – 85 °C. Compared to the impact of pressing temperature described in the previous section, the increase of final briquette density while increasing the compacting pressure is not as significant and its development is rather linear.

The test also confirmed that when using pressing temperature of 85°C at higher levels of material moisture, firstly the temperature is spent on excessive moisture, the contained water in the compacted material evaporation. Thus it stresses the importance of pressing temperature.

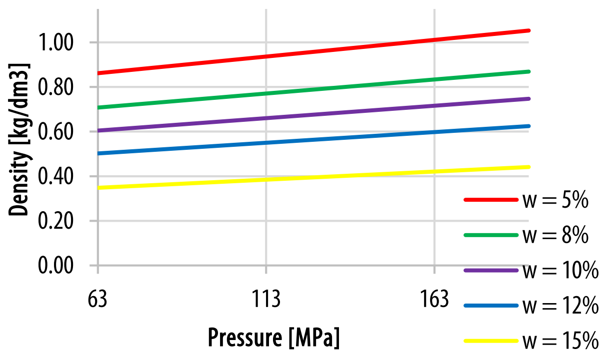
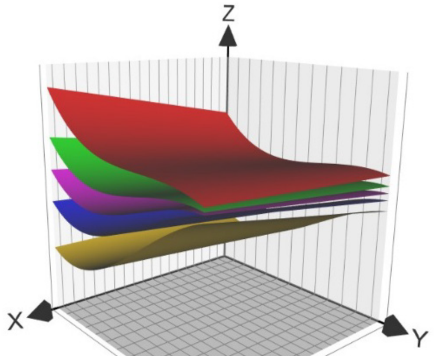
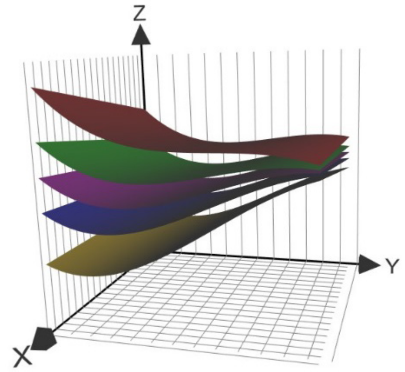


***Figure 2**: Impact of compacting pressure on the briquette density*

The pattern of the response surface of the final briquettes density can be seen in Figure 3. The following graphs show the development of briquettes density (Axis z) during the increase of compacting pressure (Axis x) and pressing temperature (Axis y) at different levels of compacted material moisture. The presented response surfaces are shown at constant value of fraction size - 1mm, and various values of the compacted material moisture (5%, 8%, 10%, 12% and 15%). The initial value (point zero on the axis) is in this case compacting pressure of 63MPa and pressing temperature of 55°C. As it can be seen, at lower levels of moisture and with increasing compacting pressure the final briquette density increases. At higher levels of moisture, when the pressing temperature is spent on evaporating of the excessive moisture, with the increased pressure the final value of briquette density increases too. It can be noticed that increasing the pressing temperature has more positive impact on the briquette density increase than increasing the compacting pressure. This response surface graph confirms the hypothesis about using the suitable temperature during compacting and at the same time about the suitable initial level of compacted material moisture. Such graphic presentations offer complex overview of the selected parameters mutual interaction within the compacting process and the influence on the briquettes final density. Based on the calculated and proposed mathematical model it is possible to get specific values for each monitored parameter at any point on the presented surfaces.

This provides a very simple tool for briquettes density prediction for any specific setting.





Axis designation: axis X⟶compacting pressure [MPa]; axis Y⟶pressing temperature [°C]; axis Z⟶density [kg/dm^3]
Legend of colours ⟶ material moisture level: red = 5%; green = 8%; purple = 10%; blue = 12%; yellow = 15%
Figure 3: The pattern of the response surface – constant value of fraction size

DENSITY RESPONSE SURFACE AT VARIOUS VALUES OF MATERIAL FRACTION SIZE

The next part is dedicated to density analysis using the response surface at constant value of material moisture and different values of fraction size. Presented response surfaces (Figure 6) are calculated with constant value of moisture - 10% and different values of compacted material fraction size (0.5 mm, 1 mm, 2mm, 3mm, 4 mm).

Analysis considering fixation of compacting pressure and material moisture

This section deals with analysis of briquettes final density using fixation of the compacting pressure and compacted material moisture. Fig. 4 shows two-dimensional presentation of the pressing temperature influence on the briquette density. As the graph shows the influence was monitored at various values of compacted material fraction size while the fixed parameters were the moisture of the compacted material – 10%, and compacting pressure – 95 MPa. As it can be seen in the graph, increase of temperature during compacting causes briquette density value increase at all levels of fraction size. When compared to the following graph it is obvious that the influence of higher pressing temperature causes more significant density increase at constant pressure than at increased compacting pressure and constant pressing temperature.

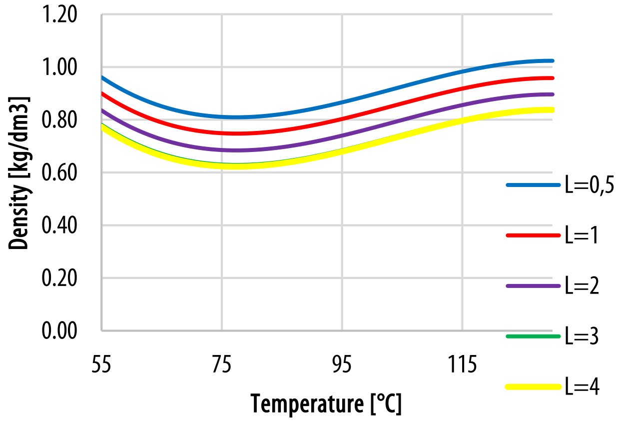


Figure 4: The influence of the pressing temperature on the briquette density

Analysis considering fixation of pressing temperature and material moisture

The following section discusses analysis of the final briquette density using fixation of pressing temperature and the compacted material moisture. Figure 5 presents two-dimensional display of the relations, the influence of the compacting pressure on the briquette density. As the graph shows, the influence was monitored at different values of compacted material fraction size while the pressing temperature was the fixed parameter - 85°C as well as the compacted material moisture level – 10%. As the following graph shows, higher fraction size requires higher compacting pressure to get higher value of final density. In total, the level of final density value is lower due to the choice of fixed moisture value -10% and also the temperature, while the density increase would be reached by increasing pressing temperature combined with moisture. Comparing to the previous graph, it is obvious that the higher pressure influence does not cause so significant increase of density as the higher pressing temperature.

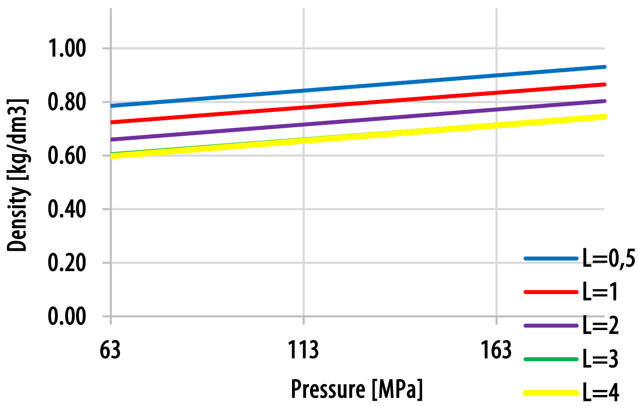
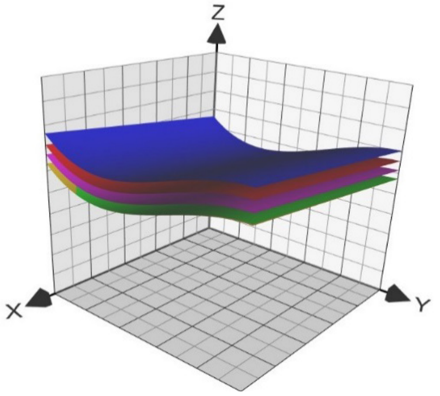
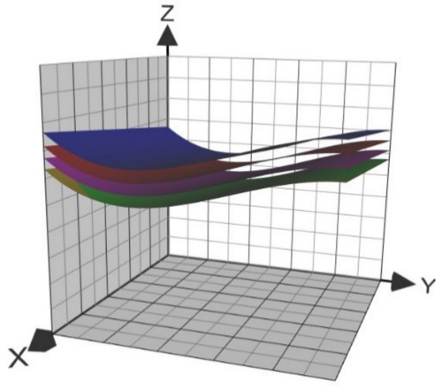


Figure 5: Impact of compacting pressure on the briquette density

Similarly as in the first section, also here we took a moment to look closely at the pattern of the response surface of the final briquette density – Figure 6. The following graphs present development of the briquettes density (Axis z) at the increase of compacting pressure (Axis x) and pressing temperature (Axis y) at different levels of the compacted material fraction size.





Axis designation: axis X⟶compacting pressure [MPa]; axis Y⟶pressing temperature [°C]; axis Z⟶density [kg/dm^3]

Legend of colours ⟶ material fraction size level: blue = 0,5mm; red = 1mm; purple = 2mm; green = 3mm, yellow=4mm

Figure 6: The pattern of the response surface – constant value of moisture

Presented response surfaces are displayed at constant moisture value - 10%, and different values of compacted material fraction size (0.5 mm, 1 mm, 2 mm, 3 mm, 4 mm). The initial value (point zero on the axis) is in this case the compacting pressure of 63 MPa and pressing temperature of 55°C, the same as in the previous case. From both perspectives it is clear that the final briquette density increases with increasing compacting pressure. However, the influence of the pressing temperature, its increase, increases the final briquette density even more, at all fraction sizes. This graph of response surface confirms again that using the pressing temperature in combination with optimal set-up of compacted material moisture and fraction size represent significant parameters which have an impact on the final density of the briquette.

CONCLUSION

The article presented results of a research performed at our workplace, aim of which was to define the influence of selected parameters mutual interaction within the process of densification to the final quality of oak briquettes. We also tried to point out how significant role the response surface can have within the analysis of output quantity – in our case the final briquette density. Thanks to the three-dimensional spatial display of the output, it is possible to better define the characteristics of analyzed quantity and predict its further development and direction. In the future we are planning to work with the response surface by the means of intersection of compacted materials individual surfaces and optimization of various compacting materials mixtures. We believe that the presented method will be beneficial and also utilizable for briquettes quality increase.

ACKNOWLEDGMENT

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[1.] Eva ŠEBELOVÁ, [2.] Josef CHLADIL

STUDY OF THE TOOL WEAR PROCESS IN THE MACHINING OF NON-METALLIC MATERIALS

[1.] Department of Furniture, Design and Habitat, Faculty of Forestry and Wood Technology, Mendel University in Brno, Zemědělská 1, Brno 613 00, CZECH REPUBLIC
[2.] Institute of Manufacturing Technology, Faculty of Mechanical Engineering, Brno University of Technology, Technická 2896/2, Brno 616 69, CZECH REPUBLIC

Abstract: *The issue of tool wear in the machining of non-metallic materials is a very under-researched area. The theory is based on the findings known in metals and is extended by interaction of the tool with wood-based materials. These materials have completely different properties, most of them are characterized by poor thermal conductivity and a different behaviour in different directions of load (axial, radial and tangential). The course is based on a tool wear in the wear curves. Criterion wear defines the maximum wear – a period corresponding to the working state of edge. Studying the process of wear is monitored mainly due to determine dependencies between the durability of the cutting tool and the cutting speed. Addiction is characterized by Taylor's relationship. Determination of tool life vs. cutting speed (T - vc) is the starting basis for determining machinability . It is a material property that characterizes its suitability for machining. Measurement of tool wear in metal materials was carried out mainly on the back or top rake. However, for non-metallic materials, this wear is negligible and difficult to measure. This article is focusing on the issue of defining and measuring the radial edge wear.*
Keywords: *cutting tool, wear, machinability, tool-life, non-metallic materials*

INTRODUCTION

The cutting process of wooden materials and wood-based materials is different from the process of cutting metal materials, mainly in the fact that they are materials with very different properties especially in terms of deformation processes. Materials made of solid wood, but also agglomerated and laminates have significantly different properties in different directions of loading - axial, radial and tangential [5, 6].

In terms of the cutting process and degree of cutting tool wear, wood based materials can be divided into materials that can cause abrasive effects of the cutting tool and materials which cannot cause the abrasive. Furthermore, most of the non-metallic materials have a poor thermal conductivity.

When viewing their work in the cutting process it is always necessary to consider also their effects onto the cutting tool. Here significantly different characteristics in terms of their effect on the tool wear processes are reflected. Unlike metals, where tool wear is most frequently observed on the clearance plane, such wear is hardly traceable on wood based materials [6, 9].

The cutting process and effects of the work material on the cutting tool in terms of its dulling relates to its machinability. The machinability of the material expresses its suitability for machining. Experiments may serve to machinability determination, in which the tool life time in relation to the selected cutting conditions is observed. From the resulting dependencies – the tool wear curves are also made for machinability evaluation [7, 9].

METHODOLOGY

Methodology of machinability determination of wood-based materials was used to determine the material properties in cutting process. For this methodology was necessary to choose the most widely used materials in the woodworking industry - laminated chipboard (DTD-L) and medium density fiberboard (MDF). Selected materials were assigned to the group of materials marked by the free letter for marking material groups "w" due to determination of their machinability. Both materials were tested on the same machine center - SCM Tech 99 by left-hand flat-end-mill with two teeth (D = 19 mm) and replaceable blades made of sintered carbide HW 29.5x12x1.5 4s T04F at the same working conditions (Table1). Conventional milling was chosen for testing. [1, 7].

Measuring device

The gauge Passametr Somet was used for measuring tool wear in machining process of chosen materials. This is a comparative gauge measuring the deviation from the set-up of original blade dimension. The gauge had the micron range $\langle +25;-25 \rangle$ with one movable contact, when the other was fixed with a screw and the movable one was connected to a built-in dial indicator.

***Table 1:** Cutting conditions*

Cutting conditions	Symbol	Value	Units [-]
Diameter of the tool	D	19	mm
Number of teeth	z	2	-
Feed per tooth	f_z	0.05	mm
Depth of cut	H	9.5	mm
Depth of milled layer	a_{pmax}	9.5	mm
Machine speed	n	8000 12000 15000 18000	$rev \cdot min^{-1}$
Feed rate	v_f	800 1200 1500 1800	$mm \cdot min^{-1}$
Cutting speed	v_c	477 716 895 1074	$mm \cdot min^{-1}$

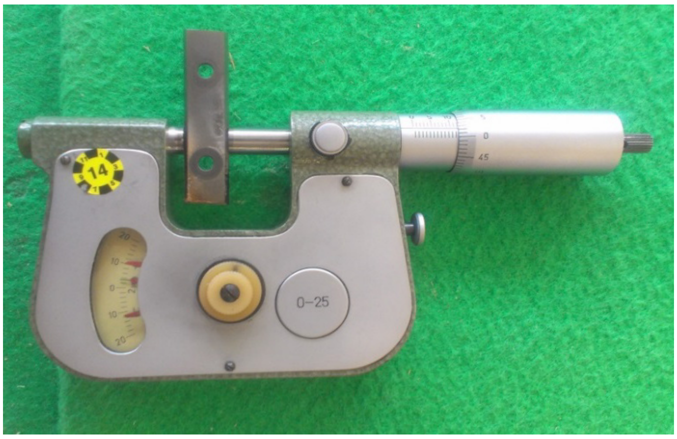

***Figure 1:** Comparative gauge Passametr Somet*

Curves of radial tool wear - KR

The measured values were processed in the form of diagrams for both materials in a plot wear vs. machining time [3, 8, 10]. Individual curves of tool wear were in colour differentiated according to the cutting speed, respectively machine rpm. The radial tool wear rate (criterion) 10 μm from the original size of blade was determined for both materials and this value was highlight into the curves of wear diagram. On the x-axis individual life-times of the tool were subsequently plotted with following condition: $v_{c1} < v_{c2} < v_{c3} < v_{c4}$; $T_1 > T_2 > T_3 > T_4$ (Figure 2 and Figure 3) [11, 12].

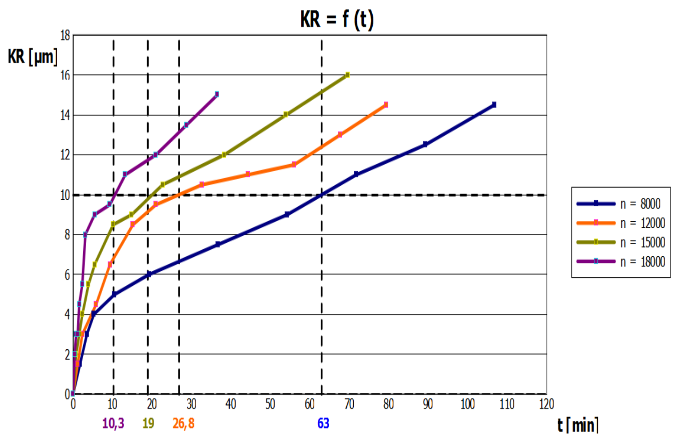

***Figure 2:** Tool wear curves of laminated chipboard - KR = f (t)*

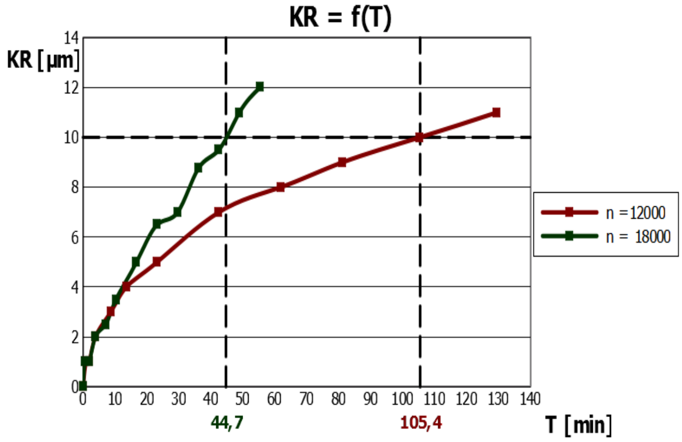

***Figure 3:** Tool wear curves of medium density fiberboard- KR = f (t)*

Taylor's equation

There was also determined the relation between tool life-time and the tool wear rate by dependence life-time vs. cutting speed (T - v_c) which is characterized by Taylor's equation [2, 3, 10]:

$$T = C_T \cdot v_c^{-m} \quad [min] \tag{1}$$

where the (T) is the life-time, (C_T) is the constant, (v_c) is the cutting speed and (m) is the exponent.

Individual life-times T1, T2, T3, T4 were converted to logarithms and were plotted to the $T = f(v_c)$ diagram due to expression the linear dependence. Then the statistical method - linear regression was applied where individual life-times of the tool were line interpolated with the gradient a [4]:

$$f(x) = a \cdot x + b \;\Rightarrow\; f(x) = -m \cdot \log v_c + \log C_T \tag{2}$$

where the (m) is the exponent, (v_c) is the cutting speed and (C_T) is the constant.

Both tested materials (DTD-L, MDF) were inserted into the diagram $T = f(v_c)$. Then it was necessary to define a tool life time and highlight this value in the diagram. The line corresponding to the selected tool life-time $T \approx 44.7$ min ($\log T \approx 1.65$) was plotted and cutting speed values ($\log v_c$) were determined on the x-axis (Figure 4, Table 3). Graphical representation of dependence between life-time and cutting speed the angle α (exponent m) indicates [2, 3, 10]:

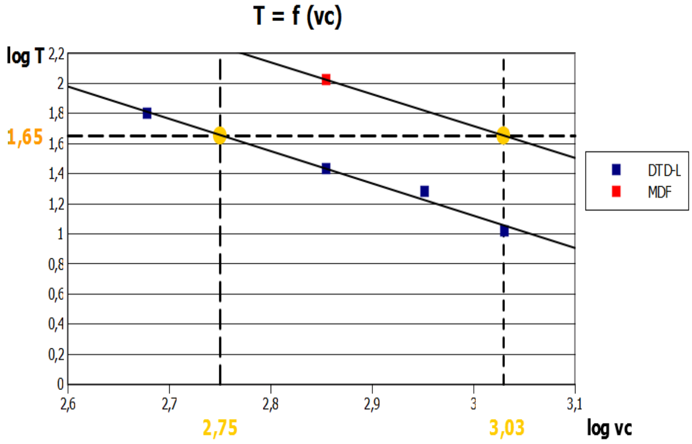

***Figure 4:** Dependence $T = f(v_c)$*

Index of kinetic machinability

From those tested materials the laminated chipboard was selected as reference sample for further comparison. Index of kinetic machinability determines assigning material to the class of machinability whose mean value represents the suitability of the material for machining due to reference sample. The rule applies that materials with a lower number of machinability classification than the reference sample have worse machinability; materials in classes with higher number have better machinability. Index of kinetic machinability is calculated as follows [8, 10]:

$$K_V = \frac{v_{c(T)}^{\text{tested material}}}{v_{c(T)}^{\text{reference sample}}} \quad (3)$$

where the (K_V) is the index of kinetic machinability, $(v_{c(T)})$ is the cutting speed v_c corresponds to the selected tool life-time T.

Material classification

The classes of machinability are marked by a number situated before the letter of each material group. This classification is defined according to the index of kinetic machinability K_V which is determined by interval with mean value of K_V in relation to reference sample. Reference sample has a value of $K_V = 1{,}00$ [3, 8, 10].

Table 2: Index of kinetic machinability values for material classification

Median Kv	Interval Kv	Class of machinability
0.32	0.29 – 0.35	6
0.40	0.36 – 0.44	7
0.50	0.45 – 0.56	8
0.63	0.57 – 0.71	9
0.80	0.72 – 0.89	10
1.00	**0.90 – 1.12**	**11**
1.26	1.13 – 1.41	12
1.59	1.42 – 1.78	13
2.00	1.79 – 2.24	14
2.50	2.25 – 2.82	15
3.15	2.83 – 3.55	16

The following table consist of reference sample and tested material cutting speed values correspond to selected tool life-time based on diagram $T = f(v_c)$ (Figure 3).

Table 3: Values of cutting speed v_c corresponds to life-time T

	T [min]	$v_{c\ \text{ref.sample}}$ [$\text{mm}\cdot\text{min}^{-1}$]	$v_{c\ \text{tested mat.}}$ [$\text{mm}\cdot\text{min}^{-1}$]
log x	1.65	2.75	3.03
x	44.7	562	1074

Index of kinetic machinability was calculated using equation (3) and its result is $K_V = 1.91$.

The result corresponds to the range (1.79 to 2.24) and the mean value of $K_V = 2.0$. According to the table of index of kinetic machinability values, the MDF material is assigned to the 14^{th} class of machinability.

This material is thus better machinable than the reference sample (DTD-L) [11, 12].

Table 4: Results of material machinability

Material	Class of machinability
DTD-L	11w
MDF	14w

CONCLUSION

The tool wear process in the machining of non-metallic materials is based on the methodology of wood-based materials machinability determination. This methodology is based on the measurement of tool wear during cutting materials and monitoring the process of wear depending on the machining time. Material machinability determination deals with defining of a selected material as a reference sample for comparison with another material. Next step is focused on determination of dependence between tool life-time and cutting speed. The final material classification to the class of machinability is based on the kinetic machinability calculation - K_V. K_V is expressed by the ratio of material cutting speeds: it means tested material at the chosen tool life-time and reference sample at the same tool life-time (3). The resulting value is assigned to the corresponding interval of K_V and the material is classified to the appropriate class of machinability.

Next step will reduce time-consuming process of measuring which will be based on the change of tool wear measurement principle without disassembling blades from milling cutter. It will be used a new measurement jig for determination of radial tool wear to ensure and improve measurement accuracy. It will be consist of stand for dial indicator and fixture part for stabilization of whole flat-end mill. This would significantly reduce the time needed to complete the experiment.

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[1.] A. S. ADEKUNLE, [2.] K. A. ADEBIYI, [3.] M. O. DUROWOJU

PERFORMANCE EVALUATION OF GROUNDNUT OIL AND MELON OIL AS CUTTING FLUIDS IN MACHINING OPERATION

[1.] Mechanical Engineering Department, University of Ilorin, Ilorin, NIGERIA
[2, 3.] Mechanical Engineering Department, Ladoke Akintola University of Technology, Ogbomoso, NIGERIA

Abstract: *Coolants are used during machining for variety of reasons such as improving tool life, reducing work-piece thermal deformation and surface finish. Traditionally, coolants in machining are based on conventional oil as the base fluid, but because of its non-biodegradability which results in environmental pollution and danger to human health, there is a growing demand for biodegradable material thus opening an avenue for vegetable oils for use as coolants. In this work, groundnut and melon oils were used as coolants during the turning operation of mild steel using carbide cutting tool at different spindle speeds and depths of cut. The cooling ability, surface finish and chip shapes were studied during the machining process. The results showed that the cooling ability of melon oil was better than that of groundnut oil and the surface finish produced by the vegetable oils was better than that of soluble oil with melon giving the best surface finish. Soluble oil extracted heat the most. The chips formed using vegetable oil coolants are more ductile and continuous than those obtained using soluble oil coolant. Vegetable oil coolants were seen to enhance tool life better than the conventional oil and as such can be used as alternative to soluble oil coolants.*
Keywords: *coolant, machining, groundnut oil, melon oil, operation, cutting, soluble*

INTRODUCTION

Machining processes have an important place in the traditional production industry. During machining process, friction between workpiece-cutting tool and cutting tool-chip interfaces causes high temperature on the cutting tool. The effects of this generated heat include decrease in tool life, increase in surface roughness and decrease in the dimensional sensitivity of work material. This is more important when machining materials that are difficult to cut, where more heat would be generated [1]. This brought about the incorporation of coolants in the manufacturing process. The use of coolants permit higher cutting speeds, higher feed rates, greater depths of cut as well as lengthened tool life, decreased surface roughness, increased dimensional accuracy, and reduced power consumption [2, 3]. The development of coolants was traditionally based on mineral oil as a base fluid and this was because of the good technical properties and the reasonable price of mineral oils. However, the Report to the Club of Rome in 1972 and the two oil crises of 1979 and 1983, pointed out that mineral oil is a limited resource [4]. Also, conventional cutting fluids are not eco-friendly due to the several negative impacts they have had on the environment. When in-appropriately discharged, cutting fluids may damage soil and water resources, cause serious environmental impacts and adverse effects on human health [5, 6]. Vegetable oil on the other hand occurs naturally and has the extra advantage of biodegradability. Compared to mineral oil, vegetable oil can even enhance the cutting performance, extend tool life and improve the surface finish [7, 8]. Although, they have many environmental benefits, vegetable oils are more susceptible to degradation by oxidation or hydrolytic reactions.

Cutting lubricants may consist of pure oil, a mixture of two or more oils or a mixture of oil and water [9]. Oils are generally divided into two groups: the fixed oils and the mineral oils. The fixed oils have greater oiliness than the mineral oils, but they are not so stable and tend to become gummy and decompose when heated. In this group are animal and vegetable oils. On the other hand, the mineral oils group is obtained from crude petroleum mined from the oil fields. The most common type of lubricant used for cutting is soluble oil, which when mixed with water, forms a white solution known as "suds" or "slurry". This has better cooling properties than oil, but does not lubricate as much. The oil part of it is generally a mineral oil mixed with a soap solution [10, 11]. The successful application of bio-oils in metal cutting operation has been restricted to few percentages. Vegetable oils provide intrinsically strong and lubricious film and as such possess higher lubricating ability than conventional mineral oil metal working fluid [12, 13]. Biological oil coolant has some superior features compared to the petroleum-based cutting fluids. There are reduced overall volume of fluids due to higher viscosity, minimized health risk to workers and minimized bio-contamination. Ojolo et al [14] studied the effect of vegetable oils on cutting force during cylindrical turning. Their work demonstrated that *the performance of vegetable based coolants is comparable or better than the performance of the traditional petroleum based metal working fluids. This work is aimed at investigating the possibility of using vegetable oil as an alternative coolant to soluble oil when machining mild steel on a lathe machine by determining; the temperature generated at the cutting zone when different oils are used as coolant at different cutting speeds on the workpiece, the effect of oil coolants on the chips formed during machining and the effect of coolants on the surface finish of the workpiece.*

EXPERIMENTAL DETAILS

Mild steel with chemical composition shown in Table1 was used for the experiment. The tool material used was a round half carbide cutting tool soldered on a mild steel holder. The mild steel holder was bored through and tapped at a point very close to cutting edge of the carbide tool before soldering. A thermocouple of 0-600°C was tightly screwed into the tapped hole until the tip of the thermocouple made a direct contact with the carbide tool. Unrefined vegetable oils of groundnut oil and melon oil were used as alternative coolants to the conventional soluble oil during machining. The vegetable oils were obtained from the south-western region of Nigeria, while the mild steel was obtained from Federated Steel Limited, Otta, Ogun State, Nigeria. The major test parameter used to investigate the performance of the vegetable oil as cutting fluid were temperature at cutting zone, spindle speed and chip thickness. Mild steel bar of diameter 35mm and length 120mm was prepared for machining using conventional soluble oil, groundnut oil and melon oil as coolants. During machining, various spindle speeds of 80, 108 and 260 rpm were investigated at depths of cut of 0.4, 0.6, 0.8, 1.0 and 1.2 mm. The temperature of heat generated between the surface of work piece and the carbide tool was captured during turning operation using a 3 channel SD card data lodger thermometer monitor of model number MTM-380SD connected via the thermocouple at a time interval of 5seconds Figure 1. During machining, coolants were applied using dripping method at a constant rate of 0.28cm^3/s. Maximum temperature for each reading was taken and the chips obtained during machining for various speed and depth of cut were observed. The work piece was then removed and labelled against the spindle speed and the specific coolant used. The procedure highlighted above was used for dry cut, conventional soluble oil, groundnut oil and melon oil in order to compare the effectiveness of the coolants. The composition of the base metal was determined using an Atomic Absorption Spectrometer. The tests carried out on the mild steel metal showed the following percentage composition as given in Table 1.

***Table 1:** Chemical Composition of the Mild steel used*

Components	Fe	C	Si	Mn	P	Cr
Composition (wt%)	99.200	0.131	0140	0.347	0.015	0.013
Components	Ni	Cu	Al	Ti	Co	Sn
Composition (wt%)	0.004	0.038	0.004	0.016	0.001	0.001

***Figure 1:** Experimental setup*

RESULTS AND DISCUSSION

The results obtained showed that temperature at the cutting zone increases as the depth of cut and spindle speed increases irrespective of the coolant used Fig. 2 - Fig. 4. The temperature of the dry cut machining was higher at all speeds while soluble oil absorbs heat better than all other coolants at low, medium and high spindle speeds of 80, 108, 260 rpm respectively. At all spindle speeds, melon oil absorbs heat better than groundnut oil but soluble oil absorbs heat the most. At spindle speed of 80rpm, the amounts of heat absorbed by melon and groundnut oils are almost the same as that of soluble oil which indicated that the properties of the vegetable oils are similar to that of soluble oil Fig. 2.

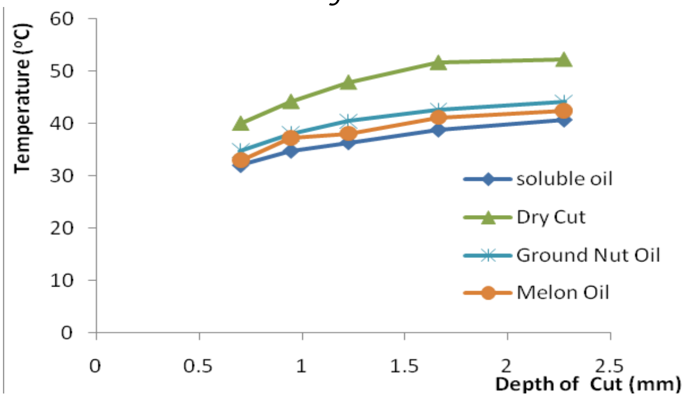


***Figure 2:** Variation of temperature and depth of cut at 80 rpm*

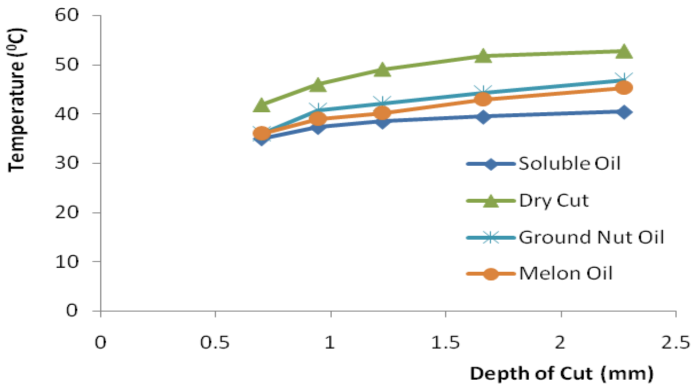


***Figure 3:** Variation of temperature and depth of cut at 108 rpm*

At medium spindle speed of 108rpm and high spindle speed of 260rpm, the amount of heat absorbed by melon and groundnut oils is similar to that of soluble oil at lower depths of cut; but at higher depths of cut, the property of melon and groundnut oil begins to *change and their performance in heat absorption begins to decline as shown in Fig. 3 and Fig. 4 which resulted in high temperature rise.*

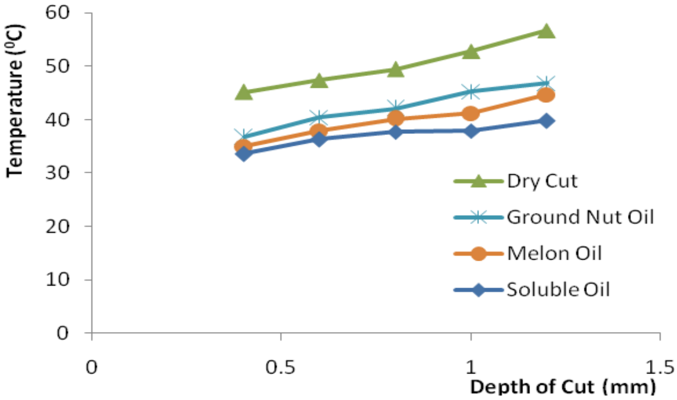
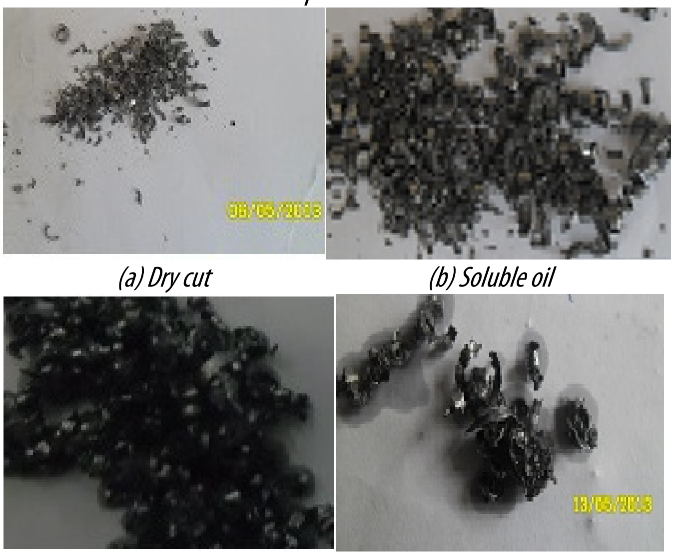


Figure 4: *Variation of temperature and depth of cut at 260 rpm*

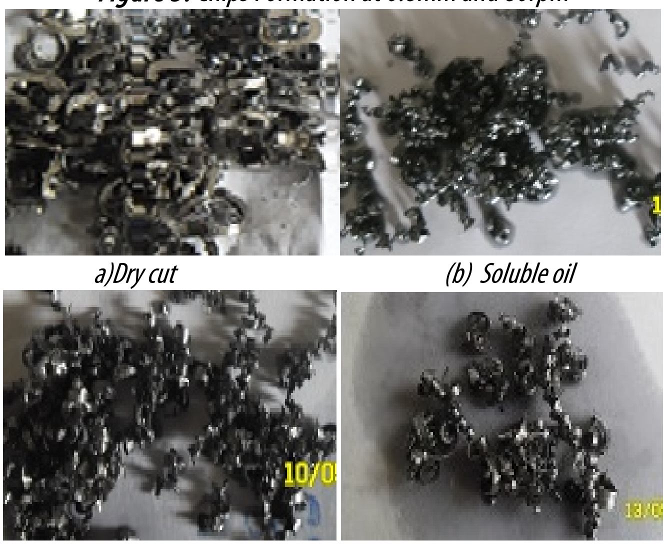
At low spindle speed of 80 rpm, the chips from the work piece using soluble, groundnut and melon oils as coolant were discontinuous Fig.5b – Fig. 5d. Burnt and discontinuous chips were obtained for dry cut machining as a result of the high heat generated in the cutting zone and this also makes the chips formed brittle.



