# ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering


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*University "POLITEHNICA" Timisoara,*
*Faculty of Engineering Hunedoara,*
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*http://acta.fih.upt.ro*

*We are very pleased to inform that our international scientific journal* ***ACTA TECHNICA CORVINIENSIS - Bulletin of Engineering*** *completed its six years of publication successfully [2008 - 2013, Tome I - VI].*

*In a very short period it has acquired global presence and scholars from all over the world have taken it with great enthusiasm.*

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

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# Aims & 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:*

- *surveys of work accomplished to date*
- *current trends in research and applications*
- *future prospects.*

*As an open-access journal ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering will serve the whole engineering research community, offering a stimulating combination of the following:*

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

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

## Mission

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

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

*Submission of a paper implies that the work described has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis) that it is not under consideration for publication elsewhere. It is not accepted to submit materials which in any way violate copyrights of third persons or law rights. An author is fully responsible ethically and legally for breaking given conditions or misleading the Editor or the Publisher.*

*The Editor reserves the right to return papers that do not conform to the instructions for paper preparation and template as well as papers that do not fit the scope of the journal, prior to refereeing. The Editor reserves the right not to accept the paper for print in the case of a negative review made by reviewers and also in the case of not paying the required fees if such will be fixed and in the case time of waiting for the publication of the paper would extend the period fixed by the Editor as a result of too big number of papers waiting for print. The decision of the Editor in that matter is irrevocable and their aim is care about the high content-related level of that journal.*

*The mission of the ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering is to disseminate academic knowledge across the scientific realms and to provide applied research knowledge to the appropriate stakeholders. We are keen to receive original contributions from researchers representing any Science related field.*

*We strongly believe that the open access model will spur research across the world especially as researchers gain unrestricted access to high quality research articles. Being an Open Access Publisher, Academic Journals does not receive payment for subscription as the journals are freely accessible over the internet.*

## General Topics

**ENGINEERING**
- ☐ Mechanical Engineering
- ☐ Metallurgical Engineering
- ☐ Agricultural Engineering
- ☐ Control Engineering
- ☐ Electrical Engineering
- ☐ Civil Engineering
- ☐ Biomedical Engineering
- ☐ Transport Engineering
- ☐ Nanoengineering

**CHEMISTRY**
- ☐ General Chemistry
- ☐ Analytical Chemistry
- ☐ Inorganic Chemistry
- ☐ Materials Science & Metallography
- ☐ Polymer Chemistry
- ☐ Spectroscopy
- ☐ Thermo-chemistry

**ECONOMICS**
- ☐ Agricultural Economics
- ☐ Development Economics
- ☐ Environmental Economics
- ☐ Industrial Organization
- ☐ Mathematical Economics
- ☐ Monetary Economics
- ☐ Resource Economics
- ☐ Transport Economics
- ☐ General Management
- ☐ Managerial Economics
- ☐ Logistics

**AGRICULTURE**
- ☐ Agricultural & Biological Engineering
- ☐ Food Science & Engineering
- ☐ Horticulture

**COMPUTER & INFORMATION SCIENCES**
- ☐ Computer Science
- ☐ Information Science

**EARTH SCIENCES**
- ☐ Geodesy
- ☐ Geology
- ☐ Hydrology
- ☐ Seismology
- ☐ Soil science

**ENVIRONMENTAL**
- ☐ Environmental Chemistry
- ☐ Environmental Science & Ecology
- ☐ Environmental Soil Science
- ☐ Environmental Health

**BIOTECHNOLOGY**
- ☐ Biomechanics
- ☐ Biotechnology
- ☐ Biomaterials

**MATHEMATICS**
- ☐ Applied mathematics
- ☐ Modeling & Optimization
- ☐ Foundations & methods

## History

*ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering has been published since 2008, as an online supplement of the ANNALS OF FACULTY ENGINEERING HUNEDOARA – INTERNATIONAL JOURNAL OF ENGINEERING. Now, the ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering is a free-access, online, international and multidisciplinary publication of the Faculty of Engineering Hunedoara.*

*ACTA TECHNICA CORVINIENSIS – BULLETIN OF ENGINEERING exchange similar publications with similar institutions of our country and from abroad.*

## Invitation

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

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

*Submission of a paper implies that the work described has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis) that it is not under consideration for publication elsewhere. It is not accepted to submit materials which in any way violate copyrights of third persons or law rights. An author is fully responsible ethically and legally for breaking given conditions or misleading the Editor or the Publisher.*

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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. ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering encourages the submission of comments on papers published particularly in our journal. The journal publishes articles focused on topics of current interest within the scope of the journal and coordinated by invited guest editors. Interested authors are invited to contact one of the Editors for further details.*
*ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering accept for publication unpublished manuscripts on the understanding that the same manuscript is not under simultaneous consideration of other journals. Publication of a part of the data as the abstract of conference proceedings is exempted.*
*Manuscripts submitted (original articles, technical notes, brief communications and case studies) will be subject to peer review by the members of the Editorial Board or by qualified outside reviewers. Only papers of high scientific quality will be accepted for publication. Manuscripts are accepted for review only when they report unpublished work that is not being considered for publication elsewhere. The evaluated paper may be recommended for:*

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

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

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

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*The Editor and editorial board members do not receive any remuneration. These positions are voluntary.*

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

*The members of the Editorial Board may serve as scientific reviewers.*

*ACTA TECHNICA CORVINIENSIS – BULLETIN of ENGINEERING is 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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**Abstract:** *This research evaluates the suitability of SCBA as a partial replacement for cement in concrete productions. Total weight of 34.7kg of sugarcane bagasse (SCB) was obtained and burnt at 700$^0$C. A total of 2.71kg of SCBA was obtained after passing the residual through 45µm sieve, standard size of ordinary portland cement (OPC). Chemical test was conducted on SCBA to evaluate its percentage composition. It was then used to replace OPC by weight in ratio of 0%, 10%, 20% and 30%. Total of 48 pieces of 100mm concrete cubes of design mix ratio 1:1.66:2.77 were prepared. The cubes were tested at 7, 14, 21 and 28days of curing ages for density and compressive strength. The results of chemical test showed that SCBA has pozzolanic properties having met ASTM-595 (1985) with total sum of silica, alumina and ferric composition of 80.55%. The results showed a decrease in concrete density with increase in % replacement of SCBA. Average compressive strength of 26.8N/mm$^2$ was obtained for control specimens at 28days (i.e. 0% SCBA) while 22.3, 20.1 and 17.3N/mm$^2$ compressive strength at 28days were obtained for 10%, 20% and 30% replacement respectively. Pozzolanic activity index (PAI) of 83.2%, 75% and 64.5% were obtained. This showed that only 10% and 20% replacement of cement by weight of SCBA satisfied ASTM-595(1985) specification for PAI. It was concluded that SCBA is a low weight material and 10% replacement of SCBA has the highest PAI. Also, 10% and 20% replacement of SCBA with compressive strengths of 22.3N/mm$^2$ and 20.1N/mm$^2$ are recommended for reinforced concrete.*



**Abstract:** *Biodiesel is a renewable alternative fuel to the fossil diesel and is getting more popularity because of depletion of fossil fuels and their lower environmental pollution. When biodiesel is used as a substitute for the diesel in the internal combustion engines, it significantly increases the energy security and rural economy of the country and also helps to reduce the environmental pollution. However, there are concerns over the compatibility of biodiesel on the engine components due to its corrosive characteristics which can corrode the metallic components and degrade elastomer parts. Hence, the study of corrosion characteristics of biodiesel is important for long term durability of engine components. This paper discuss the production of biodiesel from Jatropha oil and the effects of Jatropha biodiesel on the fuel filter, gasket and fuel tubing of the fuel systems used in the diesel engine.*



**Abstract:** *Technologies of Rapid Prototyping (RP) represents the rapid production of 3D physical parts using by additive manufacturing technology. The start these techniques became available in the late 1980s and were used to produce 3D models and prototype parts. Today they are used for a much wider range of applications and are even used to manufacture production-quality parts in relatively small numbers. There are a multitude of experimental Rapid Prototyping methods either in development or used by small groups of individuals. Rapid Prototyping is widely used in the automotive, aerospace, medical, and consumer products industries. This paper is focused on application of Rapid Prototyping technique that is currently commercially available, Fused Deposition Modelling (FDM) technique. In paper is presented application of Fused Deposition Modelling rapid prototyping technology for realization of models of manufacturing systems components represent by industrial robot.*



**Abstract:** *Nowadays, there are so much pollution and problem to the earth which make the human realize to work on something in order to save the world holistically.. Meeting made by United Nation (UN) to take this issue as a main agenda is being use by all country around the world. It might take a long time to make sure the process of agenda being using around the world. Green Building Index (GBI) indicator and Agenda 21 for sustainable development have been introduced to decrease the effect of pollution during the development and surrounding. Since the industrial Revolution, the world has witnessed incalculable technological achievements, population growth, and corresponding increases in resource use. We are recognizing the side effects of human activities like population landfills at capacity, toxic waste, global warming, resource and ozone depletion, and deforestation. These efforts are straining the limits of the Earth's carrying capacity and its ability to provide the resources and required to sustain life while retaining the capacity to generate and remain viable. As the world's population continues to expand around the world, the implementation of resource-efficient measures in all areas of human activity is imperative and the build environment is one clear example of the impact of human activity on resources. Buildings have a significant impact on the environment, accounting for one-sixth of the world's freshwater withdrawals, one-quarter of its wood harvest and energy flow.*

**Abstract:** *Space Vector Pulse Width Modulation SVPWM Is the best modulation techniques to generate sinusoidal voltage and current due to its facility and efficiency with low harmonics distortion. In this paper we presents the study and power control of a variable speed wind energy conversion system based on a doubly Fed Induction Generator (DFIG) using space vector modulation to achieve control of active and reactive powers exchanged between the stator of the DFIG and the grid to ensure a Maximum Power Point Tracking (MPPT) of a wind energy conversion system and to reduce significantly Powers and Torque ripples. The Simulation results have shown good performances of the system under these proposed control Compared to PWM control strategies.*



**Abstract:** *Interest for magneto-dielectric nanocomposites is motivated by their interesting properties [1]: high electrical resistivities, low losses in turbionar currents and hysteresis, endurance at high temperature, chemical stability. Such materials offer many appealing technological properties: can easily be fabricated in various shapes and dimensions with low technological losses and at low prices. These properties open the possibility of using these materials instead common magnetic materials for electric machines and other electromagnetic devices. In this context the simulation problems of this materials behaviour in electromagnetic fields is very important. This paper proposes a study on how the PRNG type influences the results obtained through a simulation models for magnetodielectric nanocomposites behavior in electromagnetic fields. The case study model allows the calculation of the Néel time in nanoparticles systems with magnetic dipole interactions.*



**Abstract:** *Decades ago, agriculture and rural areas primarily focussed on producing industrial raw material as well as foodstuffs of appropriate quality and substantial quantity, which entailed the employment of a big chunk of rural labour in the agricultural sector. Later a trend emerged requiring the reduction of agricultural pressure on the environment, primarily by minimizing the use of chemicals. This trend then evolved into organic agricultural production and ecological farming, which both have been enjoying wide success in the develop world (see HOLLÓ et al., 2009) and have significantly risen in importance over the past few years as key factors of sustainable agriculture both in Hungary and across the globe. A shift from industrial agriculture to ecological agricultural production is evidently in progress both in the European Union and in Hungary (KISSNÉ, 2000).*



**Abstract:** *Green building is a kind of sustainable development and energy-saving building, has a very important significance for alleviating strained resources, protecting the environment to reduce pollution. And the solar energy is not only an energy, and a renewable energy, but which rich in resources. It not only free use of, but also not to be transported, and it produces no pollution to environment and more widely using in the green building. Early, solar building just passed the light and heat of the Sun in order to light up and heat the building. But now, the green building obtains solar energy by adopting 'active'. This 'active' green building is a kind of heating system consists of solar energy collector, radiator, pump and fan, or air conditioning-building combined with absorption chiller. One of the green building which is Shanghai Research Institute of Building Science contain multiple green energy technologies, such as solar thermal technology, solar photovoltaic, natural ventilation, natural lighting, and indoor virescence. Here, there an example of solar integrated energy system including heating, air conditioning, natural ventilation and hot water supplied which applied in the green building*



**Abstract:** *Identification and treatment of risks in early phases of a product lifecycle are becoming more commonplaces nowadays. Since state-of-art companies that want to keep up with competitors have to consider all actions which might prevent loses or customer's dissatisfaction. This paper deals with a new risk management procedure concerning the early phases of a product lifecycle. Proper risk identification in early phases may result in mitigation or removal of an impact that might cause considerable property, health or the environment losses in late phases of a product lifecycle. Phases of conceive and design are considered as early phases in this study. It is always very complicated to assess risks in an early phase of a project since almost no data is available. Therefore, this procedure has been developed to help to manage such risks. Procedure combines so far known methods and adds new possible steps that may be taken advantage of.*

**Abstract:** *Bitumen is generally material obtained as the residue of vacuum distillation process during the refining of crude oil. In order to obtain appropriate properties, bituminous binders are used not only in the form of pure bitumen (unmodified bitumens = paving grade bitumens, PBS) but they are modified by synthetic polymers. Bituminous binders are broadly used for asphalt mixtures in construction of roads. They are often modified by synthetic polymers to improve their physical properties (to increase their softening point and decrease their breaking point). This paper deals with comparison of rheological parameters η*, G', G" of selected polymer modified bituminous binders at the temperatures of 60 and 80 °C.*



**Abstract:** *The noise emitted from engines has been studied long time back. Signal processing is an important technique to separated various noise sources. FFT transformations have been used as an effective method of signal analysis. Combustion is the main type of noise radiated from diesel engines. Several methods have been devised to reduce the noise levels. Fourier tranformation methods along with block attenuation curves have been used to study the correlation between cylinder pressure and noise radiated from engines. In this work wavelet method has been used to study noisee mitted from a dual injection diesel engine. The results show high variation in cylinder pressure levels and noisee mitted which indicate non stationary nature of combustion process. Engine noise signals needs time, frequency or time-frequency parameters for complete disciption. With help of time-frequency plots contribution of various sources can be studied. An important application of such plots is in condition monitoring of engines where problems in parts of engines can be detected. This method also provides a more reliable method to correlate various events occurring in the engine operation process.*



**Abstract:** *Differential equations are mathematically studied from several different perspectives, mostly concerned with their solutions – the set of functions that satisfy the equation. Only the simplest differential equations admit solutions given by explicit formulas; however, some properties of solutions of a given differential equation may be determined without finding their exact form. Differential equations are mathematically studied from several different perspectives, mostly concerned with their solutions – the set of functions that satisfy the equation. The purpose of this paper is to discuss numerical solutions of differential equations including the evolution, progress and types of differential equations. Special attention is given to the solution of differential equations by application of spline functions. Here we are interested in differential equation based problems and their solutions using polynomial and nonpolynomial splines of different orders. It contains crux of various recent research papers based on application of splines of different orders.*



**Abstract:** *Currently it is possible in technical and technological experience to watch a permanent increase in demand for both quality and accuracy of production equipment and technology, but also of industrial and non-industrial areas. This requirement is particularly associated with the search for more effective design solutions different parts of machine technology. This is also the search for suitable alternatives to transmission mechanisms resulting in the possibility of their application. This article describes output transmission mechanisms. Transmission (transmission mechanism) transmits or distributes power from the prime mover to the driven machine. He changes the frequency of speed, torque and driving forces. Transfer changes rotary motion into rotary motion of other parameters or on straight sliding movement and vice versa.*



**Abstract:** *The aim of this research is to investigate the optimized some properties of thermoelectric system such as efficiency and power production in generator systems. First, the maximum efficiency and power production in multi-stage thermoelectric systems, which are connected electrically in both parallel and series, are computed. Then, the performance of these systems is compared and the priorities of their usage at their operating temperatures are determined. In this study, despite other studies which use thermoelectric characteristics of materials at the average temperature of the system, the characteristic average operating temperatures of each stage is used. The procedures for optimizing the system are the particle swarm optimization method (PSO) and Imperialist competitive algorithm (ICA) and finally these two methods is compared with each other in order to calculate the efficiency of thermoelectric systems and the results of this investigation represent that: ICA method is 5 percent closer to experimental results.*

**Abstract:** *Nowadays an intense interest is taken in novel, clean and environmental–friendly energy sources due to several urgently important reasons. These kind of reasons e.g. the world running out of the traditional energy supplies, which sources also heavily encumber the nature, or the problem of global warming–up, but also the nuclear power not an alternative because its dangerousness. By this time the technology has reached a highly advanced level, which enables us to study physical effects that can't be described using the well–known scientific theories. The science can be treated on novel scientific bases by recognizing the elementary block together with the working mechanism – and the system technique of our Universe. With the help of new scientific bases, which are supported by the CERN measurements, its axioms can be derived and all the experimental results can be well explained. Understanding the controlling property of the field energy gives the opportunity to make it use of work as a new energy source.*



*The ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering, Fascicule 3/2014 [July-September/2014] includes scientific papers presented in the sections of Conference on:*

- *The 3rd INTERNATIONAL CONFERENCE INDUSTRIAL ENGINEERING and ENVIRONMENTAL PROTECTION – IIZS 2013, organized in Zrenjanin, SERBIA (30th of October, 2013), jointly by the University of Novi Sad, Technical Faculty "Mihajlo Pupin", Zrenjanin, SERBIA. The new current identification number of the papers are the # 1, 3, 5, 7 and 9, according to the present contents list.*
- *The DISSEMINATION CONFERENCE of the Centre of Excellence at the University of Miskolc, entitled INNOVATIVE MECHANICAL ENGINEERING DESIGN and TECHNOLOGIES, organized in Miskolc, HUNGARY (24th of January, 2014), jointly by the University of Miskolc, Miskolc, HUNGARY. The new current identification number of the papers are # 2, 4, 6 and 25, according to the present contents list.*
- *The 2nd INTERNATIONAL CONFERENCE on APPLIED SCIENCES – ICOAS 2013, organized in Wuhan of Hubei Province in CHINA (26 – 27 October, 2013), jointly by the Military Economy Research Center of Chinese People's Liberation Army, Military Economy Academy, Wuhan University, Huazhong University of Science and Technology, CHINA and "Politehnica" University of Timisoara, ROMANIA. The new current identification number of the papers are # 8 and # 10, according to the present contents list.*

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# PYROLYSIS FURNACE TUBE DAMAGING AND INSPECTION

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***Abstract:*** *This paper explain the most occurring failure mechanisms for pyrolysis furnace radiant tubes. Basic damaging mechanism is the combined action of carburization and creep ductility exhaustion. This results in bulging, bending and ovalization of the tubes. The second dominant failure mechanism is brittle fracture during furnace trips, which can result in large, longitudinal cracks on many tubes.There are several methods for estimating and damage detection of furnace tubes. In assessing the state of furnace tubes we use an optimal combination of methods, as individual methods cannot detect any potential damage. The methods are related to the assessment of damage due to creep, and the material carburization which underlying the creep.*
***Keywords:*** *pyrolysis furnace, furnace tube, tube inspection*

## INTRODUCTION

*Pyrolysis coils in ethylene cracking furnaces (Fig. 1) are exposed to very severe conditions, e. g. high temperatures up to 1150 °C, severe start/stop and decoke cycles, oxidizing and nitriding flue gases at the outside and carburizing atmospheres at the tube inside surface. Therefore, high-alloyed centrifugal cast Ni-Cr-Fe alloys with adequate high temperature corrosion resistance, good high temperature strength, good machinability and weldability (even after years of service) are required.*

*Radiant coils have a limited life and failure is caused by a variety of factors, many being related to furnace operation. However, each pyrolysis plant experiences specific operational conditions and operational philosophies. Therefore, each plant has typical causes for radiant coil failure and it is of importance for operators to analyze and to understand the typical failure mechanisms. This will enable them to consider the material grades, which would be best suited for those particular conditions and also to keep failures within limits by proper furnace operation. Mechanisms which causing the majority of failures in radiant tubes are: coke formation, creep ductility exhaustion, thermal fatigue, brittle fracture, erosion, overheating, human factor, creeping, carburization, oxidation, nitridation, chromium evaporation. Tube sheets and tube supports should be examined to determine their physical condition and fitness for further service. Supports should be examined carefully for cracks, oxidation, corrosion, distortion and sagging.*

*There are several methods for assessing and detecting the damage of the furnace tubes. All heater tubes should be inspected, preferably early in life, to establish base-line conditions for tube diameter, wall-thickness, microstructure, and metal hardness.*

*Figure 1. Pyrolysis furnaces in ethylene plant*

## FURNACE TUBE FAILURE

*Tube failures result from progressive deterioration from a variety of deterioration mechanisms. Therefore, one needs to understand the active and potential mechanisms in a particular pyrolysis furnace in order to prevent them from causing a*

*failure. Tube reliability not only requires an understanding of the mechanisms by which the tubes can fail, but also requires data on how the previous operating history has impacted tube life, predictions of deterioration rate, how the future operation will impact tube life, and finally, monitoring of operation sand deterioration to ensure the analyses and predictions are accurate and appropriate. Historically, inspection data gathered during outages assessed the immediate condition of the tubes with varying degrees of accuracy or success.*

*Creep is the primary cause of the furnace tube damage. It usually initiates within the tube wall some two-thirds of the way through from the outer surface, making it impossible to detect by in situ metallography [2]. This is opposite to boiler super heaters and headers where creep damage initiates at the outside surfaces, making it much easier to detect.*

*Creep elongation (also called stretching) occurs because of creep by the self-weight of the tube and the coke layer present in the tube and is influenced by temperature, the load carrying cross section of the tube, and the material used. A consequence of a high creep rate is the need to shut down the furnace and to shorten the coils (some end-users have lowered to bottom floor). Failures can occur if tubes are not shortened before they reached the heater floor (Figure 2). The coils are warped and bowed, resulting in higher tube stresses and creep rates.*

*During service, hard deposits of carbon (coke) build up on the inner wall of the tube, reducing heat transfer and restricting the flow of the hydrocarbon feedstock's. About every 20 to 60 days, the furnace must be taken off-line and "decoked" by burning out the accumulated carbon.*

*Carburization is the carbon enrichment and carbide formation in the tube material under influence of the presence of carbonaceous gases and high temperatures. This accelerates carbon diffusion in tube material, especially during the decoking period. Carburized material in the inner wall of the radiant tube has a higher thermal expansion coefficient and tends to increase in volume and place stresses on the tube. These thermal stresses make the tube more susceptible to creep failure [5]. The deposition of the coke at high temperature is generally inhibited by the presence of a $Cr_2O_3$ layer on the inner surface of the tube. When this film in present carbon diffusion into the tube is retarded. However, during decoking, the tube may be subjected to severe thermal shock that results in removal of the $Cr_2O_3$ layer, so the carburization attack increased [8]. Because of exposure of tube at elevated temperature, carbon diffusion could promote formation of continuous and/or separated carbides in grain boundary and matrix [1,7,8]. These carbides decrease the creep resistance and ductility at high temperature.*

*Figure 2. Pyrolysis furnace radiant zone - consequence of a high creep rate*

*Metal dusting is a catastrophic form of carburization that can result in rapid metal wastage in both ferritic and austenitic alloys. This damage mechanism typically has the appearance of localized pitting, or grooving, along the inner walls of pipe and tubes [8].*

*The ductile failure can be recognized by a bulge on the tube and a short longitudinal crack on top of the bulge. In the micro-structure creep voids can be observed between matrix and carbides [1].*

*The brittle fracture can be recognized by a long longitudinal crack which "ends" in a fork-like appearance. Sometimes, the cracks result in circumferential rupture or "windows" that fall out of the tube. The cracks can be many meters long, and many times, a thick coke layer is present inside the tube. In the micro-structure can be observed that the carbides have split. This is a marked difference to the ductile fracture and can be recognized easily [9].*

*Another failure mechanism is overheating, which results in local melting or overall melting of the tubes. Such an overheating can happen due to lack of flow, coke blockage or burner problems (flame impingement). Lack of flow can occur when inlet valves fail or in case of compressor problems.*

*Above 1100°C nitriding respectively internal nitride formation occurs from the outer diameter of the radiant tube (flue gas side). Nitrogen penetrates through the oxide and reacts with chromium by precipitation of nitrides. Due to nitriding the rough as-cast surface disappears and the surface becomes a smooth and glazed appearance [4]. The nitrides may cause spallation of the oxides. As a result a thick layer of oxides (up to 10 – 20 cm thick) can be found on the furnace floor. Sometimes, this is called oxide shedding.*

*Another form of elevated temperature degradation of austenitic stainless steel is sensitization. This caused by precipitation of chromium carbides preferentially at grain boundaries. The immediately adjacent chromium-depleted zone is susceptible to accelerated corrosion in some aqueous corrodents. Sensitization has little or no effect on mechanical properties but can lead severe inter granular corrosion in aggressive aqueous environments such as polythionic acid. Polythionic acid can form during downtime on equipment that has been even mildly corroded by hydrogen sulphide at elevated temperature. The iron sulphide corrosion product combines with air and moisture to form the acid and induces intergranular corrosion and cracking [4].*

*Erosion can be observed in 90 or 180 bends or in Y-pieces. The most accepted theory is that erosion is caused by hard coke particles during decoking. Some investigators believe that this erosion is caused by coke particles, which are present during normal operation. The remedy is to modify the decoking procedure, so that the coke is gasified instead of being spalled. Second remedy is to lower the gas velocity during decoke below 200 m/s. Third remedy is to apply "internally stepped fittings", which have been applied successfully on many occasions.*

## *FURNACE TUBE INSPECTION*

*Inspecting furnace tube is sometimes not an easy task. Everyone is looking for inspection method or test equipment that will find cracks or leaks 100% of the time. There are a variety of methods of inspecting or testing furnace tubes.In assessing the state of furnace tubes we use an optimal combination of methods, as individual methods cannot detect any potential damage. Test methods which involve the removal of pipe from the furnace is the most expensive as it is necessary to remove the tube from furnace and then remove the pattern.*