(a) Dry cut *(b) Soluble oil*

(c) Groundut oil *(d) Melon oil*

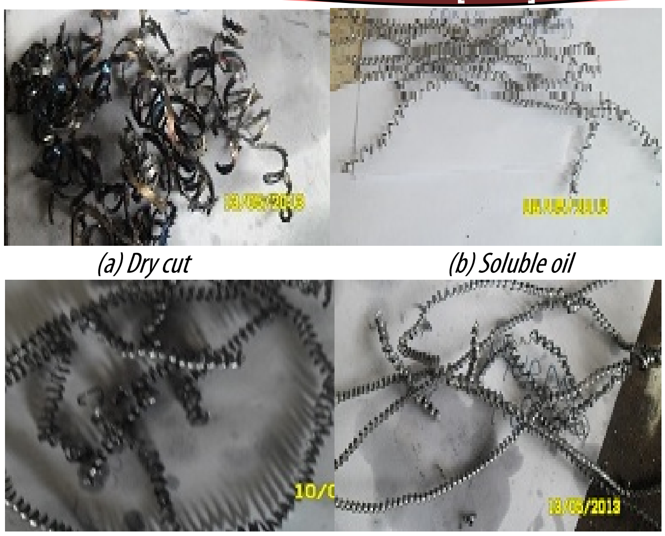
Figure 5: *Chips Formation at 0.8mm and 80rpm*



a)Dry cut *(b) Soluble oil*

(c) Groundnut oil *(d) Melon oil*

Figure 6: *Chips Formation at 1.0mm and 108 rpm*



(a) Dry cut *(b) Soluble oil*

(c) Groundnut oil *(d) Melon oil*

Figure 7: *Chips Formation at 1.2mm and 260 rpm*

At spindle speed of 108rpm the metal chips are continuous for melon oil and groundnut oil while soluble oil gave slightly continuous chips Fig.6a-d. At spindle speed of 260rpm, melon oil and groundnut oil gave ductile and continuous chips Fig.7c and Fig 7d). Soluble oil gave continuous and tiny chips while dry cut gave burnt and continuous chips.

CONCLUSION

The cooling ability of melon oil is better than that of groundnut oil but closer to soluble oil which absorbs heat the most from the cutting zone; the good performance cooling ability of melon oil over groundnut oil may be attributed to its higher kinematic viscosity. Investigation of the machined surfaces shows that the surface finish produced using vegetable oils as coolant was better compared to that of soluble oil, with melon oil giving the best surface finish among all the coolants used. The chips formed by vegetable oils are continuous and more ductile in nature than that produced using soluble oil coolants and dry cut machining; the continuity or discontinuity of chips depends on the spindle speed and the lubricity of the coolant used in machining. During machining, vegetable oil coolants produce less wear on the cutting tool compared to soluble oil as coolant thereby prolonging the tool life. The volume of vegetable oil used was less than that of conventional coolant used during the experiment which is in the ratio 2:3. Though the cooling capacity of conventional oil is better than that of the vegetable oil based coolants, vegetable oils can be used as coolants during machining as they produce better surface finish, longer tool life, continuous chips coupled with the fact that less quantity was expended during the machining process.

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Csaba Attila GHEORGHIU

STUDY ON THE INFLUENCE OF CONTINUOUS CASTING PARAMETERS ON QUALITY OF SEMI-FINISHED PRODUCTS

University Politehnica Timişoara, Faculty of Engineering Hunedoara, ROMANIA

Abstract: *In today's siderurgical industry, more than 99% of the global steel production is made using two types of metallurgical facilities, i.e. oxygen converter and electric arc furnace. Worldwide, for both types of processes, there are several versions of construction and key technology, but the basic principle is maintained in each case, i.e. intensive use of the oxygen in oxygen converters and of electricity in the electric arc furnaces. Regardless of the steelmaking method/facility, more than 99% of the entire steel production is cast using the continuous casting method, and not more than 1% as ingot (destination: steel forging, tool steels, etc.). This paper deals with the influence of continuous casting parameters on the quality of semi-finished products, i.e. chemical composition, steel casting temperature, casting speed, drawing and solidification, and the billet cooling parameters influence on the defects generated during casting, solidification and cooling.*
Keywords: *steel production, steelmaking method, continuous casting, parameters, semi-finished products, quality*

INTRODUCTION

The continuous casting producing steel billets, compared with the conventional casting method, has a number of technical and economic advantages, as follows [1, 2, 3, 4, 5]:

- ✓ *Increases the metal yield from 83-85%, obtained at the classical casting methods (ingots), to minimum 96% (sometimes more than 99%) at sequential casting;*
- ✓ *Reduces the consumptions of energy (electrical and heat energy), refractories and manpower;*
- ✓ *Reduces the investments;*
- ✓ *Increases the productivity and reduces the manufacturing costs.*

The continuous casting, compared with the classical casting method, imposes a stricter observance of the casting parameters, especially when the section of semi-finished products decreases.

The continuously cast billet quality is determined by several steel making & casting parameters, as follows [1, 2, 3, 4, 5, 6, 11]:

- ✓ *The steel chemical composition that is prescribed and must be observed, and according to which the casting parameters are selected;*
- ✓ *At the continuous casting, in order to avoid the formation of internal defects, the sulphur content must be very well correlated with the manganese content, and also the hydrogen and nitrogen contents;*
- ✓ *In order to avoid clogging of the immersion tube with Al_2O_3, the aluminium content must be kept as low as possible;*
- ✓ *The steel casting temperature, from the ladle into the tundish and from the tundish into the mould;*
- ✓ *The specific consumption of heat insulation powders in tundish;*
- ✓ *The specific consumption of ointment powders in the mould;*
- ✓ *The parameters of cooling water, (flow, pressure and temperature);*
- ✓ *The speed of casting, solidification and drawing;*
- ✓ *The constructive parameters of the continuous casting facility.*

The inconsistency of the casting parameters with the prescribed limits leads to the generation of defects, therefore affecting the quality of the billets.

STUDY OF THE PROBLEM

In contact with the cold walls of the mould, there is a strong cooling of the steel to a depth of 140 ... 200 mm below the level of the liquid steel, when there is rapid growth of the marginal crust with fine uniform and equiaxed crystals, forming the first solidification zone. When passing away from this distance, the crust detaches from the mould walls, and up to the exit there is a slow cooling, due to the insulating air space. Thus appears the second solidification zone, or the intermediate zone containing columnar crystals [2-4, 6, 11, 12]. This area is much less large compared with the area afferent to the conventional casting, because the solidification speed is much higher and the crystals do not have time to increase along the heat transmission preferential directions.

It follows the cooling in the secondary cooler, by spraying with water and by direct contact with the heavy guiding rollers, when occurs the solidification of the billet centre. This area consists of equiaxed and unoriented medium-sized crystals. It represents the fifth zone of solidification. Compared with the conventional casting, the fifth zone of solidification contains much less impurities, because a large part of them are decanted in the mould.

After leaving the secondary cooler, the surface temperature of billet must be about 1200^{0}C at the exit from the mould and 900-1100^{0}C after the secondary cooler, i.e. between the straightening / drawing rollers. The temperature of the sheared pieces is 800-850^{0}C and, when reaching the warehouse, the temperature becomes uniform throughout the section.

In order to obtain solidification adequate to the steel chemical composition, a number of factors shall be taken into account [1, 2, 3, 11, 12], as follows:

The chemical composition of the steel determines the drawing speed of the billet and must range within precise limits. It is required advanced silicon deoxidation, restriction of the aluminium content (Al<=0.007%, to avoid Al_2O_3 deposition on the hopper opening and its clogging) and other elements that increase the tendency to form fissures (P<0.02%, S<0.02%, As<0.03, Cu<0.3%, or P+S+As<0.065).

The marginal crust thickness, x, is calculated with relation:

$$x = \frac{Q_e^{'}}{k^{'} * v_{tr} * P} \quad (1)$$

where: $Q_e^{'}$ – amount of heat actually removed; $k^{'}$ – coefficient of proportionality; P – perimeter of the section, v_{tr} – drawing speed.

The amount of heat removed, for a given section/perimeter) is determined from the parameters of the cooling water (flow and pressure), drawing speed, lubricating film thickness and its thermal conductivity. The marginal crust must have such a thickness to not form fissures on the billet surface.

For a height of the mould of 0.6 ... 1.5 m and a drawing speed de 0.5 ... 1.2 m/min, the thickness of the marginal crust reaches 40 ... 50 mm after approx. 3 minutes.

The secondary cooling is chosen according to the steel grade and billet section. The increase of the cooling intensity leads to the increase of compactness in the billet centre, but inner cracks can occur. The heat q removed in the secondary heater can be determined more precisely than in the mould. It can be expressed according to the heat conductivity (λ), the temperature gradient between the liquid and the solid phase (ΔT) at the solidification front, and the thickness of the crust (x,), by using the relation:

$$q = \frac{\lambda * \Delta T}{x} \quad (2)$$

The length of the secondary cooler, L_s, is expressed by the relation:

$$L_s = \frac{v_{tr} * x_1^2}{k^2} \quad (3)$$

where: x_1 – the thickness of the crust from which the heat transfer by radiation is sufficient; k – the solidification constant.

The distance L, from the steel entrance in the mould to the place of complete solidification (after the secondary cooler) is proportional to the drawing speed:

$$L = K * v_{tr} \quad (4)$$

where: K – constant of proportionality (≅6).

The continuous casting facilities can serve any type of steel plant, but they are recommended for the steel plants with oxygen converters, which has short steelmaking process, and EAF plants working in Ultra High Power regime, in particular Supra Ultra High Power.

The section of billets must ensure a processing ratio of at least 5 ... 6, to obtain good quality rolled or forged products. It also needs to provide large cooling surfaces.

By continuous casting, slabs were produced with dimensions of up to 2100x300 for killed steel, 1300x150 for stainless steel, tiles of 50x50 in simple or composite moulds, round, hexagonal & octagonal products, profiles. No satisfactory results have been obtained for steels sensitive to cracking, or secondary oxidation, such as titanium alloy steels. In practice, it is necessary to know how the solidification of molten steel is progressing, when and where a strand is completely solidified. Just knowing the progress of solidification we can take decisions on the casting speed or cooling water flow (spraying).

The solidification of liquid steel in a continuous casting mould depends on the heat flow in the strand that transfers heat to the cooling water (which absorbs heat). This phenomenon depends on a great number of factors and varies according to the casting condition, especially the casting speed, cooling of the liquid steel and strand geometry. The heat balance in the mould is affected by the reduction in overheating, thickness of the strand crust and temperature gradient in the strand crust and along the strand surface.

The calculation of the liquid core length, for a strand cast with a given casting speed, requires information regarding the strand crust increase. The total heat transfer Q between the strand and the mould depends on the heat resistance of the solidification crust R_{Fe}, on the transition resistance from the transition surface of the strand to the cooling wall of the mould R_{FeCu}, on the resistance in the mould wall R_{Cu} and on the transition resistance of the surface between the copper wall and the cooling water R_{CuH2O}.

By considering the temperature uniformity in the strand and mould, and taking into account the solidification heat as single heat source, in the literature are shown calculation relations for the total heat flow [1, 2, 3].

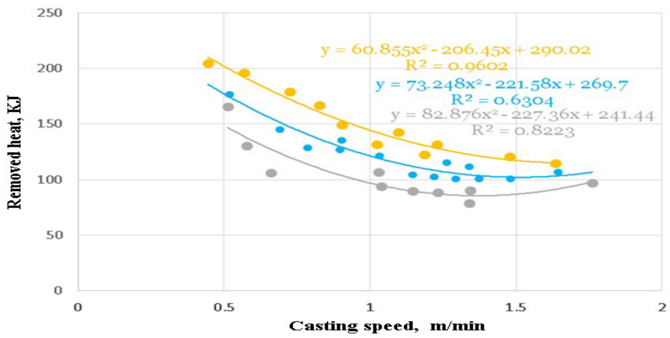

Figure 1. The removal of heat from the mould

The removal of heat from the mould is directly influenced by the casting speed, as shown in Figure 1. It is noted that higher casting speeds are resulting in an evenly decrease in the amount of distributed heat. This decrease is due to the fact that the rapid cast strand are in contact with the cooled wall of the mould for a short period of time and thus a lower amount of heat can be removed per unit of volume or weight of steel from a strand which is cast with a lower speed and is in contact with the mould for a longer period of time.

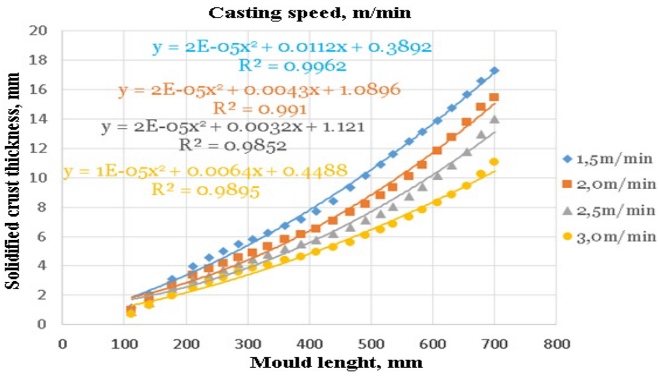

Figure 2*. Variation of the strand crust thickness versus the mould length*

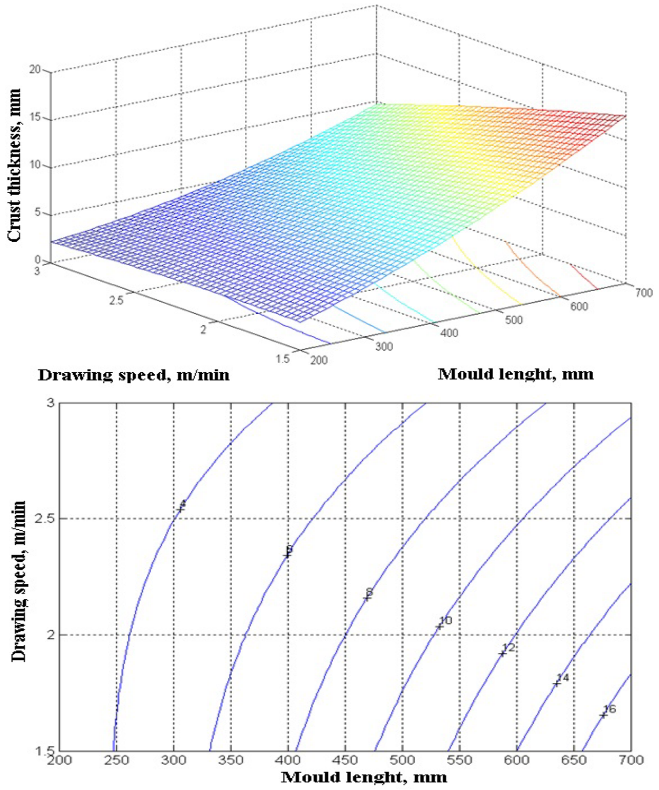

Figure 3*. The influence of the mould length and casting speed on the billet thickness*

Figure 2 shows the variation of the strand crust thickness versus the mould length, in which there is a decrease in the thickness of the crust with the increase of the casting speed, as a result of reducing the possibility to remove a higher amount of heat.

$$Z = -0.45y^2 - 0.0096xy + 0.0283x + 3.4450y - 4.6339;$$

x – mould length, mm; y – drawing speed, m/min; z – crust thickness, mm.

Saddle point; x=62.1780; y= 3.1645; z =1.6955; $R^2 = 0.9939$

The inflection point of the correlation surface (saddle), the coordinates being located outside the technological limits.

From the analysis of data presented in Figure 3, we can see that that an increase in the mould length and casting at slower speed determine a thick crust (over 10 mm). It is very important that, at continuous casting using a given mould (i.e. a known, established length), the casting speed for a semi-finished product with known section to exceed a certain limit.

QUALITY ANALYSIS OF THE CAST BILLETS

Below we show some continuous casting defects of the billets, caused by the failure of some values of the technological parameters to range within the limits set.

Longitudinal cracks *(Figure 4) - are formed in the direction of extraction of the steel strand from the mould, the billet presenting this type of defect being usually integrally rejected. [7, 8]*

The causes of longitudinal cracking are:

- ✓ *uneven heat removal in the mould and, as a consequence, uneven growth of the strand crust, determining transversal strains that lead to strand cracking if the crust is not strong enough (primary uneven cooling);*
- ✓ *liquid metal turbulent flow and variation of the meniscus level in the mould;*
- ✓ *secondary cooling too intense or uneven;*
- ✓ *uneven and advanced wear of the mould, which results in a different heat conductivity coefficient;*
- ✓ *high casting temperature (failure to observe ΔT);*
- ✓ *high strand extraction speed;*
- ✓ *inappropriate behaviour of the casting powder. [5, 6, 7, 8]*

Figure 4. *Longitudinal cracks*

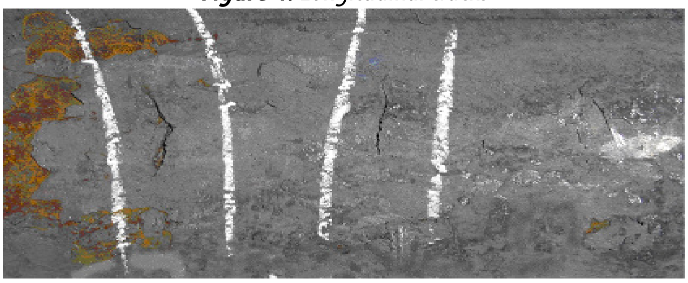

Figure 5. *Transverse cracks*

Transverse cracks *(Figure 5) - are rarely found in round profiles. They appear due to the strains in the longitudinal direction of the strand.*

If not deep, they are grinded (within the limits allowed by the deviations prescribed for diameter and ovality).

The causes of the transverse cracks (fissures) are:

- ✓ *heat strains due to non-uniform solidification of the crust, additional strains due to the turbulent flow below the meniscus, and variation of the meniscus level;*
- ✓ *oscillation mark depth, presence on the bottom of oscillation marks of the segregations that are cooling slower, and the austenitic grain boundaries;*
- ✓ *strain friction in the mould (at high casting speeds, the melt flow found between the mould wall and crust decreases, the marginal friction increases proportionally with the viscosity of the powder used) , or in the segments of the rolls [9, 11, 12]*

c. Stellar cracks *(Figure 6) and those caused by hot brittleness – are very fine and visible only on the scale-free surface. The surface is locally grinded for removing the defect (if it is not deep).*

Figure 6 *. Stellar cracks*

The causes of the stellar cracks are:

- ✓ *intense local cooling which induces local strains;*
- ✓ *the presence of copper at the austenitic grain boundary.[12, 13]*

Figure 7. *Internal fissures in the centre*

d. Fissures in the centre *(Figure 7) – internal fissures extended in the core, that arise due to the following causes [10, 11, 12, 13]:*

- ✓ *high casting temperature;*
- ✓ *high pressure exerted by the drawing rolls on the incompletely solidified strand.*

These defects can be remedied by observing the follows:

- ✓ *maintaining ΔT within the prescribed limits;*
- ✓ *correlating the casting speed, ΔT and cooling regime;*
- ✓ *reducing the casting speed.*

CONCLUSIONS

The continuous casting has significant metallurgical advantages compared with the classical casting method, as follows:

- ✓ *it substantially reduces the chemical and structural heterogeneity of the product due to rapid cooling (the second zone is less extensive, because the elements do not have time to segregate);*
- ✓ *the grain size is easily to control (relatively small primary grains are obtained);*
- ✓ *the non-metallic inclusions are fewer, smaller and more evenly distributed in the semi-finished product (because of the high-speed cooling, they do not have time to coagulate or agglomerate);*
- ✓ *the metal yield is higher, amounting to more than 96%, due to the fact that the shrinkage cavity is formed only once, at the end of casting;*
- ✓ *the failure to observe the set values for the casting parameters generates manufacturing defects, most of which couldn't be remedied, especially the internal ones;*
- ✓ *the semi-finished product surface is good (clean), the surface defects being mostly eliminated;*

The continuous casting has economic advantages as well, i.e.: the facilities are used more intensively, they provide a rhythmic rolling mill supply, the primary rolling mills are eliminated, the material and manpower expenses are reduced, the facilities are suitable for full mechanization and automation.

It is noted that higher casting speeds are resulting in an evenly decrease in the amount of distributed heat. This decrease can be explained by the fact that the rapid cast strands are in contact with the cooled mould wall for a short period of time and, therefore, a lower amount of heat can be removed per unit of steel volume or weight from a strand cast with a lower speed, which is more time in contact with the mould.

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[1.] Libor HARGAŠ, [2.] Dušan KONIAR, [3.] Miroslav HRIANKA, [4.] Anna SIMONOVÁ, [5.] Zuzana LONCOVÁ

DIAGNOSTICS OF RESPIRATORY DISEASES BASED ON VIRTUAL INSTRUMENTATION

[1-5.] Department of Mechatronics and Eletronics, University of Žilina, Faculty of Electrical Engineering, Žilina, SLOVAKIA

Abstract: *Since the stethoscope was found, acoustic analysis was used for diagnostics of patients with pulmonary diseases. This method is characteristic with high level of subjectivity and results of auscultation vary between specialists. Last 10 years we can see significant development of signal digitization and its processing, what is the main engine of auscultation objectivity. Modern medical methods are characterized by influence of electronics to conventional and subjective diagnostics. In this article we propose integration of virtual instrumentation based on LabVIEW to respirology. Designed LabVIEW instruments can be applied each phase of implementation: sound acquisition, signal filtering and processing, representation and results visualization. Flexible LabVIEW instruments can replace many specialized and expensive tools and detectors.*
Keywords: *wheezing, LabVIEW, respirology, acoustic analysis*

INTRODUCTION

Since the stethoscope was found, acoustic analysis was used for diagnostics of patients with pulmonary diseases. This method is characteristic with high level of subjectivity and results of auscultation vary between specialists. Last 10 years we can see significant development of signal digitization and its processing, what is the main engine of auscultation objectivity.

With increasing quality of life and the age of mankind comes demand for monitoring of patient health. Automatic and continuous monitoring of respiration of patients with respiratory pathologies is crucial for correct diagnosis and therapy. Notably sensitive group of patients are children. Early control of disease can fully or partially improve the quality of their life.

The expression wheezing is a general name for group of artifacts covering sounds in normal respiration with duration from 80 to 250 ms and frequency range 100 – 2000 Hz. Wheezing is continual sound caused by air oscillation in the place of stenotic airways. Frequency of oscillation depends on thickness and elasticity of relevant airways segment, also from local air flow. Wheezing partially correlating with the level of obstruction in respiratory tract. Polyphonic wheezing is hearable like compound of variable tones. This type of wheezing is present in expiration in the place of small airways. In the case of strong obstruction the air flow is minimal and wheezing absents.

Wheezing diagnostic importance is in early beginning of therapy in clinical units such as asthma bronchiale. Nowadays, big accent is put for detecting wheezing in the place of small airways, which are critical for asthma; single and accessible detector of this type of wheezing is missing in clinical praxis. Wheezing monitoring helps us to control therapy success.

ACTUAL METHODS USED IN MODERN RESPIROLOGY DIAGNOSTICS

The most common clinical diagnostic methods for wheezing and pathology sounds contain physical methods (auscultation), CLSA – Computerized Lung Sound Analysis (electronic auscultation method), functional lung diagnostics (for obstructs in bronchus and bronchial hyperreactivity), oscillometric method for detection of obstructions in small airways and flexible bronchoscopy (or bronchoalveolar lavage) for patients with persistent wheezing durative 6 weeks or longer and resistive for bronchodilatation therapy.

Intersection of medicine and technical branches increased objectivity and automation of basic diagnostic methods. The simplest method for pathological artifacts detection is calculation of PSD (Power Spectral Density) as an application of Fast Fourier Transformation (FFT) for random sequence of finite duration. Acoustic record of breathing is sequentially divided into windows with width of tenths of milliseconds (e.g. 100 ms). Then power spectrum of each finite sub-sequence is characterized with dominant frequency and frequency band (Figure 1).

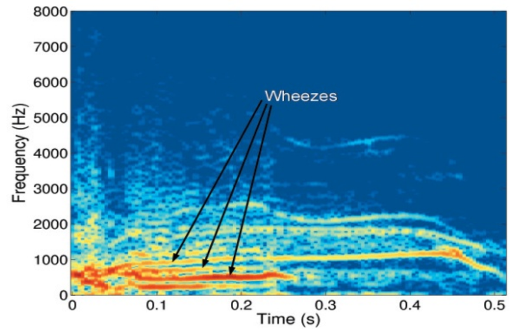

Figure 1. Power spectrogram for half-second recording of breathing sounds with pathological segments in range to 1 kHz

Methods for automatic detections of pathological artifacts could be divided into two basic categories [1] - [9].

First category contains methods based on harmonic analysis (FFT) and its basic applications. These methods use evaluation of amplitudes in computed spectrograms or CSAs (CSA = Compressedd Spectral Array). Methods are often completed with empirical decision and thresholding of amplitude, frequency, duration and number of pathological statuses. Advantage of these methods is in their relative simplicity, fastness and suitability to answer the question of presence of pathological segments in recording and their basic parameters.

Second category of methods is based on extraction of high level features of analyzed sub-sequences. These features are elements of feature vectors. Harmonic analysis is also input for these methods, but in the role of additive tool for feature extraction. Feature vectors are the key components for classification process which is sophisticated mean for diagnosis support. Training of classification algorithm or neural network requests wide statistical group of patients (wide group of recordings with and without pathologies) for creating fine (accurate) classification classes. Classification is modern and developing task in signal processing which brings detailed segmentation of analyzed signal. Basic methods can be as follows:

a. *MFCC – Mel-Frequency Cepstral Coefficients;*
b. *LPC – Linear Prediction Coefficients;*
c. *AR Model;*
d. *Multivariable AR model;*
e. *SVM – Support Vector Machine;*
f. *GMM – Gaussian Mixture Models;*
g. *SVD – Singular Value Decomposition – for feature vector reduction*
h. *PCA – Principal Component Analysis – for feature vector reduction.*

An interesting research work comes from R. J. Riel and his team from Brazil [10], where wheezing is detected by conversion of spectrogram obtained by Fourier analysis to the image. Wheezing in the spectrogram is shown as horizontal system of frequency peaks in the range up to 1 kHz. These peaks are selected by image thresholding, which are next converted to the spectrum after shape analysis and thus wheezing selected during this step is classified in multilayer perceptron (Figure 2). The accuracy of this method ranges from 92 to 94%. Accuracy depends on the occurrence of distracting sounds and noise at specific frequencies. Record length for analysis was tentatively set for at least 5 seconds (while breathing cycle has a standard length of 2 seconds). The authors acknowledge the possibility of optimization algorithms for use in real-time.

Present methodics for detecting pathologies in breathing sounds is based on 24-hour recording (similar to "holter" monitoring), its transmission to computer and offline digital processing. Development of DSPs (Digital Signal Processors) and their peripherals makes possibility to do this analysis as real-time and complete whole detection system with "threat sense" module for acute status mainly for pediatric patients.

From medical point of view, it is necessary to specify suitable group of investigated patients. Optimal statistical group in the process of designing of biomedical application plays key role for setting up the parameters of algorithms, mainly for developing problematics of signal identification and classification.

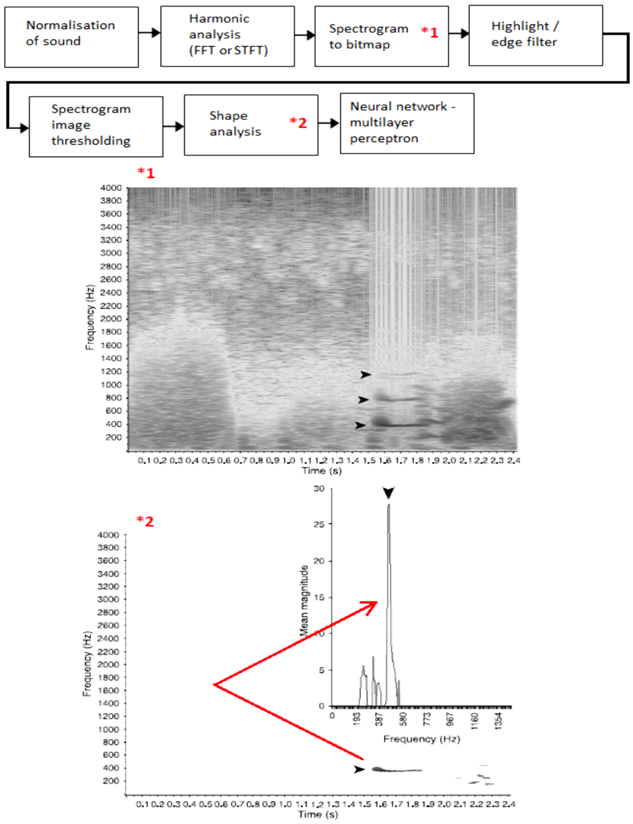

***Figure 2**. Principle of detection and classification of wheezing with respiratory spectrogram conversion sounds and neural network*

VIRTUAL INSTRUMENTATION MODULES

Currently, there are several types of automatic detectors for wheezing and other sound phenomena. The algorithm is, of course, know-how of particular manufacturer. Websites inform that general tool is classic FFT or short-time (STFT) Fourier analysis, where its sensitivity is around 91% and a specificity of 89%. Audio recording is done via contact piezoelectric sensors or pressure-sensitive switches, which application can be problem in young pediatric patients. Random movement can cause the occurrence of intrusive sound elements, which must be recognized, selected and removed. From this perspective, non-contact recording using a sensitive microphone eliminates some discomfort senses of patient (child).

Literature overview for last decade brings information about range of sampling frequencies used for audio recordings from units of kHz (4, 5, 8 kHz) to 22 kHz. Selection of microphone with upper cut-off frequency for example 40 kHz can answer the question, if the signals contain potential high frequency artifacts. Condenser microphones satisfy this condition. [11]

Higher sampling rates put higher requirements on DAC / ADC converters, memory devices of DSPs and time for analysis (computing power). But higher sampling frequencies can make final analysis more accurate. Fast Fourier Transformation (FFT) and its derivatives (e.g. cepstral analysis, power spectrograms or feature extraction for classification process) are basic operations with raw signal. Relevant *literature specify optimal block of data (input for analysis) as 20-100 ms: for sampling rates to 10 kHz the FFT is 256 – 1024 point; for higher sampling frequencies the FFT is 2048 or 4096 point. But this fact is not problem for hardware implementations of FFT in modern DSPs. Hardware solution for harmonic analysis significantly decreases time consumption calculating time in the side of DSP core. We can also apply wide palette of lowpass or noise killing filters, which create basis of implemented tools for each good DSP [12] -[17].*

LabVIEW Development system from National Instruments Company is complex environment for designing applications in many fields of interest. In our work we have successfully started implementation of LabVIEW virtual instruments and relevant hardware peripherals in a place of Sleep Laboratory in Clinic of Children and Adolescents in Faculty hospital in Martin (Slovakia). LabVIEW toolboxes Sound and Vibrations and Signal Express are suitable to cover the basic needs for creating efficient tools in modern respirology. On the other side, LabVIEW virtual instruments can replace many specialized and expensive devices.

Implementation and use of LabVIEW in our work can be divided into following phases: sound acquisition with NI DAQ means, sound processing and representation (diagnostic support).

ANALYSIS OF SOUND RECORDINGS

Condenser microphones are suitable for wide range of measurement applications. Their advantages are the highest sensitivity from all types of microphones and high level of fidelity. Each condenser microphone contains two thin metallic plates which create classical condenser. Supplying circuit generates electric potential in the condenser. On of these plates is solid electrode and the second is movable (in the function of acoustic membrane). Mutual movement of electrodes generates capacity changes and output voltage. Membrane thickness is several micrometers and is covered with precious metal (gold) – similar technology is used for transistors. Capacity is converted to output voltage thank to soft power supply or preamplifier with very high input impedance. The first microphones were constructed with tubes.

It is necessary to have distance between membrane and preamplifier very small. Membrane diameter is usually 1 inch (2.54 cm). Diameter of membrane implies upper cut-off frequency of microphone. Merchants often distribute microphone sets with several membranes of various diameters and sensitivities. With special membrane insert we can significantly influence directional characteristics of microphone.

Preamplifier is a important part of each microphone set. It adjust level of acquired signal to the acceptable one for purposes of digital processing. Preamplifiers also contain several noise-killing filters or corrections.

In experimental measurement in sound acquisition phase we used following components (Figure 3): preamplifier and microphone set Robotron 00 017, measurement I/O card NI PCI – 6229 with BNC – 2120 terminal, PC with LabVIEW toolbox Sound and Vibration.

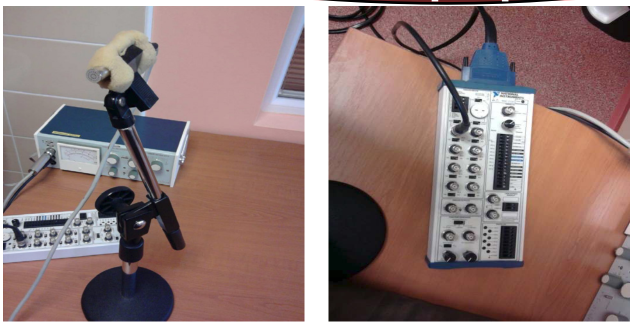

Figure 3. *Components for sound acquisition*

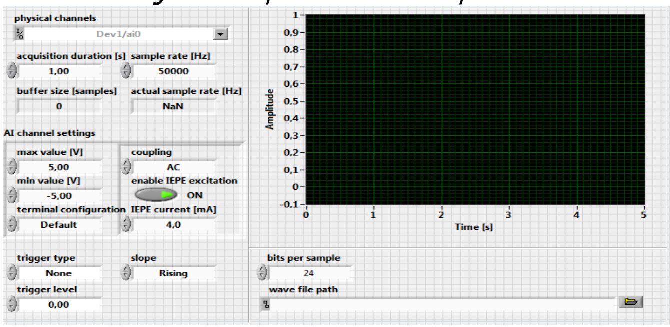

Figure 4. *Sound recording LabVIEW module*

Microphone was placed over patient's bed in Sleep Laboratory room and signal was transmitted to computer via cable to control room. In LabVIEW sound recording module user can define basic parameters for wave file: bits per sample, coupling, voltage range, acquisition duration, sampling rate and many other parameters (Figure 4).

LabVIEW I/O card NI PCI-6229 enables to acquire 16 independent sound (voltage) channels simultaneously, so we can obtain multiple data from one patient or breathing sound from multiple patients in one time. Sampling frequency can reach 250 kHz, but its value depends on microphone upper frequency (40 kHz in our case).

EXPERIMENTAL RESULTS

LabVIEW contains many tools for basic or advantage signal processing and statistics. After acquisition phase, recorded sound is converted to discrete vector. To evaluate LabVIEW possibilities for sound signal processing for respirological purposes we recorded sounds from three children patients with acute bronchitis and symptoms of wheezing. The sound was sampled with frequencies of 50 kHz and duration of each sample was 5 seconds (Figure 5).

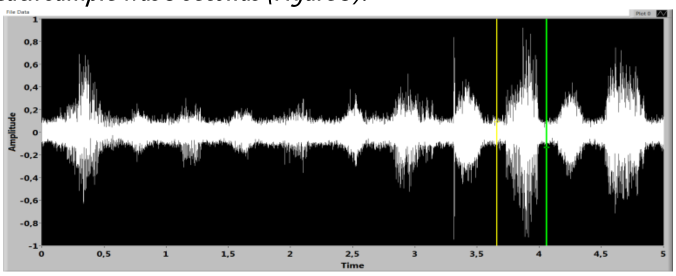

Figure 5. *Sound waveform of patient with acute bronchitis and symptoms of wheezing*

In designed LabVIEW module we can provide manual or automated segmentation of obtained signal and calculate basic parameters for selected segments: maximal or minimal value, mean value, correlation factors, FFT spectrum, PSD or cestrum. In Figure 6 we can see Fourier spectrum of selected region in waveform in Figure 5.

Spectrogram of entire sound file from Figure 5 is displayed in Figure 7 (interlaced windows with size of 2048 samples, representing 50 ms frames).

Calculation of statistical parameters and basic features in defined shifting window is a base for automatic segmentation or searching for simple breathing phases. Applying segmentation and feature extraction process for statistically significant group of patients enables to create references and templates for early detection of pathologies in breathing sound phenomena and enables to start relevant therapy. This fact significantly increases the possibilities of patients' quality of life.

Following some approaches from [10] it is very simple to convert spectrogram to bitmap (LabVIEW toolbox IMAQ) with function ArrayToColorImage. Some significant features visible in frequency domain can be obtained by advanced image algorithms: Color, geometrical or pattern matching and position of detected object can be transformed back to position in waveform.

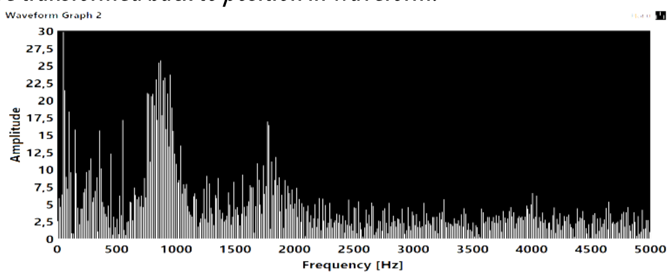

Figure 6. *A part of FFT spectrum of selected segment from sound waveform limited to 5 kHz for detailed view*

CONCLUSIONS

From the first experiments we can see, that virtual instrumentation can be fully implemented to clinical environment. Expensive and specialized detectors can be replaced with universal I/O cards and sensors. LabVIEW contains many tools and algorithms for acquisition and processing of biological signal converted to discrete vectors. Extracted signal features from spatial or frequency domain are the key information for advanced methods of pathological sound phenomena classification. On the other side, universal I/O devices support multi-channel data logging or acquisition of combined signals (sounds, potentials, video signals, signals from chemical sensors, etc.) and virtual instrumentation becomes a strong "weapon" for increasing of life quality especially in children patients.

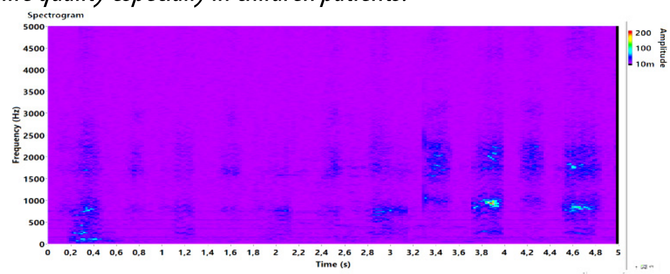

Figure 7. *Spectrogram of entire 5 second sound recording limited to 5 kHz with significant wheezing activity in range to 2 kHz*

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[1.] Neven LOVRIN, [2.] Željko VRCAN

THE INFLUENCE OF ENGINEERING ETHICS ON ECOLOGY AND SUSTAINABLE DEVELOPMENT

[1-2.] University of Rijeka, Faculty of Engineering, Vukovarska 58, Rijeka, CROATIA

Abstract: Engineering is an important and learned profession, which has a direct and vital impact on the quality of life for all people. Engineers have to be aware of the fact that by using available engineering technologies it is possible to provide abundance for all human beings, but also to destroy all life on Earth. Accordingly, engineers should be committed to improving the environment to enhance the quality of life and to sustain the balance in nature. They shall hold the safety, health and welfare of the public as paramount, and strive to comply with the principles of sustainable development.
Keywords: ethics, ecology, sustainability, responsibility, spiritual intelligence

INTRODUCTION

The end of the twentieth and the beginning of the twenty-first century are marked by developments in science which is considered to be the basis of the greatest quantitative and qualitative changes in history. We are witnesses to great benefits to mankind stemming from contemporary engineering development. The nuclear and space age that we live in, encourage the vigorous progress of science. Human technologies are developing very fast. Mechanization, automation and computerization of production processes have lessened the hazards to human physical integrity, but in spite of that, man's psychic and moral integrity in his working environment has been increasingly endangered. Modern technology has a deep impact on humankind and all life on Earth. Unfortunately, we frequently are witnesses of more and worse or even tragic consequences of scientific and technological advances markedly caused by neglecting moral principles in people's activities. The decisions and actions of engineers seriously affect the world we live in, and society at large. Engineers have to be aware of their responsibility, dignity and ethics as they make choices during their professional practice and they should not think only about profit. Therefore, a clear understanding of engineering responsibility, dignity and ethics is needed like never before.

Engineering ethics, as the field of applied ethics, is the application of philosophical and moral systems to the proper judgment and behavior by engineers in conducting their work, including the products and systems they design and the consulting services they provide. Thus, engineering ethics is defined as the rules and standards governing the conduct of engineers in their roles as professionals, and is concerned with determining the standards in engineering ethics and applying them to particular situations.

Viewing ethics as core values of human life leaves us with many important questions. Real ethics or the values behind them cannot and should not change with time, although their expression or focus may change. But nowadays we can see that human morality has declined drastically and that the ethical standards in society are very low. Engineering really improves and enriches human life but also endangers it. We have to be aware of the fact that by using available engineering technologies it is possible to provide abundance for all human beings, but also to destroy all life on Earth. Therefore modern engineers have to study and apply ethical codes, doctrines and principles in their professional engineering practice.

In the modern era, engineering profession is no longer a pure technical discipline. Therefore it is no longer possible to practice engineering without regard for the ethical context. Many engineers will face unethical situations beyond their control during their careers. However, the situation in which the engineer will take action based on the ethical dilemma, is a matter of personal choice e.g. a change of workplace or attempting to change things from the inside [1].

CONSEQUENCES OF NUCLEAR POWER PLANT DISASTERS

Nuclear power is one of the most powerful technologies humans have developed. Whether in power plants or more obviously in weapons, nuclear fission and fusion release tremendous energies and lethal byproducts. This is human power at its mightiest, and therefore ethics must here be at its mightiest as well. But it is not, hence disaster. The moral imperative with immense power is to care for it with great responsibility, to control it and direct it towards the good. It is obvious that with great power comes great responsibility.

Unlike fossil fueled power plants which stop generating heat when the fuel supply is cut, nuclear reactors generate heat until the main fission reaction has been shut down and all fission byproducts have decayed to a reasonable level. Therefore, a cooling system failure leads to a reactor core meltdown. Technology could prevent this nuclear calamity if only it is properly applied to the problem. Science could gauge the risk, and technology could mitigate it more effectively. We need to step up and take responsibility. We have more power than we admit. And in choosing not to act, we are choosing to accept the risk of disaster.

Examples of possible ethical dilemmas, regarding nuclear power plant disasters, that may occur, are discussed on the following cases.

Case 1: Chernobyl Nuclear Power Plant Disaster

The large environmental disaster, on 26 April 1986, caused by the meltdown at the nuclear power plant near Chernobyl, Ukraine, dramatically changed the world's opinion about using nuclear reaction for power [2, 3]. The Chernobyl nuclear power plant was built in the wooded marshlands of northern Ukraine, approximately 80 miles north of Kiev. Its first reactor went online in 1977, the second in 1978, third in 1981, and fourth in 1983; two more were planned for construction. A small town, Pripyat, was also built near the Chernobyl nuclear power plant to house the workers and their families.

The unit 4 reactor was to be shut down for routine maintenance on 25 April 1986. It was decided to take advantage of this shutdown to determine whether, in the event of a loss of station power, the slowing turbine could provide enough electrical power to operate the main core cooling water circulating pumps, until the diesel emergency power supply became operative. The aim of this test was to determine whether cooling of the core could continue to be ensured in the event of a loss of power. Adequate coolant circulation following completion of the test was secured by arranging power supplies to four of the eight pumps from station service power; the other four pumps were supplied by unit service power. This type of test had been run the previous year, but the power delivered from the running down turbine fell off too rapidly, so it was decided to repeat the test using the new voltage regulators that had been developed. Unfortunately, this test, which was considered essentially to concern the non-nuclear part of the power plant, was carried out without a proper exchange of information and coordination between the team in charge of the test and the personnel in charge of the safety of the nuclear reactor. Therefore, inadequate safety precautions were included in the test program and the operating personnel were not alerted to the nuclear safety implications of the electrical test and its potential danger. Two electrical engineers, not nuclear but electrical engineers were in charge of the control room.

The shutdown and test began at 1 a.m. on April 25th. To get accurate results from the test, the operators turned off several of the safety systems, which turned out to be a disastrous decision. In the middle of the test, the shutdown had to be delayed nine hours because of a high demand for power in Kiev. The shutdown and test continued again at 11:10 p.m. on the night of April 25th. Just after 1 a.m. on April 26th, the reactor's power dropped suddenly, causing a potentially dangerous situation. The operators tried to compensate for the low power but the reactor went out of control. If the safety systems had remained on, they would have fixed the problem; however, they were not. It was discovered that valves were padlocked in the open position so that they would not automatically shut down and turn off this experiment. The reactor exploded at 1:23 a.m. Two explosions were reported, the first being the initial steam explosion, followed two or three seconds later by a second explosion, possibly from the build-up of hydrogen due to zirconium-steam reactions. Fuel, moderator, and structural materials were ejected, starting a number of fires, and the destroyed core was exposed to the atmosphere (Figure 1). One worker, whose body was never recovered, was killed in the explosions, and a second worker died in hospital a few hours later as a result of injuries received in the explosions.

The world discovered the accident two days later, on April 28th, when operators of the Swedish Forsmark nuclear power plant in Stockholm registered unusually high radiation levels near their plant. When other plants around Europe began to register similar high radiation readings, they contacted the Soviet Union to find out what had happened. The Soviets denied any knowledge about a nuclear disaster until 9 p.m. on April 28th, when they announced to the world that one of the reactors had been damaged.

While trying to keep the nuclear disaster a secret, the Soviets were also trying to clean it up. At first they poured water on the many fires, and then they tried to put them out with sand and lead and then nitrogen. It took nearly two weeks to put the fires out. Citizens in the nearby towns were told to stay indoors. Pripyat was evacuated on April 27th, the day after the disaster had begun; the town of Chernobyl wasn't evacuated until May 2, six days after the explosion.

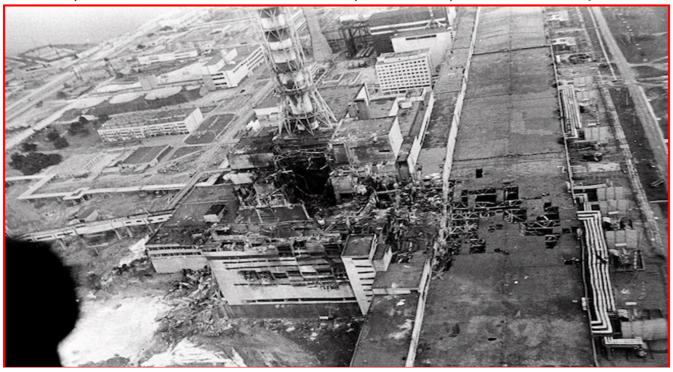

***Figure 1** – The nuclear reactor after the disaster [4]*

Physical clean-up of the area continued. Contaminated topsoil was placed into sealed barrels and radiated water contained. Soviet engineers also encased the remains of the fourth reactor in a large, concrete sarcophagus to prevent additional radiation leakage. The sarcophagus constructed quickly and in dangerous conditions, had already begun to crumble by 1997. An international consortium has begun plans to create a containment unit that will be placed over the current sarcophagus. It is expected to be completed in 2013. It is estimated that the radiation from the Chernobyl disaster was 100 times more powerful than the bombs dropped on Hiroshima and Nagasaki. Thirty-one people died shortly after the explosion, but thousands more will die from the long-term effects of radiation.

The accident caused the largest uncontrolled radioactive release into the environment ever recorded for any civilian operation, and large quantities of radioactive substances were released into the air for about 10 days. This caused serious social and economic disruption for large populations in Belarus, Russia and Ukraine. Technological disasters, unfortunately, cannot be broken down into one single root cause. The Chernobyl disaster is no exception to this principal.

Chernobyl shows the frequent disjuncture between science and technology. This can be shown by looking at the control rod design flaw. This flaw had to do with the speed in which control rods could be inserted. In reactors throughout the rest of the world, this process takes about two seconds. However, at Chernobyl, full insertion took about twenty seconds which was much too slow and contributed to the runaway of the core. The Chernobyl reactor had two crucial design flaws. First, it used graphite (carbon) instead of water to "moderate" the neutrons, which makes possible the nuclear reaction. The graphite caught fire in April 1986 and burned for four days. Water does not catch fire. Second, Chernobyl had no containment structure. When the graphite caught fire, it spouted a plume of radioactive smoke that spread across the globe. A containment structure would have both smothered the fire and contained the radioactivity.

The RBMK reactor was the type involved in the Chernobyl disaster. RBMK is an abbreviation for the Russian reaktor bolshoy moshchnosti kanalniy which means High Power Channel-type Reactor, and describes a class of graphite-moderated nuclear power reactor which was built in the Soviet Union for use in nuclear power plants to produce nuclear power from nuclear fuel. RBMK reactors don't have an exhaust gas system or a containment structure. A containment structure, similar to those built on reactors all over the world, would not only have slowed the release of radioactive material but significantly reduced the amount released, as this type of containment system is highly effective.

During the entire time the Chernobyl was active, no emergency plans were ever created. Because of this, local authorities were completely unprepared for the disaster. There weren't any medical supplies, protective clothing, or even devices to measure radioactivity on hand. This unpreparedness also contributed to an inefficient evacuation. For example, the city of Pripyat, which lies less than five kilometers away from ground zero, wasn't even informed of the explosion until thirty-six hours afterwards. It also took seven days to ban the consumption of local agricultural products. These mishandlings led to even higher mortality and morbidity rates [5].

As a result of the Chernobyl accident, tens of thousands of hectares of forests have experienced massive radioactive contamination. These were mainly single-crop plantings of Scotch pine (Pinus silvestris). It wasn't just people, animals and trees that were affected by radiation exposure at Chernobyl, but also the decomposers: insects, microbes and fungi. As a consequence, trees in the infamous Red Forest (Figure 2), an area where all of the pine trees turned a reddish color and then died shortly after the accident, did not seem to be decaying, even 15 to 20 years after the meltdown. Normally, in the areas with no radiation, 70 to 90 percent of the leaves were gone after a year. But in places where more radiation was present, the leaves retained around 60 percent of their original weight. Obviously radiation inhibited microbial decomposition of the leaf litter on the top layer of the soil and nutrients aren't being efficiently returned to the soil [6, 7, 8].

The Red Forest refers to the trees in the 10 km^2 surrounding the Chernobyl Nuclear Power Plant within the Exclusion Zone. The name Red Forest comes from the ginger-brown color of the pine trees after they died following the absorption of high levels of radiation from the Chernobyl accident (Figure 2). The site of the Red Forest remains one of the most contaminated areas in the world today [6, 7, 8].

Unfortunately, Chernobyl is a costly lesson in technological disasters. Many say the root cause of the accident is found in the human elements and although this may be the largest contributor, one also has to look at the technical design, organization and socio-cultural factors. But it is clearly evident that what blew up Chernobyl was not a lack of knowledge. It was a lack of ethics. That's a very important lesson for the 21st century.

***Figure 2** – Red Forest - dead forests in the 10 km^2 surrounding the Chernobyl Nuclear Power Plant [6].*

Case 2: Fukushima Daiichi Nuclear Power Plant Disaster

On Friday, March 11, 2011, one of the largest earthquakes, measuring 9.0 on the Richter scale, in the recorded history of the world, occurred on the east coast of northern Japan. This earthquake also generated a major tsunami, causing nearly 20,000 deaths [9]. Electricity, gas and water supplies, telecommunications, and railway service were all severely disrupted and in many cases completely shut down. Eleven nuclear reactors at four nuclear power plants in the region were operating at the time and all shut down automatically when the quake hit. Subsequent inspection showed no significant damage to any from the earthquake [10].

Not far from the epicenter of this quake, within the Fukushima Prefecture, was the Fukushima Daiichi nuclear power complex, including three functioning and three off-line boiling water reactors. After the earthquake, the power of the plant was lost. Emergency diesel generators provide power for the emergency core cooling systems for a short time. Following a major earthquake, a 14 meters tsunami overtops the seawall, designed to protect the plant from a *tsunami of 5,7 meters, disabled the diesel generators power supply and cooling of three Fukushima Daiichi reactors, causing a nuclear accident on 11 March 2011 [9, 10]. All three cores largely melted in the first three days. These disruptions severely affected the Fukushima Daiichi nuclear power plant, causing a release of radioactive materials from the reactors (Figure 3). A large amount of radioactive water has leaked from a holding tank at Fukushima Daiichi nuclear power plant in to the ocean. Tokyo Electric Power Company (TEPCO) admitted that up to 20 trillion becquerels of cesium-137, 10 trillion becquerels of strontium-90 and 40 trillion becquerels of tritium entered the ocean via groundwater, between May 2011 and August 2013. European Union study has determined that just 3 months following the 2011 Fukushima Daiichi disaster, the land area larger than 20,000 square miles around Fukushima was contaminated with radioactive nuclides. Cesium and radioactive iodine were among them. In Canada, USA and Mexico contaminated ocean water from Fukushima Daiichi was also found, as well as contaminated seafood and tuna fish [11, 12]. More than 43 million people in Japan were likely exposed to these cancer-causing elements [13]. These radioactive substances still pour into the Pacific to this day, as determined by a team of scientists [11, 12].*

This is an overview of the nuclear disaster. Who are to blame for it? Recently, some critics began to focus on the negligence of the management side in TEPCO [14, 15]. They say a decisive factor of this disaster consists in the misjudgment of the managers. What about engineers at the site? Did they take proper action? With regard to the action taken by the engineers as subordinates in TEPCO, they did their best in contrast with their managers [14]. What about the designers of the reactors? It is American company, General Electric (GE) that is often mentioned in this context. Indeed, the designs depended on ideas of GE's. Some Japanese engineers recently confessed that they did not have enough knowledge to criticize GE's idea at that time [14]. The problem is that all cooling systems in Fukushima Daiichi nuclear power plant required electrical power. Thus, in the case of a station black out, they all stop working. And this exactly happened, as emergency diesel generators were disabled by the tsunami and caused a station blackout. The subsequent lack of cooling led to explosions and meltdowns at the Fukushima facility, with problems at three of the six reactors.

What about the responsibility of seismologists? In face of the earthquake, not a few seismologists in Japan mentioned their defeat, pointing out that seismologists admitted the limitation of their science: unpredictability of an earthquake [14]. Every year, a large amount of money is spent in Japan in huge facilities to predict earthquakes, but earthquakes cannot be reliably predicted. Of course, unpredictability of earthquakes does not imply uselessness of seismology. Unfortunately, it is obvious that the construction of nuclear power plants is essentially not concerned with the researches of seismology.

The Fukushima Daiichi nuclear plant is located in Japan, which, like the rest of the Pacific Rim, is in an active seismic zone. The International Atomic Energy Agency (IAEA) had expressed concern about the ability of Japan's nuclear plants to withstand seismic activity. At a 2008 meeting of the G8's Nuclear Safety and Security Group in Tokyo, an IAEA expert warned that a strong earthquake with a magnitude above 7.0 could pose a serious problem for Japan's nuclear power stations [16].

Perhaps the Fukushima Daiichi nuclear plant was not adequately located or engineered? It probably should not have been built at all, or if it had to be located where it is, it should have been more strongly constructed and had better backup systems.

The nuclear crisis in the Japanese power plant at Fukushima also raises profound environmental ethical questions about risk and how we handle it. Fukushima Daiichi was fatally crippled during the historic devastation caused by the earthquake and tsunami on 11 March 2011 that ravaged Japan's northeastern coast. Radiation releases caused large evacuations, concern over food and water supplies, and treatment of nuclear workers. Radioactive contamination was discovered in air, soil, water, sea, vegetable and milk samples. For years, TEPCO, the operator of the Fukushima power plant, has been widely criticized for deadly accidents and improper inspections [15, 16]. The Fukushima disaster is another ethical example of the tragic nadir in a history of poor management at the company's nuclear facilities.

Figure 3 *– Fukushima Daiichi nuclear disaster - four damaged reactor buildings [9].*

The lives of hundreds of thousands of people continue to be affected by the Fukushima nuclear disaster, especially the 160,000 who fled their homes because of radioactive contamination, and continue to live in limbo without fair, just, and timely compensation. They have only a false hope of returning home, yet the Japanese government is eagerly pushing to restart reactors, against the will of its people, and without learning true lessons from Fukushima.

The Fukushima and Chernobyl nuclear disasters showed us once again that nuclear reactors are potentially dangerous. None of the world's 436 nuclear reactors are immune to human errors, natural disasters, or any of the many other serious incidents that could cause a disaster. Millions of people who live near nuclear reactors are at risk. The disaster in Fukushima Daiichi nuclear plant is clearly worse than the 1979 partial meltdown at Three Mile Island in Pennsylvania, yet not as grave as the 1986 explosion at the Chernobyl nuclear plant, which spread radioactive material over large portions of Europe.

THE ROLE OF ENGINEERS IN SUSTAINABILE DEVELOPMENT AND ECOLOGY

On the basis of the two presented cases, many ethical questions, dilemmas and considerations could arise. It is not easy to make a compromise between progress and ecology, between reliability and sustainability, between technically practical, viable, safe and economic requirements, between moral responsibility to people and the whole environment and obligations to future generations. Engineers have obligations to future generations that could be harmed by irresponsible engineering activities, because it may take decades and generations for products and facilities to have adverse effects. They should not act using immoral and unethical rules and laws. Engineers should not have a profit in mind in the first place and they should not be bribed and corruptible. They should always keep in mind the moral responsibility and obligations toward society as a whole. Their professional ethical standards have to transcend commonly accepted morality.

Engineering ethics is a crucial matter essential for our survival. It is not an option or a luxury. The human race will not survive the 21st century using the engineering ethics of the 20th century. Why is that so? The nuclear and space age that we live in, encourage the vigorous progress of science. Human technology is developing very fast. But will human ethics have grown as strong? Regardless of its scale and power, any technology is governed by the ethics of its operator. In the case of the Chernobyl nuclear disaster, it seems that two engineers in charge of the control room, decided to experiment, to play with the nuclear reactor. Thereby they caused the biggest nuclear disaster so far. In the 19th century there was no machine, no power plant like today's nuclear power plant, that was dangerous to this extend that could cause such massive destruction as today's misuse of nuclear energy.

The main problem is that we have allowed our technology to get away from our ethics. We can do so much more now than we could in previous centuries. Therefore our ethical responsibility is so much more than it once was. Technology has changed ethics we just haven't fully realized that yet. Technology has changed ethics because technology has changed the scope of human action.

Engineering profession has a significant role to play in sustainability. Engineers work to enhance the welfare, health and safety of all, with the minimal use of natural resources and paying due regard to the environment and the sustainability of resources. Their work is influenced by the opportunities and challenges that sustainability brings. Engineers are the providers of options and solutions to maximize social value and minimize environmental impact. It can be summarized in six principles to guide and motivate engineers when making decisions for clients, employers and society which affect sustainability [17]: 1. Contribute to building a sustainable society, present and future; 2. Apply professional and responsible judgment and take a leadership role; 3. Do more than just comply with legislation and codes; 4. Use resources efficiently and effectively; 5. Seek multiple views to solve sustainability challenges; 6. Manage risk to minimize adverse impact to people or the environment.

The goal of sustainable development is to enable all people throughout the world to satisfy their basic needs and enjoy a better quality of life, without compromising quality of life for future generations. Sustainable development stands on two concepts: needs, for example the essential needs of the world's poor; and limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs.

According to Engineering Council [17], the following principles have been agreed in the UK to achieve sustainable development: 1. living within environmental goals; 2. ensuring a strong, healthy and just society; 3. promoting good governance; 4. achieving a sustainable economy; 5. using sound science responsibly. To accomplish all this goals and to be a engineer of a high quality, modern engineers have to study, not only engineering, but also ethics and philosophy in order to understand relationships between man, nature and the universe and thus to become a humanist who respects, protects and welcomes all life on Earth. They have to recognize the importance of sociological and cultural context of the engineering profession.

Modern engineers also have to develop spiritual intelligence. Spiritual intelligence can be described symbolically as the backbone of human consciousness, responsible for character building and meaning making. Developing spiritual intelligence is more of an experiential rather than a theoretical process. The language of spiritual intelligence is the language of the heart. Growing in spiritual intelligence, engineers grow in their action logic from the perception of "What I can get ..." to "What I can contribute ... ". The practice of self-reflection and contemplation enhances development of spiritual intelligence, and a depth of compassion and benevolence to all life on Earth develops as well. Thus, modern engineer will develop the ability to act with wisdom and compassion, while maintaining inner and outer peace (equanimity), regardless of the circumstances. All these qualities are necessary for contemporary engineer, in order to become a humanist who, while working in his profession, respects, protects and welcomes all life on Earth.

Danah Zohar [18] defined 12 principles underlying spiritual intelligence: 1. Self-awareness: Knowing what I believe in and value, and what deeply motivates me; 2. Spontaneity: Living in and being responsive to the moment; 3. Being vision- and value-led: Acting from principles and deep beliefs, and living accordingly; 4. Holism: Seeing larger patterns, relationships, and connections; having a sense of belonging; 5. Compassion: Having the quality of "feeling-with" and deep empathy; 6. Celebration of diversity: Valuing other people for their differences, not despite them; 7. Field independence: Standing against the crowd and having one's own convictions; 8. Humility: Having the sense of being a player in a larger drama, of one's true place in the world; 9. Tendency to ask fundamental "Why?" questions: Needing to understand things and get to the bottom of *them; 10. Ability to reframe: Standing back from a situation or problem and seeing the bigger picture or wider context; 11. Positive use of adversity: Learning and growing from mistakes, setbacks, and suffering; 12. Sense of vocation: Feeling called upon to serve, to give something back.*

Robert Emmons [19] defines spiritual intelligence as the adaptive use of spiritual information to facilitate everyday problem solving and goal attainment. He originally proposed 5 components of spiritual intelligence: 1. The capacity to transcend the physical and material; 2. The ability to experience heightened states of consciousness; 3. The ability to sanctify everyday experience; 4. The ability to utilize spiritual resources to solve problems; 5. The capacity to be virtuous.

Ancient Chinese people summarized all these highest virtues in three Chinese words: Zhen (truth, truthfulness), Shan (kindness, benevolence, compassion) and Ren (endurance, forbearance, tolerance) [20]. In ancient China when moral values still prevailed, there was only one law for judging a person – virtue (de - in Chinese language). Ancient Chinese people stressed cultivation of one's xinxing (a Chinese idiom for the mind or heart nature, moral character and ethics). A Chinese proverb says, "A man without any virtue is no more than a beast". When a person does not have any virtue left, he is no longer considered worthy of being a human and therefore should have no place in the human society. From this, one can see how highly virtue was regarded in ancient China. Therefore, virtue, ethics and moral should be deeply rooted in the history, society and culture of human beings [20].

CONCLUSION

Engineering ethics is a crucial point and essential for our survival. It is not an option or a luxury. Engineers have to be aware of ethics as they make choices during their professional practice. Therefore, a clear understanding and application of engineering ethics to ecology and sustainable development is needed like never before. Engineers must perform under a standard of professional behavior that requires adherence to the highest principles of ethical conduct including honesty, impartiality, fairness, and equity, and do so in the absence of bribe and corruption. They should also contribute to environmental protection and to sustaining the balance in nature. To be an engineer of a high quality one has to study, not only engineering, but also ethics and philosophy, thus to develop spiritual intelligence in order to understand relationships between man, nature and the universe and thus to become a humanist who respects, protects and welcomes all life on our blue planet, the Earth.

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[1.] Tomaz KOSTANJEVEC, [2.] Matej VOGRINČIČ

IMPROVED PRODUCT DEVELOPMENT APPROACH WITH MULTI-CRITERIA ANALYSIS

[1-2.] University Clinical Centre Maribor, Ljubljanska 5, Maribor, SLOVENIA

Abstract: *The early stages of the new product development process are most often defined as idea generation, idea screening, concept development, and concept testing. These stages represent the development of an idea prior to its taking any physical form. In most industries it is from this point onwards that costs will rise significantly. It is clearly far easier to change a concept than a physical product. The innovative approach has become an important aspect in the design and implementation of the organizational strategy. The multi-criteria (MC) model allows for the systematic planning of successful investments.*
Keywords: *product development, innovation, multi-criteria analysis*

INTRODUCTION

Multi-criteria decision-making or multiple-criteria decision analysis (MC) is a sub-discipline of operations research that considers multiple criteria in decision-making environments especially in field of early stage of product development. Usually are multiple conflicting criteria evaluated in making decisions from general specification of product to special detailed function.

A prime advantage of the improved methodology is the systematic approach, something that leads to the complete continuity throughout the whole investment cycle, even though it is already a primary tool in the early phases of the cycle.

During the application of the methodology, the number of ideas – originally in the form of futuristic projections and innovation potentials and then in detailed product concepts – is constantly being reduced. This reduction in the number of ideas through the so called idea funnel is necessary as the required work content is increasing as the ideas are becoming more and more concrete – there is a reduction in flexibility and agility available per idea.

It can be summarized that the described model of the MC analysis can be a possibility for PD in "fuzzy front end" stage. The MC approach is a powerful tool in terms of perception, resources considerations, and detailing with appropriate data support. What both concepts ("fuzzy front end" and MC) have in common is that they are based on empirical research, especially case studies of sanitary fittings. Hence, even across different companies, industries, and strategies of product and process development, the front end innovation challenges and threats seem to be very similar.