### *Visual inspection*

*On-stream visual inspection of visible flame patterns can indicate potential areas of concern. An erratic, unbalanced flame may be a sign of damaged swirl vanes, improper air/fuel mixture, coking on the burner tip or leaking tubes. An erratic flame may impinge on nearby tube walls, causing hot spots and areas of potential ruptures.*

*Structural components, such as tube supports, that are visible from inspection ports should be examined to ensure they are intact. Any external tube suspension systems and pre-load and compensating devices should also be subject to routine inspection.*

*Tubes should be inspected for bulges, sagging, bowing, localized discoloration or leakage. Hot spots may be the result of flame impingement. Tube misalignment may be caused by damaged supports, or supports that are preventing the thermal growth of the tube.*

*Refractory should be visually checked for cracking, spalling, erosion, and localized discoloration. Areas of damage should be monitored for high temperatures and identified for repair during the next planned outage. A visual examination of the external casing should be made to detect any hot spots. Infrared thermography was used to online monitoring of pyrolysis furnaces.*

*During planed downtime the tube coils should be inspected closely for bulging, bowing, sagging, splitting, scaling, corrosion, and deposits from fuel gas. Fittings may show signs of damage, distortion or corrosion. Internal inspection of tubes is limited to those types which have removable U-bend or plug type fittings. Remote examination may also be utilized, using a boroscope, video camera or other visual aids. Suitable record such as videotapes should be maintained.*

***Tube temperature monitoring***

*Tube failures are most commonly due to overheating. Therefore close attention must be paid to on-stream monitoring of tube temperatures. Routine recording of tube temperatures into a permanent record is crucial to enable the remaining safe life of the tubing and suitable inspection intervals to be established. There are two basic systems for tube temperature monitoring: contact tube- skin thermocouple and non-contact pyrometers. They serve a couple purposes. First, the thermocouples can alert to abnormal operation if temperatures dramatically change. Second, they provide a means to calculate and monitor remaining tube creep life. Strategic placement of the thermocouples is necessary so that the entire firebox can be reasonably monitored.*

*Malfunctioning burners or unbalanced firing of burners can create local hot zones in the firebox and lead to premature failures. In addition, tubes that historically operate hot due to their placement in the coil may need a thermocouple, especially if it represents the most severe service of the tubes.*

*Infrared thermal scanning of tubes helps fill the gaps created with the tube-skin thermocouples. Infrared scanning inspection can determine local tube metal temperatures in the areas not covered by the tube skin thermocouples. Generally, tube rupture occur in very local areas of overheat. Infrared scanning has proven effective in identifying localized "hot spots" before they cause a failure. A periodic scan of heaters is common practice although some heaters whose tubes are particularly prone to coke buildup may require more frequent scanning. Additionally, infrared scanning with non-contact pyrometers provides a means to check the accuracy of tube-skin thermocouples.*

***Thickness measurements***

*Ultrasonic thickness readings should be taken at specified locations on tube coils in the radiant section, accessible shock (shield) tubes in the convection sections and return bends. A recent technological advance in furnace tube inspection has seen the development of a multi-module pig which can increase the number of data points from the typical 200-300 to in excess of 300,000. The tool can be used to inspect both the convection and radiant sections. However, since it uses ultrasonic, the inside of the tubes must be cleaned prior to inspection.*

***Tube growth measurements***

*Tube coils and return bends should be gauged for bulging or creep growth and the history of tubes that have been replaced due to thermal growth should be kept. Thermal growth may occur when the tubes are subjected to localized short-term overheating, long-term high temperature exposure (creep), or localized thinning of the tube through corrosion or erosion.*

*The maximum limits of diametrical growth based on acceptable levels of creep must be established and readings checked against these limits. Special pre-set gauges can be used to quickly scan the length of a tube and a micrometer used to take precise measurements at pre-selected locations or areas of concern.*

*Inspection methods that are based on laser technology in recent years has experienced rapid growth. With the advent of laser measuring profilometry outer / inner diameter of the pipe, as well as elongation, is given a new dimension to overcome the disadvantages of an earlier measurement methods. Ability to accurately measure and record the growth of creep means that the condition of pipes can be measured from the first day.*

***Carburization assessment***

*Carburization - is the diffusion of elemental carbon into solid steel in contact with a carboniferous material at high temperature. This results in a brittle material. Austenitic tubes are essentially nonmagnetic. Carburized areas of the tubes become magnetic, and if these areas are large, they can be detected with a magnet. A magnet on a string dropped down a tube will indicate areas that are*

*magnetic but will not indicate the depth of carburization. An eddy current instrument (Hall Effect hand held probe) called a magneto-scope should be used to build up a history of magneto-scope measurements. Any tube that indicates higher magneto-scope readings in any region should be checked by dye penetrant on the O.D. for cracking. Radiography should be carried out on the region to determine the condition of the I.D.*

***Radiography***

*Radiography may be used to inspect weldments, tubes, and return bends etc. It will provide evidence of wall thinning, deposits, pitting, cracking and internal obstructions etc. In circular heaters the film can be placed behind each set of tubes or return bends at a given elevation, and the source can be located in the center. One panoramic exposure can then be taken that includes all of the tubes.*

*When radiographing a tube to determine if corrosion, deposits or coke is present, it is important to remember that these will usually occur on the fire side of the tube, as this is the hottest side of the tube. If a radiograph is taken on a horizontal tube, the film should be placed as close to the horizontal plane as is practical. The resulting film will show the profile of the fire side of the tube wall and the opposite side furthest from the source of heat.*

***Hardness measurements***

*Hardness testers -mechanical and electronic hardness testers can be used to determine the hardness of base metal, welds, and heat-affected zones. Electronic testers must be used with extreme care on thin materials or erroneous readings may be obtained. Hardness tests should only be specified only after it has been determined that the base material is suitable; as some materials (i.e. carburized, cast materials) may well be damaged if hardness readings are taken.*

*Hardness considerably increases with the extent of degradation, compared with virgin material. There is a relation between carburization and hardness, and electrical resistivity and carburization, so the electrical resistivity is inversely proportional to the hardness [6].*

***Metallurgical analysis and mechanical testing***

*It may be necessary to remove samples to assess the mechanical and metallurgical integrity of furnace components that are approaching their design life and cannot be assessed in place due to the design (i.e. finned tubes), or when inspection results indicate that sample removal is required to enable the overall condition of the furnace to be verified. Metallurgical considerations for sample removal would include: suspected high temperature creep damage, sensitization, carburization, decarburization, spherodization, oxidation, embrittlement, etc. The investigation included tensile tests, optical microscopy, scanning electron microscopy (SEM), energy dispersive spectroscopy (EDS), and X-ray diffraction (XRD) analysis.*

*Scale/deposits- Samples of surface scale and deposits can be analyzed to determine composition, source of contamination and provide an indication of the degree of overheating.*

*In site metallography- provides metallurgical information to check for material deterioration, creep damage etc., without destroying its function.*

*Analyses of a pyrolysis furnace tube microstructure show that essential changes in material structure and properties appear during the operation at high temperatures. Uncontrolled carburization process result in coke deposits on tube causing heat stresses. Therefore, but also due to material creep, radial micro-cracks and fracture appear [5]. The fracture propagation is along the grain boundary where carbides are extracted in chains [7]. Initial austenitic structure has changed its characteristic in some places appearance of delta ferrite formation and sigma phase, which reduce material ductility together with the carbides inside and along the grain boundaries.*

***Pressure test***

*Before the furnace is returned to operation, a pressure test on the tube coils will reveal any leakage not apparent from a visual inspection. All pressure tests should be performed in accordance with a written procedure which includes the safety precautions to be taken, test pressure and temperature, how water will be drained from vertical coils etc. A full temperature compensated hydrostatic test is required when welded repairs to the pressure envelope have been made. When a full*

*hydrostatic test is not practical, a pneumatic test or alternative testing may be conducted.*

## CONCLUSION

*Process furnaces are critical components in the oil and petrochemical industry, and the process equipment damage assessments have great importance for providing a safe, highly effective and long-term work. Traditional means of monitoring these high temperature vessels have frequently been more art than science, often relying on highly subjective analyses and/or frequently inaccurate thermocouple data. Time interval replacement of tubes is essential in costs reducing and productivity maintenance in the process industry.*

*Heater reliability often depends on periodic internal inspections and routine, on-stream monitoring/inspection. These techniques of tubes inspection provide adequate assistance in collecting data about their condition. Typical on-stream inspection programs incorporate visual examination of the firebox, external visual examination of casing and components, infrared examination of tubes and heater casing, and monitoring of tube-skin thermo couples. Before the inspection, the tools needed for inspection should be checked for availability, proper working condition, and accuracy.*

*External and internal inspections should be scheduled periodically considering the age of equipment, conditions of operation, type of equipment, kind of fuels, previous inspection result, etc. However, the length of time between internal inspections should consider the historic and predicted deterioration rates for components (including the impact of any process change), the historic inspection findings, the results of on-stream monitoring/inspection, previous maintenance activities and their quality.*

## REFERENCES


[1.] *A. Al-Meshari, M. Al-Rabie, M. Al-Dajane, Failure Analysis of Furnace Tube, J Fail. Anal. andPreven. (2013) 13:282–291.*

[2.] *A. Shibli, S. Holdsworth, Creep and fracture in high-temperature components – Designand life assessment issues, International Journal of Pressure Vessels and Piping 85, 2008.*

[3.] *A.Reihani, S.A.Razavi, E.Abbasi, A.R.Etemadi, Failure Analysis of Welded Radiant Tubes Made of Cast Heat-Resisting Steel J Fail. Anal. And Preven.(2013), DOI 10.1007/s11668-013-9741-y.*

[4.] *D.J.Tillack, J.E. Guthrie, Wrought and cast heat-resistant stainless and nickel alloys for the refining and petrochemical industries, Nickel Development Institute, Technical Series No. 10071, Toronto, 1998.*

[5.] *Jakobi and Gommans, Typical failures in pyrolysis coils for ethylene cracking, Materials and Corrosion 2003, 54, No. 11.*

[6.] *Seung, Hoon, Nahm, et. al., Degradation evaluation of HK-40 steel using electrical resistivity, International Journal of Modern Physics B, Vol. 17, Nos. 8 & 9, pp.1615–1620, 2003.*

[7.] *T. Filetin, F. Kovačiček, D. Lisjak, Analiza mikrostrukturnih promjena u materijalu cijevi peći za pirolizu, Tehnički vijesnik 4(1, 2)13-17(1997), Zagreb.*

[8.] *V. Guttmann, R. Burgel, Corrosion and Mechanical Stress at High Temperatures, Applied Science Publishers, Ltd. London, 1980.*

[9.] *Z. Odanović, I. Blačić, D. Vračarić, V. Grabulov, Ispitivanje uzroka loma katalitičke cevi od vatrootporne legure HK 40, Tehnički izveštaj VTI 04-01-0196, 1999, Beograd.*



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# EXAMINATION OF THE BIG JOINT PROSTHESIS

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**Abstract:** *The hip joint arthrosis is one of the most common musculoskeletal disease and its occurrence is so common that almost everyone has heard of it or met someone who was operated on due to this disease [6]. Currently the lifetime of the prosthesis is approximately 10 years [1]. Unfortunately, prosthesis loosens beyond this period, thus replacement is needed. In this paper we present the geometric construction, modelling and Finite Element Analysis of the hip-joint prosthesis.*
**Keywords:** *hip joint, prosthesis, modelling, Finite Element Analysis*

## INTRODUCTION - THE HIPS

*The hip joint (Fig.1.) is one of the largest joints in the human body and is what is known as a 'ball and socket joint'.*
*In a healthy hip joint, the bones are connected to each other with bands of tissue known as ligaments. These ligaments are lubricated with fluid to reduce friction.*
*Joints are also surrounded by a type of tissue called cartilage that is designed to help support the joints and prevent bones from rubbing against each other. The main purpose of the hip joints is to support the upper body when a person is standing, walking and running, and to help with certain movements, such as bending and stretching. [7]*

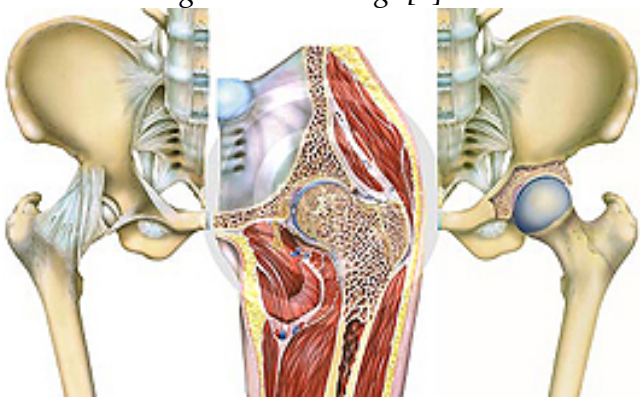

*Figure 1. Hip joint [8]*

## PARTS OF THE HIP PROSTHESIS

*The anatomic hip prosthesis may be cemented and cementless depending on the type of fixation used to hold the implant in place.*

*Construction (Figure 2):*
- *socket;*
- *metal head;*
- *metal stem of different types.*

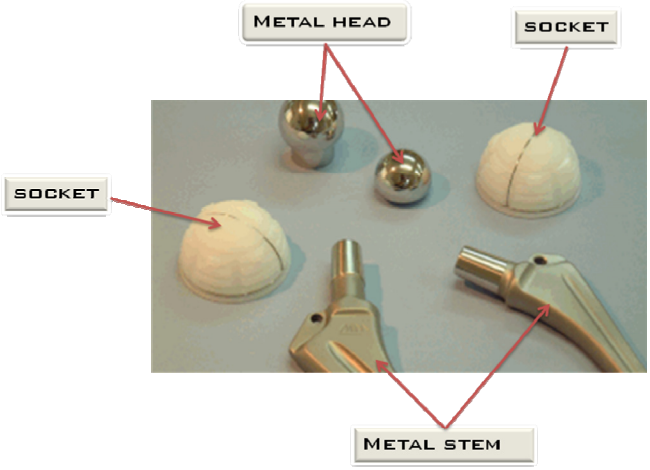


*Figure 2. Parts of hip joint prosthesis*

## THE MEASUREMENT OF THE SOCKET

*We measured with 3D measuring machine The measurement happens in the coordinate system defined by the planner and the equipment. It is one of the main characteristics of the CMM that under normal circumstances, it records the features to be examined point by point on the surface of the workpiece.*
*The concept of the point by point analysis gives the CMM universal usability; thus, all metrological problems that can be described mathematically, can be solved in practice with help of it.*

*We fixed the measurement data and drew the curves with the help of PC_DMIS software (Figure 3). This program translates the top level commands into a form that makes it possible to control the Coordinate Measuring Machine. It is an advantage for the user, that he can start the measurement with the familiar drop-down menus, windows, dialogue boxes and icons. The variability of the user's surface of the PC-DMIS simplifies customization, so the user may apply his personal settings in the software, which yields more comfortable and more efficient work.*

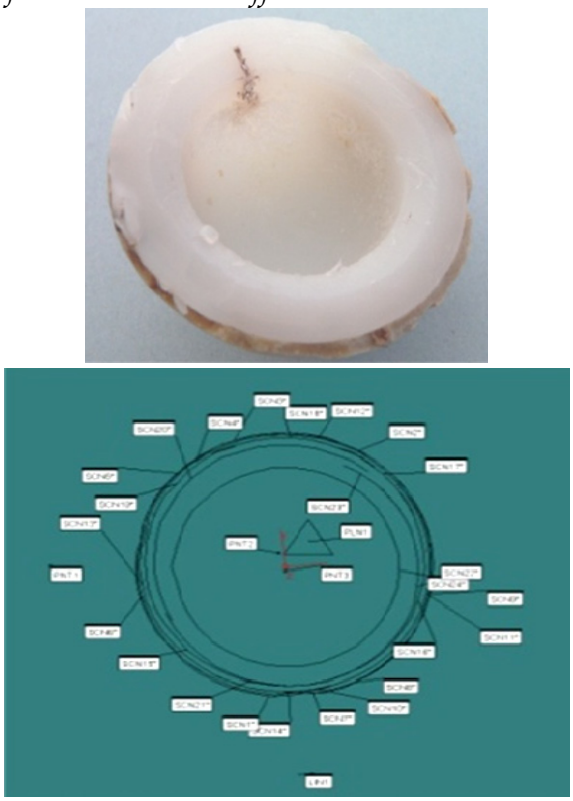

*Figure 3. Picture of the measured socket and graphical representation*

## *RECONTRUCTION OF THE MEASUREMENT POINTS*

*The reconstruction of the measurement points happened with the help of several types of 3D design software. We drew and analysed the measured points with CAD software (for example AutoCAD).*

*Steps:*

- *entering the measurement points into the software (entering the coordinates into the AutoCAD software);*
- *drawing the contour lines;*
- *drawing the Hermite - sheets;*
- *turning the curves (around the rotation axis) (Figure 4);*
- *drawing the differences (Figure 5).*

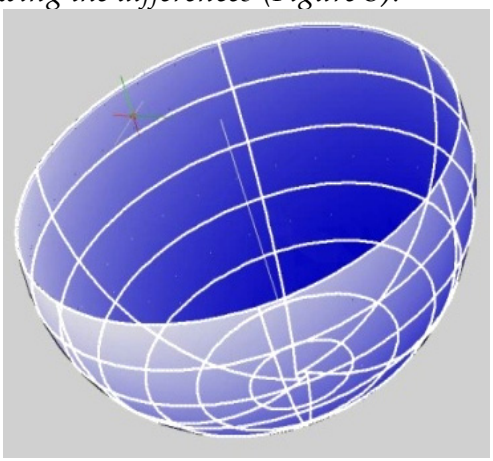

*Figure 4. Drawing the surface*

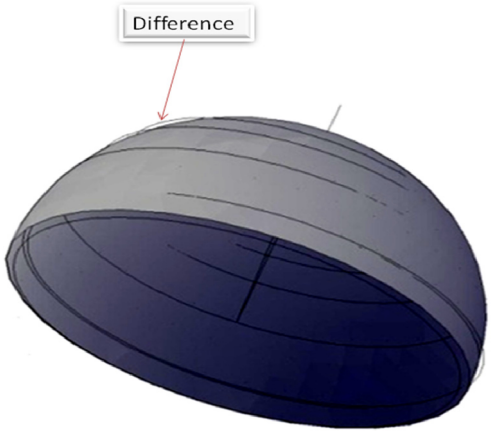


*Figure 5. Difference of the theoretical and real surface*

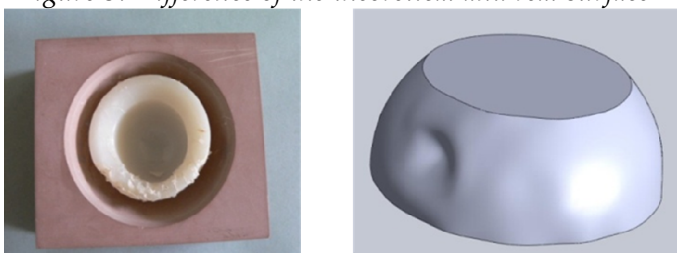

*Figure 6. The measured socket and model of the socket, drew the CAD*

*After the theoretical surface we drew the real surfaces, on which the distortions, bulging and buckling are clearly visible. On the figures below examples of the measured sockets can be seen (Figure 6).*

## *MODELLING*

*For creating the 3D model of the sphere head and the socket (Figure 7) we used the results of the 3D measurement of the "etalon" socket and the data appearing in the specifications of the sphere head and the socket. We used the Solid Edge planning software to do the planning as the 3D model*

*formed in this way can be used in the research with the FEM software.*

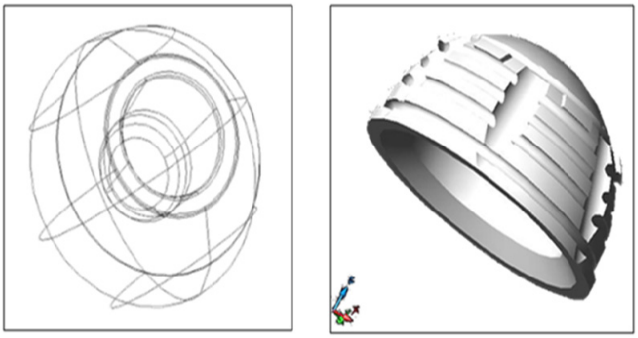

*Figure 7. Model of the head and socket*

**FINITE ELEMENTS METHOD ANALYSIS**

*The FEM analysis is executed with the help of the so called ANSYS FEM software [3,5].*

*Introduction of the ANSYS FEM analysis software*

*The ANSYS Workbench is the framework upon which the industry's broadest suite of advanced engineering simulation technology is built. An innovative project schematic view ties together the entire simulation process, guiding the user through even complex multiphysics analyses with drag-and-drop simplicity. With bidirectional CAD connectivity, an automated project update mechanism, pervasive parameter management and integrated optimization tools, the ANSYS Workbench platform delivers unprecedented productivity that truly enables Simulation Driven Product Development.*

*The test was made in two different ways:*

1. *First we put the sphere head and the socket in each other and some force was applied towards the centre (Figure 8). After the test we analysed the findings separately for the sphere head and the socket (Figures 9 and 10).*

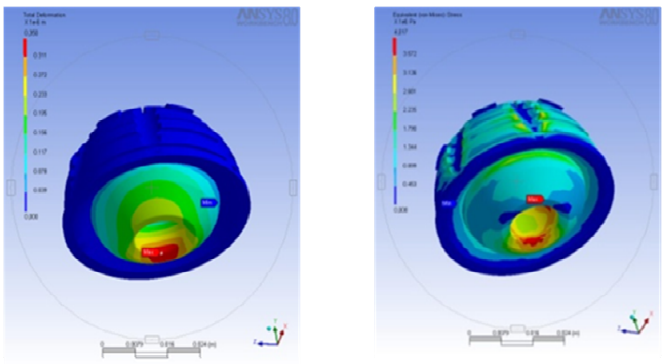

*Figure 8. The analysis of tenseness and deformation, in a complex state*

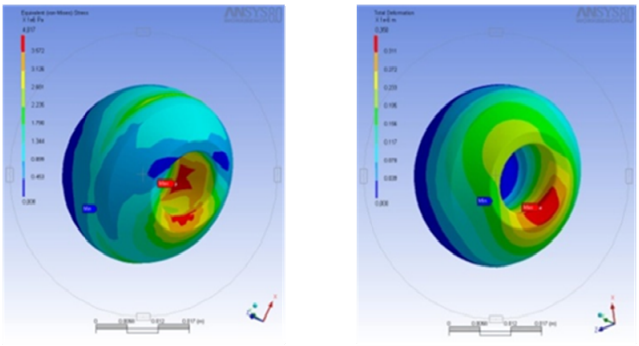

*Figure 9. The analysis of tenseness and deformation on the head*

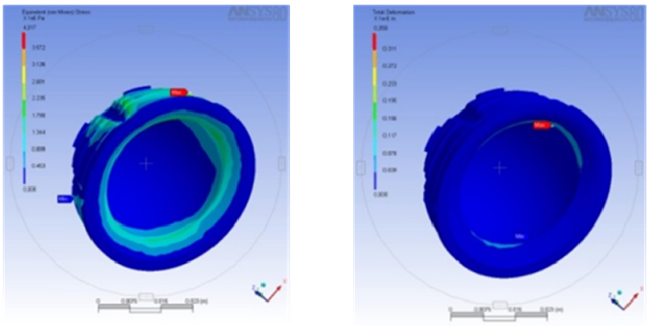

*Figure 10. The analysis of tenseness and deformation on the socket*

2. *In the second stage we applied the torque to the system and we examined tension and values of deformation (Figures 11).*

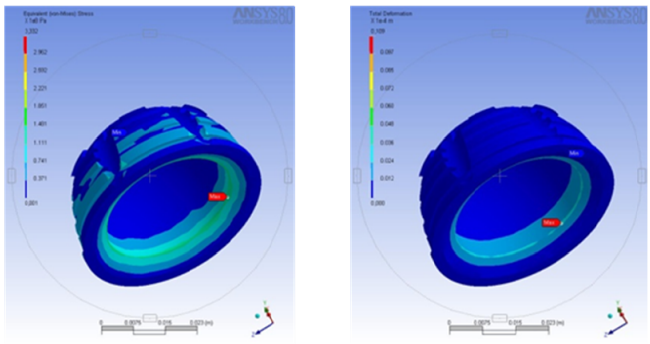

*Figure 11. The analysis of tenseness and deformation on the socket*

**SUMMARY**

*I presented the elements of the hip-joint prosthesis. Within that however I dealt with the socket in detail. I checked the socket, which is removed from some patient with the help of 3D measuring machine. I covered about the measured data and I reconstructed co-ordinates with the help of different software with computer aided design. From these I received a theoretical surface and the exact and deformed surface.*

*I drew the 3D model of the head and socket with the help of the Solid Edge designing software. On*

*this using model I analysed the head and socket values of tension and deformation with the ANSYS software with finite-element. Without exception we examined it together first, then however it is separate the head and separately the socket. The received results come up to our expectations.*

***Aknowledgement***

*„This research was (partially) carried out in the framework of the Center of Excellence of Innovative Engineering Design and Technologies at the University of Miskolc."*

***References***

[1] *Gábor Horányi: Prostheses life (Talking with prof Imre Bertóti). Life and Science, 2002. 11. szám*
[2] *Juhász Imre: Computer geometry and graphics. Miskolci Egyetemi Kiadó, 1993.*
[3] *Dr. F. Szabó – Z. Bihari – F. Sarka: Finite element modeling and optimization of the products, structures, machinery parts, Miskolc 2006.*
[4] *www.metrimed.hu, www.protetim.hu*
[5] *www.econengineering.com*
[6] *http://vaczidr.hu/csipokopas-csipoprotezis*
[7] *http://www.nhs.uk/Conditions/Hip-replacement/Pages/Introduction.aspx*
[8] *http://www.budaigyogytorna.hu/csipoartrozis*


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# INVESTIGATION OF THE INFLUENCE OF THE LEVEL OF CARBON AND NITROGEN POTENTIAL AT HIGH TEMPERATURE CARBONITRIDING OF Mn-Cr STEEL

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[2.] Faculty of Technical Sciences in Kosovska Mitrovica, SERBIA

***Abstract:*** *High temperature carbonitriding is a process of heat treatment that is used to increase the surface hardness of components, in order to reduce wear. The worm press for production of vegetable oil was chosen as an example of a system in which the high temperature carbonitrided components, made of Mn-Cr steel, are also built in. In exploitation, the extraction cage knife is exposed to a significant influence of the abrasive media, and the fatigue of material. A decrease of installed capacity efficiency is the result of local damages of components due to wear. The determined dimensional criterion of seizure makes the process of high temperature carbonitriding very suitable for the production of components that are used in the given exploitation conditions. The possibility of changing the level of carbon and nitrogen potential, as well as the effect on the possible life of extraction cage knives, were analysed. The use of a different carbon and nitrogen potential at the high temperature carbonitriding of test samples results in an extremely favourable flow of hardness at the cross-section. It can be observed that the achieved course of hardness is an extremely important indicator that had a significant impact on the final decision on the suitability of the observed process of thermochemical treatment for the intended purpose.*
***Keywords:*** *heat treatment, thermochemical treatment, Mn-Cr steel, carbonitriding, high temperature*

## INTRODUCTION

*In the worm presses for production of vegetable oil, the extraction cage consists of built-in knives (Figure 1).*

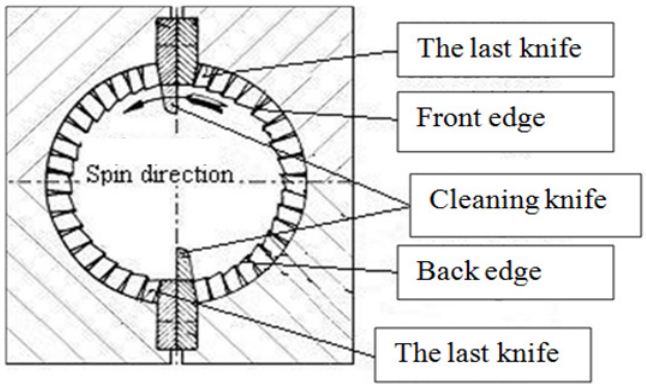



*Figure 1. Cross-section of extraction cage knives of worm press*

*Due to the presence of abrasive media and the appearance of fatigue of material that the extraction cage knives are exposed during exploitation, they were usually made by the cladding procedure. The costs of production by cladding, and extremely strict dimensional criterion of seizure and the problems during exploitation (Figure 2), emphasize the need to examine the use of other methods of production and prolonging life.*

*Taking into consideration the previous experiences, it can be assumed that the high temperature carbonitriding could give the optimum results, both from the production, but also from the standpoint of behavior in exploitation. The high temperature carbonitriding is a thermochemical surface treatment. The simultaneous diffusion of carbon and nitrogen in the surface forms different depths of martensite, according to the applied temperature. Even though this is an industrial process, which is used to harden the surface of components in order to reduce the wear, the wear mechanism was not intensively studied. Furthermore, there is little information on the wear of materials and their properties, which vary from the surface to the core. First of all, it is necessary to*

*determine the suitability of high temperature carbonitriding process for application on the steels for cementation that would have not only an affordable price, but also the required properties. If the satisfactory properties of layer are determined, the subsequent testing and the analysis of wear intensity will be performed.*

*Figure 2. Damaged extraction cage knife – made by cladding*

## MATERIAL AND METHODS

### Steels for cementation

*Steels for cementation belong to the group of structural steels. They usually contain from 0,1 up to 0,2%C before carburisation, and can be non-alloyed or low-alloyed. Steels with that low carbon content during hardening cannot achieve sufficiently high hardness, which is necessary to achieve resistance to abrasive wear. Therefore, steels for cementation, after the chip forming treatment with the addition for grinding of surfaces, which should be grinded after the cementation (gear teeth, fits for bearing, crosshead guides, etc.), are subjected to carburisation. Carburisation in granulate, salt bath or gas results in the increased amount of carbon from 0,8 up to 0,9%C in the surface layer of material. Thus enriched surface edge of material becomes hardenable, i.e. by quenching from a suitable temperature of austenitization, it takes the structure of high-carbon martensite, resistant to wear [1]. The hardnesses after quenching can reach between 60 and 65 HRC. The process of cementation consists of the carburisation and hardening of carburised part, as well as the low-temperature tempering. After camentation, the core of material stays ferritic-pearlitic if the product is not hardened, i.e. it becomes low-carbon martensitic if the core is hardened. Both these structures of core have a high toughness, i.e. after the process of cementation, steel will have a hard surface with good wear resistance, and with relatively tough core.*

*With alloyed steels, hardening is preferred, because the cemented steels are low-tempered at the temperatures below 220 °C, and greater toughness of the core can be achieved only by the low-carbon martensite. The aim of alloying is to improve hardenability of steel at quenching of carburised object. Due to better hardening of the core, we get the structure of low-carbon martensite, which provides high strength properties of core, its increased fatigue strength and high toughness (diagrams in Figure 3). Alloying elements have an impact on the process of carburisation of edge of object, i.e. on the speed of the process of carburisation, carbon content in the edge of carburisation of object, depth of carburised boundary layer. Non-carbide-forming elements, like nickel, silicon and cobalt, accelerate the diffusion of carbon in austenite, but also lower the solubility of carbon in the boundary layer, while carbide-forming elements, like chromium, molybdenum, vanadium and manganese, lower the diffusion coefficient of carbon in austenite, and thus increase the carbon content in the boundary layer [1], [2], [3].*

*One of the main problems when choosing the parameters for the process of carburisation and hardening is how to determine the correct temperature of quenching. Considering the fact that at the same time, there are areas with a high carbon content (the edge with over 0,8%) and low carbon content (core with less than 0,2%), it is necessary to choose a compromise temperature of quenching. The temperature of quenching should be lower than the ideal one for the core (the temperature at which the boundary layer overheats causing a coarse-grained martensite and increased fragility) and higher than the ideal for the high-carbon edge (at which there is incomplete hardening of the core). In this respect, the least problems occur with non-alloyed steels, in which the so called direct hardening, i.e. quenching with the temperature of carburisation, is permitted. From such non-alloyed steels, the products of smaller dimensions, and the products for secondary purposes that are exposed to lower impact stresses, are manufactured [1], [2], [3], [4].*

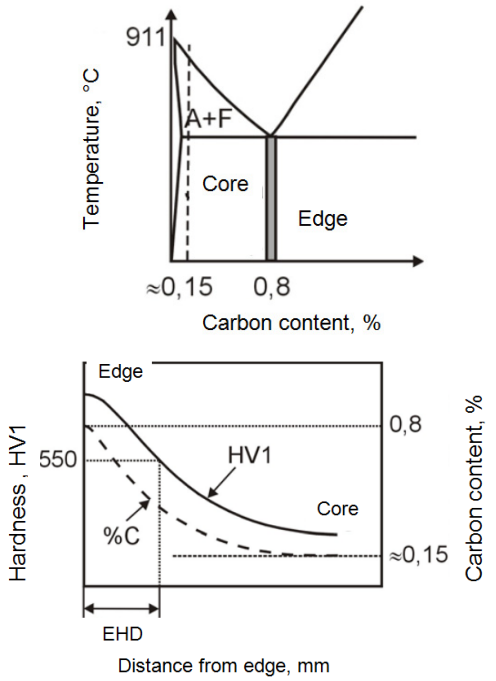



*Figure 3. Carbon content (a) and hardness (b) during carburisation [1]*

*The process of carburisation can be performed in the granulate, molten cyanide salts and in a gaseous medium. The process of hardening can be done directly or after the process of carburisation, so called single hardening. Direct hardening is usually applied after carburisation in salt bath, and single hardening after slow cooling in granulate or gas. The hardening is followed by the low temperature tempering in the temperature interval from 170 up to 220°C.*

*When choosing the steels for cementation, the determining factor is the dimension of finished product. Since it is possible to achieve a high surface hardness (that guarantees wear resistance) on all steels for cementation, there is a special request for the approach to the hardenability of core.*

*The main characteristic of Mn-Cr steels for cementation is that despite the high percentage of chromium, and due to the presence of manganese, they are not prone to separation of carbides in the boundary layer. The presence of manganese and chromium increases hardenability, so these steels are used for the medium size products, such as gears and shafts of machine tools. Mn-Cr steels are sensitive to overheating, and therefore, after carburisation, they are slowly cooled and re-austenitizated and quenched, and then tempered [2], [3].*

*In order to investigate the influence of the level of carbon and nitrogen potential (on the properties of steel), the high temperature carbonitriding of Mn-Cr steel for cementation will be made, (chemical composition is shown in Table 1).*

*Table 1. Chemical composition of 20MnCr5 steel [5]*

| *Proportion of chemical element, %* | *C* | *Si* | *Mn* | *Cr* |
|---|---|---|---|---|
| *Composition of sample* | *0,19* | *max. 0,4* | *1,25* | *1,15* |
| *According to EN 10084:2008* | *0,17÷0,22* | *max. 0,4* | *1,1÷1,4* | *1÷1,3* |

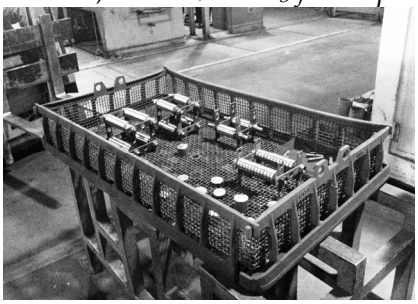
***High temperature carbonitriding***

*The high temperature carbonitriding is a thermochemical treatment where the surface layers of steel in the austenitic condition are enriched simultaneously by carbon and nitrogen. After hardening, the object is quenched in oil or water, and low temperature tempered [2].*

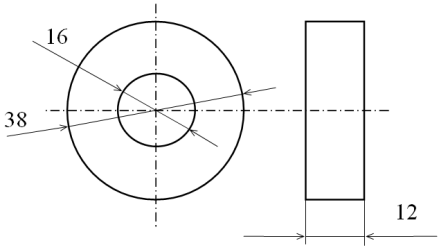
*The high temperature carbonitriding process is carried out between 700 °C and 900 °C, and with the lower temperature of carbonitriding, nitrogen enrichment prevails over carbon. With the increase of temperature of carbonitriding, the amount of diffused carbon is increased, and the amount of diffused nitrogen is decreased. The structure of layers is carbon-nitrogen martensite, and the outer part of the layer is a zone of carbonitride compounds. The process of high temperature carbonitriding can be performed in liquid, solid or gaseous agents. Temperature, duration of the procedure and the chemical composition of steel have the most significant effect on the process of high temperature carbonitriding. Nitrogen in the carbonitrided edge increases wear resistance, and if a zone of compounds is created in a carbonitrided layer, fatigue strength of machine parts will be increased. The process of high temperature carbonitriding is carried out in liquid or gaseous media. Liquid media are salts for carbonitriding, which are the mixtures of alkaline cyanides, cyanates, carbonates, chlorides and activators. The high temperature carbonitriding in gas atmospheres is a process of cementation with the same gas atmosphere, which is enriched by the gas with nitrogen (ammonia $NH_3$). The procedure is used as a substitute for the cementation of objects sensitive to measuring.*

*Unlike nitriding, the carbonitrided components are more resistant to high specific pressures and impacts. The materials that can be used for the carbonitriding are the steels for cementation, improvement, sintered iron and cast iron [3].*

*The test samples in a form of disc are shown in Figure 4. The process of high temperature carbonitriding was performed in the protective atmosphere of a furnace, rich with earth gas and ammonia, at the constant parameters of temperature (920 °C) for the duration of 10 hours. The use of different values of carbon potential ($C_{pot}$) and nitrogen potential ($N_{pot}$) was planned. $C_{pot}$ values were read directly on the measuring equipment which is part of the furnace. For Experiment 1, $C_{pot}$ = 0.5% C, and for Experiment 2, $C_{pot}$ = 1.0% C. $N_{pot}$ values were regulated by the flow of ammonia. They were as follows: 10 % $NH_3$ for Experiment 1, and 5 % $NH_3$ for Experiment 2.*



*a) Test samples (prepared for the furnace)*



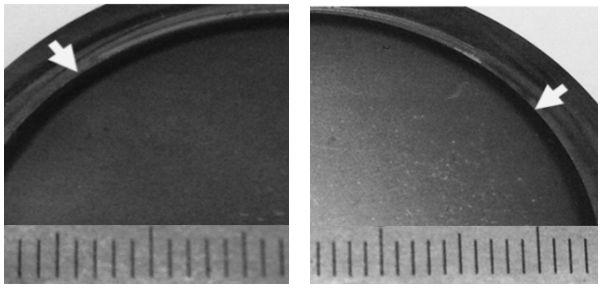

*b) Test sample (shematic representation)*

*Figure 4. Test samples for high temperature carbonitriding*

## RESULTS AND DISCUSSION

*Using HV1 method, the hardness measurement was performed at the cross-section of test samples (Figure 5). A characteristic dark edge (marked by the arrows) can be noticed on the surface layer of the test samples sealed in polymer.*

*Figure 6 shows the hardness measured at the cross-section of samples (high temperature carbonitrided for 10 hours). The achieved effective depth of carbonitriding was 1÷1,3 mm (represented by the points C1 and C2 in Figure 6).*



*a) Experiment 1* *b) Experiment 2*

*Figure 5. Cross-section of high temperature carbonitrided samples sealed in polymer*

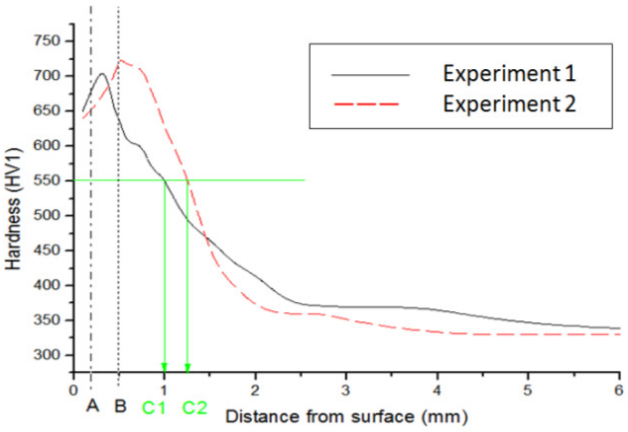



*Figure 6. Hardness (HV1) measured at the cross-section of test samples shown in Figure 5*

*In the components with the rod-shaped form, like an extraction cage knife, there is a risk of deformation at the high temperature carbonitriding, Figure 7. From the flow of hardness, Figure 6, it can be observed that by the use of different levels of carbon and nitrogen potential, different effective depths of carbonitriding are achieved (points C1 and C2, Figure 6). Despite the observed differences, the high temperature carbonitriding still proves to be a very effective procedure of thermochemical treatment. It also allows the subsequent steps of grinding to correct the dimensional deviations caused by deformations up to the level of hardness marked with A for Experiment 1, and the level of hardness marked with B for Experiment 2. The letter symbols (in Figure 7) represent the zones of hardness at depth of high temperature carbonitrided knife of extraction cage, which are taken from the diagram in Figure 6. The maximum permitted level of wear in exploitation is up to the point C1, when using the parameters of Experiment 1, and up to the point C2, when using the parameters of Experiment 2.*

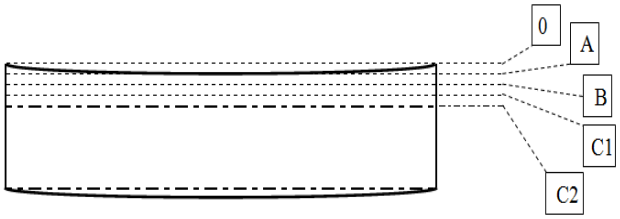



*Figure 7. Schematic representation of tolerance areas of the extraction cage knives, where the corrections by machining are allowed*

*Using the device SMT-1 2070 (Figure 8), it is possible to simulate the conditions most similar to real, operating conditions.*

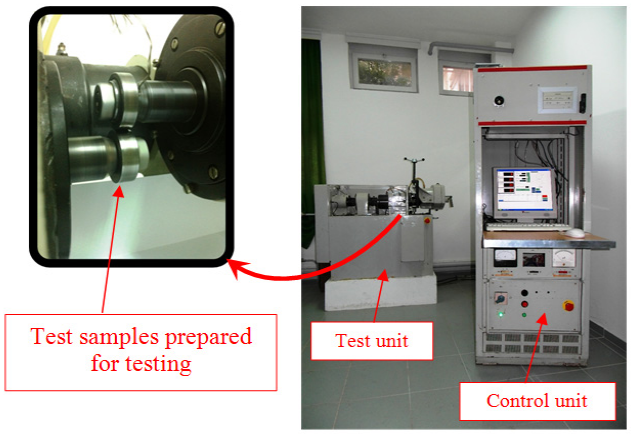



*Figure 8. Device for testing of friction and wear, SMT-1 2070*

## CONCLUSION

*The main objective of the high temperature carbonitriding is an increase of surface hardness and wear resistance. Since the dimensional criterion of seizure for the extraction cage knives is approximately 0,2 mm (point A in the diagram, Figure 6), the high temperature carbonitriding can be applied for their production regardless of the level of carbon and nitrogen potential. With regard to the wear resistance, it is necessary to perform the additional tests of prepared samples. The obtained results will give a complete picture of the properties in conditions of wear.*

*They provide an adequate basis for the future research. The testing for the prepared samples is designed, making it possible to carry out the testing of wear resistance of the layers at the desired depth of layer. By monitoring the wear intensity of adhesive type with the component of sliding, it is possible to get an insight in the current properties, as well as the possibility of better synchronisation of the necessary surface properties of machine elements.*

## REFERENCES

[1.] *Kožuh, S., Specijalni čelici (skripta), Metalurški fakultet Sveučilišta u Zagrebu, pp. 1-57, 2010.*
[2.] *Krumes, D., Površinske toplinske obrade i inženjerstvo površina, Strojarski fakultet Slavonski Brod, pp. 31-114, 2004.*
[3.] *Novosel, M., Krumes, D., Posebni čelici, Strojarski fakultet Slavonski Brod, pp. 93-165, 1998.*
[4.] *Stupnišek M., Cajner F., Osnove toplinske obradbe metala, 1996*
[5.] *EN 10084:2008*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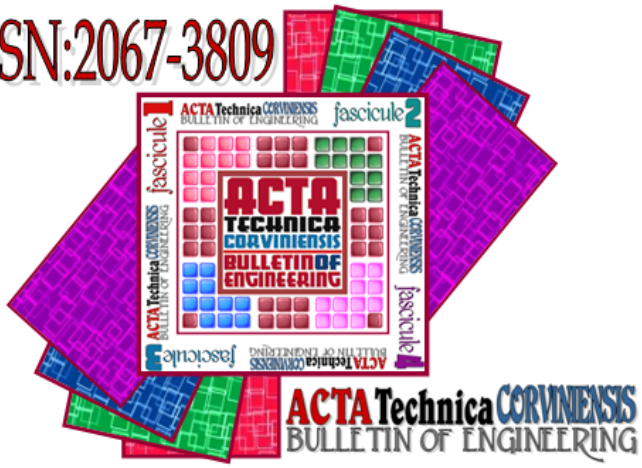


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# EXAMINATION OF MATERIAL REMOVAL PROCESS IN HONING

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***Abstract:*** *The paper examines the possibilities of increasing of material removal rate of honing in case of use of superhard tools. Tool having superhard grains significantly increases performance of chip removal, technological process becomes more stable and the increase of tool life is meaningful. The author experimentally examined the effects of increase of grain size, cutting speed, tool pressure on changing of cutting time. The result of this is a two stage honing, in which the first stage assures removing of increased allowance, and the second stage is the final or fine stage which assures the realization of the prescribed accuracy and surface roughness.*
***Keywords:*** *superhard tools, chip removal, honing, grain size, cutting speed, tool pressure, cutting time*

## INTRODUCTION

*Precision or finish machining procedures of high accuracy and good surface quality are used in automative industry (e.g. bores of cylinder and winch), bearing industry and in mass production of hidraulic elements.*

*The most frequent finish machining procedures of bores are: fine turning, fine drilling, broaching, reaming, fine grinding, honing (superfinishing), lapping, bore burnishing.*

*These procedures indispensable in machining of outer cylindrical, flat and shaped surfaces [1, 3, 4]. About the new research results of hard machining of hardened surface bores reported Kundrak [2]. Varga examines the features of diamond burnishing of outer cylindrical surfaces [4].*

*The primary aim of honing is*

- *removing microgeometrical irregularities originating from the previous procedures,*
- *or removing the destructed surface layer which was evolved because of significant cutting forces and temperature set in machining,*
- *reduction of surface roughness,*
- *formation of micro scratch system which is favourable from the point of viev of tribology and lubrication.*

*Further aim is working out of honed surface with prescribed macrogeometrical accuracy (dimension, shape, accuracy).*

*Very small value of allowance is removed in finish or fine honing, 2 $R_{max.e}$ = 5-20 µm in each side. $R_{max.e}$ is the maximum value of surface roughness made by careful cutting operation before honing. The obtainable average roughness is $R_a$ = 0,09-0,02 µm.*

*Pre-honing, executed in between the finish or fine honing and the previous machining operation, of course, applies that type of tool and technological parameter, by which larger volume of material, and allowance can be removed.*

*This paper shows the results of newer research results of honing of bores, particularly detailing of material removal, economically removable allowance.*

## GRINDING OR HONIG OF BORES?

*The technologist must decide in many cases and has to anwser the question above. Assuming that both machine tools are avaitable. We know the difficulties of grinding of bore, the small grinding spindle stiffness is the main problem, which limits the accuracy and material removal [1]. The Table 1 summarizes the comparison of the two procedures.*

*Symbols in table: $d_f$ and $d_s$ – bore and tool diameter, $B_s$ – width of grinding tool, $L_h$ – prism length, $1_f$ – bore length, a – the dept of cut, $d_{eq}$ – equivalent bore diameter, $n_h$ – number of columns, $B_h$ – column width, $d_s$ – grinding disc diameter.*

*Bore grinding equivalent bore diameter:*

$$d_{eq} = (d_s + d_f)\ (d_f - d_s)^{-1} \qquad (1)$$

*The Table 1 also shows the anwser that honing at low cutting speeds, low cutting temperature and design of the tool is there fore balanced and works*

with equilibrium positions and radial cutting forces. Consequence of the foregoing: damaged, remove the surface layor being transformed and does not cause. Substantially similar changes in the surface layor.

If the

$$l_f / d_f > 1 \qquad (2)$$

then it is recommended to choose honing, if no other restrictions preclude.

Table 1. Comparison of methods

| Characteristic | Grinding of Bore | Honing |
|---|---|---|
| cutting speed | $v_c \geq 25$ m/s | $v_c \geq 45$ m/min |
| tool diameter<br>tool length | $d_f > d_s$<br>$l_f <$ or $> B_s$ | $d_f = d_s$ (adjustable)<br>$l_f \geq L_h$ (stroke adjustable) |
| ratio of bore length and diameter | $l_f / d_f \leq 1,5$ | 1,0…20 |
| length contact of tool and bore | $i = (a.d_{eq})^{0,5}$; (small) | $i = n_h.B_n$; (large) |
| cutting temperature | > 700˚C | < 120˚C |
| characteristics of removed chips: length, form, temperature | short „mustache" shaped (melting, oxidation) | cast iron, hardened steel: broken short chip; soft, ductile materials: long continuons chip in cold state |

## INCREASING MATERIAL REMOVAL RATE OF PRE-HONING

If the allowance of machining should be increased, because of the amount of inaccuracies of machining before honing, then a two-stage honing is planed. Pre-honing provides the majority of separation, in this case the material removal rate should be increased. Following by finishing, or fine honing.

If the bore is measured directly in the plant or growth experiments, the data obtained can be used immediately. The accuraly diameter of bore can be measured in different ways: 3- point micrometer gauge; air gauge; while working built in air jets in the honing tool.

In experiments we used the first and third method. The honing material removal rate increase is possible in several ways important opportunities for increasing:

Machine tools:

– chousing a machine to make it clear that a force – locking or shape locking to the die pressure adjustment and regulation;
– $v_c$ cutting speed and p die pressure adjustment range;
– two – (pre – and fine honing) or multispindle machine tool needs;

Tools:

– choosing of best tool construction for workpiece;
– hon-tool - good, choise to the material being machined quality, grain size of the active formation;
– application of super-hard grain size, grain concentration, bond-material; etc.

Technology data selection:

– $v_c$ cutting speed the right to establish and $v_a$ axial $v_t$ tangential components, increase the possibility of;
– p tool to increase the allowance pressure, economical tool wear of value;
– t honing time setting, taking in to account of the allowance amount;
– choose coolant fluid, ensure filtration and flow rate, compliance with fluid replacement time.

The optimal solution when serial and mass manufacturing – the workpiece can be reached in this case, next to machine tools, tools and technology designed consistency of data. The so called universal honing machines fills individual and small series production needs, next to compromisation.

## EXPERIMENTAL STUDIES

In order to favourable hedge in the technical data. I made honing experiments at University of Miskolc on a SzFS 63x315B type of machine tool. The machine features a range of test limits.

The experiment aims at examining the material removal rate. Mesured attributes: $\Delta$ detached allowance (diameter), $R_a$ roughness (arithmetical mean deviation of the profile) and other surface parameters, H – cyrcularity error, $\Delta_s$ tool wear (radial direction). In the experimental tests $v_c$ cutting speed, p tool pressure and t machining time was varied using a variety of synthetic, superhard grains tools. The figures 1 and 2 show the experiments according to the results of experimental work the presented experiments happened on bores made of cast iron materials (GG. 25, Hungarian norm, HB=170…240).