The purpose of the future analysis phase is the identification of innovation potentials and the formulation of specific innovation activities for the company. To start off with, general trends as well as more specific developments within the chosen formation fields are analysed. Following this, the impact these will have on the formation fields and the company in general is projected. Based on this, and taking into account the company potentials, innovation potentials are deduced which will correspond with future market or technology developments. Output from this phase is therefore information regarding the company innovation potential or more specific innovation tasks [1].

Today's computer aided design technology, for example, makes it relatively easy to create three dimensional (3D) models of a part. However, simultaneously translating inarticulate customer tastes into a product concept, or a verbal product description into visual styling designs and numerical specifications remain difficult. Similarly, the timing of problem solving in consecutive stages of development, such as prototyping or tool building, and the number of iterations in the design-build-test cycle may affect the overall lead time and the productivity of the development process [2].

During the application of the methodology, the number of ideas - originally in the form of futuristic projections and innovation potentials and then in detailed product concepts - is constantly being reduced.

The main requirement for a methodology used to plan technical innovation can be summarized by the innovation funnel presented in Figure1. The multi-criteria (MC) method used in the methodology is mapped and modified according to this relationship between the concreteness of an idea and the number of ideas. This means that the more concrete the formulation of an idea - depending on the stage within the planning timeframe - the more detailed and specific the relevant methods used become (push for creativity, analysis, evaluation etc.). The MC method is integrated in all stages of the innovation funnel. Figure 1 shows how computer-aided engineering (CAE) can be used. From that point of view a new product can be tested and examined in a virtual environment.

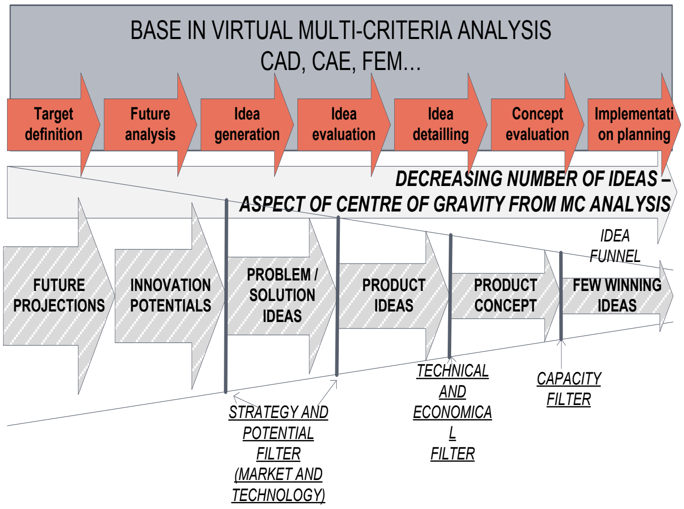

Figure 1 *– Successive choice or elimination of ideas and refining / focussing them and possible CAE use*

In our article we present a unique approach to a product development project in the area of an idea recognition and of investment idea evaluation in the early phase. This model has already been proven on various products and has already been used for the development of potential ideas with software such as CAE. It is the broad usage of computer software to aid in engineering analysis tasks and to build in the MC analysis in that virtual environment.

IMPROVED PRODUCT DEVELOPMENT APPROACH WITH MULTICRITERIAL ANALYSIS

It is useful for firms to regard their projects as living things. A PD is accepted only because the management believes that the combined technologies and market opportunities fit well with each other and with the firm. Concept testing and forecasting does not assure financial success but intended users agree that there is a need for something like the developed concept and want to try it out.

An early look and test of a potential product – prototype will also not assure success, yet it can say whether intended users like what they see. The marketing and developing engineer cannot guarantee success either, but he can assess whether the new item will be brought to the attention of potential new buyers. From the production point of view it is also possible to optimize the shape and material used for the prototype and final product.

In some cases the potential user does not know the purpose of a certain element in a product, in which case the functionality of a product is in a complete domain of engineers and they have to optimize the product though body optimization – for example weight and size. The software solution tested was SC/Tetra – from the CRADLE software which can, with simple operation and hi-speed computation, reduce the development time and costs.

Since the mid-seventies of the 20th century, CAE has advanced within most of mechanical engineered based industries rapidly enough that it is an indispensable part of the PD process. Companies which are using large-scale application of CAE in every phase of PD have an advantage. In fact, the timing of the PD phase has been shrinking continuously since the early nineties, largely due to the trust that the CAE has gained as a dependable tool for engineering decision-making for all major attributes. In comparison to the centuries, in which the maturity of traditional engineering methods can be measured, the CAE has been considered a viable engineering tool for two to three decades. The CAE is an emerging technology and its advantage is in robust engineering solutions.

The confirmation prototype is much more expensive to build and test, compared to the first production model. Obviously, this is the area where the future development in CAE methodology needs high priority. Learning about defects from the confirmation prototypes results in information that is too little too late. [5]

Sequential CAE analyses are needed to converge to the optimized solution with the minimal physical verification. Advantages are in the field of reliability/robustness based on multi-functional design optimization which is one of important tools that support achieving this goal.

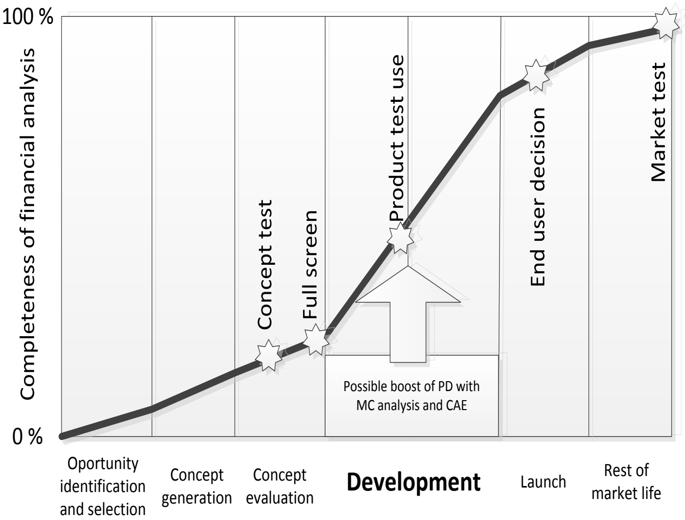

Figure 2 *– Financial analysis as a living thing: the life cycle of assessment [4]*

Figure 2 presents the organic approach with PD in product test use area where additional use of the CAE, such as computational fluid dynamics (CFD), can overlap with the process of product prototyping. CFD is a branch of fluid mechanics that uses numerical methods and algorithms to solve and analyse problems that involve fluid flows. Computers are used to perform the calculations required to simulate the interaction of liquids and gases with surfaces defined by boundary conditions. With high-speed supercomputers better solutions can be achieved. The on-going research yields software that improves the accuracy and speed of complex simulation scenarios such as transonic or turbulent flows.

A simulation can involve moving and rotating boundaries, also including passive motion by the surrounding flow and it can be used in a variety of turbulence models as well as a variety of analysable fluid multiphase flows and even in cavitations. In the field of free surface flow and in Figure 3 we can analyse aerodynamic noise which can give the engineer the opportunity to shape the body by reducing the air flow.

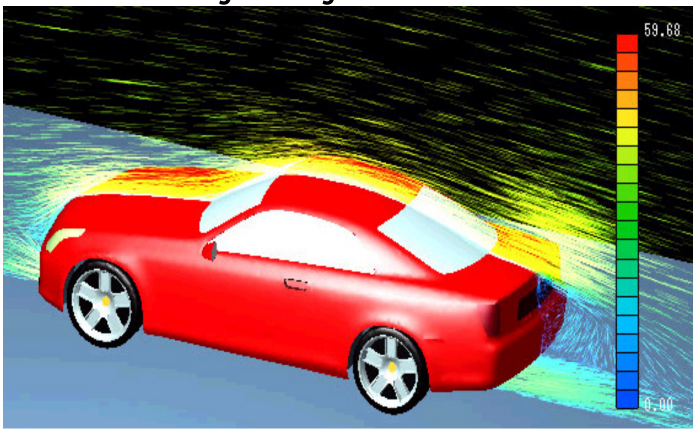

***Figure 3** – Analysis with multi-propose CFD unstructured mesh (SC/Tetra CRADLE)*

Besides strategic goals, for product innovation planning an analysis of the technological potentials is required. Here the enterprise potentials refer to the totality of all company capabilities, in answering requests for problem solutions and reacting quickly to new market requirements as well as to develop and apply new products and commercial success.

The analysis and collection of trends is a continual process used in the early clarification. A trend can be described as the basic direction of either a development or a development bias. The "trend scanning" takes place in different observation areas, which together form the observation field. It represents the global environment of the formation field. In the ideal case, detailed information on developments in single observation areas already exists in the business so that these can be analysed formation field-specifically.

If the trend-scanning in a business is established, a list of trends from the various observation areas exists, that is reviewed, updated permanently and/or analysed regarding its relevance. In addition to the available trends, the observation areas can be examined formation field-specific. Obviously, a complete analysis of the collection of trends is required.

CONCLUSION

Future product developments can be predicted independently from the current production boundaries. This gives development much more flexibility. Reliable trends for the most important product parameters can be evident from market demands.

The need for CAE engineers to enable the effective application of more efficient CAE methods is escalating. However, competitive pressures and the ever-growing need to keep PD costs within reduced money spend often lead to a reduction in the CAE headcount.

From the perspective of the decision makers within the industry, the continuous growth in the number of CAE engineers is not justified by the number of physical prototypes and tests that have not been realized.

In favour of the CAE is the fact that the reason for this is that while companies have spent generously to maintain a minimum level of required CAE resources, the customer requirements that are satisfied largely with the help of CAE have grown at a faster rate than in previous decades. This is especially true for the field of the automobile industry – the area of safety and relation quality / durability.

Figure 4 presents a simple operation and hi-speed computation to reduce development time and costs on all the managerial fields. All fields are well-balanced between functionality and usability to meet various demands from clients.

In empirical evaluations of projects and publicly provided goods, multi-criteria decision theory seems to be an appropriate policy tool, since it makes it possible to take into account a wide range of assessment criteria (e.g. environmental impact, distributional equity, etc.), and not simply profit maximization, as a private economic agent would do [6].

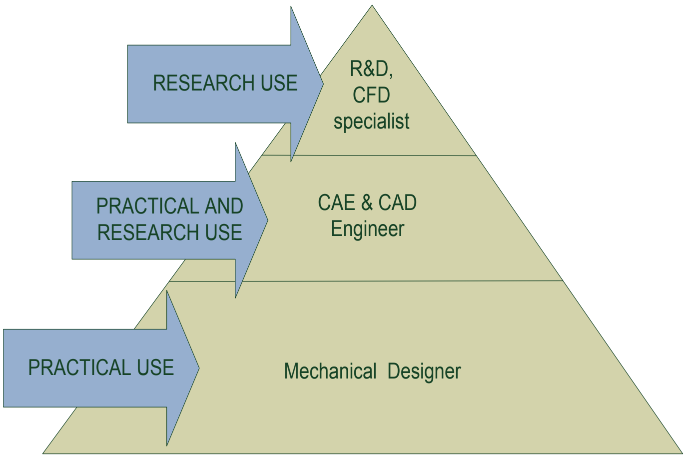

***Figure 4** – Use of CAE / CAD as opportunity for mechanical engineer in PD process*

Life cycles of technologies, products and processes are becoming ever shorter, so technological foresight is a very important aspect of their planning. In a time when foretelling the development of products is difficult and the price of error as steep as it is, the article offers a solution for the development of products through multidimensional analysis. Future products developments can be predicted independent from current production capabilities. This gives much more flexibility. Reliable trends forecasted in MD analysis can be evidential for the most important product parameters hence an idea generation route of product development can be established.

This concept can be applied in the development of mid-range washing machines, which according to mathematical results and in accordance with the time change, move from the direction of unexplored elements to the direction of product design.

In the presented model, the fulfilment of requirements within a company is not viable or technologically possible, capacities are not achieved or that is not in the strategy of the company. A graphic display makes it easier to show the direction of movement of the most important parameters within the company, through a visualization of the problem. Using inputs from the process of generating ideas, analysis by lead users and MC concept selection, the PD team creates a smaller set of high-potential product concepts and with a higher forecast ability set affective product diffusion. [7]

Following their concept the PD team gives the result with great potential. This means linking engineering solutions to customers' needs and vice versa not only on the analytical basis but also on the basis of future trends' mathematical analysis. In this paper we suggest further integration of the possibility introducing CIM methods into the development of new products directly, and by forecasting the trends based on years of experience. This model of developing products by multi-criteria analysis is useful for almost all large-scale products. [1]

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[1.] Michal WIECZOROWSKI, [2.] Thomas MATHIA,
[3.] Serge CARRAS, [4.] Damian SMIERZCHALSKI

SURFACE TOPOGRAPHY INSPECTION IN MULTISENSOR APPROACH

[1.] Poznan University of Technology, Division of Metrology and Measurement Systems, Piotrowo 3, 60-965 Poznan, POLAND
[2.] Ecole Centrale de Lyon, Laboratoire de Tribologie et Dynamique des Systèmes, 36 Av. Guy de Collongue, 69134 Ecully, FRANCE
[3.] ALTIMET, 1 bis Avenue des Tilleuls, F - 74200 Thonon les Bains, FRANCE
[4.] ITA, ul. Poznańska 104, 60-185 Skórzewo, POLAND

Abstract: *In contemporary solutions for surface asperities measurements some concepts appear where different sensors, basing on different physical principles are used. It is an idea from one side to measure various surfaces impossible to inspect with a standard tactile inductive probe, and from another to measure the same surface with several sensors. Thus it is possible to get more information and draw more complex and versatile conclusions. In the paper a concept of such a multisensor device was shown with a construction and some applications. Here, confocal probes as well as interferometric one and tactile sensors were used.*
Keywords: *multisensor, topography, surface*

INTRODUCTION

Modern systems for quality control require more and more versatility. With surface roughness it is sometimes critical issue, as different measurement techniques show different features causing variations in measurement results. Future trends show optics as interesting solutions, still such devices – despite their impressive speed of measurement - are nowadays very rare in industrial applications [1]. This is due to the fact that optical techniques tend to show some non-existing artifacts on the surface, what in some cases can significantly distort the whole analysis. On the other hand for more and more industry branches a need emerge to inspect surfaces too soft to be touched. This includes paper, skin, wood and biological material, bioengineering applications [2], but also plastics and sometimes graphite [3]. For this reason new ideas are tested and multisensor concept is one of them.

In many devices used in length and angle metrology manufacturers try to use different sensor obtaining thus a multisensor solution. It allows inspecting certain features with tactile and non-contact probes collecting data together and presenting measurement results together. Such examples are in CMMs where optical probes are used to compliment tactile ones or in 3D scanners where tactile probe is an auxiliary one for optics. Also in surface metrology such a solution can be very beneficial.

For this reason a concept appeared to create a multisensor device that would make it possible to measure roughness on different surfaces and to be introduced for production. This idea turned into a product is showed in this paper.

OPEN ARCHITECTURE AND MULTISENSOR CONCEPT

Altimet provides a large range of metrological solutions based on the profilometry technology (Fig. 1). The analyzed sample is scanned point by point on its surface.

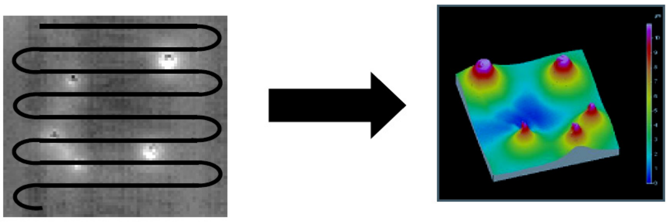


***Figure 1 –** Area scanning in optical profilometry*

This scanning can be performed by various optical contactless sensors or by a mechanical stylus. The open architecture of the systems makes it possible to embed several types of sensor in the same device. There are two ways to scan the surface:

1. *the sensor is fixed, and the object is placed on a movable stage. The movement of the stage is controlled in both directions (X and Y) with precision,*
2. *the other option is to move the all sensor system on top of the object.*

In both solutions, the 3D mapping of the surface is performed by adding the different measured scans. An open architecture of the system offers a wide range of sensors possible to use in surface measurements. Among them, there are different solutions, both tactile and non-contact ones, used for inspection of different features of surfaces. Starting with conventional tactile sensor it is possible to check surfaces on which diamond tip would not make any harm, including steel, ceramics and hard plastics. It is also possible to another tactile probe where measuring force is significantly reduced, *i.e. a micro force sensor. This is not making any scratches even on very soft materials, what make it possible to compare a tactile probe with optical one.*

Non-contact probes comprise many different confocal sensors, depending on required range and resolution. It works on the principle shown at figure 2. An incident white light pinhole is imaged through a chromatic objective into a continuum of monochromatic images along the Z-Axis, thus providing a 'color coding' along the optical axis. When an object is present in this 'colored' field, a unique wavelength is perfectly focused at its surface and then reflected into the optical system. This backscattered beam passes through a filtering pinhole into a spectrograph in order to analyze which wavelength has been perfectly focused on the object, and then accurately determine its position in the measuring field.

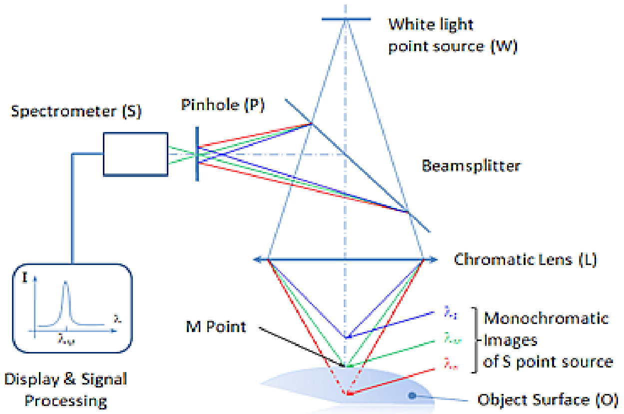


***Figure 2** – Working principle of confocal sensor*

The ranges of confocal sensors start from 110 micrometers and can reach as much as 27 millimeters.

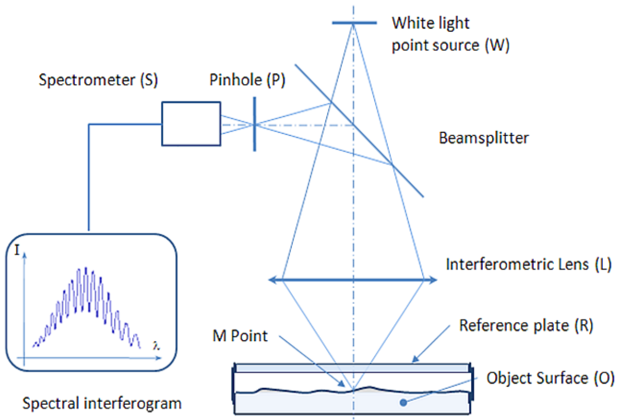


***Figure 3** – Working principle of interferometric sensor*

For more precise inspection an interferometric probe can be used. The working scheme was presented on figure 3. The light from a white-light point source W passes through an interferometric objective L and a reference plate R before it reaches the sample surface. The superposition of the light beams reflected from the sample surface and from the reference plate generates an interference phenomenon. The reflected beams pass through the interferometric lens L in the opposite direction, and arrive at a pinhole P which filters out all light rays except those originating from the object point M. The spectrometer S measures the channeled spectrum of the interference signal. The thickness of the air gap between the sample and the reference plate can be extracted with sub-nanometric resolution from the spectral phase of this spectrum.

If a measurement task is contour inspection more than purely asperities than a triangulation laser can be used. Furthermore, a system can be equipped with a CCD camera to precisely adjust a starting point or area on surface.

MEASUREMENT SYSTEM

The whole setup (Fig. 4) allows using different probes with relative distances calibrated to each other. Thanks to this feature it is possible e.g. first to use a CCD camera to find a place on the surface where roughness is to be measured. Second, a non-contact probe is applied and measurement is taken in the same place that was chosen with CCD camera. Afterwards it is possible to inspect the same (within repeatability of drives) place with another contact or non-contact sensor.

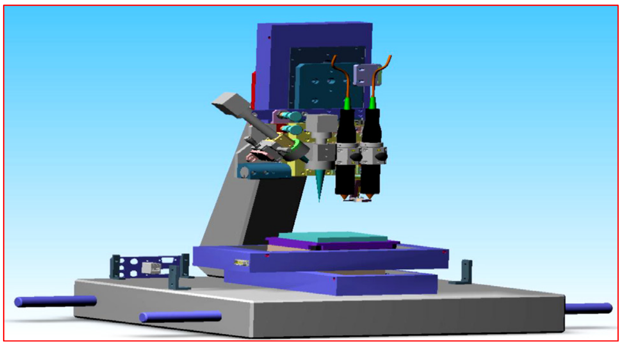


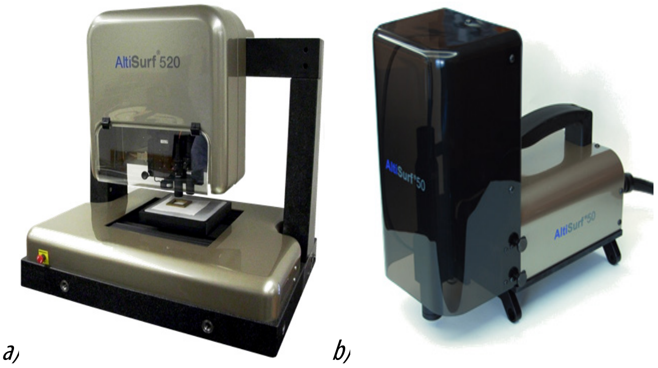
***Figure 4** – Open architecture and different sensors*

Such architecture allows using the device in multifunction configuration for different purposes:

- ✓ *to evaluate surface state parameters in polishing, erosion, grinding corrosion, tribology, fretting, adherence, rolling etc.,*
- ✓ *to elaborate flatness contact, vibration and acoustics, perform filtering,*
- ✓ *to calculate step-height features for steps and engravings,*
- ✓ *to execute reverse Boolean analysis for diameter of grinding tool, radius for tool settings, to make extraction from cylinders, spheres*
- ✓ *to check thickness of paper, film, mechanical parts, foils and boards or varnishes.*

The whole structure of open architecture concept is governed by a controller equipped with PheNix© Technology. PheNix© software is a toolbox of easy to use functions to program your measurements, calibrate, loop some actions, and select any of the sensors. PheNix© Technology means mostly modularity of the systems for a lab to line control and open architecture based on standards components available 'on the shelf'.

The measurement device was presented on figure 5a. It can have different table options from 100x100 mm to 300x300 mm and more for special requirements, equipped with precise DC motors with local flatness not exceeding 2 nm. Also Z traverse can vary from 100 mm to 300 mm. Traverse speed can reach 30 mm/s. Further rotary axis is also available. The device can work in automatic production mode with shop floor control card (green/red light), and through self-learning *function. On the other hand it can be also used in clean rooms. A portable version of presented concept allows to measure topography using confocal sensor (Fig. 5b). It has 25 mm x 25 mm x 25 mm strokes and can be located directly on top of large work pieces to be measured.*

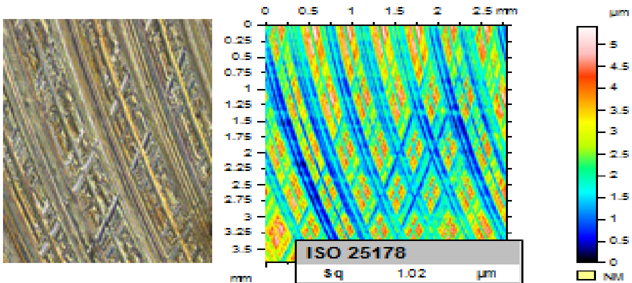


a) b)

***Figure 5** – A standalone multisensor profiler (a) and a portable topography measuring system (b)*

EXAMPLES OF MEASUREMENT TASKS

Looking at possible fields of application we should start with mechanical engineering and what is related to it: cutting, tribology, wear etc. [4]. In this example, a metal surface has been polished using a robot with different settings. A pertinent topography measure with an accurate post-processing treatment allow for the quantification of the effect of the various settings. An example of surface image is shown on figure 6.



ISO 25178		
Sq	1.02	µm
Ssk	0.777	
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Sp	3.43	µm
Sv	2.00	µm
Sz	5.43	µm
Sa	0.819	µm

***Figure 6** – A robot polished surface*

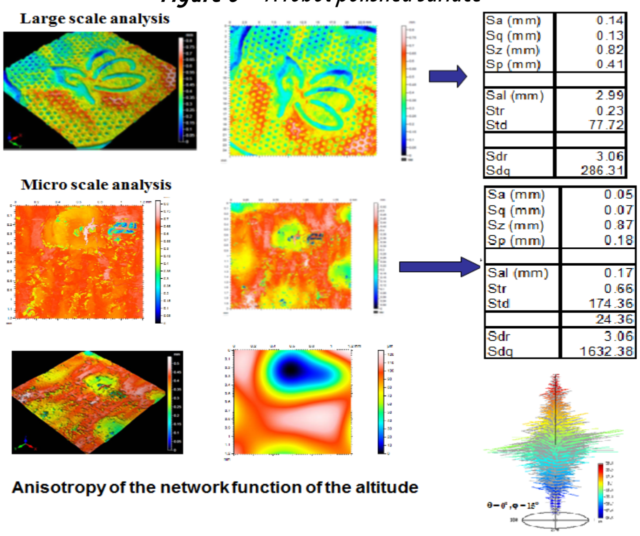

***Figure 7** – Multiscale tissue paper analysis*

As optical roughness measurements are very useful for paper measurements [5, 6], the next example shows multi-scale tissue paper analysis, concerning both: roughness and anisotropy (Fig. 7). Starting from large scale inspection it is possible to go down to micro scale analysis with parameters calculated for both scales. Furthermore modal analysis of the open porosity and fibers orientation as well as anisotropy of network function of altitude was presented.

Another important application for surface analysis is glass. Here, nano scratches were a matter of research using interferometric probe. The results are presented on figure 8.

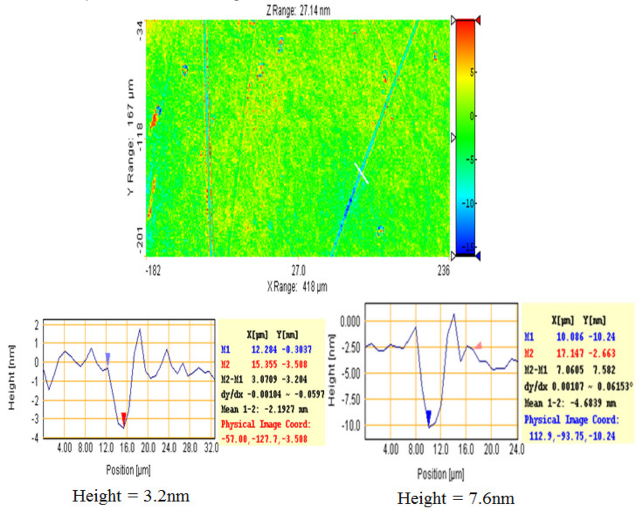

***Figure 8** – Analysis of nano scratches on glass*

Using the confocal sensor, one can determine the contact angle of liquid on a solid surface. This is particularly important for all the research works concerned with wettability [8]. Furthermore, the roughness of the solid can be taking into account and included in the calculations (Fig. 9).

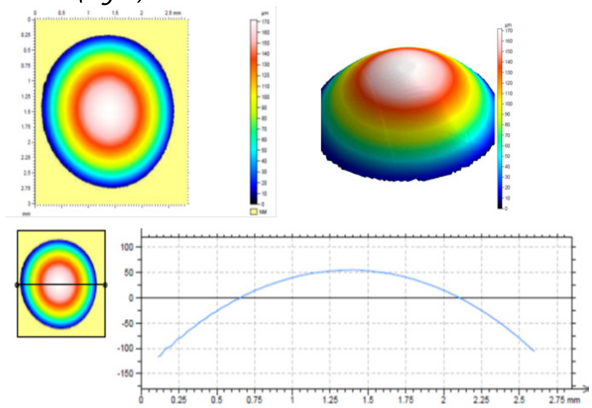

***Figure 9** – A drop of liquid on solid surface*

One of the unique attribute of the confocal technology, is measurement through a layer of glass. This is useful in biological applications [7]. Measurement through a glass layer is also a nice feature in the next presented application. By taking advantage of this interesting property, the evolution of a soft surface under compression can be studied. In this example, exactly the same area was measured at two stages of compression (the pressure is applied by the glass on top of the sponge). One can then calculate the porosity variation caused by the compression (Fig. 10).

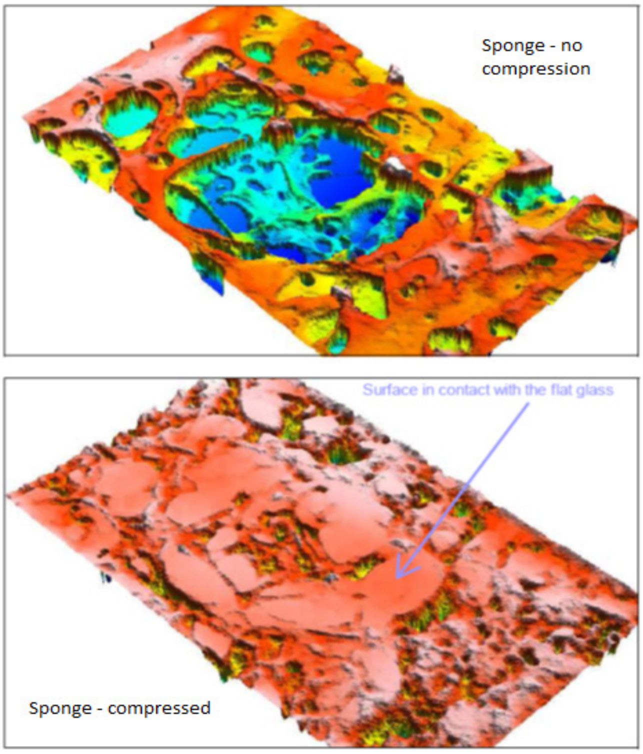

***Figure 10** – Sponge measurement in compressed and not compressed version*

These few examples show how big can be application range of multisensor profilometer. Different sensors can be used for different surfaces. Furthermore, in questionable results case, it is possible to measure the same area with two or more different sensors and compare them, verifying fidelity of representation.

Accuracy of the system after initial adjustment was verified on standards, manufactured according to ISO 5436 part 1. A and D type standards were used to get information regarding performance of tactile probes, while optical flat served for inspection of drives. These tests were performed for each probe individually. They showed that results for Ra, Rz and Rt (or Rmax) values were within uncertainty of the standard. For confocal and interferometric probes we use special standards, checked by accredited laboratory. They also show good conformity of results.

5. CONCLUSIONS

As it was pointed out, modern systems for quality control require more and more versatility. Future trends quite clearly show optics as potential solution, thanks to its impressive speed of measurement. A concept of multisensor devices to measure surface roughness proved to be a good solution in many applications. It is possible to use several sensors calibrated against each other with a CCD camera to find exactly an interesting space from measurement point of view. An open architecture and modular idea makes such a device a versatile unit for different branches of industry.

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[1.] Juraj ŽDÁNSKY, [2.] Karol RÁSTOČNÝ

INFLUENCE OF REDUNDANCY ON SAFETY INTEGRITY OF SRCS WITH SAFETY PLC

[1-2.] Department of Control and Information Systems, University of Žilina, Faculty of Electrical Engineering, Žilina, SLOVAKIA

Abstract: *PLCs produced at present have incomparably wider range of application options than PLCs produced in the past. One of the options where the using of PLC has not yet been common is the safety-critical processes control. PLCs used for this purpose form a special category of PLCs and are known as safety PLCs. Safety PLCs (Programmable Logic Controller) are one of the appropriate tools for implementation of safety-related control system (SRCS). Their modular construction allows implementation not only control systems of defined safety integrity level (SIL), but even redundant control systems with defined availability. The contribution considers influence of redundant architectures on safety integrity of SRCS with safety PLC.*
Keywords: *SRCS, safety PLC, safety integrity level, probability of failure state, redundancy*

INTRODUCTION

PLCs produced at present have incomparably wider range of application options than PLCs produced in the past. As an example of the PLC application options expansion can be mentioned [1], [2], [3]. One of the options where the using of PLC has not yet been common is the safety-critical processes control. PLCs used for this purpose form a special category of PLCs and are known as safety PLCs.

Attribute of safety PLC is after failure transition with defined probability into pre-defined safe state (it's an attribute marked as fail-safe). For all commercially available safety PLCs, safe state is considered as state in which output is disconnected - state without power (logical level 0 in output). This attribute is related to safety PLC, not to SRCS which also includes a safety PLC. Safety PLCs are primarily used for the implementation of SRCS at process level, therefore sensors and actuators must also be considered as a part of SRCS[4].The basic parts of safety PLC consist of sensors, F-I module/modules (Fail-safe Input module), F-CPU (Fail-safe Central Processing Unit), F-DO module/modules (Fail-safe Digital Output module) and actuators (Figure 1.).Due to the safety functions implemented by SRCS for example contactors can be used instead of actuators, as it's considered in this contribution.

By combining the different architectures of the input part, the logic and the output part, a wide range of architectures of SRCS with safety PLC can be achieved. The contribution is more detailed about the output part architectures of SRCS with safety PLC. Influence of some input part architectures on the reliable and safety properties of SRCS is given for example in [5].

The fundamental difference in manufactures attitude to ensuring required availability and safety of safety PLC is that some manufacturers observe these properties separately (they offer PLC with increased availability and safety PLC with increased safety) and some manufactures offer safety PLC with modular architecture, which allows synchronously observing of availability and safety increasing of created SRCS.

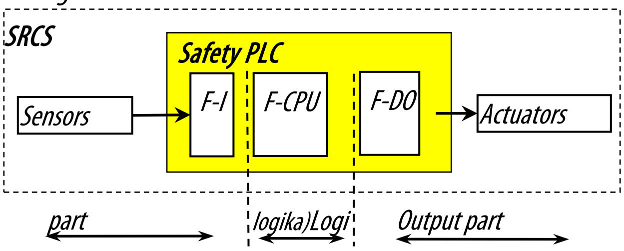

Figure 1. *Basic parts of SRCS with safety PLC*

As the achievement of required safety properties, as well as the achievement of required availability is implemented by appropriate application of redundancy. Literature relating to the SRCS with safety PLC often says about using of redundancy only in the context of increasing availability. This specificity is due to the fact that the redundancy associated with increasing safety properties is mainly applied in the modules of the safety PLC and therefore from user viewpoint it's "invisible" redundancy. Conversely, the redundancy associated with increasing availability is from the user viewpoint "visible", because it's implemented by using number of modules the same type.