The tool pressure increasing, according to a linear equation, increases the material removal rate. The

*Figure 1 ACB 160/125-100 %-M1 synthetic diamond grains-tool (8 x 100 mm, 3 parts) the pre-honing measurement results are shown, in the t honing time funtion. The Δ(t) detached allowance (diameter) after 10-15 s increases linearly. Increase is significant.*

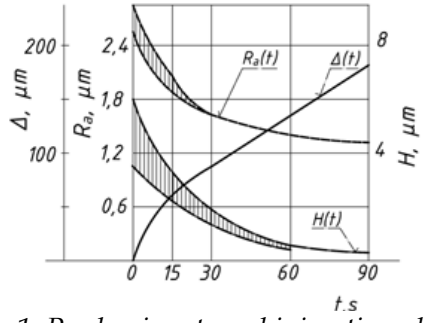


*Figure 1. Pre-honing: t machining time changes depending on the important characteristics. Data: $v_t$=44 m/min; $v_a$=14 m/min; p=0,9 MPa; cooling lubricant: honilo 460.*

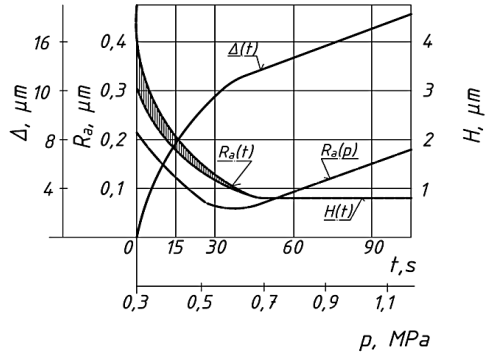


*Figure 2. Finishing or fine – honing: t machining time and p tool pressure function changes and important characteristics. Data from the t – dependence curves: $v_t$ = 40 m/min; $v_a$ = 12 m/min; p = 0,5 MPa; Data from the p – dependence curves: t = 60 s, other data as described above.*

*The non-linear stage of careful machining and finishing a relatively high roughness, caused by the roughness peales of intense isolation.*

*The H(t) circularity error and $R_a$(t) average speed decreased rapidly.*

*Figure 2 shows Δ(t) removed allowance (diameter), $R_a$(t) and $R_a$(p) average roughness change ACM 28/20-100%-M1 tool as the function of honing time t and tool pressure p.*

*Metal removal rate decreased by an order of magnitude. The surface roughness $R_a$ = 0,09 µm decreased after t = 40–45 s. The $R_a$(p) curve minimum place developed between t=32–36 s, where shows a value of $R_a$=0,07–0,08 µm. This value is a positive indicator for fine finishing or honing.*

*Futher experimental studies, some important results in the following: cast iron under optimized process conditions when working with a specific dramond use. ACB 160/125 és ACP 125/100, ACP 100/80, ACM 28/20 particle sizes (-100 %-M1) 0,05-0,07; 0.03-0,04; 0,02-0,07 mg/g I valued. These values are compared with international standards are very favorable.*

*I have established some important conclusions based on experimental results: on cast iron ACP 125/100; ACB 160/125 etc. when honing with particle sized tools high stock removal performance can be achieved, such as (100x8 mm, 3 parts) ∅42x65 mm bore in 60 s 0,4-0,5 mm (2 sides) allowance can be separated.*

*Improve the quality of the surface – reduced roughness $R_a$ = 0,06-0,04 µm – with fine – gains tool (eg. ACM 28/20; 20/14-100 %-M1) can be ensused.*

*With hardened steel (100Cr6, Hungarian norm, HRC=60±2) compared to the previous ones less stock removal performance, but still can replace grinding of bore. The two – stage (pre-and fine) honing it is beneficial for use of burden-sharing tribology and lubrication or plateau honing process pre-honing is happened with a bigger graning tool and established high roughness peales with fine honing and a super-hard microdust material removal tool cumed at the development of the platform (Figure 3). The microdust's particle size 63…10 µm is anwsered in province. The surface of machined parts such as residnal crossing micro scrathes are excellent lubricant reservoirs, a fine platform, cross scrathes hydrodynamic lubrication system, to ensure long-term oil film formation. The Figure 3 illustrates the formation of micro-geometry of the workpiece surface while using plateau honing [7].*

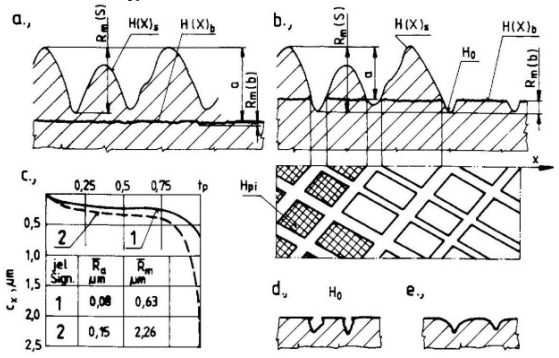


*Figure 3. Microtopography after plateau-honing*

*The Figure 3/a and b, shows a detailed version of the roughness profile. The $H(x)_b$ profile. Int he case of a completeln int he case of b, only partly separated using pre-honing, the $H_o$ double oil storage systems and $H_{pi}$ platforms (plateaus) are converted. The d, and e, details show the $H_o$ scratches-edge after using metal bonding, and bonded flexible tools (plastic, scratehes burssed edges, In, e case (flexible binder) it is rounded. The tool used in figure 3/c $t_p$ relative bearing surface curves and the corresponding values $R_a$ and $R_m$ are shown. After pre-honing the curve 2. and the curve 1. after plateau-honing, the $t_p$ support development of the specific length. The gauge: Perthometer 58 with FOCODY, laser detektor.*

## *SUMMARY AND CONCLUSIONS*

*We have seen that material removal rate Q ($mm^3/s$) of the honing can be increased in several ways. This way the economically seperated margin can be increased. The superhard grain material, larges grain tools provide significant productivity and accuracy compared to traditional grain material tools.*

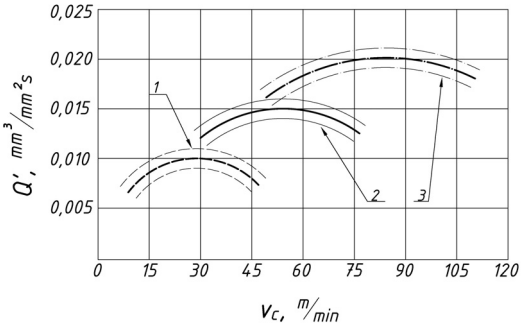


*Figure 4. The different types of grain material honing tools Q′ specific material removad rate in the $v_c$ cutting speed function. Symbols: 1-$Al_2O_3$, SiC; 2 – diamond; 3 – CBN*

*The tools have a high stability and life. During serial and mass production using these tools is economical. More specific metal removment rate increase, takes place by increasing the cutting speed and die pressure. Two-staged honing should be used. Pre-honing detaches a relatively large masgin, fine-honing decreases roughness and improves the surface and a combination of the two gives plateau-honing. Longer processing of the results of research work and literature (de Beers data, etc.) data allowed the approximate nature of the 1 – traditional grains ($Al_2O_3$, SiC, etc.); 2 – diamond, 3 – cubic = boron nitride – can be avaitable using grain material honing, a specific material removal rates Q′ ($mm^3/mm^2.s$) simplified mapping of the $v_c$ cutting speed. This is shown in figure 4.*

*Using the CBN the material removal rate is more productive than using diamond grain tools. Increasing the particle size, increuses the material removal performance. The quality of the workpiece material, technical data and working conditions are different, therefore the a scattering is large as indicated in the figure. The $v_c$ cutting speed range of modern machines towards higher speeds increased significantly [6] of course the adjustable p die pressure values are larger. The superhard particle material and those developed metal bonding (tin-bronze, nickel, etc.) makes this possible. Required to do so: large cutting speed and larger tool pressure insured honing machine, automotive honing machine and new tool constructions and procedures [3,5,6].*

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***Literature***

*[1] KÖNING W., KLOCKE F.: Fertigungsverfahren, Schleifen, Honen, Läppen, Band 2, VDI-Verlag, Düsseldorf, 1996.*

*[2] KUNDRÁK J.: Hard Boring of Gears, Journal of Production Processes and Systems, V.6.No.1. 2012. Miskolc University Press, pp. 61-70. HU ISSN 1786-7983.*

*[3] SZABÓ O.: Optimisation of Technology and Quasi Honing of Polygon Bores. Journal of Materials Processing Technology, ELSEVIR, Dublin, 2002. 119. pp. 117-121.*

*[4] VARGA Gy.: Effects of Technological Parameters ont he Surface Texture of Burnished Surfaces, Key Engineering Materials, ol. 581. 2014. pp. 403-408.*

*[5] BURKHARD G., REHSTEINER F.: High Efficiency Abrasive Tool for Honing, Annals of the CIRP V. 51/1/2002. pp. 271-274.*

*[6] DEGEN, W.: Honen in High-Speed, WB Werkstatt-Betrieb Zeitschrift für spanende Fertigung, 7-8. 2010. 143. Jahrgang pp. 63.*

*[7] SZABÓ O.: Optimization of the Tool-Pressure at Honing, Journal of Production Processes and Systems, V.6.No.1. 2012. Miskolc University Press, pp. 39-44. HU ISSN 1786-7983.*

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# DESIGN OF NEW PORTABLE VERTICAL CONE PENETROMETER

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**Abstract:** *This paper describes new portable vertical penetrometer design for the agricultural soil compaction measuring. The Department of Machine Design and The Department of Electrical Engineering, Automation and Informatics on FoE SUA in Nitra are currently preparing a new measuring system with modern electronic parts as well as application of new measuring principles for depth and force sensors. Design has a new arrangement of the elements in the body. Major innovation is the use of a colour touch screen which one allows real time monitor: the laboratory measurements, the measured data saved on SD card, Excel and formatted data, the ultrasound sensors values for the indirect ground depth measuring, the user friendly setup options of the device parameters and the incorporation of GPS into the device housing. Connection with personal computer remained unchanged from the previous type. In this paper is described the enhanced algorithm for penetration resistance measuring of a soil in dependence on depth and on place of the pushed sensing head.*
**Keywords:** *soil compaction, portable vertical cone penetrometer, penetration resistance measurement, cone index*

## INTRODUCTION

*Harvesting, sowing and protection and mechanisms for tillage negatively affect soil compaction despite new design solutions, especially in extreme weather conditions.*

*There is necessary to have detailed and accurate information about the condition of land and constantly specifies those models of the soil particles spatial arrangement for finding appropriate solutions to minimize soil compaction. Monitoring of soil compaction is performed mainly by penetrating devices which are mainly used in mapping the immediate condition of the soil.*

*Soil compaction is most often defined by penetration resistance (Cone Index, CI) when measured cone and sensor, measure the value of the resistive force exerted per unit area at the base of the cone. To ensure comparability and reproducibility of results and objectively assess the changes of soil compaction it is used standard size cone by American standards ASAE S 313.3. This article describes the design of a new penetration device designed at DMD and DEEAI at FE SUA in Nitra (Slovakia) and the first results in the implementation of this device.*

## MATERIAL AND METHODS

*Microprocessor and computer technology and research and development in this sphere influences on the development of penetration devices in positive direction due to which we can make the measurement quickly and results processed into more transparent and comprehensible form. The cooperation of work between DMD and DEEAI at TFE SUA in Nitra (Slovakia) was made 15 years ago penetrometer P-BDH 3A (Figure 1).*

*This penetrometer was founded on the principle of sensing the force of soil resistance against solid shape (cone) pushed into the soil by capturing incremental value after pressing deeper every centimetre. For measurements were used optoelectronic measurement systems, digitization and record of measured values in memory, which was transported into a computer and processed further. The measuring device was very simple and reliable with over 10,000 possible record data. Through digital indicator can be adjusted input parameters, calibrate the device and check the measured data values. Wide application of penetration method just for its benefits will likely continue in other areas. Increasingly sophisticated*

*equipment available with electronics and modern processing methods and evaluation techniques can position the field tests keep at the forefront of scientific and agricultural interest.*

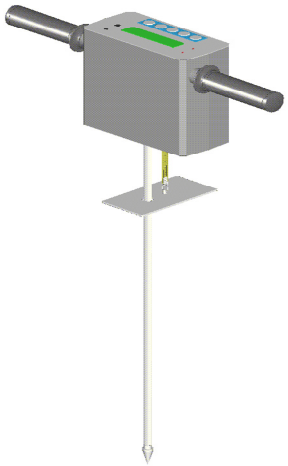


*Figure 1. Penetrometer P-BDH 3A*

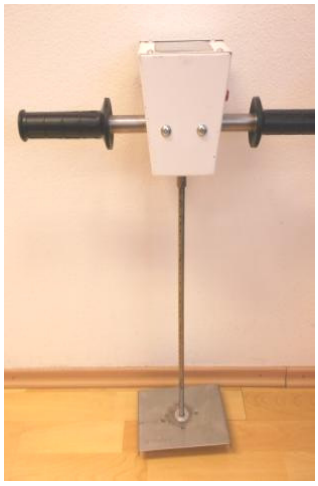


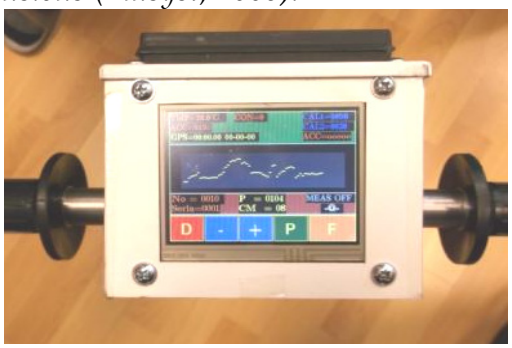
*Figure 2. Penetrometer PE 90*

*Years of experience in the measurement and evaluation of measurement the authors prompted to upgrade the device so as to remove some of the shortcomings of the device in terms of measurement system, as well as increased measurement comfort and control. During the measurement at P-BDH 3A was not possible to follow the course of the measured forces, depending on the depth and it was not able to locate the measurement location by a GPS system.*

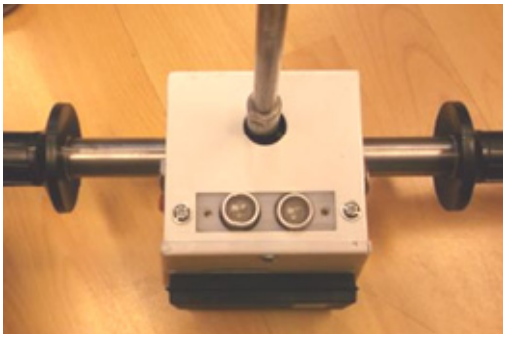
*Finally, the authors decided technical and technological improving to meet the new requirements of the practice. The concept of the new device was based on the requirement of control options during the penetration resistance measurement and so extreme values (errors) can be immediately erased. It was also our aim to prepare a reliable measuring instrument with a low price that was unlike now commercially produced devices cheaper and more accessible for practice (Figure 2). Therefore into this new concept were applied commercially produced force and depth sensors (ultrasonic sensors) modern electronic and microprocessor technology, including the use of a colour touch screen.*

## *RESULTS AND DISCUSSION*

*Penetrometer marked as PE 90 is new variant of penetration device, which consists of a steel casing, cut out and welded out of sheet metal which one is associated with the metal housing with countersunk screws. To this housing is bolted carrying case with attached handles inside which is fixed force sensor (Líška, 2008), the bottom of the sensor is attached to the rod with cone probe. On the top of the metal cover is placed colour touch screen (Figure 3a). To measure the force of resistance was chosen sensor type EMS 20 with a measuring range up to 5 kN, which has minimal dimensions (Emsyst, 2008).*



*a)*



*b)*

*Figure 3. Device view: a) view on display unit, b) location of ultrasonic probes*

*At the new concept were used current possibilities of modern electronic and microprocessor technology. The device uses a colour touch screen for entering measuring conditions, parameter setting and control over the measurement on the display screen.*

*There is mounted ultrasonic sensor for measuring of depth to the bottom of the housing, and is*

clamped sliding reflector plate to ensure a correct reflection of the ultrasonic signal to the measuring rod (Figure 3b). The device can be externally connected to a computer to export data and GPS position for their further process. It has the ability to connect to an external power source with controlled charging of battery capacity. Handles, measuring rod and the GPS sensor is removable, which allows better storage-ability and its transfer.
Measurement algorithm of penetrometer resistance depending on the soil depth should take into account the following aspects:

- the measuring system have to do the calibration of sensors due to temperature after power on (1),
- to determine of the GPS signal activity,
- measuring rod speed in the recess have to be max. 0.01 $ms^{-1}$,
- device has an audible alarm to warn the possible destruction of the force sensor under strong recess,
- in case of the wrong methodology recess irregular movements of measuring rod, for example impact on stone or finding an air gap, attention to the possible incorrect results.

Built-in temperature sensor is used to calibrate ultrasonic sensor distance covered by the adapted known equation:

$$s=(165.9+0.305.(T_s-273.15)).t \qquad (1)$$

where: s - is sensed soil depth, m
$T_s$ - is air temperature, K
t - is measurement time interval, s
After the first layout of the components in the new device were resolved other parts like battery, location of some controls, GPS sensor, battery charge and computer connection. It has got GPS sensor with SiRFstar III chip, which in addition to determining the exact position of measurement what also provides information about the current altitude and the time of measurement. Values of ambient and soil temperature is an additional indication of measurement. The measured data are stored on the microSD card format in *.csv file that is readable in MS Excel or other spreadsheets (Géci, 2007).
Today a new variant of penetration device PE90 shown is designed with the technical characteristics shown in Table 1.

Table 1. Technical characteristics of PE 90

| | |
|---|---|
| Measuring range | 0 - 10 MPa (cone index) |
| | 0 - 600 mm (measurement depth) |
| Measuring step depth | 10 mm |
| Number of measurements | cca 100 000 on 256 MB microSDcard |
| File type | .csv (.txt, .bin) |
| GPS module | SirfStar III |
| Connectivity | USB, RS232C, SD card |
| Unit Dimensions | 120 x 140x 90 mm (body) |
| Length of the rod | 600 mm |
| Weight | 2.6 kg |
| Size cone (diameter of base / top angle) | 12.8 (20.3) mm/ 30 ° |
| Battery life | min. 10 hours |

Nowadays is well known companies Eijkelkamp Penetrologger that has a measuring range up to 10 MPa, measuring the depth in interval 10 or 20 mm, depth measurement is max. 800 mm. Cone used for measuring has got angle of 60° on special request also available with cone according to ASABE. The device can be added with GPS without connection to system memory.
ELE International Company offers Proving Ring penetrometer with ASABE cone, it has analogue pointer without electronic record of the measured resistance and depth and no GPS. A few years ago they offer ELE CCP model with a measurement range up to 600N, depth measurement up to 450mm with a reading offer 15mm, 16 digit display with record up to 600 measurements. Currently, it is not in the catalogue.
Australian company AGRIDRY RIMIK PTY LTD in Toowoomba offers RIMIK CP 40 CONE, which one has advanced electronic components, display unit, strain gauge force transducer with a measuring range up to 5.5 MPa and depth measurements up to 600 mm at the rate 15, respectively 20 mm. It also has a built-in GPS. Measuring capacity is about 2047 measurements. This device appears to be the most advanced on the market.
It may be noted that the PE 90 penetrometer has comparable properties with worldwide manufacturers. However, our penetrometer has improved the intuitive management and has bigger recording memory.

## CONCLUSION

The reason for the research and development of new penetrometer equipment is not only to design

*lightweight, portable and reliable equipment, but also a consistent device enabling a wider usable and able to obtain data comparable to each other. Modern penetrometer devices except the new options (GPS, colour touchscreen, high memory capacity, autocalibration) must take into account the versatility and ease of use in a variety of conditions by affordable price. The new proposal penetration device can meet all these requirements and provide greater comfort and productivity.*

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***REFERENCES***

[1.] *Bajla, J. 1998. Penetrometrické merania pôdnych vlastností. Metódy, prístroje a interpretácia. Monografia. 1. vyd. Nitra, VES SPU Nitra 1998. 112 s. ISBN 80-7137-543-8.*

[2.] *Géci, T., Lukáč, O. 2007. Porovnanie formátov súborov pre spracovanie dát nameraných prenosnými meracími prístrojmi. In: Informačné a automatizačné technológie v riadení kvality produkcie, 5.-7. septembra 2007 Nitra : SPU 2007. ISBN 978-80-8069-927-7, p. 37-41.*

[3.] *Emsyst s.r.o.:[online] [cit.2008-10-7].Available from: <http://www.emsyst.sk/>*

[4.] *Líška, E. 2008. Všeobecná rastlinná výroba. 1. vyd. Nitra. 2008. Slovenská poľnohospodárska univerzita. 2008. 452 s. ISBN 978-80-552-0016-3.*

[5.] *Raper, R.L., Kirby, J. M. 2006. Soil Compaction: How to Do It, Undo It, or Avoid Doing It. In: ASAE Distinguished Lecture Series No. 30, pp. 1-14. 2006*

[6.] *Rataj, V. 2000. Geografické informácie pre poľnohospodárstvo[online]. Available from: http://www.cddesign.cz/h/clanky/ar.cesp?ARI=19*

[7.] *Tekeste, M., Z. 2008. Site - specific characterisation, modeling and spatial analysis of subsoil compaction (hardpan) for precision agriculture on south-eastern US soils. [online.] Available from :http://www.ifaanet.org/Social%20 Science/mehari_zewde_tekeste_j_phd_40606.pdf*

[8.] *Tekin, Y. - Kul, B. - Okursoy, R. 2008. Sensing and 3D mapping of soil compaction In: Sensors 2008, 8, 3447-3459*

[9.] *www.eijkelkamp.com*

[10.] *www.eleinternational.com*

[11.] *www.agridry.corn.au*

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3. István BOKROS, 4. Zoltán SIMÉNFALVI

# HEAT TRANSFER ANALYSIS OF BAYONET TUBE HEAT EXCHANGER

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**Abstract:** At intensive heat-removal in chemical autoclave treatment the bayonet tube heat exchanger is well adaptable equipment in the working zone. Our goal is to create criterion equitation what causes the easy usage to describe the heat transfer of that specific equipment.This paper shows a numerical simulation of bayonet type heat exchanger. This procedure allows to calculate the temperature, pressure, and velocity distribution and to calculate the heat transfer coefficient in case of different geometry and different boundary conditions.
**Keywords:** Bayonet, CFD, heat transfer coefficient

## INTRODUCTION

At intensive heat-removal in chemical autoclave treatment the bayonet tube heat exchanger is well adaptable equipment in the working zone. Detailed examination of such an equipment had been evaluated by many authors [1,2,3], however the casualties in the professional literature are useless to determine the heat transfer coefficient what is one of the decisive parameters in heat transfer. Our goal is to create criterion equitation what causes the easy usage to describe the heat transfer of that specific equipment.

## DESCRIPTION OF THE EXAMINED EQUIPMENT

The structure contains two concentric tubes placed in each other. The cooling fluid (here is water) enters into the inner tube, while discharges the end of the tube into the return band. It flows through between the outer and inner tube in an annular place, eventually the water leave the structure at the outer tube's end. Between the two tubes the gap is relative small accordingly the velocity in the annular space is respective high. The Figure 1 shows evolving of the structure. The heat exchanger approximate an axially symmetric model, therefore this will be a reducible calculation. During the numerical simulation only the marked area will be modelled.

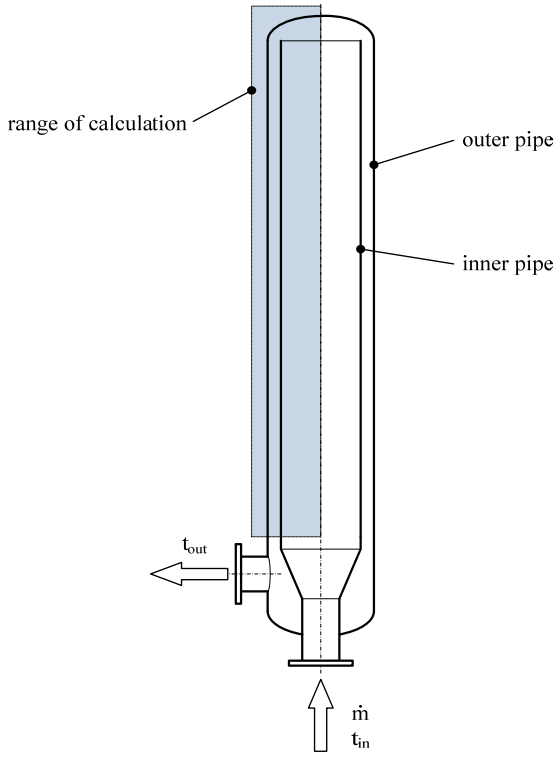


Figure 1. The model of the examined structure

Inside the heat exchanger a dual heat transfer occurs, firstly between the working zone and the outer annular space, secondly between the outer annular space and the inner tube. During the simulation the working zone is considered to a complete mixing space, the temperature of it is constant therefore the heat transfer coefficient of the working zone is also constant.