From this viewpoint SRCS with safety PLC can be divided to:

- ✓ *SRCS with safety PLC without redundancy;*
- ✓ *SRCS with safety PLC with redundancy.*

In this understanding, objective of redundancy of SRCS with safety PLC is enhancing its reliable properties (in relation to the availability of SRCS). This doesn't automatically lead to an increase of its safety integrity. The contribution refers the interdependencies between the influence of redundancy of SRCS with safety PLC on safety integrity (expressed through the dangerous failure rate) and on the probability of failure state of SRCS with safety PLC.

EVALUATION OF RELIABILITY AND SAFETY INTEGRITY OF SRCS WITH SAFETY PLC

If we want to observe the redundancy influence on reliable and safety properties of a system, it's necessary to establish indicators by which we will evaluate reliability and safety integrity. In this contribution the observed properties are evaluated considering consequences of the random hardware failure. The software evaluation isn't object of this contribution (software evaluation is based on qualitative methods).

In the next section of this contribution let's assume that:

- ✓ *individual considered parts of SRCS are independent of each other in the meaning that an occurrence of failure in one part of SRCS doesn't affect the probability of failure in other part of SRCS;*
- ✓ *SRCS implement one safety function and thus SIL SRCS correspond to the SIL of the safety function.*

Then the probability of SRCS failure state (decomposed according to Figure 1) can be expressed by term:

$$P(t) = P_I(t) + P_L(t) + P_O(t) - P_I(t).P_L(t) - P_I(t).P_O(t) - P_L(t).P_O(t) + P_I(t).P_L(t).P_O(t)$$

where $P_I(t)$, $P_L(t)$ and $P_O(t)$ are probabilities of failure state of the input part, the logic and the output part of SRCS.

The safety integrity level for SRCS is expressed by the dangerous failures rate per hour and the function [6]. The dangerous failures rate for SRCS according to Figure 1 can be expressed by term:

$$\lambda_H(t) = \lambda_{HI}(t) + \lambda_{HL}(t) + \lambda_{HO}(t)$$

where $\lambda_{HI}(t)$, $\lambda_{HL}(t)$ and $\lambda_{HO}(t)$ are dangerous failures rates of the input part, the logic and the output part of SRCS.

THE OUTPUT PART OF SRCS WITH SAFETY PLC WITHOUT REDUNDANCY

In the above given output part architectures, we consider one controlled value. Implementation of specific safety function may require more controlled values and therefore a greater number of F-DO modules and actuators. Analysis of reliable and safety properties of the output part of SRCS with safety PLC must cover all actuators and F-DO modules that are involved in the implementation of the safety function.

Connection with one actuator

Connection of the output part with one actuator (Figure 2) may be used if the F-DO module and also the connected actuator comply the required SIL.

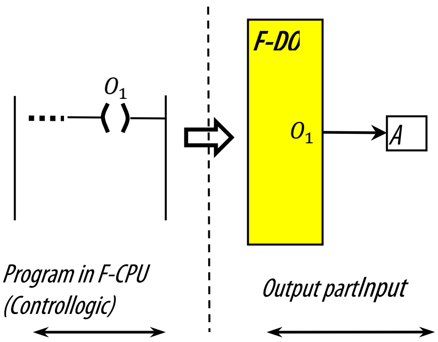

Figure 2. *Connection of the output part with one actuator*

For the probability of failure state of the output part of SRCS with one actuator (Figure 2) is valid:

$$P_O^{1A}(t) = 1 - \big(1 - P_A(t)\big)\big(1 - P_{DO}(t)\big)$$

where $P_A(t)$ is the probability of failure state of actuator A and $P_{DO}(t)$ is the probability of failure state of F-DO module.

For dangerous failures rate of the output part of SRCS with one actuator (Figure 2) is valid:

$$\lambda_{HO}^{1A}(t) = \lambda_{HA}(t) + \lambda_{HDO}$$

where $\lambda_{HA}(t)$ is the dangerous failures rate of actuator A and λ_{HDO} is the dangerous failures rate of F-DO module.

Connection with two actuators

Connection with two actuators (Figure 3) may be used if actuator with the required SIL isn't available. This connection doesn't impose special requirements on the safety properties of actuators and presumes safe disconnection of controlled object RO from the power source (due to the serial actuators connection).

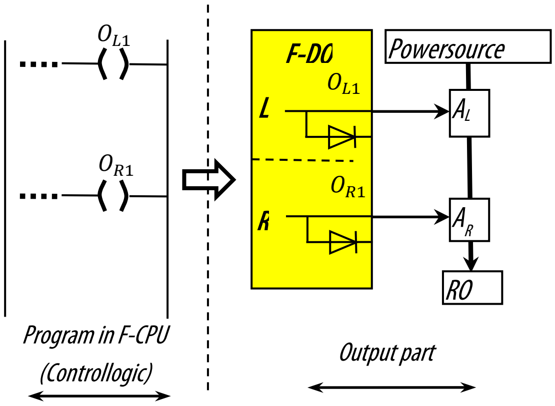

Figure 3. *Connection of the output part with twoactuators*

For the probability of failure state of the output part of SRCS with two actuators (Figure 3) is valid:

$$P_O^{2A}(t) = 1 - \big(1 - P_{AL}(t)\big)\big(1 - P_{AR}(t)\big)\big(1 - P_{DO}(t)\big)$$

where $P_{AL}(t)$, respectively $P_{AR}(t)$ is the probability of failure state of actuator A_L, respectively A_R and $P_{DO}(t)$ is the probability of failure state of F-DO module.

For the dangerous failure rate of the output part of SRCS with two actuators (Figure 3) is valid:

$$\lambda_{HO}^{2A}(t) = \frac{\frac{dP_{HA}(t)}{dt}}{1 - P_{HA}(t)} + \lambda_{HDO}$$

where $P_{HA}(t)$ is the probability of dangerous failure of actuators pair A_L and A_R, λ_{HDO} is the dangerous failures rate of F-DO module.

The probability of dangerous failure of actuators pair A_L and A_R can be expressed by term:

$$P_{HA}(t) \le P_{AL}(t).P_{AR}(t)$$

The probability value $P_{HA}(t)$ depends on the detection time with the failure negation time of actuators (the failure negation time is due to the failure detection time generally negligible).The failure detection of actuators can be implemented by functional or test diagnostics (the actuators diagnostics isn't shown in pictures in this contribution).For the implementation of functional diagnostics is possible to consider the failure detection time as the maximum time between operational commands for changing of actuators state. For the implementation of the test diagnosis is possible to consider the failure detection time as the maximum time between the executions of test procedures.

For considerations in the next section of this contribution is valid:

- *the failure detection time with the failure negation time is* t_{0A};
- *the random failures rates of actuators are constant (exponential distribution of the failures occurrence).*

Then the probability of dangerous failure of actuators pair A_L *and* A_R *can be expressed by term:*

$$P_{HA}(t_{0A}) \leq \left(1 - e^{-\lambda_{AL}.t_{0A}}\right).\left(1 - e^{-\lambda_{AR}.t_{0A}}\right)$$

where λ_{AL}, *respectively* λ_{AR} *is the random failures rate of actuator* A_L, *respectively* A_R.

If $\lambda.t \ll 1$, *so the dangerous failures rate of actuators pair* A_L *and* A_R *can be determined by term:*

$$\lambda_{HALR}(t_{0A}) \cong 2.\lambda_{AL}.\lambda_{AR}.t_{0A}$$

The dangerous failures rate of the output part of SRCS with two actuators can be determined by term:

$$\lambda_{HO}^{2A}(t_{0A}) \leq \lambda_{HDO} + \lambda_{HALR}(t_{0A})$$

where λ_{HDO} *is the dangerous failures rate of F-DO module.*

THE OUTPUT PART OF SRCS WITH SAFETY PLC WITH REDUNDANCY

Redundancy at actuators level

If the safety properties of actuators are significantly worse than the safety properties of F-DO module it's appropriate to apply redundancy at actuators level. The actuators control must be solved in the application program. The principle of actuators control is shown in Figure 4.

For the probability of failure state of the output part of SRCS with redundancy at actuators level (Figure 4.) is valid:

$$P_O^{RA}(t) = 1 - \left(1 - P_{A1}(t).P_{A2}(t)\right)\left(1 - P_{DO}(t)\right)$$

Where $P_{A1}(t)$ *is the probability of failure state of actuators pair* A_{L1} *and* A_{R1} *and* $P_{A2}(t)$ *is the probability of failure state of actuators pair* A_{L2} *and* A_{R2} *and* $P_{DO}(t)$ *is the probability of failure state of F-DO module.*

The probability of failure state of actuators pair A_{L1} *and* A_{R1} *can be expressed by term:*

$$P_{A1}(t) = 1 - \left(1 - P_{AL1}(t)\right)\left(1 - P_{AR1}(t)\right)$$

where $P_{AL1}(t)$, *respectively* $P_{AR1}(t)$ *is the probability of failure state of actuator* A_{L1}, *respectively* A_{R1}.

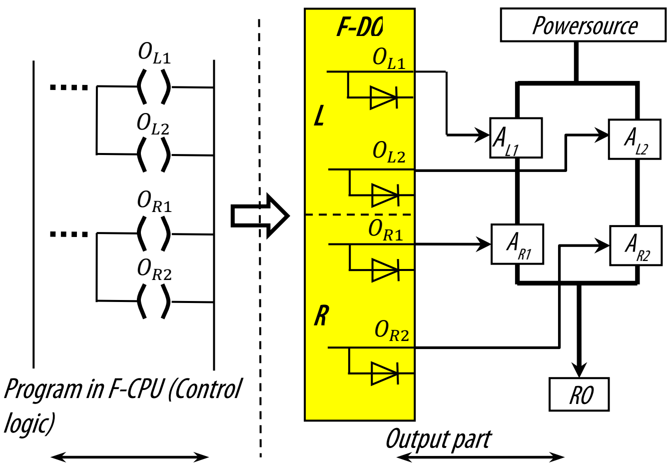

Figure 4. *Connection of the output part with redundancy at actuators level*

The probability of failure state of actuators pair A_{L2} *and* A_{R2} *can be expressed by term:*

$$P_{A2}(t) = 1 - \left(1 - P_{AL2}(t)\right)\left(1 - P_{AR2}(t)\right)$$

where $P_{AL2}(t)$, *respectively* $P_{AR2}(t)$ *is the probability of failure state of actuator* A_{L2}, *respectively* A_{R2}.

For the dangerous failures rate of the output part of SRCS with redundancy at actuators level (Figure 4) is valid:

$$\lambda_{HO}^{RA}(t_{0A}) \leq 2.\lambda_{AL1}.\lambda_{AR1}.t_{0A} + 2.\lambda_{AL2}.\lambda_{AR2}.t_{0A} + \lambda_{HDO}$$

where λ_{AL1}, λ_{AR1}, λ_{AL2} *and* λ_{AR2} *are random failures rates of actuators* A_{L1}, A_{R1}, A_{L2} *and* A_{R2}.

Redundancy at F-DO modules level

Redundancy at F-DO modules level can be implemented (Figure 5) but requires the application of additional measures. Objective of these measures is to prevent short circuit of outputs of modulesF-DO1 and F-DO2 (by two outputs it's necessary to control one actuator).In assessing the reliable and safety properties of the output part with redundancy at F-DO modules level it's necessary to analyse the influence of the implemented measures. There is in Figure 5 preventing the short circuit realized by the separating diodes.

There are also F-DO modules that have measures to prevent the short circuits implemented by internal circuits of the module. In this case there is no need to deal with the analysis of the safety of these measures.

It's necessary to set the redundancy at F-DO modules level by using the F-DO modules parameters (not every type of safety PLC supports this type of connection). Then a user accesses the modules pair F-DO1 and F-DO2 as in the case of one module.

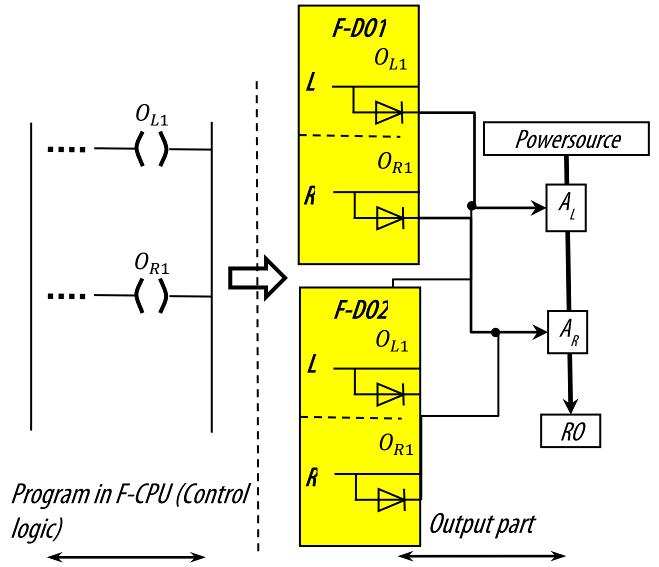

Figure 5. *Connection of the output part with redundancy at F-DO modules level*

The probability of failure state of the output part of SRCS with redundancy at F-DO modules level (Figure 5.) can be expressed by term (assuming that measures to prevent short circuits are realized by internal circuits of the module):

$$P_O^{RM}(t) = 1 - \left(1 - P_{AL}(t)\right)\left(1 - P_{AR}(t)\right)\left(1 - P_{DO1}(t).P_{DO2}(t)\right)$$

where $P_{AL}(t)$, *respectively* $P_{AR}(t)$ *is the probability of failure state of actuator* A_L, *respectively* A_R *and* $P_{DO1}(t)$, *respectively*

$P_{DO2}(t)$ is the probability of failure state of the module F-DO1, respectively F-DO2.

The dangerous failures rate of the output part of SRCS with redundancy at F-DO modules level (Figure 5.) can be expressed by term:

$$\lambda_{HO}^{RM}(t_{0A}) \leq 2.\ \lambda_{AL}.\lambda_{AR}.t_{0A} + \lambda_{HDO1} + \lambda_{HDO2}$$

where λ_{HDO1}, respectively λ_{HDO2} is the dangerous failures rate of the module F-DO1, respectively F-DO2.

Redundancy at actuators and F-DO modules level

If the reliable properties of the actuators pair A_L and A_R aren't sufficient and reliable properties of F-DO module also aren't sufficient, the connection according to Figure 6 can be used.

For the probability of failure state of the output part of SRCS with redundancy at actuators and F-DO modules level (Figure 6.) is valid:

$$P_O^{RAM}(t) = P_{01}^{2A}(t).P_{02}^{2A}(t)$$

where $P_{01}^{2A}(t)$ is the probability of failure state of the first channel (components F-DO1, A_{L1} and A_{R1}) and $P_{02}^{2A}(t)$ is the probability of failure state of the second channel(components F-DO2, A_{L2} and A_{R2}). $P_{01}^{2A}(t)$ and $P_{02}^{2A}(t)$ can be determined by term (5).

The dangerous failures rate of the output part of SRCS with redundancy at actuators and F-DO modules level (Figure 6) can be expressed by term:

$$\lambda_{HO}^{RSM}(t_{0A}) \leq 2.\lambda_{AL1}.\lambda_{AR1}.t_{0A}$$
$$+2.\lambda_{AL2}.\lambda_{AR2}.t_{0A} + \lambda_{HDO1} + \lambda_{HDO2}$$

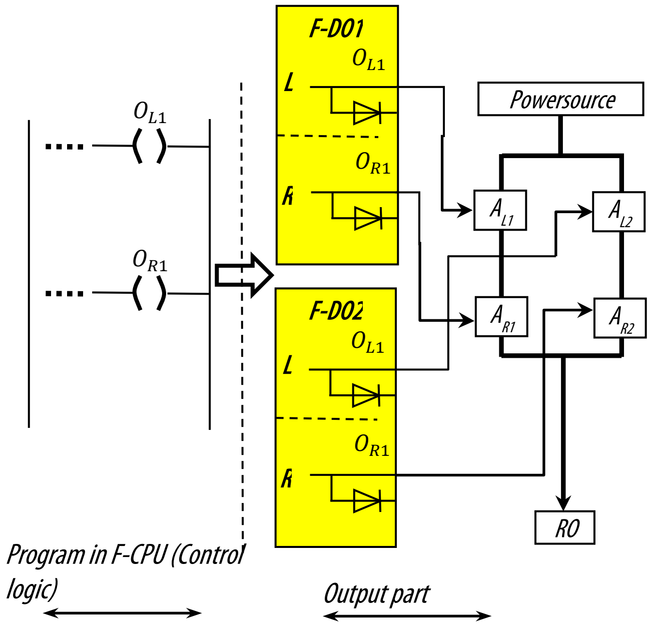

***Figure 6.** Connection of the output part with redundancy at actuators and F-DO modules level*

THE PROPERTIES COMPARISON OF INDIVIDUAL ARCHITECTURES

Curves comparing the architectures of the output parts of SRCS with safety PLC are shown in Figure 7 and Figure 8. And are built for SRCS with safety PLC Simatic (reliable parameters of components of Simatic system can be found in [7] and safety parameters are part of the technical documentation of individual modules). Estimated random failures rate of actuators is $5.10^{6}\ h^{1}$.

For both images applies the curves numbering according to Table 1.

***Table 1.** Curves numbering in Figure 7 and Figure 8*

Curve number	Corresponding architecture
1	Connection of the output part with twoactuators (Figure 3); terms (5) and (10).
2	Connection of the output part with redundancy at actuators level (Figure 4); terms (11) and (14).
3	Connection of the output part with redundancy at F-DO modules level (Figure 5); terms (15) and (16).
4	Connection of the output part with redundancy at actuators and F-DO modules level (Figure 6); terms (17) and (18).

The graph in Figure 7 shows curves of the probability of failure state of the output parts of SRCS with safety PLC. From these curves the influence of redundancy on the probability of failure state of individual architectures of the output part of SRCS with safety PLC is obvious.

There are in Figure 8.curves of the dangerous failures rates of the output parts of SRCS with safety PLC depending on the failure detection time with the failure negation time of the actuator(t_{0A}).

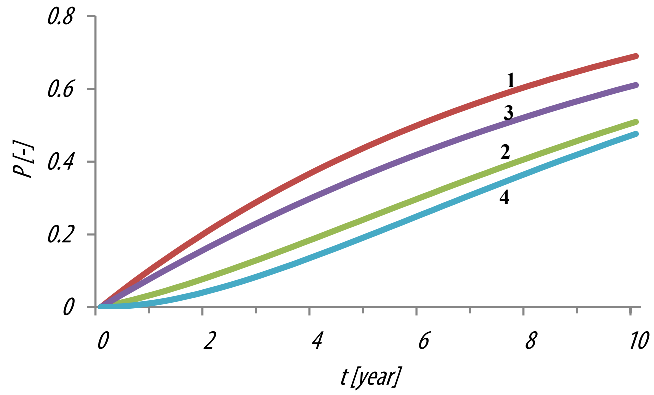

***Figure 7.** The probability of failure state of the output parts of SRCS*

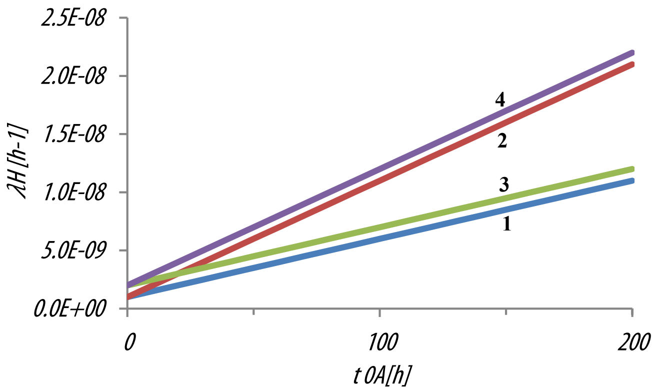

***Figure 8.** The dangerous failures rate of the output partsof SRCS*

From the graphs in Figure 7 and Figure 8 can be seen that by influence of using the redundancy we can achieve an improvement of the reliability (reducing the probability of failure state) but it also leads to deterioration of safety integrity (increase of the dangerous failures rate).This is caused by influencing the safety of the output part of SRCS with redundancy by parts forming the reserve.

There isn't in graphs in Figure 7 and Figure 8 curve corresponding to the architecture of the output part with one actuator (Figure 2). It's because this architecture requires an actuator satisfying the required SIL. Such an actuator has different parameters (the probability of *failure state and dangerous failures rate) as actuators used in other architectures and therefore a comparison of such architecture with the other architectures loses its meaning.*

CONCLUSION

Reliable and safety properties of SRCS with safety PLC can be influenced by the choice of an appropriate SRCS architecture. Choice of architecture shouldn't be based only on observing one property because its improvement doesn't automatically mean improvement of other properties. Architecture should be chosen so as to fulfil the minimum required level of all observed properties.

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[1.] R. K. ABDULRAHMAN, [2.] I. M. SEBASTINE, [3.] R. A. SURAMAIRY

REDUCING AND CONTROLLING THE HYDROCARBON EMISSIONS FROM RICH AMINE REGENERATOR UNITS IN THE NATURAL GAS SWEETENING PROCESS: A CASE STUDY AND SIMULATION

[1.] Faculty of Engineering, Koya University, Kurdistan Region, IRAQ
[2.] School of Science and Engineering, Teesside University, UNITED KINGDOM
[3.] Faculty of Engineering, Koya University, Kurdistan Region, IRAQ

Abstract: *Natural gas has been the most popular fossil fuel in recent years, and the demand for it has been dramatic. In fact, natural gas possesses several useful features: it has a high heating value, it can be utilised as a raw material in several petrochemical industries and it is a cheap fuel source. However, raw natural gas usually contains a variety of non-hydrocarbon components, e.g., acid gases, helium, nitrogen and mercury. Raw natural gas sources with large amounts of acid gases are known as sour gas. Sour gases should be treated and sweetened to meet natural gas pipeline specifications and sale contracts. The amine gas sweetening process is widely utilised in the gas industry, either to reduce or to remove acid gases from sour natural gas streams. Indeed, amine gas sweetening has several advantages over other sweetening processes; it is more economical than other processes, and it operates continuously. Indeed, the global hydrocarbon emissions from the oil and gas industries have been dramatic. Moreover, methane, ethane and propane may be the most obvious gases that are emitted by the natural gas industry. In many cases, these emissions occur from gas processing units, e.g., gas sweetening and gas dehydration processes. In fact, these hydrocarbon gas emissions contribute to global warming and environmental pollution. Moreover, hydrocarbon emissions lead to huge losses of precious hydrocarbons every hour. Therefore, this study aims to study the effects of the solvent circulation rate on the hydrocarbon carryover from the amine gas sweetening using Aspen HYSYS software. The study also used a Murban gas stream in the simulation process because it is loaded with a high concentration of acid gases. The study determined that the amine circulation rate may have significant effects on the hydrocarbon losses during the sweetening process. Moreover, the study also recommended several methods to reduce this effect and the emission, e.g., balancing the amine circulation rate with both the sweetening efficiency and the hydrocarbon emissions.*

Keywords: *Natural gas sweetening, Murban field, Amine solution, Process simulation, Aspen HYSYS, Process optimisation, Global warming, Hydrocarbon emission, Amine circulation*

INTRODUCTION

In recent years the demand for and consumption of natural gas have been notable. Indeed, natural gas possesses several advantages, e.g., a high heating value, environmental friendliness and low cost. However, raw natural gas may contain several impurities, e.g., water vapour and acid gases [1]. Therefore, it should be processed in a natural gas processing plant to either remove or reduce these impurities (i.e., natural gas sweetening and dehydration). Indeed, during the operation of these processes large quantities of hydrocarbons (for example, methane and ethane) may be emitted into the environment, and these hydrocarbons could be contributing to the global warming phenomena. In fact, global methane emissions from the natural gas industry have been inadequately recognised and quantified in many countries [2]. As a result, in many cases, the emissions are not well known even at the country level [3]. Indeed, in many cases, the emissions from the wellhead and gas processing sector are included but emissions from the equipment associated with the fractionation of propane, butane, and natural gas liquids were excluded [1]. Due to growing environmental concerns, limiting the hydrocarbons emissions (e.g., BTEX and methane) from gas processing plants is of primary importance. Indeed, glycol units have been under scrutiny for some time [2]. However, the amine process has recently been targeted as well. Indeed, switching from coal and oil to natural gas fuels could serve as an interim measure to reduce the effects of global climate change caused by greenhouse gas emissions. Methane is the main greenhouse gases and its content in the atmosphere has increased dramatically over the past 300 years [3]. Amine solutions can absorb a considerable amount of light hydrocarbons, e.g., methane, ethane, propane and BTEX. Furthermore, these dissolved hydrocarbons in rich amine solution are obtained via contact with feed gas during the sweetening process. The rich amine solution with dissolved hydrocarbons is processed in the amine regenerator unit to recover the lean amine and reuse it in the sweetening process [3]. In fact, the dissolved hydrocarbons in the *rich amine solution are released in the regenerator's overhead. This overhead either vents to the atmosphere or feeds a sulphur recovery unit. The HC content discharged from the regenerator vent to the atmosphere must comply with the recently established stringent regulations. For acid gas feeds to a Claus unit, a high HC content may result in catalyst fouling, a low quality sulphur product, or the need for a more sophisticated burner design. However, many oil and gas companies may release these hydrocarbons into the environment. Amine gas treatment is considered one of the most common processes in petrochemical plants, onshore refineries and offshore natural gas processing plants, as well as other industries [2].*

BASIC AMINE PROCESS DESCRIPTIONS

The amine process could be considered the most economical and common process in the gas industry sector. This process is uses an alkanamine solution as a chemical solvent to remove acid gases from natural gas streams [7]. Alkanamines possess high affinity toward acid gases, and there are several types of amines that are used in the amine process, e.g., monoethanolamine (MEA) and dimethylamine (DEA). The amine process consists of several operation units: the contactor tower, regenerator tower and heat exchanger [6]. Figure (1) shows a typical amine process.

The chemical reaction of amines with H_2S and CO_2 are given below:

$$2RNH_2 + H_2S = (RNH_3)_2S$$

$$2RNH_2 + CO_2 = RNHCOONH_3R \quad *R = \text{mono, di, tri-ethanol.}$$

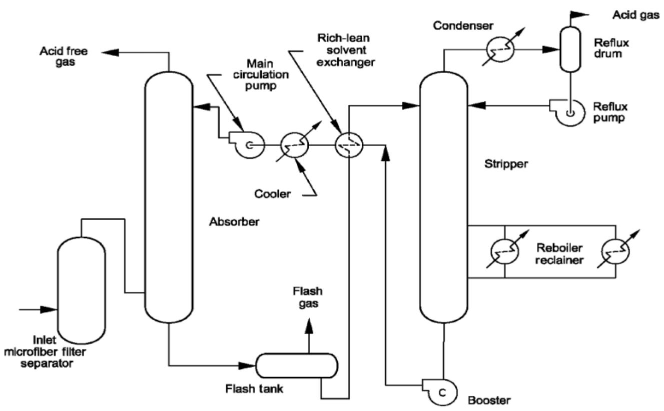

***Figure 1**: General flow diagram for an amine plant [6].*

MURBAN GAS COMPOSITION AND WATER CONTENT CALCULATIONS

The Murban gas stream composition and operating conditions are show in table (1). Based on the gas composition, it appears that these values were determined on a dry basis. Thus, estimating the water content before the process design or simulation is recommended.

Table 1: Murban associated natural gas [4].

Murban Field data		Component	Mole %
		Methane	76.4
		Ethane	8.1
Location	United Arab Emirates	Propane	4.7
Gas density	0.65 Kg/m^3	Butane	2.6
Gas S.G (Air=1)	0.67	pentane	1.9
Pressure	7000 K.pa	Carbon dioxide	4.5
Temperature	38 ℃	Nitrogen	0.1
Flow rate (Assumed)	120,000 stdm^3/hr	Hydrogen sulphide	1.7

The natural gas water content can be estimated using the McKetta-Wehe Chart [6]. Therefore, the raw natural gas water content is approximately 1000 kg/MMstd.m^3 = 128.265 kg/hr. The new natural gas composition could be calculated and summarised as shown in table (2).

***Table 2**: Murban natural gas compositions and quantities (wet basis).*

Component	Mol%	Mwt	Kmol / hr	kg/hr	Mol%
H_2S	1.7	34.076	91.0145	3101.41	1.69774
CO_2	4.5	44.01	240.921	10602.9	4.49402
N_2	0.1	28.02	5.3538	150.013	0.09987
CH_4	76.4	16.02	4090.3	65526.6	76.2984
C_2H_6	8.1	30.07	433.658	13040.1	8.08923
C_3H_8	4.7	44.09	251.628	11094.3	4.69375
C_4H_{10}	2.6	58.123	139.199	8090.65	2.59654
C_5H_{12}	1.9	72.15	101.722	7339.25	1.89747
H_2O		18	7.12585	128.265	0.13292
TOTAL	100		5360.92	119074	100

MURBAN SOUR GAS SWEETENING SIMULATION

The amine gas sweetening plant for Murban sour gas is simulated using Aspen HYSY. DEA is utilised as an aqueous absorbent to absorb acid gases from the sour gas stream. An amine fluid was adopted for the simulation work, and figure (2) shows the Murban sour gas sweetening process. It is important to use an inlet gas separator to remove any undesirable impurities, e.g., solid particulates and liquids. The amine contactor is also an important part of the sweetening plant, and it has certain requirements, for example, stream temperature and pressure. Moreover, the rich amine needs to be regenerate, which could be achieved by installing the amine regenerator after the amine heat exchanger. The installation of a flash tank for the rich amine solution is important to avoid any technical problems that might be caused by rich amine impurities. The water content of the stream should also be considered in the process to maintain the amine concentration during the process. See appendix A (Figures 6-11) for more details of the HYSYS work.

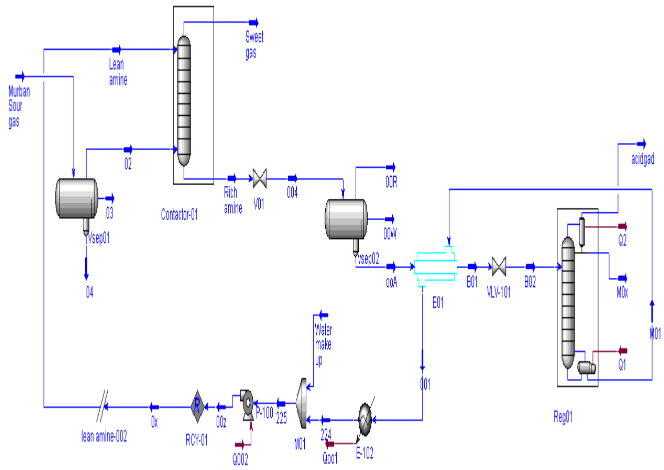

***Figure 2**: Process flow diagram of the Murban gas sweetening plant*

RESULTS AND DISCUSSION

First, the study used a 35 % (w/w) DEA amine solution to perform the sweetening process, which achieved an acceptable sweetening result. Figure (3) shows the relationship between the amine circulation rate *and the hydrogen sulphide mole percent in the sweet gas stream. Furthermore, figure (4) shows the relationship between the amine circulation rate and carbon dioxide mole percent in the sweet gas stream.*

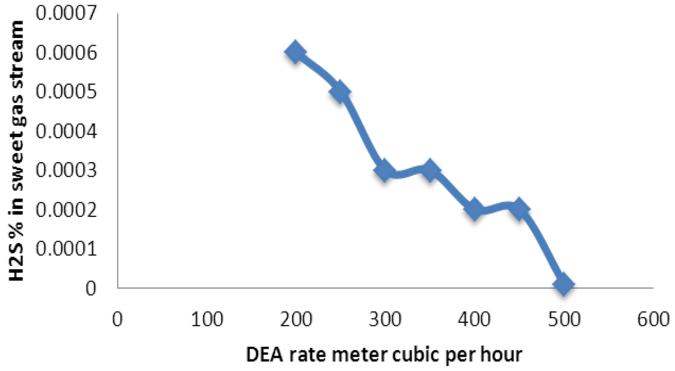

***Figure 3**: Effects of the 35 % DEA circulation rate on the hydrogen sulphide mole fraction in the sweet gas stream.*

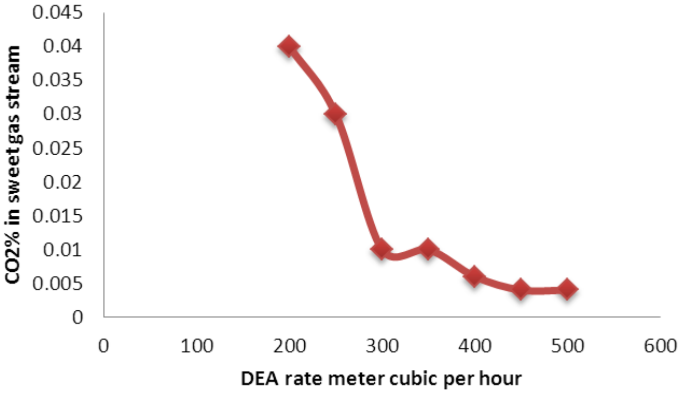

***Figure 4**: Effects of the 35 % DEA circulation rate on the carbon dioxide mole fraction in the sweet gas stream.*

Based on figure 3 and 4, increasing the 35 % DEA circulation rate will lead to an increase the acid gas removal. Moreover, at an amine rate of 400 m^3/hr the amount of H_2S in the sweet gas was approximately 5 ppm. However, the optimum amine rate is about 300 m^3/hr, which results in 4 ppm H_2S in the sweet gas stream, resulting in the optimum liquid residence time on the tray. However, the cost of the amine process should be considered because any increase in the amine rate leads to an increase in the operation cost.

Figure (5) shows the relationship between the amine circulation rate in cubic meters per hour and the hydrocarbons emission from the amine regenerator unit.

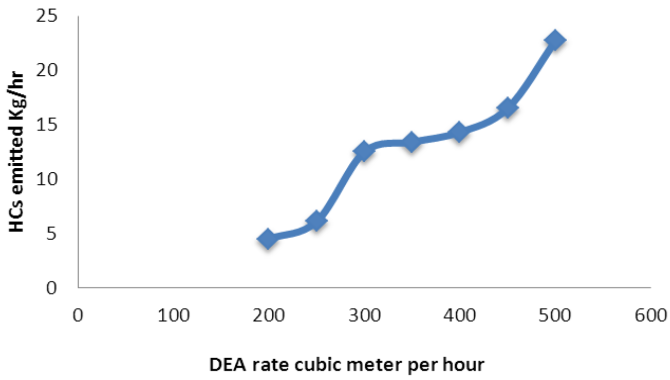

***Figure 5**: The relationship between the 35 % DEA rate and the HCs emitted from the amine regenerator unit in kg/hr.*

Based on figure (5), increasing the DEA circulation rate will lead to an increase in the amount of hydrocarbons emitted from the rich amine regenerator unit. The total hydrocarbon emission at an amine circulation rate of approximately 530 m^3/hr is quite high, approximately 25 kg/hr. The emissions at 200 m^3/hr are lower, approximately 5 kg/hr. Thus, a 300-m^3/hr amine circulation rate is recommended because it achieves an acceptable sweetening result and produces a moderate hydrocarbon emission of approximately 14 kg/hr.

Appendix (A)

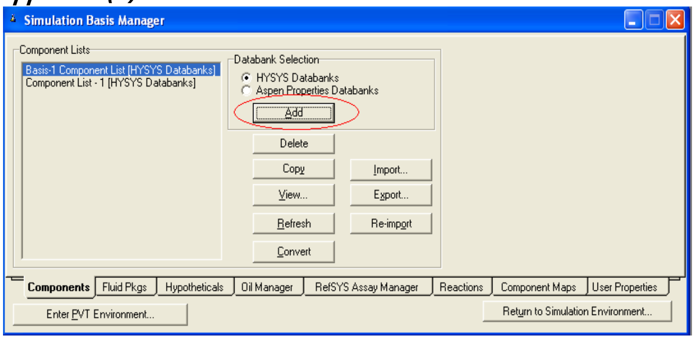

***Figure 6**: Shows the simulation basis manger.*

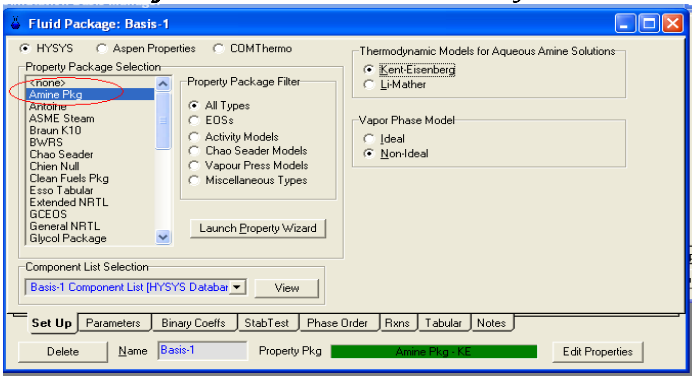

***Figure 7**: Shows the simulation fluid package manger.*

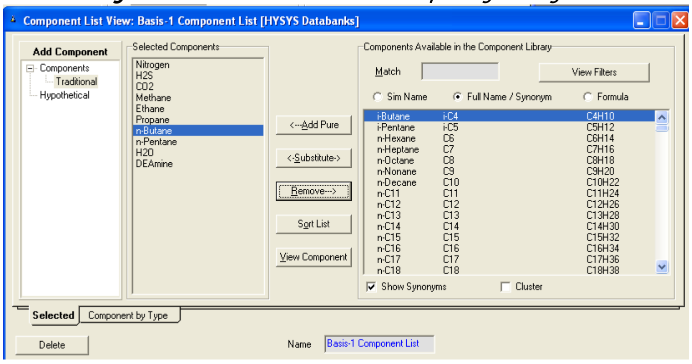

***Figure 8**: Shows the simulation component manger.*

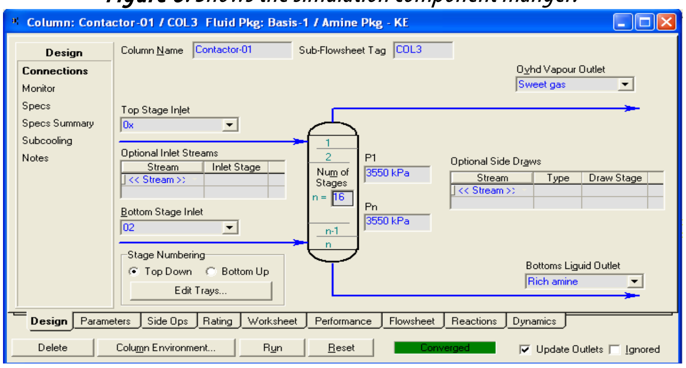

***Figure 9**: Shows the simulation contactor tower manger.*

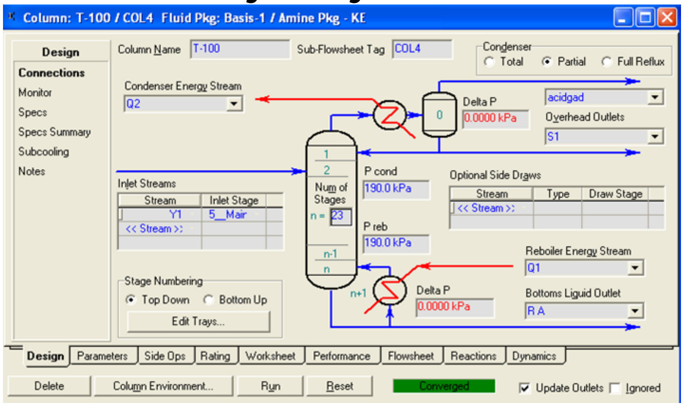

Figure 10: Shows the simulation regenerator tower manger.

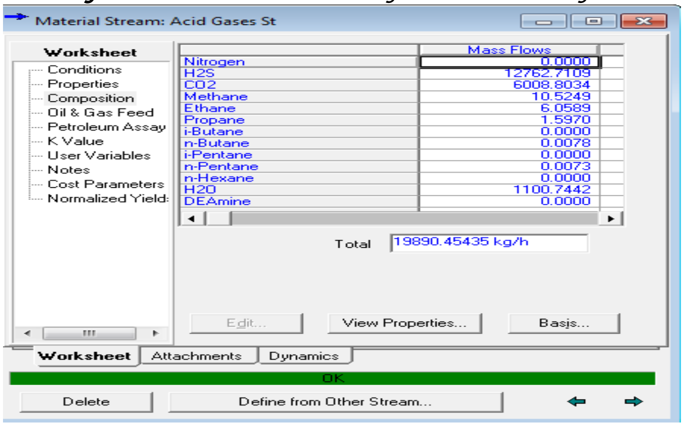

Figure 11: Shows the material stream for acid gases that were emitted from amine regenerator unit.

CONCLUSIONS

This study successfully simulated a Murban gas sweetening process using Aspen HYSYS. Moreover, it attempted to investigate and describe the effects of the lean amine circulation rate on the hydrocarbon emissions or losses from the sweetening process. The Murban gas contained a high concentration of acid gases. Moreover, the simulation work showed high removal of the acids, which met the gas pipeline specifications. A 35 % DEA solution with a 300 m^3/hr circulation rate achieved optimum gas removal, and the outlet natural gas stream met the gas pipeline specifications. Furthermore, using 35 % DEA is recommended for the process. The amine circulation rate has a significant effect on the hydrocarbon losses from the amine regenerator tower. In other words, increasing the amine circulation rate will increase the hydrocarbon emissions into the environment. Therefore, maintaining a moderate amine circulation rate in the amine gas sweetening process is recommended. Minimising the lean amine circulation rate could reduce the hydrocarbons emissions from amine regenerator unite.

Nomenclature

RMM Relative Molecular Weight
H_2S Hydrogen sulphide
CO_2 Carbon dioxide
DEA Dimethylamine
BTEX Benzene, toluene, ethylbenzene, and xylenes

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Lateef Owolabi MUDASHIRU

RESPONSE SURFACE METHODOLOGY FOR STUDYING THE EFFECT OF OPERATING VARIABLES ON QUENCHING IN OIL MEDIUM

Department of Mechanical Engineering, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, NIGERIA

Abstract: *Quenching is being described as one of the most common heat treatment processes used to impart the desire mechanical properties such as high strength, hardness and near resistance to metal parts using quenchants such as air, water and polymer solution. The quenching process parameters such as time, radial distance and immersion speed played a major role in deciding the heat treatment quality of the steel sample. In this research, response surface methodology was used to study the effect of process parameters on temperature distribution during the quenching process of AISI1020 steel sample. A total of seventeen experimental runs were designed using the three variables adopting Box-Behnken design with full replication technique and mathematical model was developed. Sensitivity analysis was carried out to identify critical parameters. Time was found to be the most influencing parameter on the temperature distribution, followed by immersion speed and the least effect was given by radial distance. The quadratic model developed was evaluated at p-value greater than 95% confidence level, having correlation coefficient R-squared of 0.9997, adjusted R-squared of 0.9993 and predicted R-squared of 0.9953.*
Keywords: *Analysis of Variance (ANOVA), quenchant, austenitization, Response Surface Methodology (RSM), Box-Behnken*

INTRODUCTION

Heat treatments can be broadly described as processes or an operation or combination of operations that involves heating and cooling of solid metals to acquire appropriate mechanical properties or for the purpose of obtaining specific properties which could be suited for particular working environments [1,2] (Houghton, 2000; Grum et al., 2001). The heat treatment process include, heating of the steel to a definite temperature; holding (or soaking) at that temperature for a sufficient period of time and cooling at rate in order to change the mechanical properties, the metallurgical structure or the residual stress state.

Quenching of steel involves the cooling from the solution treating temperature, typically 845-870°C (1550-1600°F), into the hard structure-martensite [3] (Bates and Totten, 1992) and is typically performed to prevent ferrite or pearlite formation and to facilitate bainite or martensite formation [3] (Bates et al., 1992). Although quenching is the most difficult part in the heat treatment process, as the material properties depends heavily on the cooling rate [4](Buche et al., 2005), it is an integral part of industrial heat-treatment processes for steels and provide means by which mechanical properties of a steel part can be controlled [5](Woodard, 1999). Therefore, quenching operation is one of the most important steps that determine the quality of heat–treated product and the quenching quality is decided by the cooling ability and temperature field distribution of the quenching medium [6](Li Qiang et al., 2003). The quenching medium also known as quenchant includes water, oil, brine, air, molten salts and polymeric materials. The quenchant to be employed in a quenching process depends on the type of steel.

Among the quenching medium, oils had an excellent quenching properties as a quenchants, provide moderate cooling rate and therefore result in minimal distortion in the component [7](Ndaliman, 2006). Many components use oil quenching to achieve consistent and repeatable mechanical and metallurgical properties and predictable distortion patterns. The reason oil quenching is so popular is due to its excellent performance results and stability over a broad range of operating conditions. Oil quenching facilitates hardening of steel by controlling heat transfer during quenching, and it enhances wetting of steel during quenching to minimize the formation of undesirable thermal and transformational gradients which may lead to increased distortion and cracking. For many, the choice of oil is the result of an evaluation of a number of factors including: Economics/cost (initial investment, maintenance, upkeep, and life), Performance (cooling rate/quench severity), Minimization of distortion (quench system), Variability (controllable cooling rates) and Environmental concerns (recycling, waste disposal, etc.).[8](Herring, 2010).

Oils are generally classified by their ability to transfer heat as fast, medium, or slow "speed" oils. Fast (8-10 seconds) oils are used for low hardenability alloys, carburized and carbonitrided parts, and large cross sections that require high cooling rates to produce maximum properties. Medium (11 – 14 seconds) oils are typically used to quench medium to high hardenability steels. Slow (15-20 *seconds) oils are used where hardenability of a steel is high enough to compensate for the slow cooling aspects of this medium [9](Herring D et. al, 1986). The temperature of the metal surface is reduced to the boiling point (or boiling range) of the quenching liquid. Below this temperature, boiling stops and slow cooling takes place by conduction and convection. The difference in temperature between the boiling point of the liquid and the bath temperature is a major factor influencing the rate of heat transfer in liquid quenching.*

Response Surface Methodology (RSM), invented by Box and Wilson, is defined as a collection of mathematical and statistical tools or techniques useful for modeling, analyzing and simultaneously solving problems in which a response of interest is influenced by several variables and the objectives is to optimize this response (Giovanni, 1983). Response surface methodology also quantifies the relationship between the controllable input parameters and the obtained response surfaces. It is a well-known up to date approach for constructing approximation models based on physical experimented observations [10](Box et al., 2005). The main advantage of RSM is the reduced number of experimental runs needed to provide sufficient information for statistically acceptable results [11](Montgomery, 2001).

Karthikeyan et al. [12] developed mathematical models to optimize the heat treatment conditions for maximum yield strength and ductility of aluminum–silicon carbide particulate composites. The response surface method was used to fit the mathematical models, and the process variables included the volume fraction of SiC, aging temperature, aging time, and solutionizing time. RSM was used for technologic parameter optimization of gas quenching process by Huiping et. al [13]. In this present study, response surface methodology was considered to study the effect of process variables (time, radial distance and immersion speed) on cooling rate of oil quenched process.

METHODOLOGY

Parameter Evaluation of Oil quenched process

During the process of oil quenching, the process parameters were classified as the independent parameter and the dependent parameter. The independent parameters during the oil quenching process include time, radial distance and immersion speed while temperature distribution is the dependent parameter. Yao et al. (2003)[14] investigated the transient temperature, structure and internal stress evolution and distribution of oil–quenched centric and eccentric cylindrical tubes by a finite element method. They discovered that at the initial stage of quenching process, the residual axial stresses are tensile at the surface and compressive in the core for both geometries.

Therefore, in this research, the temperature distribution is regarded as a variable to be predicted, the range of values for the independent parameters are shown in Table 1. The material of the quenching process is AISI1020 mild steel bar and the quenchant is oil.

Sample Preparation

A solid cylindrical mild steel bar (AISI1020) purchased at local steel market was machined at the Fabrication workshop, Department of Mechanical Engineering, Faculty of Engineering and Technology, LAUTECH, Ogbomoso Nigeria to produce a specimen of 100 mm long of 30 mm diameter illustrated in Figure 1. Three 2 mm diameter hole are drilled to a depth of 5mm at 5mm, 15mm and 25mm from outside diameter of the specimen, to accommodate the thermocouples that are used for temperature measurements. Ten samples of the specimen are produced and used for the experiment.

Experimental Set-up

The prepared samples of steel probes of length 100mm and diameter 30mm were connected with a chrome/alumel K-type thermocouple via a tight fitting screw to prevent the quenching media from entering the drilled holes during quenching. The thermocouples were connected to a 12 channel temperature recorder model BTM-4208 SD with SD data logger to conduct the data acquisition process of the temperature and time.

The complete assembly of the specimens (the specimen and thermocouples) was placed in a temperature controlled furnace Vaster 232 models available at the New Chemical Laboratory, Department of Chemical Engineering, LAUTECH, Ogbomoso Nigeria. Heated and soaked at an austenitized temperature of 850°C for one hour to promote complete austenitization of the specimen. The heated specimen was quickly transferred from the furnace into 1000ml quenching medium contained in a vertical tank under static condition and the probe dipped horizontally as practiced in industry via an immersion rig which consists of a one horse power electric motor and a voltage regulator. The speed of the electric motor which represents the speed of the immersion of the heated specimen was monitored with a digital tachometer model DT-2234B. The heating and quenching procedures were repeated twice for immersion speed of 0.1 m/s, 0.35 m/s and 0.6 m/s using mineral oil as the quenchant used.

The tensile test samples and other samples prepared for hardness tests and micro-structural analyses were also heated and quenched at immersion speed of 0.1 m/s, 0.35 m/s and 0.6 m/s.

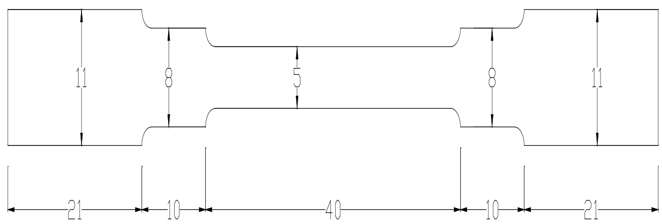

***Figure 1:** Schematic diagram of specimen used for tensile and hardness tests (All dimensions in mm)*

Experimental Design for the Response Surface Procedure

Response surface methodology has been used to study the optimization of chemical processes and products (Sudesh et al., 2010; Mane et al., 2007; Ven et al., 2002). Response surface methodology was used in this study to investigate the effect of some quenching parameters for the performance of the quenched steel in heat treatment process. A three factor, Box-Benhnken Design (BBD) model was used to design the experiment. Design-Expert version 8.0.3 was used for the modeling of the identified variables. The factors considered were time, radial distance and immersion speed while the response is temperature distribution. The experimental range of the variables are tabulated was in Table 1. The experimental range was used to design experiment used for the modeling which was tabulated in Table 2.

The quadratic response surface model considering all the linear terms, square terms and linear by linear interactions terms according to Huiping et al., (2008) was described as:

$$Y = \beta_o + \varepsilon \sum_{i=1}^{k} \beta_i x_i + \sum_{i-1}^{k} \beta_{ij} x_i x_j + \sum_{i=1}^{k} \beta_{ii} x_i^2 + \varepsilon \quad (1)$$

where Y is predicted response used as a dependent variable, β_o represents the overall mean, β_i represents the linear effect of the input factor x_i; β_{ij} represents the linear by linear interaction effect between the input factor x_i and x_j; β_{ii} represents the quadratic effect of the input factor x_i and ε is the random error term.

Table 1: Design of factors for temperature distribution

Factors	Code	Level		
		Low (-1)	Standard (0)	High (+1)
Time (s)	A	2	51	100
Radial distance (mm)	B	5	15	25
Immersion speed (m/s)	C	0.1	0.35	0.6

Table 2: Box Behnken Design of Experiment Model Range in coded and actual values

Std	Coded			Actual		
	Time	Radial dist	Immersion speed	Time	Radial dist	Immersion speed
7	-1	0	1	15	0.1	56
3	-1	1	0	25	0.1	96.5
11	1	-1	1	15	0.35	71.1
8	1	0	1	25	0.35	61.9
10	0	1	-1	5	0.6	116.2
4	1	1	0	15	0.35	71.1
13	0	0	0	5	0.35	53.2
1	-1	-1	0	15	0.35	71.1
14	0	0	0	25	0.6	120.5
17	0	0	-1	5	0.35	819.9
5	-1	0	1	15	0.6	838.4
6	1	1	1	15	0.35	71.1
12	0	1	1	15	0.6	60.2
9	0	-1	-1	15	0.1	841
15	0	0	0	25	0.35	847.1
16	0	0	0	5	0.1	76.1
2	1	-1	0	15	0.35	71.1

Statistical Data Analysis

Analysis of variance (ANOVA) was used for the analyses of the data obtained from quenching experiment for oil quenching medium. The interactions between the process variables and the responses of different regression models developed for temperature distribution using oil as quenching medium were investigated. The quality of the fit polynomial model was expressed by the coefficient of determination R^2, and its statistical significance was checked by the Fisher's F-test in the same in-built statistical program of the Design Expert 8.0.3. Model terms were evaluated by the p-value (probability) with 95% confidence level. Three dimensional surface plots and their respective contour plots were obtained for temperature distribution on the effects of the three factors (time, radial distance and immersion speed).

RESULT AND DISCUSSION

Data Analysis

The experimental results, the predicted values and the residuals of data were shown in table 3. A quadratic model was developed from the data showing the relationship between temperature distribution and the input parameters (time, radial distance and immersion speed). The adequacy of the developed model was tested statistically using the analysis of variance (ANOVA) technique and the results of second order response surface model fitting are given in Table 4. The determination coefficient (R^2) indicates the goodness of fit for the model. In this case, the value of the determination coefficient (R^2=0.9997) indicates that only less than 1% of the total variations are not explained by the model. The value of adjusted determination coefficient (adjusted R^2=0.9993) was high, which indicates a high significance of the model. Predicted R^2 0f 0.9953 was also in a good agreement with the adjusted R^2. Adequate precision compares the range of predicted values at the design points to the average prediction error. The model adequate precision ratio of 120.65 indicates an adequate signal.

The model equation in terms of actual factors is given as:

$$\text{Temperature}=896.0933-23.1685*A-2.37512*B-143.838*C \; 0.00944*A*B+0.138776*A*C+0.150146*A^2 +0.13925*B^2+276.8*C^2 \quad (2)$$

where A= Time, B= Radial Distance and C= Immersion Speed.

Table 3: Experimental result of oil quenched steel sample

Run	Variables			Temperature Distribution		
	Time	Radial distance	Immersion speed	Actual	Predicted	Residuals
6	100	15	0.1	56.00	49.60	6.40
10	51	25	0.1	96.50	105.71	-9.21
17	51	15	0.35	71.10	71.10	0.00
4	100	25	0.35	61.90	59.09	2.81
11	51	5	0.6	116.20	106.99	9.21
13	51	15	0.35	71.10	71.10	0.00
2	100	5	0.35	53.20	53.19	0.01
15	51	15	0.35	71.10	71.10	0.00
12	51	25	0.6	120.50	114.09	6.41
1	2	5	0.35	819.90	822.71	-2.81
7	2	15	0.6	838.40	844.80	-6.40
14	51	15	0.35	71.10	71.10	0.00
8	100	15	0.6	60.20	69.43	-9.22
5	2	15	0.1	841.00	831.78	9.22
3	2	25	0.35	847.10	847.11	-0.01
9	51	5	0.1	76.10	82.51	-6.41
16	51	15	0.35	71.10	71.10	0.00

From the analysis of variance shown in table 4, the Model F-value of 2650.91 implies the model is significant. There is only a 0.01% chance that a "Model F-Value" this large could occur due to noise. The p values less than 0.0500 indicate model terms are significant. In this case A, B, C, A^2, B^2, C^2 are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. The input parameter which is most significant on the output performance (Temperature) is input parameter A which is Time because it shows the largest F-value of 16331.02 and minimum prob>F value, followed by the Immersion speed and the least effect is seen on Radial distance because of its least F-value of 6.1804. Interactions between the input parameters were not significant having p values >0.05.

Table 4: ANOVA for response surface quadratic model of oil quenched steel

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob> F	
Model	1772061	9	196895.6	2650.913	<0.0001	significant
A	1212981	1	1212981	16331.02	<0.0001	significant
B	459.045	1	459.045	6.180373	0.0418	significant
C	539.5612	1	539.5612	7.264407	0.0309	significant
AB	85.5625	1	85.5625	1.151975	0.3187	Not-significant
AC	11.56	1	11.56	0.155639	0.7049	Not-significant
BC	64.8025	1	64.8025	0.872471	0.3814	Not-significant
A^2	547201.1	1	547201.1	7367.266	<0.0001	significant
B^2	816.4447	1	816.4447	10.99224	0.0128	significant
C^2	1260.168	1	1260.168	16.96633	0.0045	significant
Residual	519.9225	7	74.27464			
Lack of Fit	519.9225	3	173.3075			
Pure Error	0	4	0			
Cor Total	1772581	16				

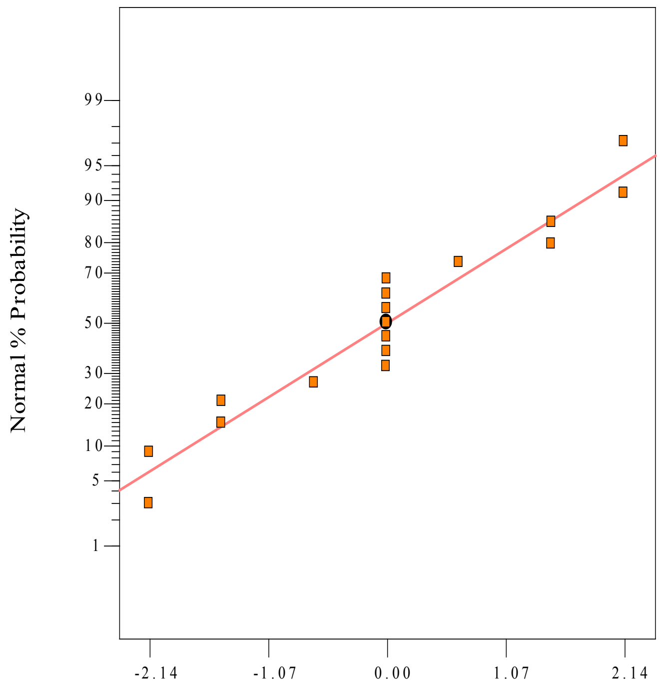

Figure 2: Normal probability plot of residuals for temperature distribution

Diagnostic plots of oil quenched steel sample

The quality of the model devloped was further tested using different diagnostic plots such as normal probability curve, residuals vs predicted, outliers and predicted against actual plots. The normal probability plot of the residuals for temperature distribution shown in Figure 2 reveal that the residuals are falling on the straight line, which means the errors are distributed normally. All the above consideration indicates an excellent adequacy of the regression model. The residual values were plotted against the individual run indicating minimum difference between the experimental data and the predicted data as shown in Figure 3.

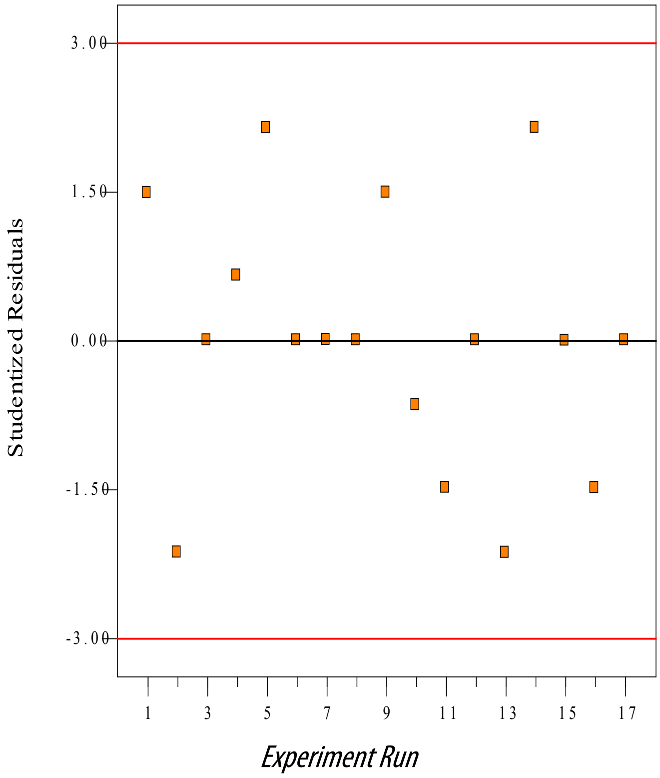

Figure 3: Plot of residuals against experimental runs.

Effect of single factor on temperature distribution

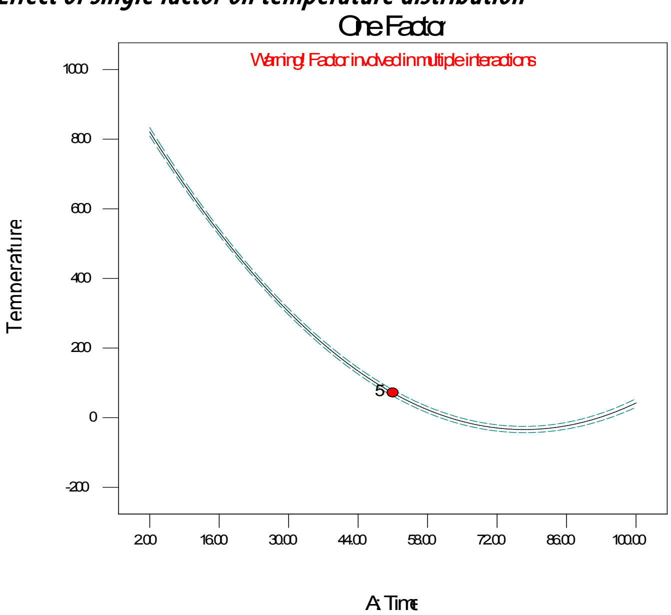

Figure 4: Plot of time against the temperature distribution

Figure 4 shows the effect of time on the temperature distribution of the quenched steel sample. As time increases from 2 seconds to 100 seconds, temperature distribution reduces.

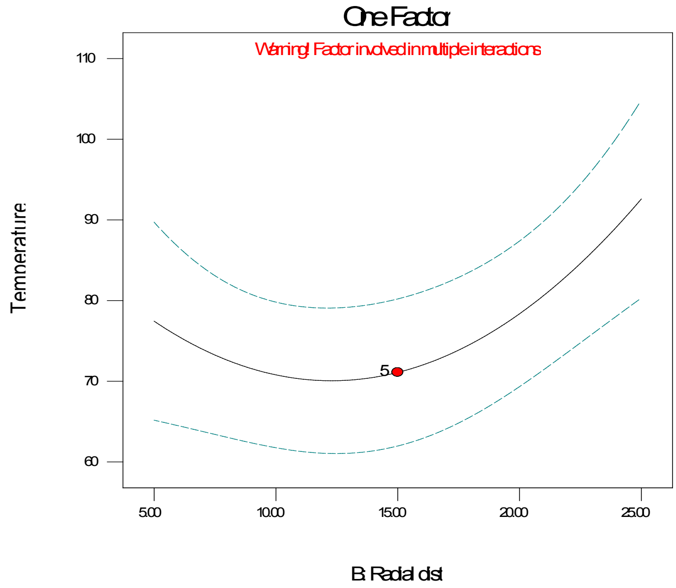

Figure 5*: Plot of radial distance against the temperature distribution*

The effect of radial distance on the temperature distribution of steel sample was shown in Figure 5. Temperature distribution decreases from 5mm to 15mm and then increases slightly from 71.5 to 92.6 °C as radial distance increases within the specified range.

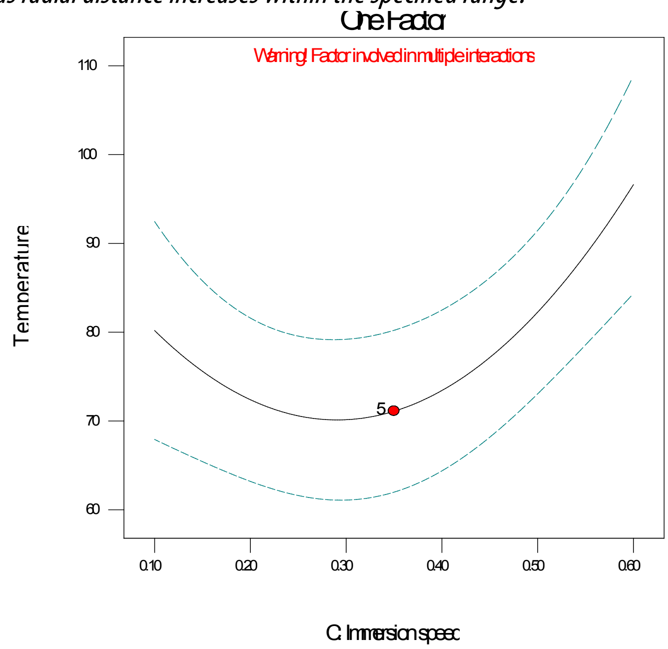

Figure 6: *Plot of immersion speed against the temperature distribution*

Figure 6 shows the effect of immersion speed on the temperature distribution of the quenched steel sample. Temperature distribution decreases as immersion speed increases from 0.10 m/s to 0.35m/s but becomes increasing as immersion speed further increases to 0.60m/s.

CONCLUSION

This paper has described the use of design of experiments (DOE) for conducting experiments on quenching of steel sample in oil medium. A quadratic model was developed for predicting temperature distribution of steel sample AISI1020 using response surface methodology (RSM). The model developed was validated giving a R-squared value of 0.9997, adjusted R-squared of 0.9993 and predicted R-squared of 0.9953. The model was satisfactory at 99% accuracy. The effects of the factors on the temperature distribution were investigated. Time is the factor that has greater influence on temperature distribution, followed by immersion speed and the least effect was seen on radial distance. The model developed can be used for process behavior prediction for performance measure, for process optimization and for training tools for operators in industrial application.

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[1.] Arshad ALI, [2.] Muhammad Ashfaq MAITLA,
[3.] Makbol Ahmed MURSHID, [4.] Shahid IQBAL

ENERGY CRISES IN PAKISTAN VIS-À-VIS DISASTERS

[1,2,4.] National University of Sciences and Technology, Islamabad, PAKISTAN
[3.] Asian Institute of Technology, THAILAND

Abstract: Pakistan by the grace of Almighty Allah is having huge energy positional but this capability has not been explored fully but with exception of some large hydel works. An endeavor has been put-in by the Govt now to incorporate renewable energy in the development strategy. The strategy will be implemented in three phases. Exploring different energy resources and their use can help Pakistan to come out from this quagmire. Hosts of allied problems like extra costs and dangers of fuel stocking, carriage, and alternative arrangements will be minimized. Global warming, green house gasses, environmental degradation and other related problems will be reduced using alternative energy resources. This will also reduce the energy related hazards.
Keywords: Renewable energy, climate change, energy consumption, impediments

BACKGROUND

Our country has hosts of energy resources however, no worthwhile effort has been plugged-in to get benefit from them and still there is an acute shortage of energy. Thereby, these resources are being received from different sources with exorbitant prices. Resources which are feasible in Pakistan are mini-hydel, bio-gas, wind and solar. But increasing requirements on these meager resources has been a prime environmental worry for the nation. This problem is more compounded owing to danger of pollution. It is an established fact that Pakistan's energy infrastructure is underdeveloped and poorly managed.

Presently the nation is experiencing awful energy shortfall. Energy capability is one of the important facets of economy and contributes tremendously in the sustainable development of a country. Owing to rapid industrialization and population growth the requirement has been increased manifold but on the contrary alternative energy sources have not been identified. Requirement is not compatible with existing capability, so situation of crisis is prevailing. It is fairly contemplated that in future if proper steps are not taken then much energy related issues can erupt, thus inviting emergency situations and disasters.