## NUMERICAL SIMULATION

*The fluid and thermo dynamics analyze was evolved of the bayonet tube heat exchanger in case of different geometry and different boundary conditions.*

*A velocity boundary condition was taken into the edge of the inner tube's inlet for four cases. For the outlet the boundary condition was the common as used for the fluid simulations, we take the pressure as the boundary condition (p=atmospherically). As the problem was an axially symmetric, the mesh would be extensive in size, therefore a 5° part of the structure was examined and the boundary condition was periodical. In that case we can draw conclusions for the whole drift space.*

*A modelled geometry was used for the meshes of the numerical simulation based on the finite element method. The mesh was built up by non-structured, 3D element (Figure 2). With the usage of the three layer structured (prismatic) mesh can be determined the velocity distribution of the boundary layer in the case of solid-liquid phase-boundary. The results are mesh-independent results. In the case of different evolving the necessary nodal points are between 278 000 and 547 000.*

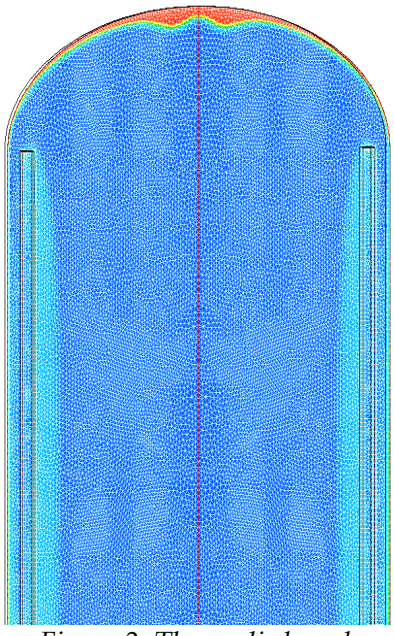

*Figure 2. The applied mesh*

*During the numerical simulation the following conservation equitations become necessary to solve:*

*Continuity equitation:*

$$\frac{\partial u_i}{\partial x_i} = 0 \qquad (1)$$

*Momentum conservation equitation (i=1…3):*

$$\frac{\partial \rho u_i}{\partial t} + \frac{\partial u_j \rho u_i}{\partial x_j} = -\frac{\partial \sigma_{ij}}{\partial x_i} + \rho g_i \qquad (2)$$

*Energy conservation equitation:*

$$\frac{\partial \rho c_p T}{\partial t} + \frac{\partial u_j \rho c_p T}{\partial x_j} = -\frac{\partial}{\partial x_i} K \frac{\partial T}{\partial x_j} + \dot{q} \qquad (3)$$

*During the application of the* $k-\varepsilon$ *model the following equitation become necessary to solve in general form:*

$$\frac{\partial \rho k}{\partial t} + \frac{\partial u_i \rho k}{\partial x_i} = \frac{\partial}{\partial x_i}\left(\frac{\mu_t}{\sigma_k}\frac{\partial k}{\partial x_i}\right) + G_s + G_t - \rho\varepsilon \qquad (4)$$

$$\frac{\partial \rho \varepsilon}{\partial t} + \frac{\partial u_i \rho \varepsilon}{\partial x_i} = \frac{\partial}{\partial x_i}\left(\frac{\mu_t}{\sigma_\varepsilon}\frac{\partial \varepsilon}{\partial x_i}\right) + C_1 \frac{\varepsilon}{k}\left(G_s + G_t\right)\left(1 + C_3 R_f\right) - C_2 \frac{\rho \varepsilon^3}{k} \qquad (5)$$

*where:*

$$G_s = \mu_t \left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)\frac{\partial u_i}{\partial x_j} \qquad (6)$$

$$R_f = -\frac{G_t}{G_s + G_t} \qquad (7)$$

*The value of the empirical constants in the equitation:*

$C_1$=1.44, $C_2$=1.92, $C_3$=0,

$\sigma_k$=1, $\sigma_t$=0.9.

*To solve the problem the SC/Tetra software was used, this software is basically a finite element method CFD software.*

## RESULTS, CONCLUSIONS

*During the simulations the outlet temperature, the overall pressure loss, the heat transfer coefficient in the outer annular space was calculated in case of different geometry (diameter, clearance) and different boundary conditions.*

*The Figure 3 and Figure 4 allowed determining if the inlet velocity is high it results high heat transfer coefficient. Increase of the dimension of the clearance results decreasing of the heat transfer. The increasing velocity in the clearance results significant high heat transfer coefficient, but it results also the overall pressure loss. This property can be determined both geometry.*

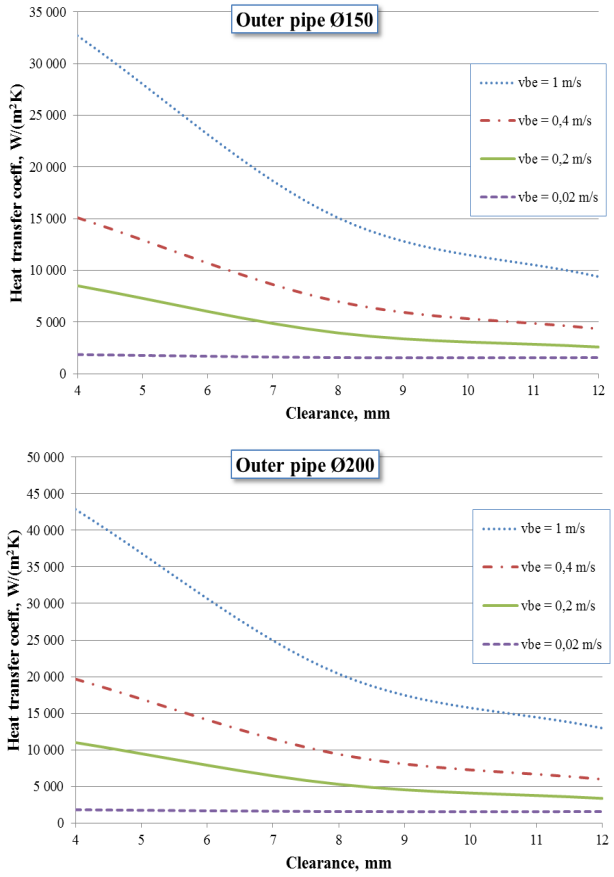


*Figure 3. The heat transfer coefficient in the outer annular space*

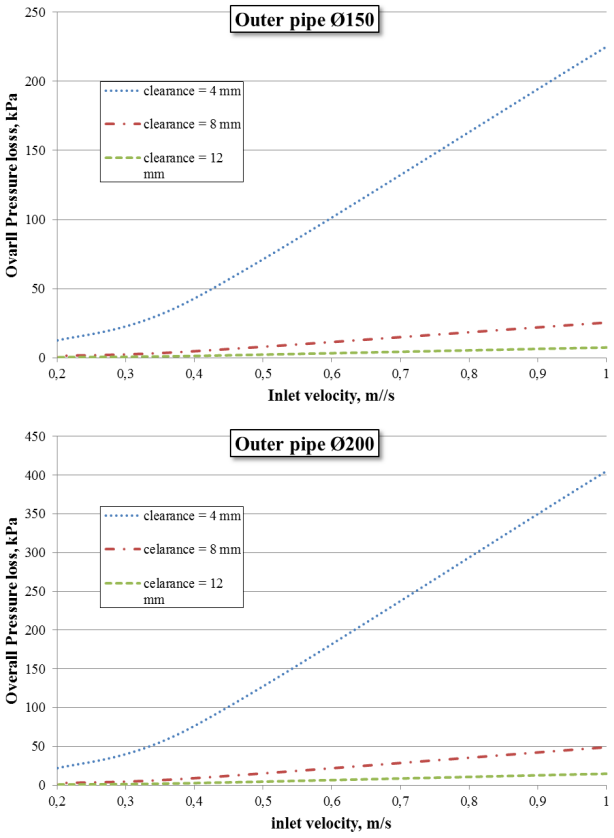


*Figure 4. The overall pressure loss*

*Our goal was to define equitation what is applicable to calculate the heat transfer coefficient in the annular space. Utilizing the results of the simulation we would like to determine the following criterial equitation's constants with an error minimization method [5]:*

$$Nu = A \cdot \left( \frac{D_b}{d_e} \right)^B \cdot \mathrm{Re}^C \cdot \mathrm{Pr}^D \qquad (8)$$

*The specific dimension is the outer tube's inner diameter in the criterial equitation in all case. The equivalent pipe diameter can calculate with the* $d_e = 4F/K$ *(F: flow section/area, K: wetted perimeter). With that procedure we got the following results:*

*A=0.0089 B=1.0624 C=0.824 D=0.326*

*The Figure 5 contains the difference between the value of the heat transfer coefficient, and additionally the results what we got with the created equitation. The errors in all case are below 6%.*

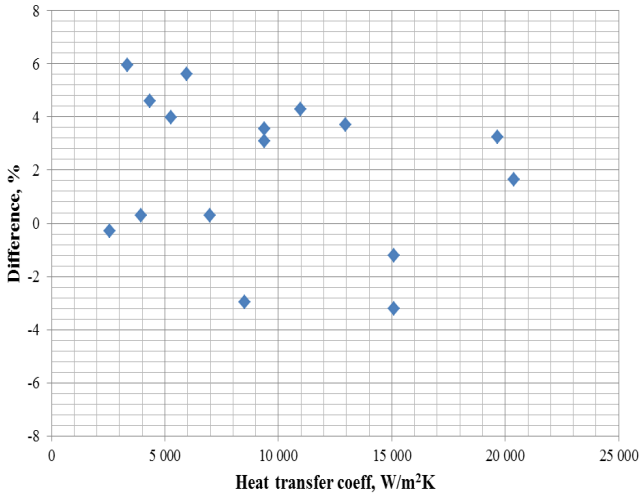


*Figure 5. The difference between the heat transfer coefficient and the value of the criterial equitation*

## Summary

*In that article the simulation of the Bayonet tube heat exchanger was presented in case of different parameters The results of the simulation runs a criterial equitation was created, what describes the heat transfer in the annular space in an adequate way in case of different geometry.*

**Acknowledgement**

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*REFERENCES*

[1] *Venczel G., Bayonet csöves hőcserélő vizsgálata CFD-vel, GÉP LXIII évf. 2012/10 pp53-57.*

[2] *T. O'Doherty, A.J. Jolly, C.J. Bates, Analysis of a bayonet tube heat exchanger, Applied Thermal Engineering 21 (2001) 1-18.*

[3] *Venczel G., Hőátvitel vizsgálata Bayonet típusú szerkezetben, Miskolci Egyetem Doktoranduszok Fóruma, Gépészmérnöki Kar szekciókiadványa, Miskolc (2004) 60-64.*

[4] *A.J. Jolly, Development and validation of a computer code for bayonet tube heat exchanger analysis, Ph.D. thesis, University of Wales, 1998.*

[5] *H. D. Baehr, Verfahrenstechnische Berechnungsmethoden, Teil 1: Wärmeübertrager. Springer-Verlag 1988.*

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# SOFTWARE SUPPORT FOR THE MANAGEMENT OF LUBRICATION

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**Abstract:** *This paper presents a software package LMSoft that automate the process of lubrication management of technical systems that is a part of the information system of preventive maintenance. Featured software package is the result of years of research by the field of information systems and the design of control systems in the process industry. The function of preventive maintenance is increasingly represented in a new form known as proactive maintenance processes where lubrication play a key role. Processes include lubrication and periodic quality control of lubricating oil, the results represent a significant technical support to the technical diagnostics. By automating management processes at the same time improving lubrication preventive maintenance and technical diagnostics.*
**Keywords:** *software support, lubrication management, preventative maintenance, technical diagnostics*

## INTRODUCTION

*Software package for managing processes lubrication LMSOFT (Lubricant Management Software) is designed to support organizations with different profiles that have technical systems with a large total number of lubrication where manual control was very difficult and unprofitable. The software package includes a database that is used to manage the process of preventive maintenance, and also for storing the results of technical diagnostics. Technical diagnostics and lubrication are key elements of preventive maintenance, which are modeled using FMEA (Failure Modes and Effects Analysis) methods. FMEA method is used in the LMSOFT in a particular area of the real work to identify all of the lubrication and to store the relevant attributes in the database.*

## MAINTENANCE – CONCEPTS AND TECHNOLOGIES

*Maintenance of the technical systems (TS) represents a set of procedures and activities which is main purpose to prevent states of failure and recovering from fails to the state of normal work in the shortest possible time and with less expenditure in the given environmental conditions and work organization. The purpose of maintenance is to increase the effectiveness of the production process, which will result, that costs per unit of production will decrease. Maintenance TS should be considered as a function of the primary production, because it contributes to the production to takes place in a rational manner with optimum reliability level of TS in the company [1].*

*Basic concepts of maintenance include: preventive, corrective (reactive) and combined maintenance. Preventive maintenance, which aims to prevent or delay the occurrence of failure, can be implemented in several ways.*

*By default, two basic types of preventive maintenance [2]:*

- *The first case refers to the periodic preventive maintenance that is based on information on the reliability of the system (division of the time of work until failures of the observed system or part).*
- *The second case, also known as maintenance of the state or predictive maintenance is based on the monitoring of parameters that represent the state of the observed system.*

*Predictive maintenance resulting in the reduction of the number of unexpected failures, increasing*

*reliability and reducing direct and indirect costs of maintaining TS [B]. A latest innovation in the field of predictive maintenance is the so-called proactive maintenance, where various technologies are used in order to extend the life of the machine and for the practical elimination of corrective maintenance. The main part of the program is a proactive analysis of the causes of failure of machinery or part thereof. The causes of the failure of the machines in this way can be removed, and the failure mechanisms gradually will be eliminated with engineering approach. Corrective maintenance is maintenance concept, which means that maintenance procedures are carried out only when there is a failure occurrence.*

*Combined maintenance is implemented as a part of the plant maintains preventative, while the remaining part of the maintenance procedures carried out as it comes to failure. Choice of area of preventive and corrective maintenance of all technical systems is in function of optimization in order to reduce the maintenance costs of the product [3]. Maintenance technology is directly linked to the development and production technology, and contains procedures and ways of their implementation, including [4,5]:*

- *basic maintenance by the operator,*
- *preventive periodic inspection and replacement of parts,*
- *random inspections regulated by the regulations and laws,*
- *lubrication of the technical system,*
- *technical diagnostics (determining the actual state of the system),*
- *repair and restore of the worn parts,*
- *identification and elimination of the weak points of the system (innovation) and*
- *general periodic repairs and modernization.*

*For the implementation of the maintenance technology it is necessary to have a clear concept that contain answers to many questions: When is a need for maintenance, why is maintenance carried out, what procedure should be used and in what order, in what part of the system maintenance works should be carried out, who will be the perpetrators [6].*

## *TECHNICAL DIAGNOSTICS*

*Determining the condition of the machines is a key issue in the process of its maintenance. It is necessary to monitor changes in the condition of individual parameters of components and machine elements, which eventually lead to a drop in performance and to failure. Technical diagnostics (TD) checks the correctness of the TS, TD checks the working capacity of the TS, TD checks the functionality of the TS. Diagnostic controls are divided in to the next sections [7]:*

- *Identification of the working state – the state assessment using appropriate instruments and observation with predefined criteria permitted and illicit states of the TS,*
- *Maintain of the working condition Analyzing the state of the TS according to a scheduled program and taking the actions to reduce the probability of the failure,*
- *Preventive examinations - periodic testing of the TS, microclimate, vibration, noise, etc.*

*For the application of the technical diagnostics there are basically two forms available:*

a) *on-line diagnosis (diagnostic devices are built into the machine, an estimation of the state of the key parts is performed in the run time and it is based on the measured parameters);*
b) *off-line diagnosis (diagnostic measures are implemented after some time the system was in working state, a machine may be excluded from the process of the work.*

## *FMEA - FAILURE MODES AND EFFECTS ANALYSIS*

*FMEA (Failure Modes and Effects Analysis) is a procedure for analysis of potential failure in the system and their impact on the system and focuses on the prevention and reduction opportunities that cancellation occurs. It is used to detect and prevent problems in the process before they arise.*

*FMEA method involves a disciplined and detailed analysis of the processes and the systems (system, subsystem, assembly or component). For the final assessment of the risks of the potential damages it is necessary to estimate the probability that they will occur. Basic terms used in the FMEA are:*

- *Failure of the system (subsystems, assemblies or components) – inability of the system to perform the function,*

– *Form of the system failure - form or the condition of the element after the failure,*
– *The cause of the system failure - a process or mechanism responsible for the initiation and failure,*
– *Effect of the system failure - a consequence of the failure to function or system status.*

*The basic concept of the FMEA method involves decomposition of the system into its constituent elements, to a level that is estimated to be significant in the analysis. FMEA method is implemented in to the worksheets that can take many forms and elements, depending on the system being analyzed and the purpose of the analysis.*

*The final FMEA method is to determine the RPN - Risk Priority Number:*

– *Assess severity (Severity - S) of each of the potential impact of the cancellation,*
– *To assess the probability of occurrence (Occurrence - A) Effect of the cancellation,*
– *To assess the probability of detection (Detection - D) effect of each failure.*

*RPN is obtained as the product S x O x D, where S, O and D rated value for a particular job.*

***LUBRICATION MANAGEMENT***

*Appliance of the Information technology (IT) in the maintenance / lubrication in order to improve the performance of the TS has become a necessity. Lubrication engineers analysis equipment, its components and guidance to reach the recommended lubricant.*

*After collecting and processing the data of the TS, the lubrication points and lubricant, the main tasks are development plans of lubrication and preventive screenings. In order to achieve the effective lubrication plans it is necessary to create the conditions for organized planning lubrication to grow into the management with computer support. Lubrication Management is based on the planning and implementation of plans of the lubrication. Monitoring the state parameters can be carried out continuously or periodically, and for each parameter condition it is necessary to determine a value of a cancellation. In this way it is achieved a preventive lubrication that meets most practical situations and types of technical systems [8].*

*However, lubrication management is a much broader process. It includes activities:*

– *Forecasting and prediction,*
– *Planning,*
– *Carrying out and coordinating the actions of a lubrication,*
– *Control deadlines and quality of execution of actions lubrication,*
– *Control the actual system performance and*
– *Control of the cost of lubrication.*

*Planning is a key function of a lubrication management. Lubrication plan must comply with the maintenance schedule / production.*

***LMSoft - STRUCTURE AND FUNCTION***

***Customer requirements***

*Software Package Management lubrication should provide, at a minimum:*

– *Entering, deleting and editing the data about technical systems, lubricants and lubrication points*
– *Integrated view of the relevant data sets,*
– *Selection of a different search options for the database,*
– *Extend the database with new tables,*
– *Adaptation of the existing search options,*
– *Creation of a new types of searches and masks to show their results,*
– *Distribution of the data,*
– *Creation of a different reports (documents),*
– *Protection of the data from unauthorized access and incorrect entry and*
– *Ease of training and use of the program.*

***Database***

*The main goal of a database design is to provide quick and full access to all of the technical systems, lubricants and lubrication points and to provide a support in the management of lubrication using a computer.*

*One of the most important tasks of the preventive maintenance is lubrication, which requires the study of the technical documentation, equipment and instructions for lubricating and finally selection of appropriate lubricants. Database for lubrication management include tables correspond key entities, such as lubricants, technical systems of lubrication, specifications, classifications, quality levels, lubrication maps, orders. These*

*tables, together with tables containing systematized results of FMEA method applied to the infrastructure to be maintained (machines, production lines, transport sredatva, equipment, ...) are the basic structure of the database maintenance scheme. The database represent an abstract model of the real system [9].*

***THE PRESENTATION SOFTWARE***

***The main form*** *– Communication between users and the application is realized through a set of a different forms. In that set we can distinguish a subsets of a forms that are characterized by a similar use: forms of presentation of search results, entry forms, delete and edit data forms, as well as a smaller number of forms to navigate additional choices and a variety of informational and warning messages.*

*Starting from the main form (Figure 1), we will present the structure and functionality of the software package LMSOFT. The main form allows the passage to the basic software functions that cover the user requirements. The main menu contains nine fields / buttons by which we come to associate the form described below. The tenth button closes the program.*


*Figure 1. The main form LMSoft*

***Form of the technical systems*** *- provides evidence of the TS with all relevant attributes such as: Name, Type, Brand, Manufacturer, Lubrication points, Owner. The TS evidence means filling the basic information about TS to their records in to the database. This data, later, can be used in the operational work. Using this form you can enter information about the technical system, view and / or edit existing ones, delete and add new information about TS and conduct searches. In the subform the selection of lubrication points can be selected for a specific TS (Figure 2).*

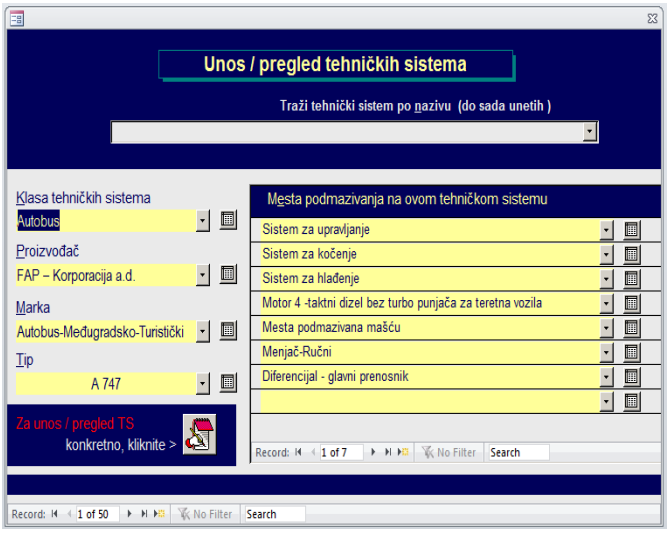


*Figure 2. Form input / review TS*

***Form Lubricants*** *- It is obvious that the choice of lubricant is one of the main input into the drafting process of lubrication. To ensure that this step in the process of lubricating is done correctly and efficiently it is neccesary to ensure:*

- *Fast access to data on lubricants,*
- *Display of all important data on lubricants for lubrication TS, and*
- *Selection of appropriate lubricants for lubrication points of each TS.*

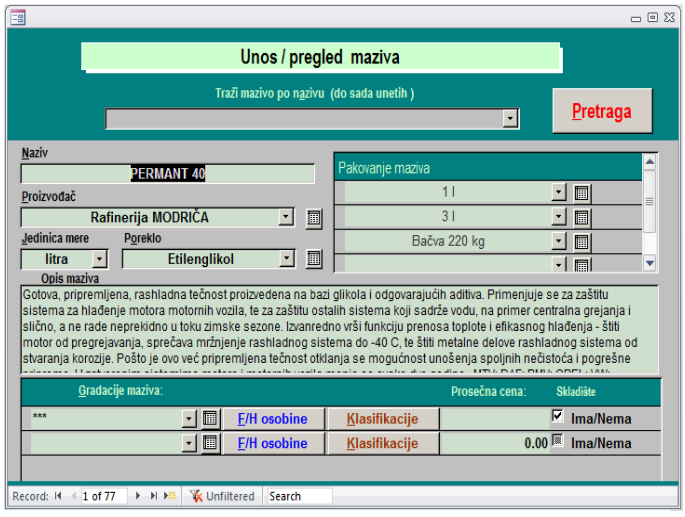


*Figure 3. Form input / review of lubricants*

*Information about lubricants are primarily related to the classification of quality levels, specifications, standards, and other attributes relevant to the lubrication process. (Figure 3).*

***Ticket lubrication form** - From the main menu, you enter into a form called Map of lubrication, where, depending on the type of a technical system, selects lubricant and its gradation for each place of lubrication. On this form are available basic data on the TS: name, group, manufacturer, model, manufacturer's number, year of manufacture, operation, pictures, of lubrication.*

*Lubrication operation includes records about lubrication, lubricants quantity, working hours (kilometers traveled) and the comments. Form has an option for a quick overview of expenditure of lubricant for each TS and all of lubrication.*

***Work Order field** - Lubrication Engineer develops a plan of lubrication (lubrication routes) that are executed in the future. Lubrication plan is executed through the Order of lubrication, which has more options (open, in operation, closed). Form contains a button to view your account.*

***Report field** - There are several types of reports relating to the consumption of lubricants and lubrication points by selecting the four time periods (random, monthly, yearly and overall). The available and the list of activities lubrication list by TS drives, sectors, facilities and places where lubrication is observed increased consumption of lubricants.*

*Form includes fields for diagnostics: analysis / test lubricants, limitations of the analyzes, the analysis of lubrication points, restrictions on service conditions and typical values for field analysis (declared by the lubricant manufacturer - catalog value).*

***Catalog of lubricants** - Any factory that produces lubricants has a catalog of their products, which describes in a detail the composition, application and other important properties of lubricants. The key advantage of electronic catalogs is reflected in the speed and capabilities of different criteria and procedures for the database search.*

## CONCLUSION

*Technical diagnostics and lubrication are key processes of maintenance system, regardless of the adopted concept and technology maintenance. On the other hand, the results of periodic control lubricants used in TS, with established critical limits for individual characteristics are important elements of technical diagnostics.*

*Contemporary concepts of maintenance include proactive maintenance computer aided classified in the production function. Maintenance costs are thus treated as production costs, so the cost of lubrication is directly involved in the pricing of products.*

*We come to the simple conclusion that the use of the software package LMSOFT directly affect the price of the product. Software support for a process lubrication maintenance management represent a module of a IS, which is opened to connect with the environment, such as a software for the laboratory analysis, software for the warehouse management, etc.*

## REFERENCES

[1.] *ZELENOVIĆ, D. 1995. Tehnologija organizacije industrijskih sistema – preduzeća, IP „Naučna knjiga“, Beograd.*

[2.] *ADAMOVIĆ, Ž., AŠONJA, A., MILOŠEVIĆ, D., PAUNJORIĆ, P. 2011. Teledijagnostika mašina, Duga knjiga, Sremski Karlovci.*

[3.] *DESNICA, E., LETIC, D., GLIGIRIC, R., NAVALUSIC, S. 2012. Implementation of Information Technologies in Higher technical education, Journal Metalurgia international, 17(3), pp.76-82.*

[4.] *ASONJA, A., MIKIC, D., STOJANOVIC, B., GLIGORIC, R., SAVIN, L., TOMIC, M., 2013. Examination of Motor-Oils in Exploitation at Agricultural Tractors in Process of Basic Treatment of Plot, Journal of the Balkan Tribological Association, 19(2), pp.230-238.*

[5.] *AŠONJA, A., ADAMOVIĆ, Ž., GLIGORIĆ. R., MIKIĆ, D. 2012. Razvoj modela laboratorijskog stola za ispitivanje pouzdanosti poljoprivrednih kardanskih vratila, Tehnička dijagnostika, 11(3), pp.27-32.*

[6.] *MCDERMONT, R, E., MIKULAK, R, J., BEAUREGARD, M, R. 2008. The Basics of FMEA, CRC Press.*

[7.] *ASONJA, A., ADAMOVIC, Z., JEVTIC N. 2013. Analysis of Reliability of Carda Shafts Based on Condition Diagnostics of Bearing Assembly in Cardan Joints, Journal Metalurgia International, 18(4), pp.216-221.*

[8.] KRUNIĆ, V., AŠONJA, A., BERAK, J., BABOVIĆ, J. 2012. Economy, Universality and Flexibility of Automatic Filler "NIVELA 12JC", ARPN Journal of Science and Technology, 2(7), pp.567-572.
[9.] KRUNIĆ, V. 2013. Informacioni sistemi i menadžment kvalitetom – model integracije, Srpski akademski centar, Novi Sad.


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# THE IMPACT OF USD-DOMINANT INTERNATIONAL RESERVES ON THE CHINESE ECONOMY

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**Abstract:** This paper is going to analyses the advantages and disadvantages of the U.S. dollar based international reserves, describes the challenges faced by China in the "dollar standard system" and then tries to disclose the severe challenges caused by the endogenous defects of dollar standard system to China's international reserve, advantages in foreign trade and allocation of assets. Considering that in current international currency system it is not possible to challenge the dominant role of the U.S. dollar, this paper also makes tentative analysis regarding the strategic deployment for China's capital security.
**Keywords:** International Reserves; Foreign Exchange Reserve; Financial Security; American dollar

## INTRODUCTION

After WWII, backed up by the powerful political, economic and military strengths of the United States, the U.S. dollar has been the standard currency for international reserves and settlements. From Bretton Woods to Jamaica, faced with the Triffin dilemma, the American government has always started from its own interests and introduced multiple monetary policies in its own favor. China, the largest creditor of the United States, also uses the U.S. dollar in its foreign exchange accounting, and is inevitably challenged by risks of huge assets loss. The strategic security of our economy is therefore greatly endangered.

## ANALYSIS ON ADVANTAGES AND DISADVANTAGES OF U.S. DOLLAR BASED INTERNATIONAL RESERVES

### A. The Inevitability of Dollar Standard System

The end of World War II ushered in a new era featured by the fact that the sovereign credit based currency was adopted in the international reserves when the US dollar replaced the British pound as the new leader in the international currency system. Although the dominance of the U.S. dollar was not what all the countries had hoped for, from the establishment of the Bretton Woods system to the Jamaica system, all the stories told pointed to both the historic and economic inevitability of present global currency status of the dollar.

First of all, the United States has strong economic power to guarantee the value of the dollar. In the Bretton Woods system, with the absolute advantage by holding three fourths of global gold reserves, the United States established the "double hook" exchange rate system based on dollar-gold convertibility, assuring the world of the reliable value of the U.S. dollar. At that time, American dollar was unparalleled as a sovereign credit currency. Later with the collapse of the Bretton woods system, the United States gave up the "gold exchange standard" under the Jamaica system led by American dollar. However, relying on its dominance in global food, crude oil, mining, technology, medicine and military industries, the United States provided strong support for the value of dollar with its financial capital in all those fields. The value of the US dollar was widely acknowledged and various national governments began to hold their international reserves in dollars.

*Secondly, the United States of America boasts that it is the largest economy in the world. With its highly open financial sector, the dollar is able to satisfy the liquidity requirements from all the other countries. The huge scale of U.S. economy enables the export of the dollar to every corner of the world through multiple channels such as merchandise trade and completely free money market, meeting the international liquidity needs of various countries. Although the exchange rate of the dollar is also volatile to some degree, America's relatively independent monetary policy and great capacity to intervene in the international affairs make the value of the dollar relatively stable in domestic market, resulting in a separation of volatility of its nominal rate and the change of its actual rate, which helps assure the stability of real purchasing power of the dollar. That the United States government has effectively curbed the inflation in subprime crisis can serve as a convincing argument in that case. The large economic scale, open financial market and independent money policy, have given the dollar natural and actual advantages in its functions as both a medium of exchange and a measure of value.*

***B. Endogenous Defect of the Dollar Standard System***

*From Bretton Woods to Jamaica, the United States has made more open and loose adjustments with the exchange rate regime without diminishing the dominant international status of the dollar. Given the context that sovereign credit currency has been used in international reserves, the Triffin Dilemma has never been relieved. As the issuing country of the mainstream currency for international settlement and reserves, the attitude of the U.S. government towards the dollar is based on the commitment to economic development by the political parties. Therefore, starting from this consideration for the interests of itself, it has caused great shocks to the world economy in its decision to adopt what kind of money policy.*

*While there have been reforms in the international monetary system, its innate endogenous defect still exists, which refers to the dilemma between international liquidity provision and currency confidence. All of the reforms including diversification of exchange rate regimes, the demonetization of gold as well as the increase of IMF shares, can only loosen the control of the dollar in the exchange rate regime and relieve the imbalance between supply and demand of the dollar. But at the current situation when sovereign credit currency is still the main international reserve currency, these relief measures relying on other foreign exchanges, reserve position in the IMF and SDR to enrich the international reserves have not substantively addressed the endogenous defect of the dollar. Real diversified development will inevitably undermine the international status of U.S. dollar, and of course will not get the support it needs from the United States. The supplies of international reserve assets and transactions in international trade of most countries are still greatly affected by the supply of the dollar, which is still the major currency of international reserves. The change of the American economy has its direct influence on the dollar, and ends with a greater influence on the world economy. This constitutes the asset impairment risk for every country that holds dollars as their international reserves.*

***CHALLENGES FACED BY CHINA IN THE USD-DOMINATED INTERNATIONAL MONETARY SYSTEM***

*The sudden rise of Chinese economy after its reform and opening-up policy has resulted in a powerful emerging economy which is further boosted in the international trade during recent years. Through the continuous trade surplus, China has accumulated large foreign exchange reserves. As America's largest creditor, as of December 2012, China holds as high as 1.2028 trillion dollars in American government debt. The huge Chinese holdings offer not so much guarantee for the stable value of RMB as the risks for the decrease in foreign exchange value due to the continuing depreciation of the U.S. dollar. The US government has further constrained the usage of foreign reserves in dollars, which limited the scope of China's investment by using its foreign exchange to some extent.*

***A. The Causes and Effects of the Depreciation of the U.S. Dollar***

*Faced with high current account deficits, American government, relying on its unique position in*

*controlling the dollar, has deliberately caused the depreciation of U.S. dollar time and again through independent monetary policy. And other countries that have held dollar reserves become the final payer of the bill. Americans have exploited the real economies in various countries by using the tool of U.S. dollar, snatching the achievements of economic development of the world economy to some extent.*

***a. Causes of Devaluation of the U.S. dollar against RMB***

*In the process of globalization, the world economy has developed too much dependence on the U.S. market. The United States is playing the role of ultimate consumer, footing the bill for the surplus of international payments of other countries. The imbalance of its current account has forced the government to resort to every means to improve the trade deficits. According to Keynesianism, there are but two ways to do this. One is to curb domestic demand through regulatory policies at the expense of dropping national income growth, for example, to reduce demands of imports, so as to improve the international payments situation. The other is to adopt quantitative easing policy to achieve orderly devaluation of the U.S. dollar, which will help boost the exportation and narrow the trade deficit. The American government will certainly not sacrifice economic development which is in accordance neither with the core interests of America itself nor with the requirements on the ruling party's administrative achievements. No wonder that the devaluation of the dollar becomes the magic weapon for the American government to improve its international payments.*

*In the process of realizing the devaluation against RMB, on the one hand, the US government affects the supply of dollar through quantitative easing policy, leading to the increase of base money and a proactive devaluation of the dollar. On the other hand, it forces the Chinese government through political means to raise the value of RMB. Just like the requirement of Federal Reserve for the appreciation of Japanese yen through Plaza Accord in 1985, in 2005, faced with the huge $ 15.8 billion trade deficits, the US government put pressure on China through various trade acts and sanctions on the ground that RMB had been undervalued, forcing China to float its exchange rate on July 21st. The effects are obvious. Within eight years, RMB has appreciated by 20% at an unprecedented speed.*

***b. Discussion on the Devaluation of U.S. Dollar and Loss of China's Foreign Reserve***

*Reserve assets, representing the capabilities of a country in terms of external liquidity abroad and monetary exchange rate adjustment at home, are both the "reservoir" and "balancer" to achieve the equilibrium of international payments. Generally speaking, there two approaches to analyze the impacts of the devaluation of the dollar on the foreign reserve of our country: one is to determine its book value from the perspective of accounting; the other is to determine its real purchasing power from the perspective of economics.*

***(1) Accounting Approach***

*This approach is based on accounting theories. It calculates the actual exchange loss based on the book value of reserve assets in the domestic currency. In the middle of May, 2011, according to the "Answers to Frequently Asked Questions about Foreign Reserve" edited by the State Administration of Foreign Exchange, the exchange rate changes of RMB against the U.S. dollar will directly result in changes to the book value of foreign reserve when converted to RMB. This change of value is not real loss, and does not affect the real purchasing power of the foreign exchange reserve. The exchange changes can be seen only when it is converted back to RMB. In this regard, the formula to examine the gains and losses of foreign exchange reserve is:*

*Real Exchange Loss=Foreign Exchange Assets Converted Back into RMB × (the Exchange Rate of RMB against USD on Exercise Date – Exchange Rate of RMB against USD on Contract Signing Date)*

*This theory has its emphasis on the loss of book value of the foreign exchange. It separates foreign exchange reserve from the domestic currency system and determines the gains and losses of assets based on actual exchange operations. Regardless of the appreciation or depreciation of the dollar, there will be no real change in foreign exchange assets unless there are actual exchange operations.*

**(2) Economics Approach**

*This approach starts from the economic theories. It derives from the purchasing power parity theory, and determines the actual change of foreign exchange reserve by the change of the real purchasing power of the dollar. Since the birth of Bid Mac Index, more and more economists are turning to the real purchasing power of a currency to determine the change of exchange rate. According to the theory, the price level has influences on the exchange rate and in turn, the exchange rate also has influences on the price level. That is to say, the real purchasing power of the dollar can have substantial impacts on the reserve assets. Based on the link between the change of real purchasing power of the dollar and the life cycle of the foreign exchange reserve, the change of foreign exchange reserve can be shown through the following two equations:*

*Decline of the Real Purchasing Power of USD=1-1/(1+International Commodity Price Index Bought in USD×Corresponding Weight + American Domestic Consumption Price Index×Corresponding Weight)*

*Loss of USD Reserve Assets = Total Value of Foreign Exchange Reserve×Proportion of USD Assets×Decline of the Real Purchasing Power of USD*

*This approach reflects the characteristics and rules of changes in the life cycle of reserve assets, and reveals the main driver for the loss of USD reserves – the decline of the real purchasing power of the dollar. However, speaking of the actual operability of the theory, the Big Mac Index alone cannot accurately reflect the true evaluation of purchasing power. There are still quite complex technical problems in practice.*

**c. Impacts of USD Devaluation of on the Chinese Economy**

**(1) Impacts on Foreign Trade**

*Relying on its international reserve currency status, America has injected large sums of U.S. dollars into the international market for great profits in international trade and acquired the reserve assets of monetary authorities in other countries with low interest rates. Essentially it is to snatch away the benefits of world economic development and taking other countries' export commodities by overprinting U.S. dollars. For example, suppose China exports 100 tires (worth $10000) to the United States, if the value of the U.S. dollar depreciates by 10%, China will earn only 90% of the real purchasing power and America can get a free tire. This is a plain exploitation of China's real economy. In addition, in more cases, the devaluation of the dollar directly influences the relative prices of commodities in the Sino-US trade, leading to the rise of American exports and decline of Chinese exports, which further exacerbates the situation of China's foreign trade.*

**(2) Impacts on China's Domestic Prices**

*Under the present sovereign credit currency system dominated by the US dollar, the inflationary pressure on the domestic market brought about by the reflux of overseas money capital is diverted externally with the export of capital by the U.S. government. Thus the economic bubbles caused by overprints of U.S. dollars spread to other countries, bringing a new wave of global inflation and huge threats to developing countries with high economic developing speed and frequent international trade transactions. With the quick emergence of Chinese economy, the over expansion of investment in fixed assets in recent years has given rise to heavy demand for raw materials. However, the devaluation of U.S. dollar has forced the rise of prices of raw materials in the international market, leading to the imported inflation brought about by primary commodities and raw materials.*

**B. Risks Faced by China's International Reserve under USD Hegemony**

*The USD hegemony shows the asymmetric rules in the international market unilaterally controlled by the U.S. capital market on the financial front. The hegemony is manifested internally as the complex and cumbersome interference with the domestic capital, externally as the intervention in the economic and financial affairs of other countries relying on its international status and financial prowess. The Chinese government has implemented various reforms in the foreign exchange policies and further opened the financial market to show the image of a responsible power. Under the pressure of declining export competitive edge, China still affirms the continued unilateral appreciation of RMB. Nevertheless, the U.S.*

*government has been accusing China of manipulating the exchange rate. And it is very irresponsible and turns a blind eye to the shrink of international reserves of other countries subject to the quantitative easing policy. Instead, the United States puts the blame on China and has been putting pressure on RMB for further appreciation, which raises the expectation for the appreciation of RMB in the foreign exchange market, leading to greater risks in China's financial market and intensified impacts on the domestic real economy by short-term venture capitals.*

*The international reserve holdings should have been directed at foreign investment for further increase of values while maintaining international liquidity. However, as the largest creditor of the United States, China's foreign reserve in the form of the U.S. dollar has been greatly restricted. China's economic scale might be comparable to that of the United States. But in terms of financial market operations, the United States can be said to have an absolute advantage, which is shown not only in its developed and prosperous financial market, but also in its great strength demonstrated in fighting against the financial crises time and again. The United States is quite familiar with the financial derivatives, and has extensive experience in speculation in financial derivatives market, which can be proved forcefully by the incident that incurred huge losses to China Ocean Aviation when it was attacked by international speculators in Singapore futures market.*

*Domestically, the US government enters the financial market with its huge dollar reserve, restricts China's investment in the real economy in America by invoking national security. Reserve assets are loaned out in low interest rates, neither satisfying the domestic needs of loans, nor obtaining stable economic returns. Under the joint influences of opportunity cost and impairment risks, the economic efficiency of the reserve assets is further lowered.*

## *CHINA'S STRATEGIC DEPLOYMENT FOR CAPITAL SECURITY*

*Given the global status of the U.S. dollar, it is not possible for China to commit itself to large-scale reduction of the dollars holdings in its foreign reserve. To protect the foreign exchange assets, we must make strategic deployment from three aspects: to reduce our reliance on the dollar in the international market, to promote the process of RMB internationalization, and to effectively manage the international reserve assets.*

### *A. Actively Push forward Reform of the International Monetary System*

*If Chinese foreign exchange is to be more secure, it must search for a more independent, reliable non-sovereign credit currency that is not influenced by the monetary policies of other countries. This fundamental change is only possible by reforming the current international monetary system. According to "Reflections on the Reforms of International Monetary System" by Zhou Xiaochuan (2009), given the endogenous defect and systematic risk of the current international monetary system, we should make active efforts to adjust the current special drawing right (SDR) currency basket, promote SDR reform, and establish super-sovereign credit currency so as to finally change the current situation of international reserves.*

### *B. Gradually Open Up the Financial Market*

*To maintain the security of international reserves, we cannot just put our hopes on the reforms from other countries or organizations. We must take the initiative. The root reason for the Chinese economy to be hijacked by the United States is the irreplaceability of the international status of the United States.*

*Therefore, if the Chinese government is to protect its domestic capital, it should, first of all, make the risks manageable and gradually open up the financial market. It should also take the chance of liberalizing capital market to strengthen the image of a responsible China and encourage other countries to have confidence in RMB. Meanwhile, China should learn from the failure of Japan at the end of the 1980s when it was undergoing similar economic development to that of present China, and take cautious reactions against the financial intervention of the United States. During the gradual opening up process, there also should be well-organized expansion of external trade and investment to realize the penetration of RMB into the global market.*

### C. Achieve Effective Management of Foreign Exchange Reserve

We should first achieve effective management of foreign reserve exchange in the short term to reach the goal of capital security. We should perfect relevant laws and establish a unified system of reserve management. We should change the structure of foreign exchange reserve, expand the investment scope of reserve assets, and increase the investment in the foreign real economy, especially in the emerging economies, so as to enhance the risk control ability for the assets. If the reserve assets are to be truly safe, liquid, and profitable, we cannot just focus on the foreign national debts. We should take advantage of our strong foreign exchange reserve to help the Chinese enterprises enter the international market. Thus our reserve assets will not only be able to gain profits at abroad, but also can provide adequate foreign exchange credit to the domestic enterprises, which will increase both the efficiency of resource allocation and economic welfare of the whole society.

### ACKNOWLEDGMENTS

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### REFERENCES

[1.] Zhou Xiaochuan. Reflections on the reforms of international monetary system (in Chinese) [J]. Chinese Finance, 2009, 7: 8-9.

[2.] Wang Shougan. Analysis of whether the value of US dollar cause loss to the Chinese foreign exchange reserve (in Chinese) [F]. Journal of ABC Wuhan Training College, 2011 (6): 31-33.

[3.] Chen Yulu. Devaluation of US dollar in international currencies competition (in Chinese) [J]. Chinese Finance, 2004, 10: 010.

[4.] Du Anguo. Analysis of courses of depreciation of dollar and appreciation of the RMB (in Chinese) [J]. Co-operative Economy & Science, 2009, 1.

[5.] Gao Di, Xiao Wanchun. The currency war documentary (in Chinese) [M]. Beijing: Central Compilation & Translation Press, 2009.139-142

[6.] He Xin. Currency storm (in Chinese) [M]. Beijing: China Book Press, 2010.

[7.] Wang Zhen. Management research of China's foreign exchange reserves (in Chinese) [M]. Beijing: China Financial Publishing House, 2007.


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# SUMMARY OF THE USING SOLAR ENERGY ON THE GLOBAL LEVEL AND IN THE REPUBLIC OF SERBIA

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***Abstract:*** *This work shows an overview on current renewable energy resources, paying special attention to solar energy. Also, an overview of perspective for the further development of their usage has been given. Global potentials have been analyzed in the area of renewable energy resources as well as available potentials in the Republic of Serbia. During the last years, the usage of the renewable energy resources has been increased so that the Europe Union Directive 2009/28/EC forsees the increase of renewable energy resources' participation in the total energy consumption until 2020, year up to 20%. Technically utilized energy potential of the renewable energy resources (OIE) in the Republic of Serbia is very significant and estimated on over 6 million tons equivalent of oil (ten) annually. However, the renewable energy resources' participation in the total energy balance, excluding big power plants as well as biomass, has still been on a low scale. The usage of renewable energy resources is one of the key components of sustainable development which provides rational economic, ecological and social effects.*
***Keywords:*** *renewable energy resources, solar energy, production, energy fuel*

## INTRODUCTION

*The term of renewable energy resources refers to the energy resources which could be found in the nature and are renewable completely or partly and these are as follows: solar energy, waterflow and wind energy, biomass, geothermal energy and etc.*

*Renewable energy resouces are used for the production with about 1% of energy production in total in the world. Development of the renewable energy resources, in particular solar, water and wind energy and biomass – is the main aim of the energy politics of European Commission – European Commission department for energy and transport.*

*Europe Union has brought several directives which refer to the renewable energy resources: Directives 2001/77/EC, 2003/30/EC and 2009/28/EC. In the last directive, it is forseen that until the year of 2020. The renewable energy resources participate with at least 20% of total energy consumption in the Europe Union. This directive also forsees that until the year of 2020, the usage of the renewable energy in transport (biogas, electric energy and hydrogen produced out of the renewable resources) will be at least 20% of total fuel consumption in the Europe Union [7].*

*The Republic of Serbia has adopted numerous documents in the area of the renewable energy resources and created the favourable conditions for a significant increase of production and consumption of these energy resources but the energy production from the renewable energy resources has still been insufficient. The usage of the renewable energy resources in Serbia is very important due to the scarce potential of conventional energy resources. Furthermore, the usage of these resources contributes to even more efficient usage of own potential in energy production which is important in decrease of the emission of "gases of the green garden effects", decrease of fossil fuel import, development of the local industry, especially in rural areas and opening of new working post. Solar energy is a form of energy with the biggest potential.*

*Solar energy presents an inexhaustable ecological energy resource whose global potential multifunctionally undergoes the world's needs for the electricity.*

## AVAILABLE POTENTIAL OF RENEWABLE ENERGY – Global production

*The most important energy of 20 century was oil. In the world's primary energy consumption oil has participated with about 31.5%, coal with about 28.8%, gas with about 21.3%, renewable energy with about 13.3% and nuclear energy with about 5.1% (See Figure 1) [1].*

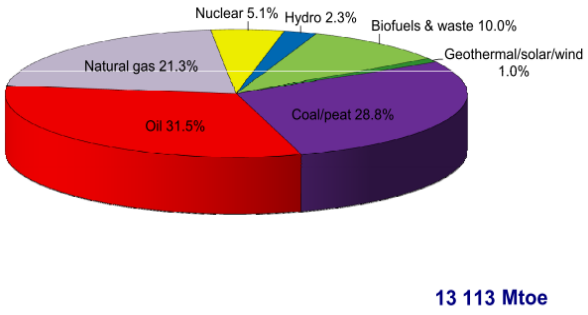


*Figure 1. Share of total primary energy supply in 2011. - Source: IAE, 2013*

*Global demand for renewable energy continued to rise during 2011 and 2012, despite the international economic crisis, ongoing trade disputes, and policy uncertainty and declining support in some key markets. Renewable energy supplied an estimated 19% of global final energy consumption by the end of 2011, the latest year for which data are available. Of this total, approximately 9.3% came from traditional biomass, which is used primarily for cooking and heating in rural areas of developing countries. Useful heat energy from modern renewable sources accounted for an estimated 4.1% of total final energy use; hydropower made up about 3.7%; and an estimated 1.9% was provided by power from wind, solar, geothermal, and biomass, and by biofuels (See Figure 2) Renewables are a vital part of the global energy mix[2].*

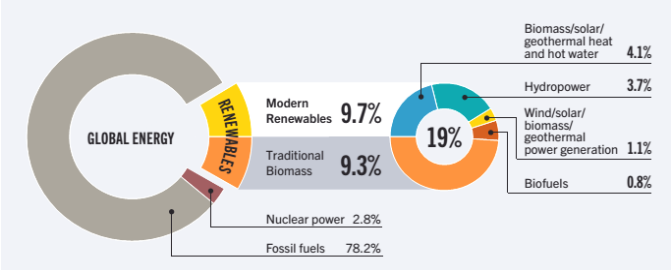


*Figure 2. Estimeted renewable energy share of global final energy consumption 2011. Source: GLOBAL REPORT, 2013*

*Renewables have accounted for an ever-growing share of electric capacity added worldwide each year, and in 2012 they made up just over half of net additions to electric generating capacity. By year's end, renewables comprised more than 26% of total global power generating capacity and supplied an estimated 21.7% of global electricity, with 16.5% of total electricity provided by hydropower (See Figure 3.) While renewable capacity rises at a rapid rate from year to year, renewable energy's share of total generation is increasing more slowly because many countries continue to add significant fossil fuel capacity, and much of the renewable capacity being added (wind and solar energy) operates at relatively low capacity factors [2].*

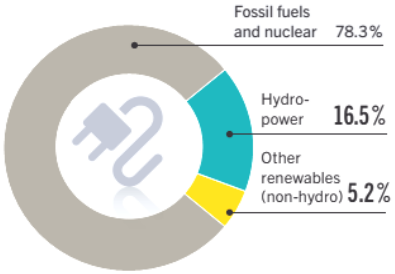


*Figure 3. Estimated renewable energy share of global electricity production end 2012. - Source: GLOBAL REPORT, 2013.*

| | | 2010 | 2011 | 2012 |
|---|---|---|---|---|
| Investment in new renewable capacity (annual)[1] | billion USD | 227 | 279 | 244 |
| Renewable power capacity (total, not including hydro) | GW | 315 | 395 | 480 |
| Renewable power capacity (total, including hydro) | GW | 1,250 | 1,355 | 1,470 |
| Hydropower capacity (total)[2] | GW | 935 | 960 | 990 |
| Bio-power generation | GWh | 313 | 335 | 350 |
| Solar PV capacity (total) | GW | 40 | 71 | 100 |
| Concentrating solar thermal power (total) | GW | 1.1 | 1.6 | 2.5 |
| Wind power capacity (total) | GW | 198 | 238 | 283 |
| Solar hot water capacity (total)[3] | $GW_{th}$ | 195 | 223 | 255 |
| Ethanol production (annual) | billion litres | 85.0 | 84.2 | 83.1 |
| Biodiesel production (annual) | billion litres | 18.5 | 22.4 | 22.5 |

*Figure 4. Average annual growth rates of renewable energy capacity - Source: GLOBAL REPORT, 2013*

*During the five-year period 2008–2012, installed capacity of many renewable energy technologies grew very rapidly, with the fastest growth in the power sector. Total capacity of solar photovoltaics (PV) grew at rates averaging 60% annually (See Figure 4). Solar PV experienced continued price reductions in 2012 due to economies of scale and technology advances, but also due to a production surplus of modules. Combined with the international economic crisis (which has helped*

*drive policy changes) and ongoing tensions in international trade, these developments have created new challenges for some renewable energy industries and, particularly, equipment manufacturers [2].*

*Total renewable power capacity worldwide exceeded 1,470 gigawatts (GW) in 2012, up about 8.5% from 2011. Hydropower rose to an estimated 990 GW, while other renewables grew 21.5% to exceed 480 GW. Globally, wind power accounted for about 39% of renewable power capacity added in 2012,*

*followed by hydropower and solar PV, each accounting for approximately 26% (See Figure 5). Solar PV capacity reached the 100 GW milestone to pass bio-power and become the third largest renewable technology in terms of capacity (but not generation), after hydro and wind. [1].*