Owing to location of the country in the seismic zone and rapid industrial advancement possibility of natural and manmade hazards is always there. To address this menace, various actions have been in the offing these are not meeting the desired requirement. In view of consequential effects of energy hazards turning into disasters, there is a need to work out a clear road map to tackling the energy related disasters that is proactive, comprehensive and progressive.

INCREASED ENERGY CONSUMPTION

It is an established fact that provision of energy supply is very less and secondly it is not being used optimally, thereby gap is increasing. Alone the electricity has decreased approximately 1.8% reduction in Grand Domestic Product. Energy has been a serious problem from year 1971 in general and for the last one decade in particular. For the last forty years no worthwhile effort has been put-in by the Government to explore new energy resources with exception of some miner works on it.

Supply of energy vis-à-vis consumption

Pakistan's energy requirements have increased manifolds for the last three decades. In comparison, China's per capita energy consumption in 2000 was 30.89 M Btu, Iran's was 80.30 and Russia's was 195.35, while America was having 341.75 M Btu.

Supply

Both supply and current availability of energy saw awful for the last couple of years. Pakistan needs around 16,000 to 19000 MW electricity per day, however, presently generation is approximately 11,000 MW per day, so this menace is badly deteriorating the economic development of the country.

Consumption

Our energy requirement currently is fulfilled by host of sources like natural gas, oil, electricity and coal. Share of gas consumption was 43.77%, oil 29.5 %, electricity 15.35 %, coal 10.45 % and LPG 1.55 %. We have been facing an acute shortage of energy for the last couple of years. The problem becomes more complex from June to August every year. The deficiency has been met owing to cheap energy produced through hydel and gas however; substantial production is contingent upon hydel energy. The authorities should take pragmatic measures on god speed bases to meet the deficit.

CURRENT AND POTENTIAL SOURCES OF ENERGY IN PAKISTAN

Owing to decrease in oil reservoirs and its ill effects of global warming and environmental degradation, the World is now near the brink of energy crunch. Countries are now realizing this problem seriously and *are trying to explore and produce energy from alternative sources other than fossil oils. Currently, hydel and nuclear energy is the safer and economical means to replace the fossil fuels. Sources of energy are proffered in the ensuing para:-*

- ***Natural Gas Exploration.*** *Pakistan still has huge untapped gas reserves. If we allocate more resources to their exploration there is a possibility that in the near future part of the energy resource gap may be met from new reserves. The current gas prices and the limits they place on increasing the profitability of this sector would not attract any reasonable amount of investment, whether local or foreign, since the cost of exploration has gone up substantially and current well head prices do not justify further investment at the current rate of return. The other factor discouraging exploration of new gas reserves, which would continue to haunt us, is the law and order situation in most of the areas where gas finds can be a possibility.*
- ***Natural Gas Import.*** *The proposed gas pipeline project to import the gas from Iran is in pipe line since long. Earnest efforts are being made by every Govt to commission this project but owing to nefarious designs of certain super powers the progress is somewhat slow on the subject. This project will at least take five years to complete. Nevertheless, it will certainly reduce the energy deficit and Govt has to vigorously pursue the issue on priority basis.*
- ***Thar Coal.*** *Pakistan is very rich in coal deposits, alone Thar has coal strip of 100 x 40 kms long and almost 40 m deep reservoir. We are 5th in the World in Coal deposits. It has electricity generation capacity more than a lac Mw for next three decades. But currently owing to non-availability of requisite capability full potential is not being harnessed. However, with the help of China some progress has been made. We have to speed up the process. In addition to electricity, water and gas will also be available from this facility.*
- ***Hydro Power.*** *Our country is having abundance of hydel energy resources; however, desired efforts are being made in this field. We have only two mega dams and some small dams, which contribute even less than 35 % of overall potential. Currently we are having only 6000 MW against the capability of more than 40000 MW.*
- ***Solar Energy.*** *Geographically we located at a point that solar energy can be fully harnessed. Almost throughout the country this facility is available. For the last two decades sense has prevailed and this area is under focus. Presently solar energy use is increasing day by day. In this regard Government has to produce requisite capability in terms of equipment and experts.*
- ***Wind Energy.*** *Almost every country is paying special attention toward this source. Developed countries like America, China etc., have done much in this field. They have achieved more than 31000 MW from this source. This energy is now considered to be the efficient source in the World. Need of the hour is to invest heavily in this field. Our Sind province is rich in wind potential and much work has been started in the region which will accrue rich dividends soon.*
- ***Tidal.*** *This is cheap type of source available in our country and can contribute tremendously in the overall grid capacity. Coastal tides are a prime source of this type of energy. Much studies and works have been in the offing to harness this potential optimally and get benefits out of it.*
- ***Nuclear Energy.*** *The "Chashrna Plant" was developed with the support of China and is being used by our scientists and engineers, thus adding 300 mw to the national grid. KANUPP was developed with the assistance of the Canadian Govt in 1960 and it has almost outlived its utility. Pakistan is the only country in the Muslim World operating nuclear power plants. Nuclear power is safer, economical and cause less degradation to the environment.*
- ***Geothermal Power.*** *This source of energy is suitable for the developing countries. Nevertheless, geothermal stations can be placed at rocks which are developed under the ground. Approximately, we have some 80,000 MW geothermal energy present in Himalayan. But it is not suited for us due to huge cost. Moreover, we have alternative sources of energy.*

HURDLES IMPEDING THE SOLUTIONS TO THIS CRISIS

There could be as many a reasons a one could think of but primarily they could be distributed in the following broad categories:-

- ***Circular Debt****. It is visualized that no one is serious in clearing the IPP's circular Debt. Upon clearing the debt, IPP's will function properly, thus delivering optimally. Till the time debt is cleared this situation will remain.*
- ***Line Losses.*** *We are experiencing huge line losses, owing to poor quality conductors, poor maintenance and theft cases. Thus in the process the overhead burden increases and this result into short fall and expensive electricity.*
- ***Inadequate Power Generation Capacity****. Most of our systems and appliances operate by using coal and gas, which is very costly. Both Gas and Coal are very expensive owing to non-availability of requisite expertise. We should try to use alternative energy sources and to increase the generation capacity.*
- ***Lack of Capacity of Distribution of Electricity****. Our distribution system is weak owing to poor end grid system as the existing infrastructure has outlived the utility. The current systems are not versatile and many problems are being faced specially during bad weather. Most of our supply system is based on two phase supply. Even by producing 3 phase electricity, it will not work if existing transmission is of 2 phase.*
- ***Issue of K.E.S.C****. After the privatization, K.E.S.C, has sufficient production but alone it is not enough, the Government must provide a dedicated transmission system as our two provinces get electricity from this source.*
- ***Dependence on IPP's****. These projects at present are providing electricity to almost 50 % of our country. Since their dues are not*

being paid regularly so now they are asking more prices from the users. This situation is affecting not only our industrial base/homes but also our imports. We must pay their dues.

ENVIRONMENTAL EFFECTS OF ENERGY AND RELATED DISASTERS

To reduce the ill effects of energy and related disasters, a pragmatic strategy is required to use the energy resources. A close interaction amongst researchers and environmentalists demands that newly developed energy sources is not only technologically feasible but also have a good impact on the environment. Less use of fossil fuels, energy security and awareness of damage by greenhouse gases are main factors in the development of future energy solutions. By using alternative energy sources problem of environmental degradation will be reduced considerably. However, both positive and negative effects are explained in ensuing para.

- ✓ ***Water Wars*** *India is planning and constructing large number of projects on western rivers (as per Indus Basin Water Treaty she cannot) allotted to Pakistan which will result in reduced share of water for Pakistan. Pakistan needs to adopt a more comprehensive, proactive and professional approach to deal with the situation. Unless tackled intelligently, Pakistan is bound to face serious shortage of water in years to come. This will not only result into tension with India but will also increase disharmony and mistrust amongst the provinces.*
- ✓ ***Civil Unrest*** *The energy crisis situation starts from nineties and still it persists. The swerve and awful amongst all the shortage of electricity. We are facing a huge electric crisis currently. So for no worthwhile solution is visible except reliance on Thar coals and Iran Pakistan gas pipe line project. If this situation persists then there are likely chances of civil unrest leading to complex situations.*
- ✓ ***Out Break of Forest Fire*** *It is an established fact that wood is being used in host of fields. In the quest of getting energy from this source if proper procedures are not in place, then there is always a great danger of forest fire, which can lead to disaster situations.*
- ✓ ***Hydel Energy and Dam Failures*** *Although the cheapest energy now a days is the hydel energy but World is now not advocating construction of large dams owing to devastation caused by these. Many countries like China are now advocating for small capacity dams instead of big ones. Thereby, there is always a danger of dam failure especially in Earth Quake of higher magnitude, thus leading to disaster situation.*
- ✓ ***Coal Mining and Associated Disasters*** *Pakistan is blessed with huge deposits but so far we do not have the requisite expertise to remove the overburden and extract the coal. Thereby, owing to non-availability of modern equipment to extract deep seated coal, our workers always remain susceptible to life dangers.*
- ✓ ***Nuclear Energy*** *We are getting handsome energy from nuclear. Although the development of energy is much safe but the possibility of nuclear hazard cannot be totally ruled out.*
- ✓ ***Natural Gas and Associated Disasters*** *We have ample untapped gas reserves. If we provide requisite resources to their exploration then there is a possibility that in the near future part of the energy resource gap may be met from new reserves. But due to fragile environment in country the events of destruction of the gas pipe lines will remain, thus creating emergencies.*
- ✓ ***Oil Spill Over*** *Although the oil transportation through sea is economical and safe as well. But the danger of oil spillage always remains, thus prone to secondary hazards in addition to losses.*

Possible Disasters Scenarios at Various Levels*. If we do not adopt a more comprehensive, proactive and professional approach to deal with the situation then disaster situations can emerge, starting from regional lvl i.e. with India, Iran and fghanistan, national, provincial, and domestic levels:*

- ✓ *Owing to water manoeuvres by the India and disregarding the Treaty, the tesion in near future can emerge.*
- ✓ *If any country wants to use the energy resources of Central Asian States (CARs) then only land route available is through Balochistan. Therby, this ares will remain under focus and tesnsion. Secondly all the foreign players also eyeing on the deep seaated resources of Balochistan Province.*
- ✓ *Currently we are facing hosts of energy crisis. And it will likely face about 6000 MW next year. Pakistan is also facing some 70 million tons of oil shortage. And is lacking behind the needs of natural gas at about 28 million ton of energy in current year and this ratio will rise in coming years. This will lead to unrest both at province, district and local level.*

PROPOSALS

We are facing huge energy crisis situation owing to hosts of factors like inadequate generation capacity, non-availability of requisite technology, miss management etc. Current electricity system is not only controversial but also lacks capacity vs. demand. Time has come that we should come out from IPP business and well upon on new and cheap energy sources to curb this crisis.

The remedial measures are.

- ✓ ***Conservation of Energy.*** *It is of paramount importance to save energy in all fields. Awareness is there amongst every citizen but there is a dire need of education the people at community level. We should educate the people how energy can be saved. Some of the ways are as under:*
- □ *Proper heat insulation of structures.*
- □ *Solarization where possible.*
- □ *Use lights which consumes less voltage & produce more lumens.*
- □ *Use of better quality conductor.*
- ✓ ***Improvement of Energy Shortfalls****:*
- □ *We must go for solarization and make use of this facility where ever is possible and there should be less reliance on expensive sources.*
- □ *Proper law should be made for use of energy by the industry which almost consumes one third of energy.*

- *Industrialist must be encouraged to produce own energy thus reducing the burden on national grid.*
- *Old plants and turbines must be replaced to increase the capacity.*
- *New techniques be introduced to decrease the losses.*
- *Communication infrastructures be improved to save on the fuels and allied expenditures.*
- *Less reliance on IPPs as they are too expensive.*
- *To reduce the line losses by using good conductors and providing pragmatic transmission and distribution.*

✓ ***Developing New Energy Resources**:*

- *Utilization of the huge deposits of Thar coal.*
- *By making best use of hydel energy by constructing small size dams.*
- *The process of gas import from Iran must be expedited.*
- *The process of import of electricity from Tajikistan must be expedited (1100 MW).*

✓ ***Alternative Energy Resources**:*

- *Wind power energy in Sindh and Baluchistan Provinces.*
- *Solarization.*
- *Wave / Tidal energy.*

CONCLUSION

The importance of hydel energy cannot be ruled out but we have so far failed to harness the importance and benefits of renewable sources of energy. In all probabilities they are most economical and beneficial. We are blessed with hosts of energy resources. But so far no worthwhile effort has been put in to get benefit from these blessings. We have to develop the Thar coal project, solar energy, wind energy etc. to pragmatically reduce the shortfall. We are certain new Govt is cognizant of the issue and will initiate a serious resolve to overcome this menace.

The need of the time is the realization of the fact that energy is being the life line for survival of the nation. Thereby, implementation of an immediate relief policy followed by a long term strategy for improvement is required.

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[1.] Y. YASREBINIA, [2.] M. DAEI, [3.] S. Esgandarzadeh FARD,
[4.] M. Sameie PAGHALEH

APPLICATION OF AMPLITUDE-FREQUENCY FORMULATION TO A NONLINEAR OSCILLATOR ARISING IN THE MICRO-ELECTRO-MECHANICAL SYSTEM (MEMS)

[1.] Department of Civil Engineering, College of Technical & Engineering, Shabestar Branch, Islamic Azad University, Shabestar, IRAN
[2.] Faculty of Civil Engineering, University of Tabriz, Tabriz, IRAN
[3.] Department of Civil Engineering, College of Technical and Engineering, Ahar Branch, Islamic Azad University, Ahar, IRAN
[4.] Department of Civil Engineering, Engineering Faculty, Azarbaijan Shahid Madani University, Tabriz, IRAN

Abstract: Study the application of microelectromechanical system (MEMS) devices especially the electrically actuated MEMS devices which require few mechanical components and small voltage levels for actuation is continuously growing. The MEMS devices are widely used as capacitive accelerometer, capacitive sensor, switches and so on. In this paper, the energy balance method has been successfully used to study a nonlinear oscillator arising in the microbeam-based microelectromechanical system (MEMS). The nonlinear ODE equation is solved by a powerful mathematical tool, the amplitude-frequency formulation. The good agreement of results got from amplitude-frequency formulation with results from fourth-order RungeeKutta method indicates that the obtained period is of high accuracy.
Keywords: micro electro mechanical system (MEMS); amplitude-frequency formulation; nonlinear vibration; analytical methods

INTRODUCTION

Study the application of microelectromechanical system (MEMS) devices especially the electrically actuated MEMS devices which require few mechanical components and small voltage levels for actuation is continuously growing. The MEMS devices are widely used as capacitive accelerometer [1], capacitive sensor [2], switches [3] and so on. Compared to the traditional mechanical systems, the MEMS devices are usually small, and their largest size will not exceed one centimeter, sometimes only in micron order. For this large surface-to-volume ratio, the integrated circuit (IC) technology in modern industry facilitates the fabrication of thousands of MEMS devices with increased reliability and reduced cost. However, electrostatic actuation, large deflections and damping caused by different sources give rise to nonlinear behavior. Nonlinearity in MEMS may cause some difficulties in computations. Until now, several techniques have been used to find numerical solutions, for example the shooting method [4] and energy balance method [5]. Although it is difficult to get analytic approximations for different phenomena in MEMS, there are some analytic techniques for nonlinear problems of MEMS. Recently, Fu et al. [5] investigated the nonlinear oscillation problem arising in the MEMS microbeam model by means of the energy balance method.

On the other hand, in the last decades, scientists have proposed and applied some analytical methods to nonlinear equations, such as variational iteration method [6-11], homotopy analysis method [12-13] and some other methods [14-19].

The main goal of this paper is to present an alternative approach, namely amplitude-frequency formulation [20], for constructing highly accurate analytical approximations to the nonlinear oscillation problem arising in the MEMS microbeam model.

PROBLEM DESCRIPTION

Figure 1 represents a fully clamped microbeam with uniform thickness h, length l, width b (b>>5h), effective modulus = $E/(1-\nu^2)$, Young's modulus E, Poisson's ratio υ and density ρ.

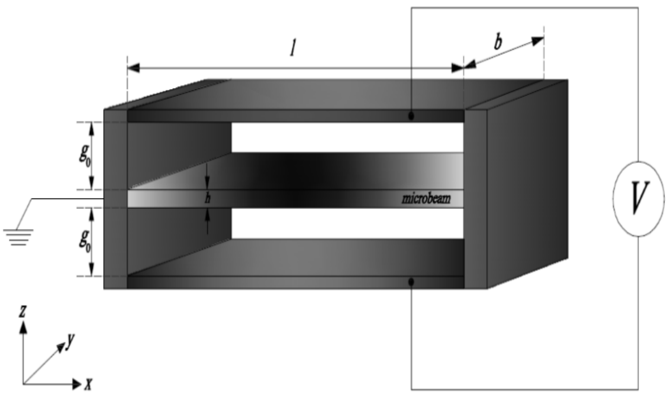

Figure 1. Schematics of a double-sided driven clamped-clamped microbeam-based electromechanical resonator

By applying the Galerkin Method and employing the classical beam theory and taking into account of the mid-plane stretching effect as well as the distributed electrostatic force, the dimensionless equation of motion for the microbeam is as follow:

$$(a_1u^4 + a_2u^2 + a_3)\ddot{u} + a_4u + a_5u^3 + a_6u^5 + a_7u^7 = 0, \quad u(0) = A, \ \dot{u}(0) = 0 \tag{1}$$

where u is the dimensionless deflection of the microbeam, a dot denotes the derivative with respect to the dimensionless time variable $t = \tau\sqrt{\bar{E}I / \rho bhl^4}$ with I and t being the second moment of area of the beam cross-section and time, respectively.

In Eq. (1), the physical parameters a_i ($i = 1–7$) are given by:

$$a_1 = \int_0^1 \phi^6 d\zeta, \tag{2}$$

$$a_2 = -2\int_0^1 \phi^4 d\zeta, \tag{3}$$

$$a_3 = \int_0^1 \phi^2 d\zeta, \tag{4}$$

$$a_4 = \int_0^1 (\phi''''\phi - N\phi''\phi - V^2\phi) d\zeta, \tag{5}$$

$$a_5 = -\int_0^1 (2\phi''''\phi^3 - 2N\phi''\phi^3 + \alpha\phi''\phi\int_0^1 (\phi')^2 d\zeta) d\zeta, \tag{6}$$

$$a_6 = \int_0^1 (\phi''''\phi^5 - N\phi''\phi^5 + 2\alpha\phi''\phi^3\int_0^1 (\phi')^2 d\zeta) d\zeta, \tag{7}$$

$$a_7 = -\int_0^1 (\alpha\phi''\phi^5\int_0^1 (\phi')^2 d\zeta) d\zeta. \tag{8}$$

which, the following nondimensional variables and parameters are introduced:

$$\alpha = \frac{6g_0^2}{h^2}, \ \zeta = \frac{x}{l}, \ N = \frac{\bar{N}l^2}{EI}, \ V^2 = \frac{24\varepsilon_0 l^4 \bar{V}^2}{\bar{E}h^3 g_0^3} \tag{9}$$

while a prime (') indicates the partial differentiation with respect to the coordinate variable x. The trial function is

$$\phi(\zeta) = 16\zeta^2 (1-\zeta)^2.$$

The parameter N denotes the tensile or compressive axial load, g_0 is initial gap between the microbeam and the electrode, V the electrostatic load and ε_0 vacuum permittivity.

BASIC CONCEPT OF AMPLITUDE-FREQUENCY FORMULATION

For a generalized nonlinear oscillator in Eq. (10), we use two trial functions [21]:

$$u_1 = A\cos\omega_1 t, \quad \omega_1 = 1 \tag{18}$$

$$u_2 = A\cos\omega_2 t, \quad \omega_2 = \omega \tag{19}$$

where ω is assumed to be the frequency of the nonlinear oscillator, Eq. (10).

The residuals are:

$$R_1(t) = -\cos t + f(A\cos t) \tag{20}$$

and

$$R_2(t) = -\omega^2\cos(\omega t) + f(A\cos(\omega t)) \tag{21}$$

We introduce R_{11} and R_{22} defined as [14]:

$$R_{11}(t) = \frac{4}{T_1}\int_0^{\frac{T_1}{4}} R_1(t)\cos(t).dt, \quad T_1 = 2\pi \tag{22}$$

and

$$R_{22}(t) = \frac{4}{T_2}\int_0^{\frac{T_2}{4}} R_2(t)\cos(\omega t).dt, \quad T_2 = \frac{2\pi}{\omega} \tag{23}$$

Applying He's frequency-amplitude formulation, we have:

$$\omega^2 = \frac{\omega_1^2 R_{22}(t) - \omega_2^2 R_{11}(t)}{R_{22}(t) - R_{11}(t)} \tag{24}$$

where $\omega_1=1$ and $\omega_2=\omega$.

APPLICATION OF PROPOSED METHOD

In order to assess the accuracy of He's amplitude-frequency formulation for solving nonlinear governing equation of motion and to compare it with the other solutions, in this section we consider this method.

According to He's amplitude-frequency formulation [20], we choose two trial functions $u1(t)=A\cos t$ and $u2(t)=A\cos\omega t$, where ω is assumed to be the frequency of the nonlinear oscillator Eq. (1). Substituting the trial functions into Eq. (9) results in, respectively, the following residuals

$$R_1(t) = -(a_1A^4\cos(t)^4 + a_2A^2\cos(t)^2 + a_3)\times A\cos(t) + a_4A\cos(t) + a_5A^3\cos(t)^3 + a_6A^5\cos(t)^5 + a_7A^7\cos(t)^7 \tag{25}$$

and

$$R_2(t) = -(a_1A^4\cos(\omega t)^4 + a_2A^2\cos(\omega t)^2 + a_3)\times A\cos(\omega t)^2\omega^2 + a_4A\cos(\omega t) + a_5A^3\cos(\omega t)^3 + a_6A^5\cos(\omega t)^5 + a_7A^7\cos(\omega t)^7 \tag{26}$$

We introduce R_{11} and R_{22} defined as:

$$R_{11}(t) = \frac{4}{T_1}\int_0^{\frac{T_1}{4}} R_1(t)\cos(t).dt = \frac{1}{128}A(40a_6A^4 - 40a_1A^4 - 48a_2A^2 + 48a_5A^4 + 35a_7A^6 + 64a_4 - 64a_3), T_1 = 2\pi \tag{27}$$

and

$$R_{22}(t) = \frac{4}{T_2}\int_0^{\frac{T_2}{4}} R_2(t)\cos(\omega t).dt = \frac{1}{128}A(48a_5A^2 + 40a_6A^4 + 35a_7A^6 + 64a_4 - 64\omega^2a_3 - 40A^4\omega^2a_1 - 48A^2\omega^2a_2), \quad T_2 = \frac{2\pi}{\omega} \tag{28}$$

Applying He's frequency-amplitude formulation, we have:

$$\omega^2 = \frac{\omega_1^2 R_{22}(t) - \omega_2^2 R_{11}(t)}{R_{22}(t) - R_{11}(t)} \tag{29}$$

where $\omega_1=1$ and $\omega_2=\omega$. Finally, the amplitude-depended frequency can be approximated as:

$$\omega_{AFF} = \frac{\sqrt{2}}{4}\frac{\sqrt{64a_4 + 48a_5A^2 + 40a_6A^4 + 35a_7A^6}}{\sqrt{5a_1A^4 + 6a_2A^2 + 8a_3}} \tag{30}$$

Its approximate solution reads

$$u(t) = A\cos\left(\frac{\sqrt{2}}{4}\frac{\sqrt{64a_4 + 48a_5A^2 + 40a_6A^4 + 35a_7A^6}}{\sqrt{5a_1A^4 + 6a_2A^2 + 8a_3}}t\right) \tag{31}$$

The comparison between energy balance method and fourth-order Rungee Kutta method is plotted in Figure 2. Herein the values of parameters are taken as N= 10 and α= 24.

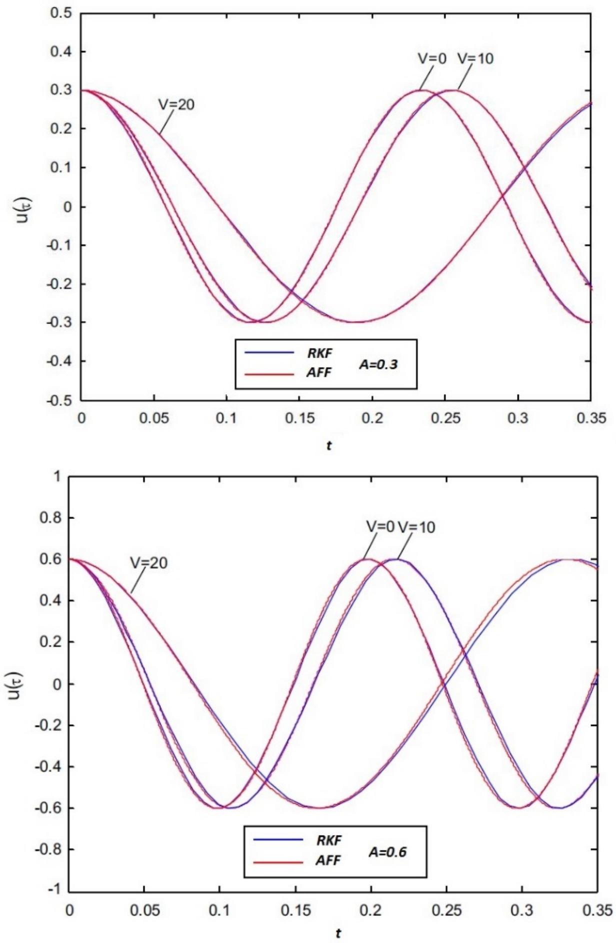

***Figure 2**. The comparison between energy balance method and the fourth-order Rungee Kutta method, solid lines: Rungee Kutta solutions and dashed lines: amplitude-frequency formulation.*

CONCLUSIONS

In this paper, the amplitude-frequency formulation has been successfully used to study a nonlinear oscillator arising in the microbeam-based MEMS where the midplane stretching effect and distributed electrostatic force are both considered. For the free vibration of a microbeam the governing equation is solved by a powerful mathematical tool, the amplitude-frequency formulation. The comparison of results got from amplitude-frequency formulation and fourth order Rungee Kutta method indicates that the obtained period is of high accuracy.

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[1.] Mohamed A. A. El-SHAER , [2.] Ghada M. El-MAHDY

STRUCTURAL ANALYSIS OF MONO-SYMMETRIC PLATE GIRDERS IN COMPOSITE BRIDGES

[1.] Civil and Construction Engineering Department, Higher Technological Institute, 10th of Ramadan City, EGYPT
[2] Steel Structures, Structures & Metallic Construction Research Institute, Housing &Building National Research Center, Giza, EGYPT

Abstract: *Mono-symmetric plate girders are often used in simply supported composite bridges to eliminate local plate buckling in the compression flange during construction. This causes the neutral axis of the plate girder to shift downwards subjecting more of the web to compressive stresses due to bending. In slender webs this increases the possibility of local buckling in the compression part of the web during construction. However, depending on the slenderness (width-to-thickness ratio) of the web, the post-buckling reserve capacity may accommodate this local buckling within the elastic limit of the web for during construction loads. Hence, this would allow for the use of more slender webs in composite plate girder construction without the need for longitudinal web stiffeners or the reduction of the overall composite section due to local plate buckling in the web. Recommended values of stress level are given for mono-symmetric plate girders in the non-composite stage based on the results of a non-linear finite element analysis.*
Keywords: *composite bridges, effective width, FEA, local plate buckling, mono-symmetric sections, plate girders, stress gradient, stress level*

INTRODUCTION

Plate girders in conjunction with a reinforced concrete slab are often used as composite plate girder bridges in positive bending. This has the advantage of the possibility of local plate buckling in the plate girder's web and compression flange as a result of composite action under service loads. In addition to this, the during construction loads acting on the plate girder section alone, DL_1, may be designed to allow for local buckling in the web while keeping the stresses within the elastic limit of the plate girder section during construction.

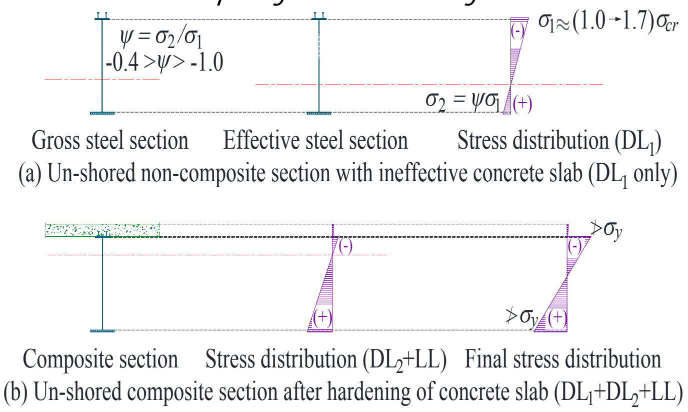


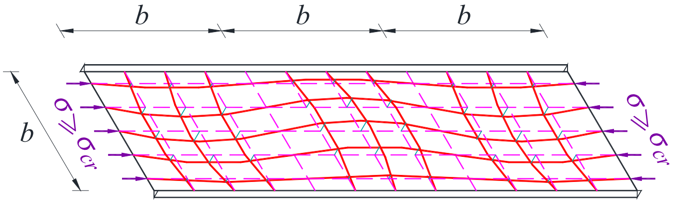
Figure 1: *Stress distribution in composite construction*

For plate girders with webs having a width-to-thickness ratio in the very slender range, the critical stress is well below the yield stress, and under the effect of construction loads only, Figure 1(a), the post-buckling state of the slender web may cause a nonlinear stress distribution, but the stresses in the web may still be in the elastic range. This would allow for the use of more slender webs for composite plate girders keeping in mind that the neutral axis will shift upwards with the onset of composite action, as shown in Figure 1(b). Hence, preventing residual strains due to the yielding of the section during the construction non-composite stage and the after construction composite stage. The stress distribution for both the non-composite and composite stages for un-shored construction is shown in Figure 1.

Other researchers to study composite I-girders are Gupta [1], Gupta et al. [2], Basker et al. [3], and Yakel and Azizinamini [4]. Recent research was also conducted on I-section flexural beams by Shokouhian and Shi [5] and Lee et al. [6].

LOCAL PLATE BUCKLING

Local plate buckling occurs in slender plate elements when the compressive stress in the plate element exceeds the critical plate buckling stress of the plate element, as shown in Figure 2. After the onset of plate buckling, a wave-like propagation of out-of-plane deformations breaks out increasing in amplitude with the increase in loading. This causes the compressive stresses to redistribute in the plate element, concentrating in the regions supported by stable boundary conditions. Due to the loss of in-plane stiffness of the unsupported regions, compressive and tensile bending stresses develop through the thickness of the plate, fluctuating along the length of the plate. The stress at the stable edges gradually increases with the increase in loading after the onset of local buckling up to the yield stress, σ_y. Once the edge stress has reached the yield stress, the plasticization of the plate element propagates in the nearby regions till the supported parts of the plate element are assumed to have reached the yield stress. Whereas, the unsupported unstable internal part of the plate element is assumed to be ineffective. Hence, the *plate element does have a post-buckling reserve capacity which can be within the elastic limit of the element if the edge stress does not reach the yield stress capacity.*



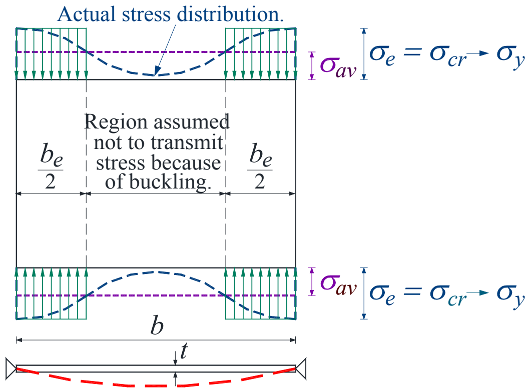


Figure 2: *Concept of effective width*

The elastic buckling stress, σ_{cr}, of slender plates as derived by von Kàrmàn et al. [7] is

$$\sigma_{cr} = \frac{k\pi^2 E}{12(1-\nu^2)}\left(\frac{t}{b}\right)^2 \quad (1)$$

which is inversely proportional to the square of the width-to-thickness ratio, b/t, of the plate element. The plate buckling factor, k, depends on the longitudinal boundary conditions of the plate element and the normal stress distribution in the plate, shown in Figure 1. Expressions for k for different boundary conditions can be found in the Eurocode EC3 EN 1993-1-1:2003 [8] or the Egyptian Code of Practice for Steel Construction and Bridges ECOP-ASD [9]. The modulus of elasticity, E, can be taken as 210,000 MPa and Poisson's ratio, can be taken as 0.3.

From the expression for the uniform elastic critical stress, given in Eq. (1), acting on a plate with a width-to-thickness ratio of b/t we get

$$\left(\frac{b}{t}\right) = \sqrt{\frac{k\pi^2 E}{12(1-\nu^2)\sigma_{cr}}} \quad (2)$$

Assuming an effective width of b_e and a uniform stress acting on it of σ_e, which can have a value anywhere from the critical stress σ_{cr} to the yield stress σ_y as shown in Figure 2, then by analogy we get

$$\left(\frac{b_e}{t}\right) = \sqrt{\frac{k\pi^2 E}{12(1-\nu^2)\sigma_e}} \quad (3)$$

Hence, the ratio of the effective width b_e, to the original width b, known as the effective width parameter ρ, is

$$\rho = \left(\frac{b_e}{b}\right) = \sqrt{\frac{\sigma_{cr}}{\sigma_e}} \quad (4)$$

Assuming that the average uniform stress of the nonlinear post-buckling stress distribution is σ_{av} as shown in Figure 2, the effective width is assumed to be the width subject to a stress equal to the edge stress, σ_e, of the nonlinear stress distribution such that it develops a strength equal to the average stress acting on the whole width. Hence,

$$b_e\sigma_e = b\sigma_{av} \quad (5)$$

giving

$$\sigma_{av} = \left(\frac{b_e}{b}\right)\sigma_e = \sqrt{\sigma_{cr}\sigma_e} \quad (6)$$

Taking the non-dimensional slenderness parameter λ_n as

$$\lambda_n = \sqrt{\frac{\sigma_e}{\sigma_{cr}}} = \sqrt{\frac{12(1-\nu^2)}{k\pi^2}}\,\frac{b}{t}\sqrt{\frac{\sigma_e}{E}} \quad (7)$$

and substituting this into Eq. (6) gives

$$\sigma_{av} = \frac{1}{\lambda_n}\sigma_e \quad (8)$$

To account for the effect of residual stresses in the moderately slender and the non-compact slenderness ranges, the American Iron and Steel Institute (AISI) [10] suggests the following expression for the average stress.

$$\sigma_{av} = \frac{\lambda_n - 0.22}{\lambda_n^2}\sigma_e \quad (9)$$

Both Eqs. (8) and (9) are plotted in Figure 3.

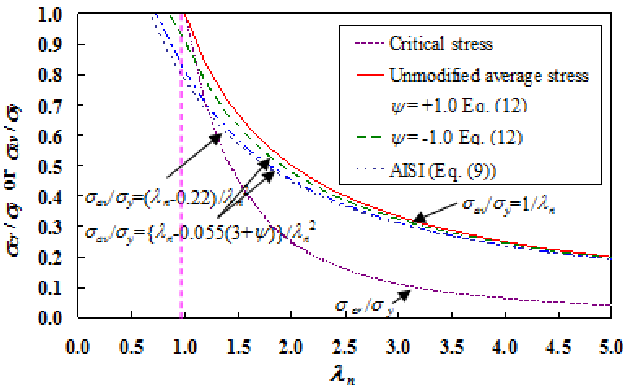


Figure 3: *Normalized plate buckling curves*

EFFECT OF STRESS GRADIENT ON LOCAL PLATE BUCKLING

To include the effect of stress gradient in the plate element due to combined compressive and flexural stresses in the member, as shown in Figure 4, the effective width parameter, ρ, is assumed to take the form

$$\frac{\sigma_{av}}{\sigma_e} = \frac{b_e}{b} = \rho = \frac{\lambda_n - x - y\psi}{\lambda_n^2} \quad (10)$$

where x and y can be determined from the limits of b/t for stiffened slender plate elements in pure compression, $\psi = +1.0$, and pure bending, $\psi = -1.0$. This is the same method used by El-Mahdy and Abu-Hamd [11, 12, and 13] to derive the current equation for the effective width of stiffened slender plate elements subject to a stress gradient in the Egyptian Code of Practice for the Design of Steel Construction and Bridges [9].

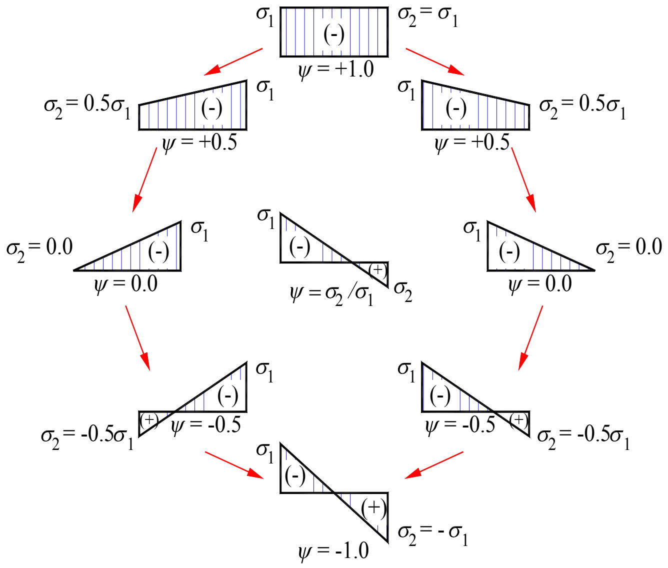


Figure 4: Schematic representation of stress gradient, ψ, due to combined compressive and flexural stresses

For example, using the limits for pure compression and pure bending given in the Eurocode EC3 [6],

$$\frac{b}{t} = 42\varepsilon \quad \text{for} \quad \psi = +1.0 \qquad \text{where} \quad \varepsilon = \sqrt{235/\sigma_y}$$
$$\frac{b}{t} = 124\varepsilon \quad \text{for} \quad \psi = -1.0 \tag{11}$$

and taking k = 4.0 for the case of pure compression and k = 23.9 for the case of pure bending and assuming $\sigma_e = \sigma_y$ gives the values 0.144 and 0.048 for x and y, respectively. Hence, according to the limits of the EC3 [8]:

$$\frac{\sigma_{av}}{\sigma_e} = \frac{b_e}{b} = \rho = \frac{\lambda_n - 0.144 - 0.048\psi}{\lambda_n^2} \tag{12}$$

Factorizing and approximating this leads to the expression

$$\frac{\sigma_{av}}{\sigma_e} = \frac{b_e}{b} = \rho = \frac{\lambda_n - 0.05(3+\psi)}{\lambda_n^2} \tag{13}$$

which is close to the expression given in the EC3 EN 1993-1-5:2006 [14]

$$\frac{\sigma_{av}}{\sigma_e} = \frac{b_e}{b} = \rho = \frac{\lambda_n - 0.055(3+\psi)}{\lambda_n^2} \tag{14}$$

The normalized average stress for the cases of ψ = +1.0 and ψ = -1.0, according to Eq. (12), are plotted in Figure 3.

FINITE ELEMENT ANALYSIS

A finite element parametric analysis, using COSMOS 2.6 software, was conducted on models of plate girders having a web depth of 1000 mm and varying the web thickness, t_w, from 5 mm to 11 mm giving a width-to-thickness ratio for the web varying from 200 to 91. The compression flange was kept constant in the non-compact range having a size of 200 x 11 mm, whereas, the size of the tension flange was increased to achieve a stress gradient in the web of ψ = -1.0, -0.8, -0.6, and -0.4, as shown in Figure 5.

A model with a simply supported span of length L = 10 m was used. In the actual finite element model the height of the web was modeled having a depth of 1000 mm plus half the thickness of both the compression flange and the tension flange. This causes a slight decrease of the stress gradient in the web due to a minor change in the position of the model's neutral axis, but this decrease is negligible. Both flanges were laterally supported as shown in Figure 6(a) to prevent any out-of-plane lateral torsional-flexural buckling occurring in the compression flange. Elastic-plastic shell elements were used to model the flange and web plate elements, however, the end parts of the top and bottom flanges were stiffened by increasing their thickness and taken as elastic shell elements to overcome local deformations due to loads applied to these flanges. The material of the model was taken as elastic-perfectly plastic with a modulus of elasticity of 210 GPa and a yield stress of 350 MPa.

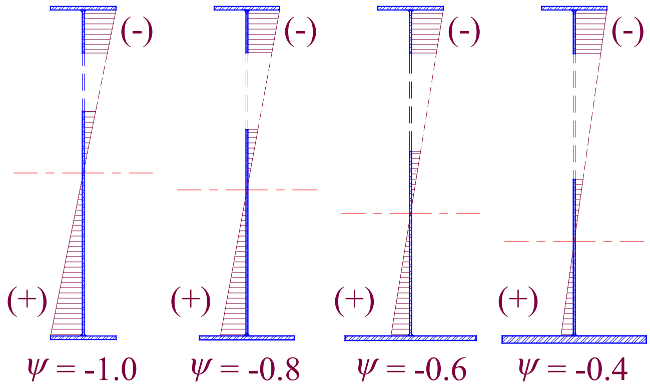
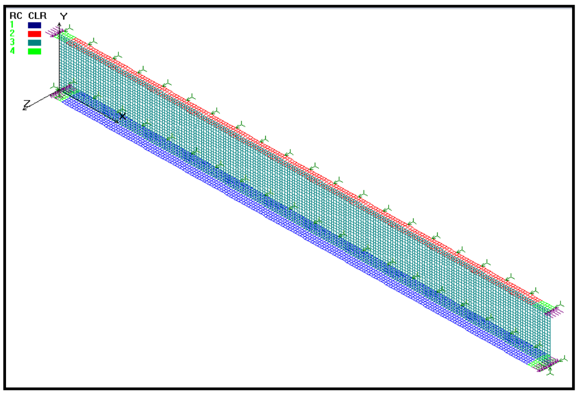
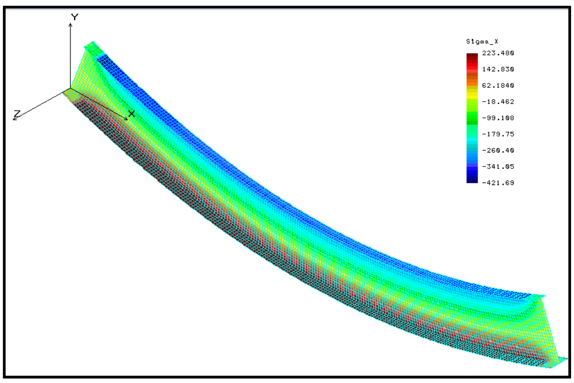


Figure 5: Schematic representation of parametric plate girder ross-sections



a)



b)

Figure 6: Typical finite element model and normal stress distribution of linear analysis; a) Finite element model; b) Deformed shape and stress distribution

The compression and tension flanges of each model were loaded to cause a moment equal to the yield capacity of the section. This was achieved by applying equivalent end compression and tension forces *in the top and bottom flanges, respectively, according to the following formulas:*

$$F_{et} = A_{tf} F_y \left(1 + \frac{A_w}{A_{tf}} \frac{1}{3(1-\psi)} \right) \tag{15}$$

$$F_{eb} = A_{bf}(-\psi) F_y \left(1 + \frac{A_w}{A_{bf}} \frac{-\psi}{3(1-\psi)} \right) \tag{16}$$

This gives a yield moment, M_y, of

$$M_y = h_w F_y \left(\frac{A_{tf} + \psi^2 A_{bf}}{(1-\psi)} + \frac{A_w}{3} \frac{1+(-\psi)^3}{(1-\psi)^2} \right) \tag{17}$$

where F_{et} and F_{eb} are the equivalent compression and tension forces assumed to be concentrated at the centroids of the flanges that cause a moment equal to the yield moment capacity of the section, respectively; A_{tf} and A_{bf} are the areas of the top and bottom flange plates, respectively; and h_w and A_w are the depth and area of the model's web plate, respectively.

The results of the linear analysis conducted on the finite element models verify that the gross stiffness of the model, calculated from the midpoint deflection, Δ, compare accurately with the analytic expression for a simply supported beam subject to a uniform moment, M, viz., $I = ML^2/8E\Delta$. The position of the neutral axis can also be determined from the normal stress distribution in the deflected model. Excessive stresses were noted in the flanges near the loaded edges. Figure 6(b) shows the normal stress distribution in the deformed model with a web thickness of 5 mm or a web slenderness of 200 and a bottom flange sized to give a stress gradient of $\psi = -0.6$.

A nonlinear analysis which follows the Newton-Raphson incremental-iterative procedure was used to detect the propagation of local plate buckling in the slender web. An initial 1 mm out-of-flatness at the center-point of the web was used in the model to initiate local web buckling.

Finally, a finite element analysis of the composite section, shown in Figure 7, using a slab of 2000 x 200 mm with a concrete cube strength, f_c', of 40 MPa and uniformly loaded above the slab gave approximate values of the residual capacity of the composite section in the after construction phase.

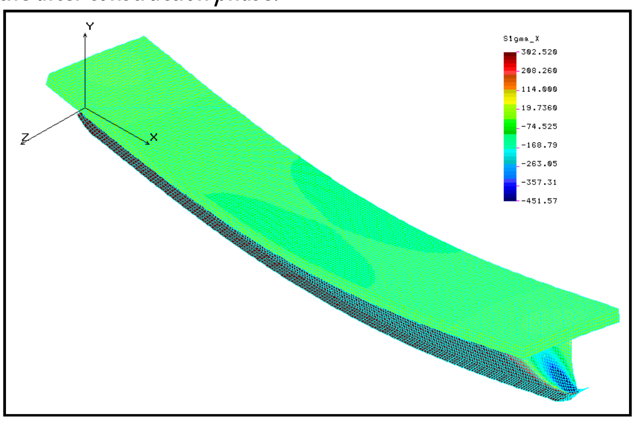


Figure 7: *Normal stress distribution in composite section*

DISCUSSION OF RESULTS

Figure 8 illustrates the in-plane membrane normal stress distribution and the out-of-plane local plate buckling of the web in flexural compression for the model with a web slenderness of 200 (i.e., $t_w = 5$ mm) and a stress ratio of $\psi = -0.6$.

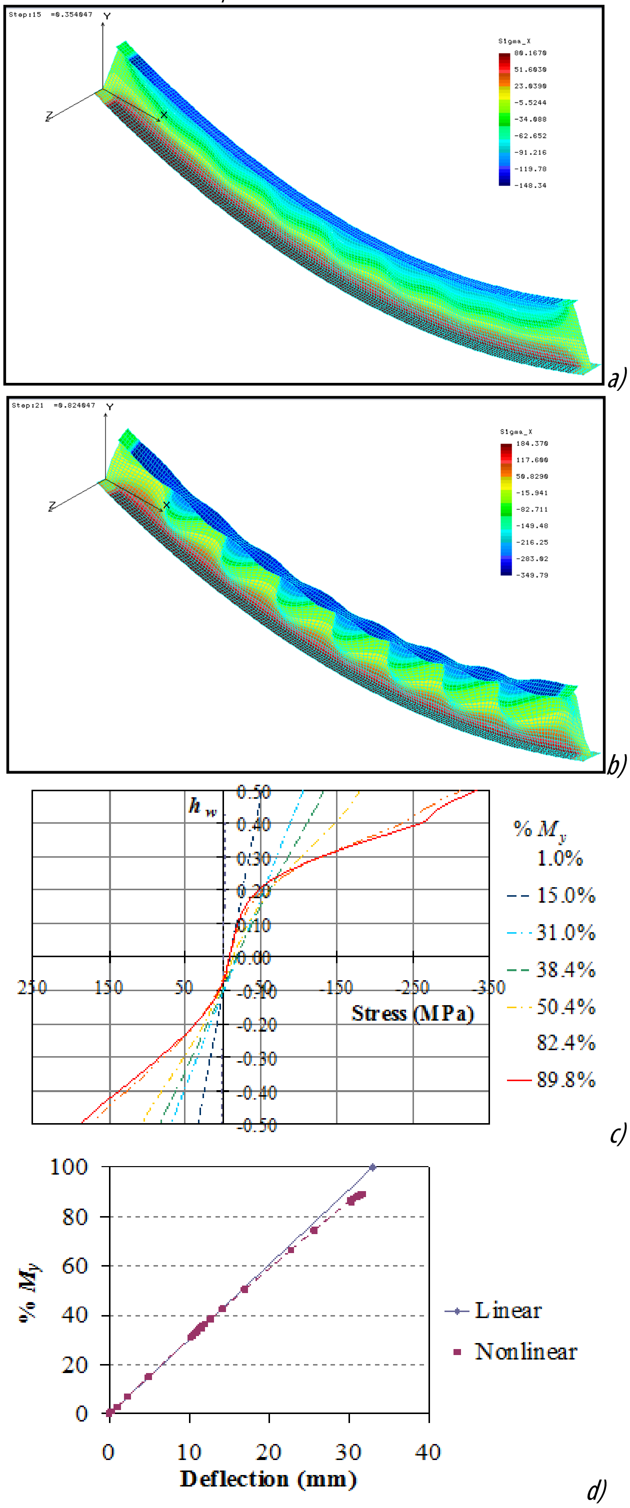


Figure 8: *Deformed shape and normal membrane stress distribution for model with web slenderness 200 and ψ= -0.6; a) Stress level $1.72\sigma_{cr}$ b) Stress level σ_y c) Stress distribution along the web at different stress levels d) Load-deflection curves*

At a stress level of $1.72\sigma_{cr}$, shown in Figure 8(a), it can be seen that a notable amount of local buckling in the compression part of the web *occurred without causing any distortional buckling in the non-compact adjacent compression flange, and without exceeding the elastic limit as shown by the maximum compressive stress of 146 MPa. Whereas, for a stress level of $\sigma_y = 350$ MPa, shown in Figure 8(b), the local buckling of the web in compression is greatly magnified causing distortional buckling in the adjacent compression flange.*

buckling has initiated at the critical stress level, however, considerable nonlinearity in the stress distribution occurs near the end of the nonlinear analysis as the stress level approaches the yield stress. This is also demonstrated by the load-deflection curves shown in Figure 8(d). It can also be noted that the neutral axis tends to shift upwards with the occurrence of local plate buckling in the web and the nonlinear stress distribution.

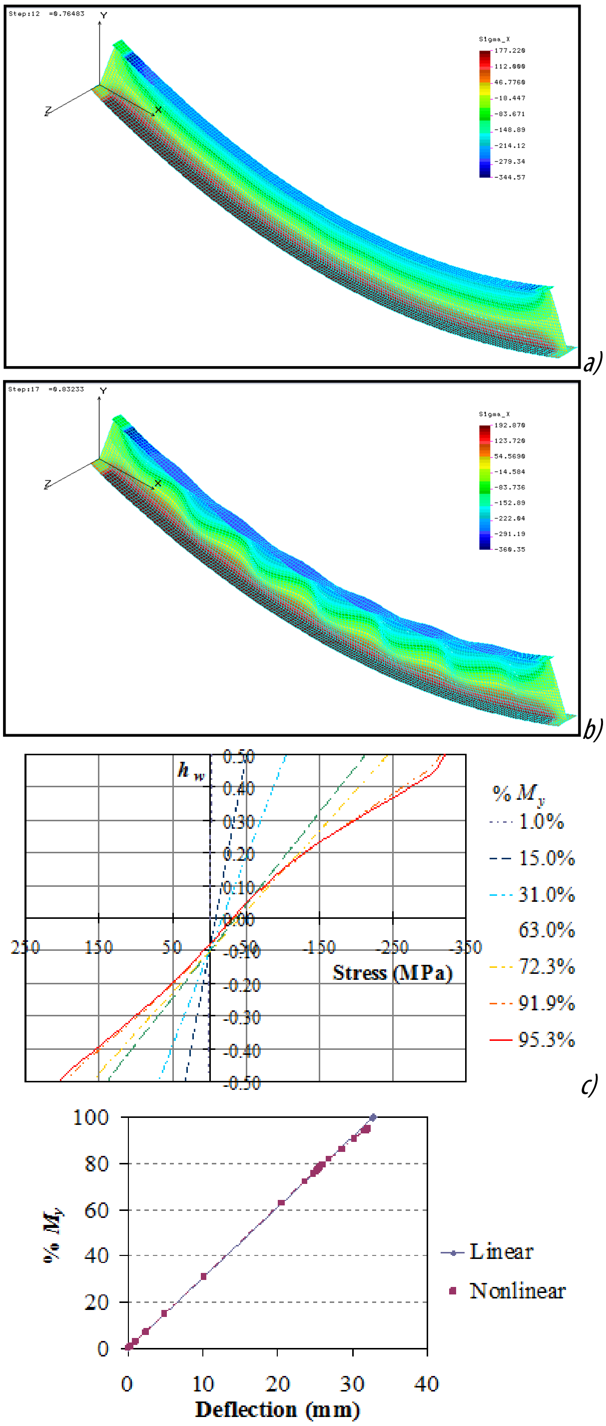


***Figure 9**: Deformed shape and normal membrane stress distribution for model with web slenderness 125 and ψ = -0.6; a) Stress level 1.47σ_{cr} ; b) Stress level σ_y; c) Stress distribution along the web at different stress levels; d)Load-deflection curves*

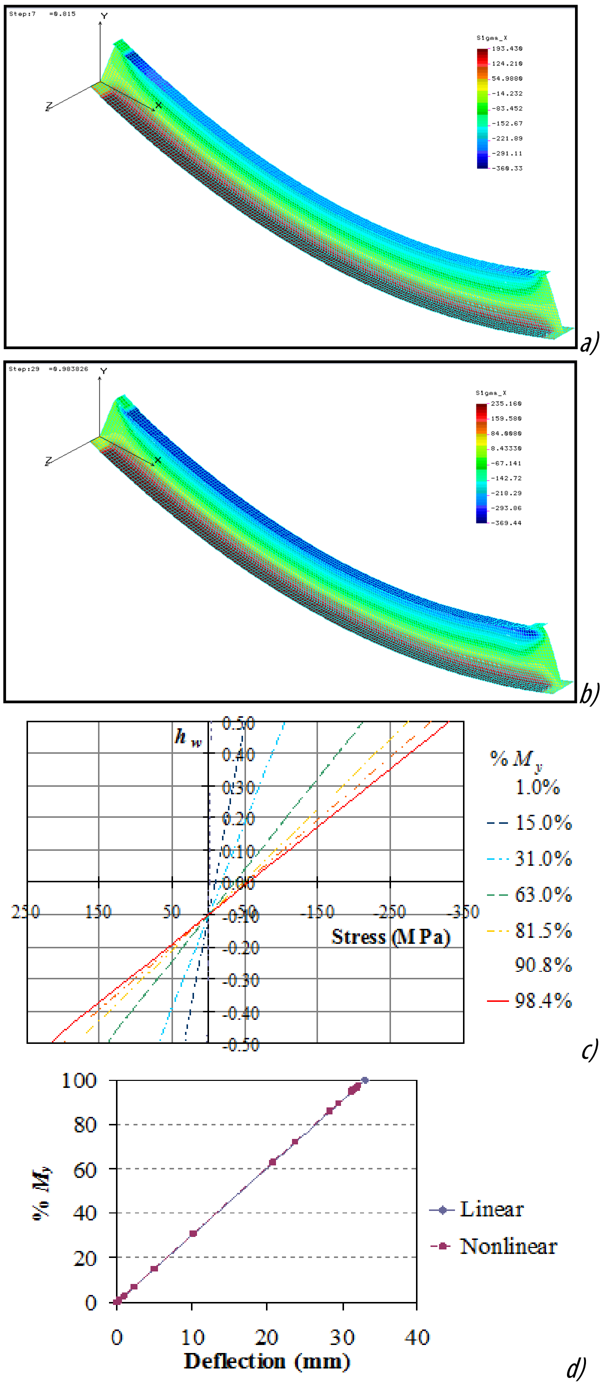


***Figure 10**: Deformed shape and normal membrane stress distribution for model with web slenderness 100 and ψ = -0.6; b) Stress level 1.09σ_y; c)Stress distribution along the web at different stress levels; d)Load-deflection curves*

Figure 8(c) shows the stress distribution along the web for the same model at different stress levels. It can be seen that the stress distribution along the web remains relatively linear even after local

Figure 9 shows the deformed shape and normal membrane stress distribution for the model with a web slenderness of 125 (i.e., $t_w = 8$ mm) and a bottom flange proportioned to give a stress ratio of ψ = -

0.6. A slight amount of local web buckling can be detected at a stress level of 1.47σ_{cr} where the maximum compressive stress is 337 MPa and hence is still below the yield stress, as shown in Figure 9(a). However, at a stress level of σ_y the local buckling in the web is magnified causing distortional buckling in the compression flange, as shown in Figure 9(b). Figure 9(c) shows the stress distribution along the web for this model at different stress levels. It can be seen that the stress distribution along the web remains relatively linear even after local buckling has initiated at the critical stress level, however, a slight nonlinearity in the stress distribution occurs near the end of the nonlinear analysis as the stress level approaches the yield stress. The slight nonlinearity is again shown in the load-deflection curve in Figure 9(d).

Finally, Figure 10 shows the deformed shape and normal stress distribution for the model with a web slenderness of 100 (i.e., t_w = 10 mm) and a lower flange proportioned to give a stress ratio of ψ = -0.6. At a stress level of ≈σ_{cr} the maximum stress is close to σ_y and very little local web buckling has occurred, as shown in Figure 10(a). In fact, at a stress level of 1.09σ_y the local buckling is still hard to detect although the section has yielded, as shown in Figure 10(b). Figure 10(c) shows the stress distribution along the web for this model at different stress levels. It can be seen that the stress distribution along the web remains linear up to the end of the nonlinear analysis as the stress level approaches the yield stress. This linearity is also depicted in the load-deflection curves shown in Figure 10(d).

The recommended values of stress level with respect to the critical stress for other stress gradients as determined by the nonlinear finite element analysis are listed in Table 1 and are plotted in Figure 11.

Table 1: Recommended values of stress level with respect to critical stress σ1/σcr

h_w/t_w / ψ	200	167	143	125	111	100
-1.0	1.56	1.50	1.39	1.00	---	---
-0.8	1.64	1.59	1.49	1.36	1.00	---
-0.6	1.72	1.63	1.57	1.47	1.35	1.00
-0.4	1.76	1.68	1.6	1.54	1.44	1.16

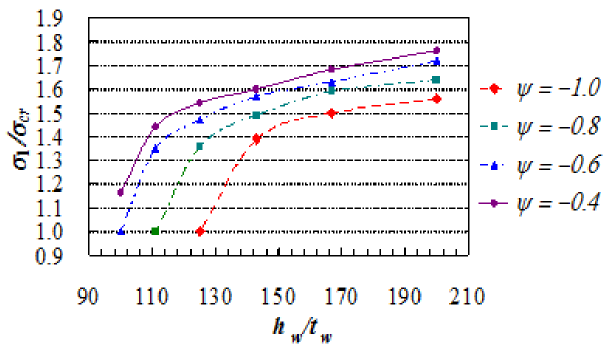


Figure 11: Recommended values of stress level for mono-symmetric girders

A process of curve fitting has led to the derivation of the formulas given in Eq. (18) for the recommended values of stress level as a function of the web slenderness ratio for each value of ψ. The formulas given in Eq. (18) are also compared to the curves obtained for the nonlinear finite element analysis in Figure 12. The maximum error between these two curves is less than 6% and is conservative for all values of σ_1/σ_{cr}.

$$\begin{aligned}
&\text{for } \psi = -1.0 \quad \frac{\sigma_1}{\sigma_{cr}} = 1.595 - \frac{2.28x10^{12}}{(h_w/t_w)^6} \geq 1.0 \\
&\text{for } \psi = -0.8 \quad \frac{\sigma_1}{\sigma_{cr}} = 1.630 - \frac{1.211x10^{12}}{(h_w/t_w)^6} \geq 1.0 \\
&\text{for } \psi = -0.6 \quad \frac{\sigma_1}{\sigma_{cr}} = 1.645 - \frac{6.74x10^{11}}{(h_w/t_w)^6} \geq 1.0 \\
&\text{for } \psi = -0.4 \quad \frac{\sigma_1}{\sigma_{cr}} = 1.665 - \frac{5.518x10^{11}}{(h_w/t_w)^6} \geq 1.0
\end{aligned} \tag{18}$$

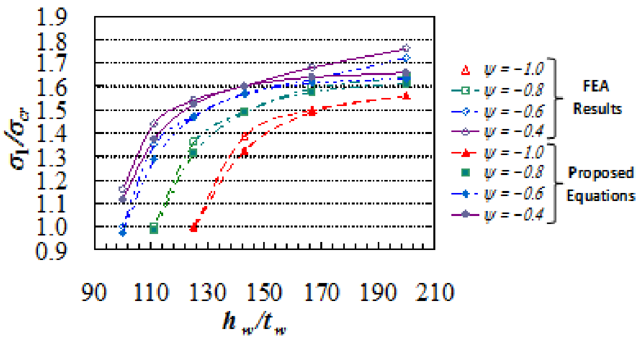


Figure 12: Comparison of Eq. (18) with the FEA results

From the finite element results of the composite sections, it can be noted that increasing the thickness of the web results in a minor increase in composite capacity. Whereas using a greater value of stress gradient (i.e., ψ = -0.4) greatly increases the composite capacity 2–3 times, and any loss in the capacity of the non-composite section due to the buckling of the slender web can be compensated for by using shoring during construction.

CONCLUSION

The finite element parametric analysis shows that mono-symmetric non-composite plate girders with slender webs can be stressed beyond the critical stress, initiating the onset of local buckling of the web in flexural compression, without exceeding the elastic limit. However, due to the occurrence of excessive local buckling deformations in slender webs causing distortional buckling in the compression flange the following stress limits are recommended depending on the stress ratio in the web; 1.7σ_{cr} for webs in the very slender range decreasing to 1.0σ_{cr} for webs in the less slender range.

Symbols

A_{bf} = area of bottom flange plate
A_{tf} = area of top flange plate
A_w = area of web plate
b = plate width
b_e = effective width
E = modulus of elasticity
f_c' = concrete cube strength
F_{eb} = equivalent tensile force in bottom flange
F_{et} = equivalent compressive force in top flange
h_w = depth of web plate
k = plate buckling factor

L = span of girder
M = bending moment
M_y *= yield moment of girder*
t = plate thickness
t_w *= thickness of web plate*
x,y = variables
Δ *= midpoint deflection*
$\varepsilon = \sqrt{235/\sigma_y}$
λ_n *=non-dimensional slenderness parameter*
ν *= Poisson's ratio*
ρ *= effective width parameter*
σ *= stress*
$\sigma 1$ *= larger edge compressive stress*
$\sigma 2$ *= smaller edge compressive stress or tensile stress*
σ_{av} *= average stress*
σ_{cr} *= critical buckling stress*
σ_e *= edge stress*
σ_y *= yield stress*
ψ *= stress gradient*

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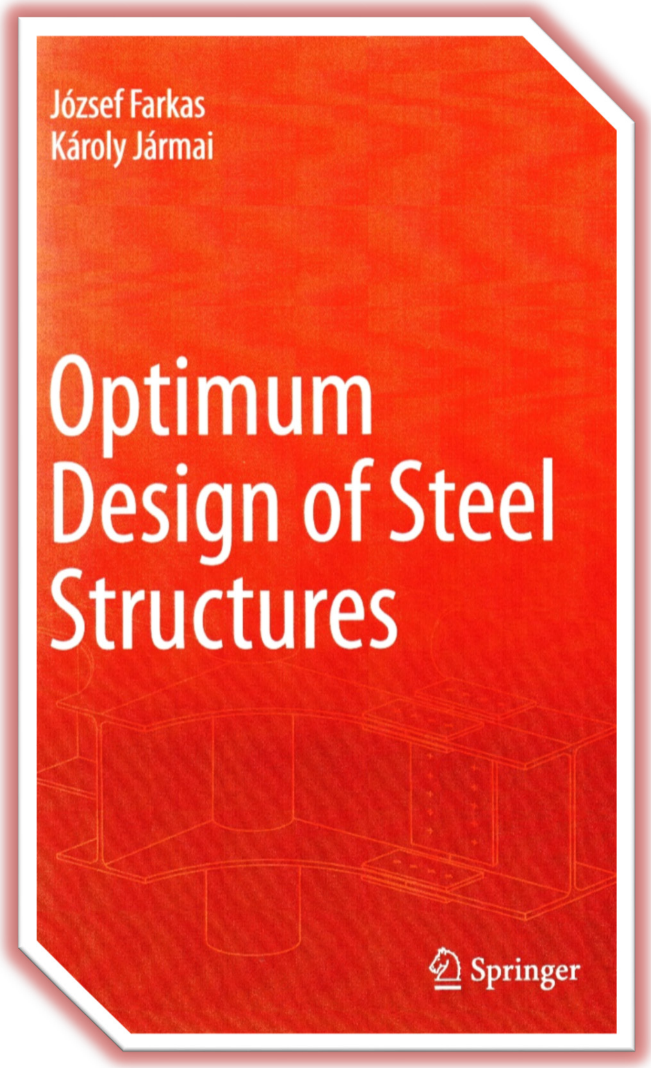
Technical Book Rewiew

József FARKAS, Károly JÁRMAI: OPTIMUM DESIGN OF STEEL STRUCTURES

Dr. József FARKAS, Professor Emeritus of Metal Structures,
Dr. Károly JÁRMAI, Professor of Structural Engineering
– University of Miskolc, HUNGARY



Springer-Verlag Berlin Heidelberg, New York, Dordrecht, London, ISBN 978-3-642-36867-7, DOI 10.1007/978-3-642-36868-4

This very useful book is carried out on 268 pages, 8 chapters and 4 Appendixes. The authors, having a significant international recognition, started their investigations basied on the important role of the cost in the engineering structures' design.

The cost's comparison helps the engineers finding out the optimal solution, which can be the cheapest or the best conceived one.

The authors focused their researches on the welded structures, in order to minimize their cost. In this sense, there are analysed meticulously: beams, tubular trusses, frames, stiffened plates, respectively shells; all of them are illustrated with numerical examples.

The main aim of this book consists of giving to designers and manufacturers useful aspects in order to finding out the optimal (the best) structural solution. It is well-known fact that a lot of structural versions fulfil the design and fabrication constrains, from where one can select the best one. In this sense, a suitable cost function offers a significant help, since a modern structure has to be not only safe and fit for production but also economic.

The meticulously-presented modern mathematical methods offer a significant help in finding out the best solution, based on the relevant international standards (Eurocodes and American ones) in the design constrains' formulation.

In Chapter 1 the authors offer a survey on their internationally recognised experiences in this field of the structural optimisation over several years.

The Chapter 2 is dedicated to the newer mathematical methods involved in the structural optimisation; respectively the Chapter 3 deals the effective cost calculation, together with several useful conclusions.

The authors analyse successively the optimal solutions for: the beams and columns (in Chapter 4); the tubular trusses (in Chapter 5); the frames (in Chapter 6); the stiffened plates (in Chapter 7), respectively for the cylindrical and conical shells (in Chapter 8).

Four useful Appendixes, numerous references, subject list and name index close this very valuable book.

Subsequently, on can put in evidence, between others, the following significant studies of the authors on the optimum design for minimum weight or cost: the fire design of a welded box beam (in Chapter 4); the transmission line tower worked out a s a welded tubular truss (in Chapter 5); the earthquake-resistant design of the braced frames (in Chapter 6); the storage tank roof, obtained from welded stiffened sectorial plates (in Chapter 7), respectively the ring-stiffened cylindrical and conical shells analysis (in Chapter 8).

The above-mentioned book is heartily recommended both to students, researches, designers and to manufacturers in order to finding the better, optimal and most competitive structural solutions.

Prof.univ.Dr.Ing. Ioan SZÁVA
Universitatea "Transilvania" din Braşov, ROMANIA
&
Prof.univ.em.Dr.Ing. Mircea BEJAN
Universitatea Tehnică din Cluj Napoca, ROMANIA

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