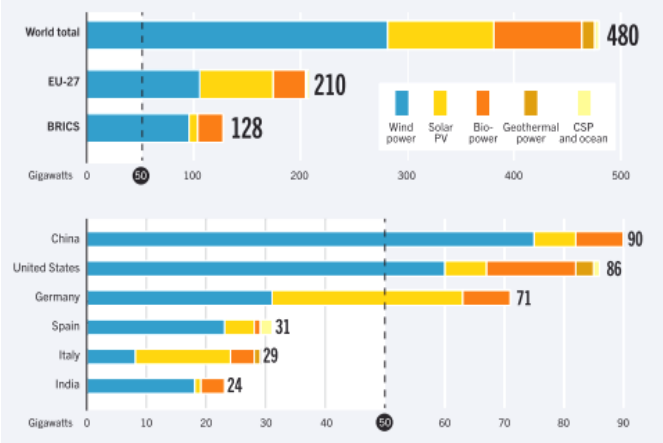


*Figure 5. Renewable energy capacities – source: GLOBAL REPORT, 2013*

*The solar photovoltaic (PV) market saw another strong year, with total global operating capacity reaching the 100 GW milestone in 2012. The market was fairly stable relative to 2011, with slightly less capacity brought on line but likely higher shipment levels, and the more than 29.4 GW added represented nearly one-third of total global capacity in operation at year's end 2 (See Figure 6) [1].*

*Eight countries added more than 1 GW of solar PV to their grids in 2012, and the distribution of new installations continued to broaden. The top markets are Germany, Italy, China, the United States, and Japan were also the leaders for total capacity. By year's end, eight countries in Europe, three in Asia, the United States, and Australia had at least 1 GW of total capacity. The leaders for solar PV per inhabitant were Germany, Italy, Belgium, the Czech Republic, Greece, and Australia (See Figure 7).*

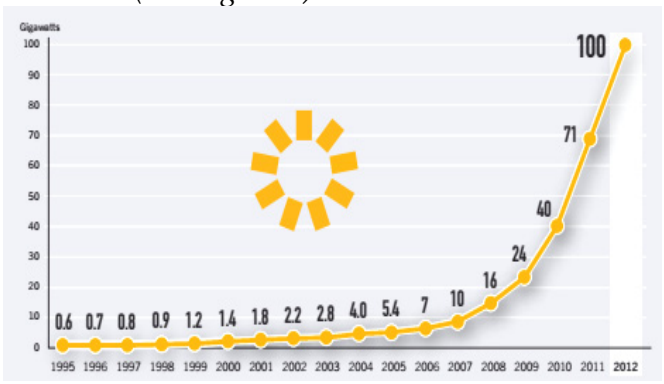


*Figure 6. Solar PV global capacity, 1995 - 2012 – source: GLOBAL REPORT, 2013*

*Europe again dominated the market, adding 16.9 GW and accounting for about 57% of newly installed capacity, to end 2012 with 70 GW in operation. For the second year running the EU installed more*

*PV than any other electricity-generating technology: PV represented about 37% of all new capacity in 2012. [1].*

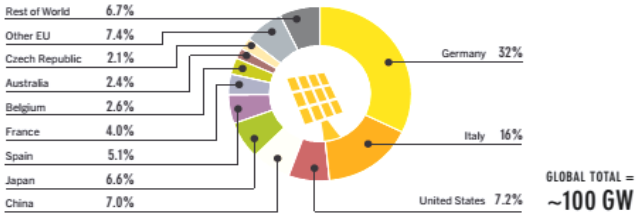


*Figure 7. Solar PV global capacity, shares of top 10 countries – source: GLOBAL REPORT, 2013*

*The number and scale of large PV projects continues to increase. By early 2013, about 90 plants in operation were larger than 30 MW, and some 400 had at least 10 MW of capacity. The world's 50 biggest plants reached cumulative capacity exceeding 4 GW by the end of 2012, and at least 12 countries across Europe, North America, and Asia had solar PV plants over 30 MW. More than 20 of these facilities came on line in 2012, including the world's two largest: a 250 MW thin film plant in the U.S. state of Arizona and a 214 MW plant in Gujarat, India. Germany held on to its lead for total capacity of facilities larger than 30 MW, with a cumulative 1.55 GW in operation by year's end, followed by the United States, France, India, Ukraine, China, and Italy. Several projects are planned around the world that range from 50 to 1,000 MW in scale [1].*

*Solar PV is starting to play a substantial role in electricity generation in some countries, meeting an estimated 5.6% of national electricity demand in Italy and about 5% in Germany in 2012, with far higher shares in both countries during sunny months. By year's end, PV capacity in the EU was enough to meet an estimated 2.6% of total consumption, and global capacity in operation was enough to produce at least 110 TWh of electricity per year [1].*

***Available potential of renewable energy in the Republic of Serbia***

*In the Serbia's primary energy consumption oil has participated with about 23.2%, coal with about 54.1%, gas with about 11.7% and renewable energy with about 11% (See Figure 8.) [5].*

*In Figure 9, shows the shares of different energy sources in electricity production in Serbia. The diagram shows that around two-thirds of electricity generation from fossil fuels, ie. coal, while other sources significantly represented hydro (with a share of 21.2%), mainly due to conventional large hydro [5].*

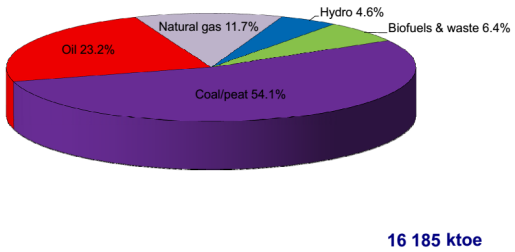


*Figure 8. Share of total primary energy supply in 2011. - Source: IAE, 2013*

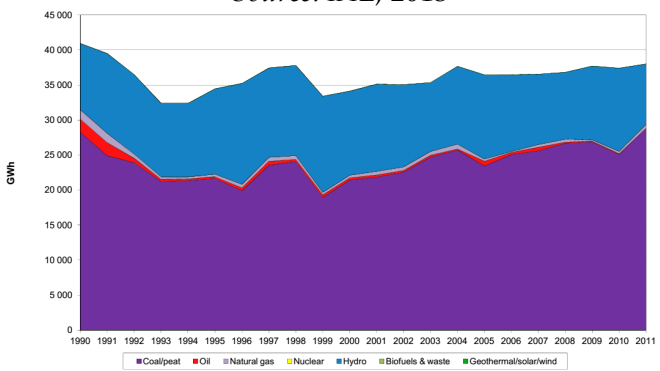


*Figure 9. Estimated renewable energy share of global electricity production end 2012. - Source: IAE, 2013*

*As far as exploitation of renewable energy sources in the Republic of Serbia is considered, these sources are widely underutilized although having a substantial potential. This is particularly true if water energy conversion is excluded. Some estimates show that total renewable energy sources technically available for exploitation are approximately 6 Mtoe annualy. For electrical energy conversion however, the major potential lies with wind, solar and water energy conversion [4].*

*Renewable energy structure in Republic of Serbia:*

- *Biomass 3.3 Mtoe - 65% of total potencial;*
- *Water energy 1.7 Mtoe - 15% of total potencial;*
- *Geotermal energy 0.2 Mtoe - 4% of total potencial;*
- *Wind energy 0.2 Mtoe - 4% of total potencial;*
- *Solar energy 0.6 Mtoe - 12% of total potencial;*

*The Republic of Serbia of all available technical potential of renewable energy is already using 33% (0.9 Mtoe of used water potential and 1.06 Mtoe of the potential of biomass), See Figure 10 [3].*

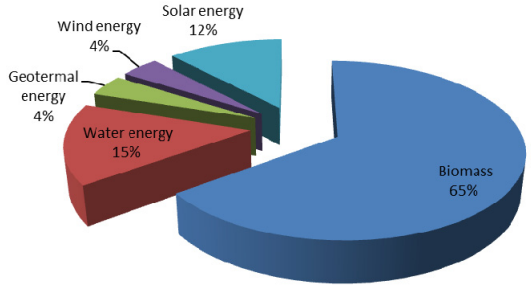


*Figure 10. Renewable energy structure in Republic of Serbia – Source: National aims and plan of the Republic of Serbia's*

*The republic of Serbia has a significant solar potential. With the solar irradiation ranging from the average of 1.1–1.7 kWh/m²/day during January to 5.9 - 6.6 kWh/m²/day during July on a horizontal plane, the Republic of Serbia has the basic element for solar power utilization. Considering the facts shown above, the irradiation on a horizontal plane of 1200 kWh/m²/year (for northwest regions) and 1550 kWh/m²/year (for south regions) can be expected.*

*These data can be further optimized by using planes at an elevation angle or solar tracking plane (positioning to the sun path). This means that optimizing the photovoltaic plane positioning and angles enables from 1560 kWh/m² /year up to 2000 kWh/m²/year irradiation in the Republic of Serbia depending on the location (Figure 11 and 12) [4].*

*According to relevant international institution data, the Republic of Serbia has substantial solar energy potentials. By establishing legal and technical regulations, as well as sublegal acts considering enhanced pricings, foundations for investments in the area of renewable power sources*

were created. A constant decrease in technology prices and a relatively high price of energy generated using photovoltaic systems are making photovoltaic systems attractive for investment.

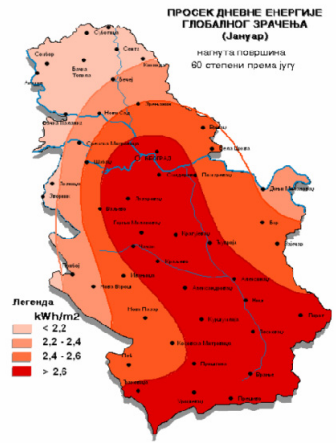


Figure 11. Average daily energy irradiation on January, on a 60 deg, kWh/m²

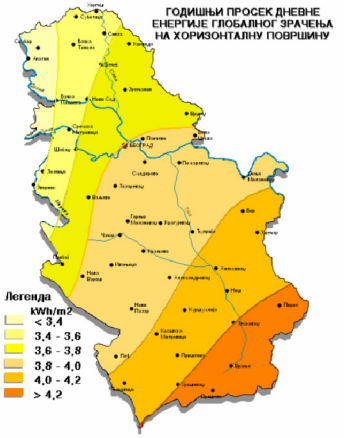


Figure 12. Annuale average daily energy irradiation ona horizontal plane, kWh/m²

## NATIONAL STRATEGY AND ENVIRONMENTAL ASPECTS OF THE USING OF RENEWABLE ENERGY

Serbia's energy import dependence in 2010. year was about 33,6%. In the future, the most important it would be to provide secure, high quality and reliable supply of energy and substances and to decrease energy dependence of the country [4].

Reserves of fossil substances, as oil and gas, are very scarce (less than 1% of the total amount of energent reserves in Serbia), and the biggest reserves are in the low quality lignites (about 92% in the total balance of reserves) [4].

National aims and plan of the Republic of Serbia's renewable energy resources usage have been determined within the Law of Energetics. The aims are established according to the energy needs, economic possiblities and obligations of the Republic of Serbia taken over according to the ratified international agreements. [4].

Ratification of the Contract regarding the energy union founding, Serbia has accepted the obligation to bring and pass the plan of application of the directive 2001/77/EC about promoting the production of electricity from OIE and directive 2003/30/EC about promoting the biogas usage and other fuels in the transort sector [6].

Development of the pure, efficient and safe energy supply, promotion of the energy usage method which pollutes less the environment, managing the natural resources and creating industries, services and societies that influence less on the environment – all these are important investments in the future. Since the environment pollution recognizes no limits, fight for the environment and preserving the environment, actually is the fight for the whole continent, but not the fight for the whole planet.

In the process of joining the Europe Union, the electroenergetic sector of the Republic of Serbia will also meet the obligatory and adittional financial costs of the emission of $CO_2$. At this moment, the Republic of Serbia as a developing country, has no international obligation of decreasing gas emission with the effect of green garden (GHG), but in the moment of joining the EU membership, it will probably be obligatory to limit, i.e. to decrease the emission of the green garden gases.

Working on the structure change of energents for the production of electricity, i.e. significant increase of participation of renewable energy resources which will bring to much lower specific emission of the green garden gases.

## CONCLUSION

In the future, global society development will greatly depend on the condition in which the area of energetics is. Problems that all countries in the world more or less confront with are connected to energy providing and preserving the environment. Explosion of human population on the Earth causes constant increase of energy needs, especially electricity demand. The trend of needs' increase on the global level is about 2,8 % annualy [5]. On the

*other hand, the current structure of the primary resources of electricity cannot provide, on the global level, such a trend of electricity production increase. The reason for this are current eco problems directly caused by fossil combustion and nuclear fuels, on which is based current electricity production in the world. Beside that, existing dynamics according to which the fossil fuels have been exploited , will in the near future also bring to the exaustion of its resources.*

*Direct consequence of these contradictory conditions of production and consumption is the constant increase of electricity cost, with which, even on the present level, is being created ecological and economical justified needs of including alternative resources in the global strategy of energetics' delevopment. These energetic flows forced very developed countries to invest huge capital and hire many professionals in the deveopment of the system for using renewable recources of electricity (solar power stations, wind power stations, biomass and biogas power stations, geothermal power stations). As a result of such investments, the technology has been adopted as well as industry for the tecnical reliable conversion of some primary renewable resources. Beside that, international protocols and obligations regarding the $CO_2$ emission decrease (Kyoto protocol) and local eco problems, forced the Governments of many countries to motivate, with different subsidies , building of eco pure power plants which use renewable resources. This kind of politics has brought to exceptional popularization and fantastic trend of increasing paricipation of certain renewable resources in the total production of electricity. Rapid increase of the photo potential industry in the world with the growth of production capacity and favourable political climate in countries such as Germany, Spain, Japan, China, Italy, Corea, Greece, etc. promise bright perspective of photo potential technology in Serbia as well. However, photo potential industry requires favourable and stable political conditions for constant and sustainable development. Rapid and rashly changes in conditions and amount of subventions and political attitudes could bring into question positive developing trend. Taking into consideration the present importance of photopotential technologies, their long term potentials and time needed for these technologies to develop, the development and application of these technologies completely justify and encourage state support and subventions. Apart from this, the photopotential industry can highly contribute to economy of a country by opening new working posts as well as causing the development of small and medium companies.*

**REFERENCE**


[1.] **** : REN21, Renewables 2007 - 2012: Global Status Report, http:// www.ren21.net/*

[2.] **** : REN21, Renewables 2013: Global Status Report, http:// www.ren21.net/*

[3.] ****: Energy balance of the Republic of Serbia for year 2012, http://www.merz.gov.rs/lat/dokumenti/energetski-bilans-republike-srbije-za-2012-godinu.*

[4.] *http://www.merz.gov.rs/lat*

[5.] *http://www.iea.org/*

[6.] *Government of the Republic of Serbia: Law on Energy, Sluzbeni Glasnik RS No. 84/2004.*

[7.] *Government of the Republic of Serbia: Law on Ratification of the Treaty establishing the Energy Community between the European Community and the Republic of Albania, Bulgaria, Bosnia and Herzegovina, Croatia, the former Yugoslav Republic of Macedonia, Montenegro, Romania, Serbia and the United Nations Interim Mission in Kosovo in accordance with Resolution 1244 United Nations Security Council, Fig. Gazette of RS ", no. No. 62/2006.*



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# CHIEF RESEARCH ON IMPROVING CHINESE LOW-CARBON ECONOMIC COMPETITIVENESS

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**Abstract:** As the world's environment getting worse, nations, developed or developing, all pay an increasing attention to the low-carbon economy which is now considered to be a method of improving their international status and competitiveness. China, one of the world's fastest developing countries, is fully aware about how the low-carbon economy could influence the industrial development, international trade and the domestic market. Taking it as an opportunity of transforming economic patterns, development on low carbon economy also improves the creativity and quality of the nation's market economy. In another aspect, China needs to reduce the factory pollution as the result of fast development, also, she has to keep the promises and take responsibility as one of the world's most powerful countries. Specify into certain strategy: China need to earn the carbon emission competitively, enhance the international cooperation; accelerate the transformation of economic development; increase the efficiency of energy utilization; improve low-carbon emission technology; popularize low-carbon idea on city scale and encourage low-carbon business that boosts the upgrade of industrial structure.
**Keywords:** Low-carbon economic competitiveness; Carbon emission reduction; strategy

## INTRODUCTION

China has made international commitment to reduce carbon emission, and it should attach the great importance to development of low carbon economy. Low carbon competitiveness is related to industrial prosperity, national strength and international development prospects. Facing the complicate international competitive environment, China needs to break through its tradition development framework, grasp the trend of low economic development. Starting from the factors affecting low carbon economic competiveness, following the characteristics and the laws governing the operations of low carbon economy, improving low carbon economy competitiveness should be considered as a comprehensive systems engineering project.

### NEW SECTION - Earning carbon emissions and participating in international cooperation

Carbon emission is a region or a country of right to develop. Especially the developed counties, which have relatively high capacity to reduce carbon emissions, control the right to speak of the design of international carbon emission reduction mechanism which would draw the mechanism favourite to the developed countries. China, as a fast developing country, inevitably takes energy driven develop model in the process of rapidly economic growing and improving of national living standards, resulting in substantial increase of carbon emissions. If China can't take the initiative to participate in the formulation process of carbon emission reduction mechanism, it would lose the right to speak, resulting in no room for carbon emissions and bearing huge obligations of carbon emission reduction as well. Furthermore, it would weaken its international competiveness, and detrimental affect future development of China.

China has always committed to adhere to the United Nations Framework of Convention on Climate Change and Kyoto Protocol, strictly follow the Bali Roadmap authorization. In the future negotiations on addressing response to global climate change, it is necessary to take up the responsibility of one of the most powerful countries and participate constructively in the process of global response to climate change, more importantly, it should adhere to principle of

*fairness and justice, safeguarding national interests and defending national development right. Regarding the responsibility, it should adhere to the principle of "common but differentiated responsibilities". Based on the historic accumulation, requires developed countries to take responsibility for their historic emissions. Taking the population into consideration, it is fair to allocate the carbon emissions based on per capita. The obligations of carbon emission reduction should be combined with level of economic development, co-coordinating the relationship among economic development, poverty eradiation and climate protection. Adhere to the ability and obligation to the principle of reciprocal. In the process of addressing to response to climate change, developed countries should take the lead in reduction emissions in a large scale to free up room for developing countries to develop, and help developing countries to lower carbon emissions by providing funds and transfer of technology.*

***Strengthening strategic planning and promoting low carbon cities***

*The government should clearly states that promoting low carbon cities is included in the national development strategies. Combining low carbon economy with construction of ecological civilization and scientific development concept, establishing a resource saving, environment friendly and low carbon development society are our national strategic vision and objectives. In addition to target carbon reduction as binding index for economic and social development planning, cultivating long-term national competitiveness should be based on forward-looking, long-term and global perspective. Long-term developing planning for the development of low-carbon economy should be rooted in the country's "development plans" and converged with "energy planning", "energy savings and emission reduction planning, introduce programs to develop low-carbon economy. Develop low-carbon economic development system at the national strategic level, ensure scientific accounting "carbon footprint" of China, build "carbon budget" system, improve the carbon emission monitor, statistics, reporting system, and carbon emission trade mechanism of China, and design low-carbon development evaluation system. In the process of urban development, the standards of energy saving materials should be established. Promoting the use of solar energy, taking full advantage of natural ventilation and lighting, developing standards for energy consumption for heating and cooling system, only suitable decoration, and promoting the use of energy saving lamps and energy efficient appliances are among the strategies to lower carbon emissions in cities. Improving transportation efficiency is another means to reduce carbon emissions. Developing public transportation system, and developing walking and cycling based slow transportation system to stop the linear upward trend of car production and sales in recent years. Avoid the excessive growth of private cars by limiting their traveling, fuel tax and crowded fee. Promote hybrid cars, electric vehicles and other new energy vehicles which consumer clean energy such as diesel, hydrogen fuel. Build a modern logistics information system, reduce transportation Kongshi rate and strengthen the construction of intelligent system to reduce transport carbon.*

***Enhancing the innovation ability of science and technology, increasing the levels of research and development of low-carbon technologies***

*The advancement of science and technology and systematical creation are essential means for fighting against the challenge of global climate changes. The leading and basic role of science and technology should be emphasized for the construction of scientific and technological supporting systems responding to the climate change. The key issues for increasing competitive ability of low-carbon are: expanding investment on innovation, prioritize some research areas, invent essential technologies, speeding up the research and development, introduction and innovation of low-carbon technologies. We should closely track domestic and international advancement in low-carbon technologies, actively introduce, assimilate and re-innovate those advanced, appropriate low-carbon technologies through the new system of international cooperation on climate, selectively introduce and assimilate foreign mature low-carbon technologies, extend the exchanges and cooperation with European and American*

*countries in low-carbon energy and related technologies, actively involve in the setting up international standardizations for industrial energy efficiencies and carbon intensity. According to the principles that are technical feasible and economic reasonable, we should propose the diagrams for the development of low-carbon technologies in China, enlarge the research and development, stimulate the research and utilization of technologies that are high energy efficiency and low-carbon emission, elevate the creative ability in technology. Step-by-step we should build up diverse low-carbon technology systems including energy saving, clean coal and clean energy, new energy and renewable energy, and forest carbon sink, accelerate the research and development on high efficiency coal-fired power generation, high capacity electricity storage, ultra high efficiency heat pump, carbon dioxide capture and storage, electricity transmission and storage, to form technology reserve, which will provide strong technical supporting system in the transformation of low-carbon and growth modes.*

*In order to increase our abilities of innovation and international competence, enterprise innovation should be predominant; national policies supporting innovation should be propagandized and fulfilled; financial support should be focused on enterprises by building up risk investment system, strengthening financial supports, introducing new financing management. To set up national and regional sharing and exchanging platforms for low-carbon technologies, those key issues of techniques need be solved, and the costs need to be greatly reduced, the technologies need to be improved, the development and extension of advanced and applicative products low-carbon need to be supported with higher priority.*

*We should make and fulfill the policies of governmental purchase of low-carbon products, giving higher priority to purchase products passed ecological design, clean producing process and satisfying the requirement of energy-saving. The privilege of purchasing low-carbon products will encourage the investment, benefit the development and increase the international compatibility of low-carbon products.*

***Changing the developing way of economy, increasing the efficiency of energy utilization***

*The development of Chinese economy is facing many issues including high investment, high consumption, high emission, non-synergic, un-circular, low efficiency. The consumption of enormous materials in current economic development and the huge wastage from repeating low-level constructions are the major causal factors of high-carbon emission. Although the per capita carbon emission in China is only one quarter of that in the United States, the overall carbon emission of China ranks No. 1, and the percentage in the world total carbon emission keeps increasing. The fast growing in the total amount of carbon emission may be avoided only if China increases the quality of its economic development through a proper way.*

*We should improve the way of current economic development, increase the efficiency of energy utilization, and reduce the consumption of energy and carbon emission. To achieve these goals, (1) facilitate the improvement of industrial structure, the economic development has to be switched from relying on secondary sector solely to relying on all primary, secondary and tertiary sectors, strategic new industry should be aggressively boosted. (2) Optimize the economic development, change the investment- and export- oriented economic structure, optimize investment structure, lean towards strategic new industry. (3) Optimize the input of the components of economic development, change the situation that the economic development mainly depends on the consumptions of resources and energy to relying on the input of technology, high-quality intelligence and higher efficiency of management.*

***Developing low-carbon industries to optimize the structure of industries***

*China is in the middle age of industrialization, dominated with heavy industry with high-carbon characteristics. We should develop low-carbon industries, reduce carbon emission, to optimize the structure of industry. In narrow sense, low-carbon industry refers to:*

*(1.) renewable energy, including hydroelectric power, solar power, wind power, bio-power, geothermal power, energy generated from*

*ocean temperature difference, hydrogen fuel battery, etc.*

(2.) *low-carbonize of fossil fuel, including recycling and storage of carbon dioxide, using clean coal and coal gas to generate electricity, liquidation of coal gas, using methane as fuel.*

(3.) *energy efficiency and low carbon consumption, including energy transmission and storage, low-carbon consumption of energy.*

(4.) *Low-carbon service field, including management of energy contracts, exchanging service of carbon emission, CDM consulting service, greening financial service, enterprise carbon management consulting service, carbon footprint, and carbon neutral service. The low-carbon industries could be enlarged to the industry development under low-carbon, especially carbon sink industry.*

*Research on forest carbon sink, ocean carbon storage, carbon fixation by marine organisms should be performed. Low carbonization should drive the improvement of industrial structure; increase the entrance threshold of marketing of high-carbon industry. The tax policies on high-carbon energy, industry and production need to be studied to restrict and eventually eliminate high-carbon industries and products. Administrative, tax, financial, and legal actions should be taken to encourage the development of low-carbon industry and support low-carbon products to make this industry more attractive.*

*The development of intelligence-intensive and technology-intensive industries should be accelerated. Advanced manufactures should be expanded by the promotion of informatization on industrialization. We should hatch and extend industrial clusters with primary low-carbon industries, build up low carbon industrial parks, expand the knowledge spillover effects among enterprises and accelerate the paces of technology innovation. We should develop the strategies for modern service industry, fully open the market, introduce capital from the society, set up fair market competition environment, and stimulate the development of service industries. The industries servicing the advanced manufacturing industries, including technology design, development of products, financial support, brand management, logistics system and online sales, should be the crucial area for the future industrial development. Meanwhile, it needs to be speeded up for the development of education, culture, news press, travel and tour, medical care, employment, to enlarge room for the development of service industries.*

***NEW SECTION***

*At the same time, reduce carbon emission levels by optimizing energy production and consumption structures, in particular, developing clean energy, and optimizing energy structures. Increase investment in clean energy generation, encourage and support the development of new and renewable energy, improve the subsidies for clean energy investment and product sales to increase the proportion of clean energy consumption in the whole society. Optimize the layout of nuclear power plants. Accelerate the construction of nuclear power plants, speed up the research and development of advanced technology and equipment. Promote the development and industrialization of the fourth generation of nuclear energy technology. Strengthen the management of construction of hydropower stations, improve the hydropower management level, and enhance the ability of water and electricity supply. Strengthen terrestrial and marine wind energy surveys, design and demonstration.*

*Increase the capacity of the wind turbine and the level wind power outputs. Promote the use of solar energy and power generation technology, speed up the construction of photovoltaic, solar thermal power plant projects, implement the acquisition system for new energy power generations to ensure full protection, reform of the new energy price subsidies system, motivate enterprises to use new energy. Adhere to the market demand, and guide social capital, technology and human factor inputs, improve the new energy market competitiveness. Furthermore, integrate the roles of government, industry associations, enterprises and the publics to promote low-carbon economic development. Embedding the low-carbon development concept into the business, industry, regional and national development strategies, stimulate enterprises to participate in the actions of carbon emission*

*reduction positively and cooperatively, and promote the production, circulation, consumption, distribution and other aspects of low-carbon. Enhance the development, production, promotion of low-carbon energy-saving consumer products to meet demands of residents for low-carbon consumption. Create the material basis of the universal low-carbon consumption patterns. Actively promote the green low-carbon lifestyles and consumption models, cultivate universal awareness of low-carbon, and carry out education activities to increase the publicity of low-carbon science. Create the atmosphere of low-carbon consumption, low carbon concept of operations in the whole society, and cultivate green consumption styles. Encourage the use of recycled products, green products, energy-efficiency products, energy and water conservation certificated and environmental labeled products, and minimize the use of disposable supplies. Reminder people to travel with green style in mind, motivate the whole society to participate and take action in low carbon economic development, and create a low-carbon consumption culture.*

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**REFERENCES**

[1.] *OECD. Globalization of Industria1 R&D: policy Implications. Working Group on Innovation and Technology Policy [R], 1998*

[2.] *Markusen, J.R. Location Choice, Environmental Quality and Publicy [M] In Handbook of Environmental and Resource Economics. C. van den Bersh, Edward Elgar, Aldershot, UK, 199: 56-550.*

[3.] *Lantz V, Feng Q, Assessing Income, Population and Technology Impacts on CO2 Emissions in Canada. Where's the EKC?[J] Ecological Economics, 2006, 57(2) : 229-238*

[4.] *The Climate Institute and E3G G20 Low Carbon Competitiveness [M] Vivid economies, 2009*


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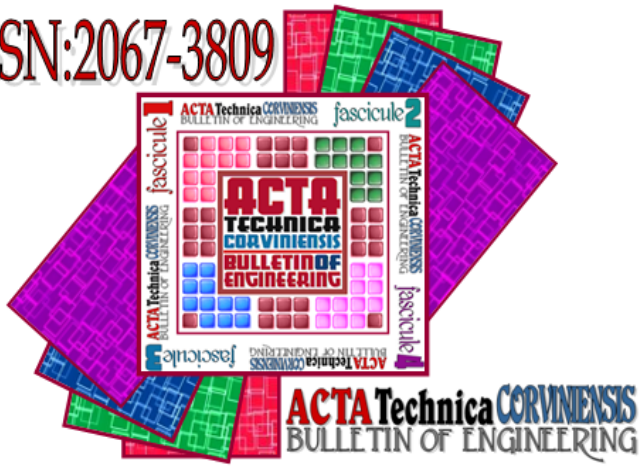


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# EVALUATION OF SUGARCANE BAGASSE ASH AS A REPLACEMENT FOR CEMENT IN CONCRETE WORKS

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**Abstract:** This research evaluates the suitability of SCBA as a partial replacement for cement in concrete productions. Total weight of 34.7kg of sugarcane bagasse (SCB) was obtained and burnt at 700$^0$C. A total of 2.71kg of SCBA was obtained after passing the residual through 45µm sieve, standard size of ordinary portland cement (OPC). Chemical test was conducted on SCBA to evaluate its percentage composition. It was then used to replace OPC by weight in ratio of 0%, 10%, 20% and 30%. Total of 48 pieces of 100mm concrete cubes of design mix ratio 1:1.66:2.77 were prepared. The cubes were tested at 7, 14, 21 and 28days of curing ages for density and compressive strength. The results of chemical test showed that SCBA has pozzolanic properties having met ASTM-595 (1985) with total sum of silica, alumina and ferric composition of 80.55%. The results showed a decrease in concrete density with increase in % replacement of SCBA. Average compressive strength of 26.8N/mm$^2$ was obtained for control specimens at 28days (i.e. 0% SCBA) while 22.3, 20.1 and 17.3N/mm$^2$ compressive strength at 28days were obtained for 10%, 20% and 30% replacement respectively. Pozzolanic activity index (PAI) of 83.2%, 75% and 64.5% were obtained. This showed that only 10% and 20% replacement of cement by weight of SCBA satisfied ASTM-595(1985) specification for PAI. It was concluded that SCBA is a low weight material and 10% replacement of SCBA has the highest PAI. Also, 10% and 20% replacement of SCBA with compressive strengths of 22.3N/mm$^2$ and 20.1N/mm$^2$ are recommended for reinforced concrete.
**Keywords:** SCBA, compressive strength, PAI, pozzolanic properties, concrete productions

## INTRODUCTION

Initiatives are emerging worldwide to control and regulate the management of sub-products, residuals and industrial wastes in order to preserve the environment from contamination. A good solution to the problem of recycling of agro-industrial residues would be by burning them in a controlled environment and use the ashes (waste) for more noble means (Ghavami et al., 1999). Utilization of such wastes as cement replacement materials may reduce the cost of concrete production and also minimize the negative environmental effects with disposal of these wastes. Silica fume, rice husk ash, fly ash, met kaolin and ground granulated blast furnace slag are well established wastes with pozzolans because of high silica content in their chemical compositions. According to Sirirat and Supaporn (2010), the calcium hydroxide (unfavorable product from the cement hydration) released during the hydration of OPC reacts with silica present in the pozzolans and water to form additional calcium silicate hydrate which is responsible for the compressive strength in concrete.

Sugarcane is an important food crop for tropics and subtropics. It is the major raw materials used for sugar production. Sugarcane bagasse (SCB) is the waste produced after juice extraction from sugarcane. The Sugarcane bagasse ash (SCBA) is obtained as by product of control burning of sugarcane bagasse. SCBA constitutes an environmental nuisance as they form refuse heaps in areas they are disposed. It is cultivated in about seventy four countries between 40$^0$N and 32.5$^0$S, approximately encompassing half of the globe (Agboire et al., 2002). Brazil and India are the world's major sugarcane producing countries with Brazil having over of 719 million tons in 2010 and recorded one-third of the world's total sugarcane (Kajima, 2012). Nigeria produced over 15 million

*tons of sugarcane last year. Some states where sugarcane is mostly produced in Nigeria are Sokoto, Taraba, Niger, Kogi and generally most Northern part. SCBA from sugar producing companies is not readily available since most developing countries relied on imported sugar import. In the past, SCB was burnt as a means of solid waste disposal. But with the increasing cost of the natural gas, electricity and fuel, and with the calorific properties of these wastes, bagasse has been used as the principal fuel in cogeneration plants to produce electric power (Aigbodion et al., 2010). SCBA is usually obtained under controlled burning conditions in the bailers of the cogeneration processes (Aigbodion et al., 2010). Thus, the ash may contain black particles due to the presence of carbon and crystalline silica when burning occurs under high temperature (above 800$^0$c) or for a prolonged time. The nature of ash can be altered by controlling the parameters such as temperature and rate of heating (Ganesan et al., 2007). Search for alternative binders or cement replacement materials has become a challenge for national development and forward planning (Oluremi, 1990). Since last few years, tremendous efforts have been made to increase the use of materials to partially replacement cement in concrete works. According to Swamy (1986), supplementation of cement production with natural pozzolans has proved attractive in developing countries. In recent years, there have been projects to develop known deposits in Indonesia, Tanzania, Trinidad, Dominica and other countries. Beside SCBA, rice husk ash, palm kernel husk ash, fly ash, ground blast-furnace slag and silica fume have pozollanic properties that can be used in partial replacement of cement. Megat (2011) investigated the effect of silica fume, metakoalin, fly ash and granulated blast fume on workability, compressive strength, elastic modulus and porosity of high strength concrete. Concrete produced from partial replacement of cement with SCBA has reaction formed by silicate, $SiO_2$ from SCBA and slaked lime, $Ca(OH)_2$ from cement to form calcium silicate hydrate which is responsible for the compressive strength (Baguant, 1995). The quality of concrete produced from SCBA beyond an optimum quantity of SCBA will leaches out silicate which does not contribute to the strength of concrete (Baguant, 1995). In the search for local building materials which is cheaper and readily available, the pozzollanic activity of SCBA is investigated and assessed in this research work by determining the strength of the mixtures when portion of cement is partially replaced.*

## MATERIALS AND METHODS

### Materials

*Ordinary Portland cement was used for the experiment. The cement conforms to BS 12 (1996). The fine aggregate was sourced from a construction site on the University of Ilorin, Ilorin, Nigeria. BS 812 (2002) that deals with testing aggregates was used in carrying out laboratory tests on the aggregates. SCBA was prepared at Department of Civil Engineering, Kwara State Polytechnic (Institute of Technology), Ilorin, Nigeria by burning SCB in blast furnace. The furnace was first heated to a temperature of 700$^0$C then off. The SCB was then put in the blast furnace till subsequent day and grayish-black ash was obtained. The ash was then weighed and sieved with a 425µm standard sieve and the quantity retained on the sieve (black carbon) was weighed and discarded. The ash collected was later weighed and grinded to fineness of 45µm sieve (conforming to American Society for Testing and Materials - ASTM C595-85 standard specification for blended hydraulic cements).*

### Laboratory Tests

*These include the determination of chemical composition of SCBA, physical tests on aggregates and the SCBA concrete. The tests carried out include the following: gradation test/sieve analysis, specific gravity, water absorption capacity and moisture content, bulk density, slump test and compressive strength test. Chemical test to determine the composition of SCBA was conducted at Department of Chemistry, University of Lagos, Nigeria. The method adopted was atomic absorption spectrometric method of analysis.*

### Production of Concrete Cubes

*SCBA, water, OPC, fine and coarse aggregate were used in producing concrete in mould of size 100x100x100mm. The mix design used for the production of cubes was 1:1.66:2.77 for characteristic strength of 25 N/mm$^2$ at 28 days.*

*The target mean strength was calculated to be 31.56N/mm². Batching by volume was adopted due to the light weight of SCBA. When batched by weight, the concrete produced was very low in workability and no binding take place. The quantity of cement required to produce concretes was partially replaced with SCBA. The percentage replacements of SCBA with cement were 0%, 10%, 20% and 30%. The volume of water used for each cube was 210m1. The internal parts of the moulds were thinly oiled for easy removal of the concrete samples from the mould. The mould was filled with fresh concrete in three layers. First layer filling about one-third of the mould was tapped with a tamping rod 25 times before another layer was added. After the third layer was tapped the surfaces of the concrete was then smoothen with a hand trowel and allowed to be hardened before removal from the mould and cured in water. Forty eight (48) cubes were produced for 7, 14, 21 and 28 days curing age (i.e. 12 cubes per age). The quantity of cement required to produce concretes was partially replaced with SCBA in percentage.*

## RESULTS AND DISCUSSION

### Preparation of SCBA and Physical Tests on Aggregates

*In the preparation of SCBA, total weight of 34.7kg SCB was collected and incinerated in furnace yielded 5.512kg of SCBA. This was sieved through 425µm to remove black carbon and 4.82kg of SCBA was collected. The percentage of SCBA obtained from SCB was 15.9%. Total usable SCBA obtained passing through 45µm sieve was 2.7Kg (conforming with ASTM-C595, 1985).*

*The particle size distribution is the analysis of soil samples which involves the determination of the percentage by mass of particles within the different size ranges. The particle size distribution of a coarse and fine aggregates used was determined by the method of sieving. 1000g and 3000g of oven dried samples of fine and coarse aggregates respectively were passed through series of standard test sieves having successively smaller mesh sizes. The mass of sample retained in each sieve was determined and the cumulative percentage by mass passing each sieve was calculated. This was used in analyzing uniformity and gradation of samples. Particle size distribution curve of fine and coarse aggregates are shown in Figures 1 and 2.*

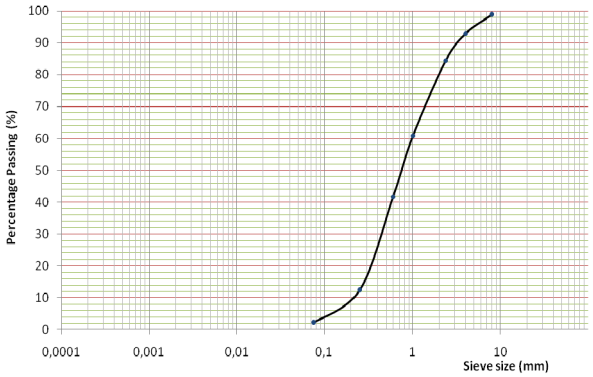


*Figure 1: Graph of percentage passing of fine aggregate Vs sieve size (mm)*

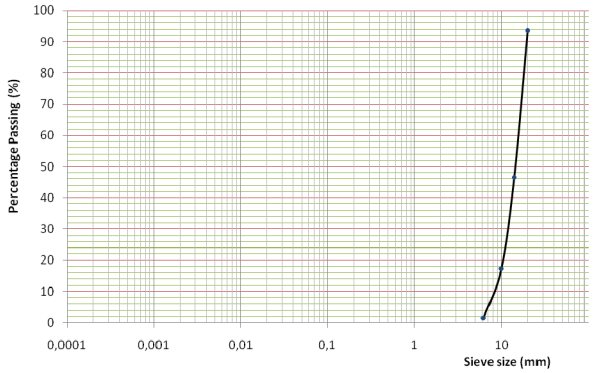


*Figure 2: Graph of percentage passing of coarse aggregate Vs sieve size (mm)*

*The effective size of particle size distribution (PSD) at 10% ($D_{10}$), 30% ($D_{30}$) and 60% ($D_{60}$) percentage passing are 0.22mm, 0.60mm and 1.50mm respectively for fine aggregates. Similarly, the effective size at 10% ($D_{10}$), 30% ($D_{30}$) and 60% ($D_{60}$) percentage passing are 8.20mm, 13.00mm and 17.00mm respectively for coarse aggregates. Coefficient of uniformity, $C_u$ and coefficient of curvature $C_c$ for fine and coarse aggregates were estimated to be 6.8 and 1.1, and 2.07 and 1.22 for fine and coarse aggregates respectively. These results revealed that the aggregates satisfied ASHTTO classification of Cu>4 and 1<Cc<3 for the aggregates.*

*The average specific gravities ($G_s$) of 2.43 and 2.77 were respectively obtained for fine and coarse aggregates through standard procedure of analysis. Also, the water absorption capacities of 20.3% and 1.9% were equally obtained.*

### Chemical Analysis Test on SCBA

*The chemical test to determine the percentage composition of compounds present in SCBA was carried out at the Department of Chemistry,*

University of Lagos, Lagos state, Nigeria. The method adopted was atomic absorption spectrometric method. The results are as shown in Table 1.

Table 1: Percentage Composition of Each Oxide of SCBA

| Oxides | % composition by mass |
|---|---|
| $SiO_2$ | 72.853 |
| $Fe_2O_3$ | 6.961 |
| $Al_2O_3$ | 1.077 |
| $PbO$ | ND |
| $Na_2O$ | 1.968 |
| $CaO$ | 9.968 |
| $MgO$ | 6.491 |
| $K_2O$ | 6.768 |
| $CuO$ | 0.096 |
| LOI | 4.233 |

The results of chemical analysis of SCBA in Table 1 and chemical component of OPC as stated by Nwofar and Sule (2010) showed that SCBA has a considerably high percentage of silicon oxide when compared to OPC. According to ASTM-595(1985), summation of silica, alumina and ferric components for pozzolanic materials must not less than 70% (ASTM, 1985). The results in Table 1 yielded 80.55% and thus SCBA is pozzolanic material.

The result of workability of concrete (slump test) for 0%, 10%, 20% and 30% replacement of SCBA are shown in the Figure 3. The effect of SCBA on the workability of the fresh paste decreases with increase in percentage of SCBA. This shows that SCBA absorbed more water than cement.

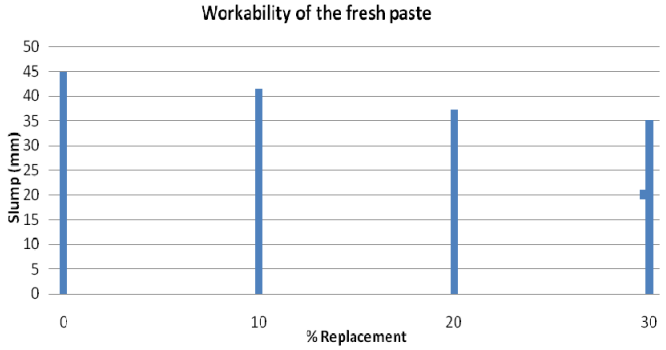


Figure 3: Graph of slump (mm) against % replacement

For different cubes of concrete produced with various percentage replacement of cement with SCBA, densities and compressive strengths were measured at different ages of curing and average computed. Figure 4 shows the variation of average density with % replacement. The results indicated that the average density decreases with increase in percentage replacement of SCBA with cement. The compressive strength of the concrete cubes for all the mix ratios increases with curing age and decreases as the SCBA content increases. The percentage reduction of compressive strength for 10%, 20% and 30% replacement of cement with SCBA compared with control are 16.8%, 25% and 35.5% respectively. Figure 5 shows the variation of compressive strength of hardened concrete with increase in percentage of SCBA. Figure 6 shows the variation of compressive strength N/mm² with curing ages. The compressive strength decreases with increase in SCBA while it increases with increase in curing age. Concrete made from OPC (0% ash) has higher compressive strength at 28 days of curing than concrete made by varying SCBA to cement content.

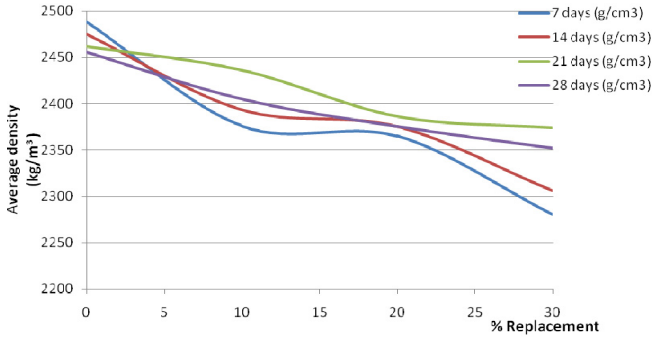


Figure 4: Variation of average density with % replacement

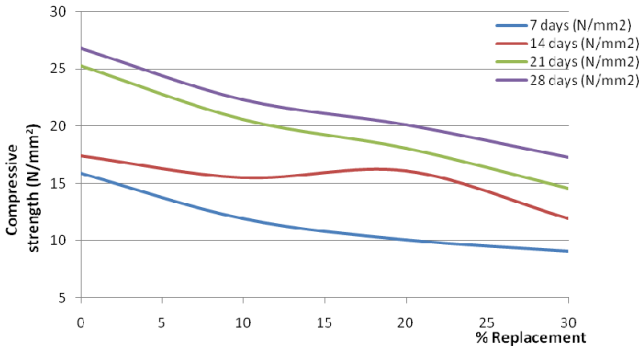


Figure 5: Variation of compressive strength N/mm² with % replacement of cement with SCBA

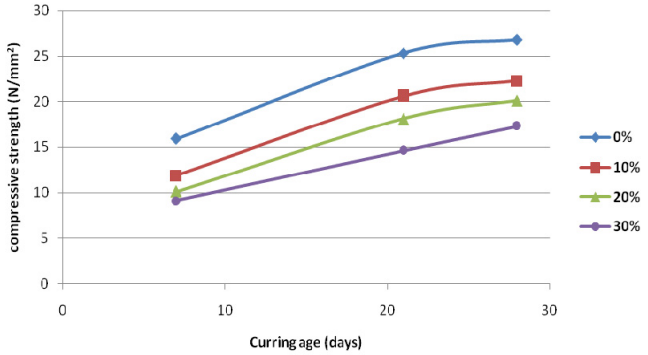


Figure 6: Variation of compressive strength N/mm² with curing ages

*The PAI of different percentage replacement of SCBA as expressed in ratio of compressive strength of different percentage replacement to that of control specimen (i.e. 0% SCBA replacement) were obtained to be 83.2%, 75% and 64.5% for 10%, 20% and 30% of SCBA replacement respectively. 10% and 20% replacement satisfied the ASTM C595–85 specification that the PAI with OPC should be of minimum of 75% PAI.*

## CONCLUSION AND RECOMMENDATIONS

### Conclusion

*Investigation of SCBA as partial replacement of cement in concrete production has been explored. The conclusions are as follows;*

*(i) The calculated target mean strength of 31.56N/mm² was not achieved. This may be as a result of some factors like mode of mixing (hand mixing), compaction and the reactivity of the SCBA.*

*(ii) For control, the compressive strength was 26.8N/mm². This can be used for plain and reinforced concrete with lightweight aggregate and reinforced concrete with normal aggregate.*

*(iii) 10% replacement of cement with SCBA yielded compressive strength of 22.3N/mm² and 83.2% of PAI; 20% replacement yielded 20.1N/mm² and 75% of PAI, and 30% replacement yielded the compressive strength of 17.3N/mm² and 64.5% of PAI. 10% and 20% replacement can be used for reinforced concrete with normal aggregates and 30% for reinforced concrete with lightweight aggregates.*

*(iv) The compressive strength of the concrete cubes for all the mix ratios increases with curing age and decreases as the SCBA content increases. The percentage reduction of compressive strength for 10%, 20% and 30% replacement of cement with SCBA compared with control are 16.8%, 25% and 35.5% respectively.*

*(v) From the density result, the SCBA concrete can be classified as normal weight concrete. The percentage reduction in density for 10%, 20% and 30% replacement of cement with SCBA are 2.7%, 6.7% and 8.47% respectively.*

*(vi) It was clearly shown that SCBA is a pozzolanic material that has the potential to be used as partial cement replacement material and can contribute to the environmental sustainability.*

### Recommendations

*SCBA is a pozzolana and can be recommended for use as partial replacement of cement in concrete production at a percentage up to 20%. For environmental sustainability, SCB can be utilized for the production of lightweight, durable and cheap concrete. Since it is available in significant quantities across the country*

### Acknowledgement

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### References

*[1.] Aigbodion, V. S, Hassan, S. B, Ause, T. and Nyior, G. B.: Potential Utilization of Solid Waste (Bagasse Ash), Journal of Minerals & Materials Characterization & Engineering, 9, pp. 67-77, 2010*

*[2.] Agboire, S., Wada, A. C. and Ishaq, M. N.: Evaluation and Characterization of Sugarcane Germplasm Accessions for their Breeding Values in Nigeria, The Journal for Food Technology in Africa, Vol. 7, No 1, pp. 33-35., 2002.*

*[3.] ASTM Standards, Concrete and Mineral Aggregates Section 4 Volume 04.01, cement, Lime, Gypsum and Section 4, Volume 04.02, USA, 1985.*

*[4.] Baguant, K.: Properties of Concrete with Bagasse Ash as Fine Aggregate, International Conference on Fly Ash, Silica Fume, Slag and Natural Pozzolans in Concrete,153 (18), pp. 315-337, 1995.*

*[5.] British Standard 12:112: Specifications for Aggregate Type, British Standard Institution, London, 1996.*

*[6.] British Standard 812: Methods of sampling and Testing of Mineral Aggregates, Sands and Fillers. British Standard Institution, London, 2002.*

*[7.] Cordeiro, G. C, Toledo R. D. and Fairbairn, E. M.: Ultrafine Sugarcane Bagasse Ash: High Potential Pozzolanic Material for Tropical Countries, IBRACON Structures and Materials Journal, 3: pp. 50-58, 2010.*

[8.] Ganesan K., Rajagopal, K. and Thangavel, K.: Evaluation of Bagasse Ash as Supplementary Cementitious Material, Cement & Concrete Composites. 29, pp. 515–524, 2007.
[9.] Ghavami, K., Toledo, R. D. and Barbosa, N. P.: Behavior of Composite Soil Reinforced with Natural Fibres. Cement and Concrete Composites, 1999.
[10.] Kajima (2012), Available at http//www.kajima.co.jp/ir/annual/2012/research-development.html
[11.] Megat, M. A., Brooks, J. J., Shahid, K. and Patrice R.: Influence of Supplementary Cementitious Materials on Engineering Properties of High Strength Concrete, Construction and Building Materials, 15: pp. 2639–2648, 2011.
[12.] Nwofar, I. C. and Sule, S.: Stability of Groundnut Shell Ash (GSA) with Ordinary Portland Cement (OPC) Concrete in Nigeria, 2010.
[13.] Oluremi, A. A.: Input of Local Materials in Building as a Means of Reducing Cost of Construction. Journal of Nigeria Institute of Quantities Surveyors, Nigeria, pp. 12 – 14, 1990
[14.] Sirirat, J. and Supaporn, W.: Pozzolanic Activity of Industrial Sugarcane Bagasse Ash, Journal of Science and Technology, 17: pp. 349-357, 2010.
[15.] Swamy, R. N.: Pozzolana - A Review, AC1 Journal USA Vol. 72 No 5, pp. 225 – 232, 1986.


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# EFFECT OF BIODIESEL ON FEW COMPONENTS OF FUEL INJECTION SYSTEM

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**Abstract:** Biodiesel is a renewable alternative fuel to the fossil diesel and is getting more popularity because of depletion of fossil fuels and their lower environmental pollution. When biodiesel is used as a substitute for the diesel in the internal combustion engines, it significantly increases the energy security and rural economy of the country and also helps to reduce the environmental pollution. However, there are concerns over the compatibility of biodiesel on the engine components due to its corrosive characteristics which can corrode the metallic components and degrade elastomer parts. Hence, the study of corrosion characteristics of biodiesel is important for long term durability of engine components. This paper discuss the production of biodiesel from Jatropha oil and the effects of Jatropha biodiesel on the fuel filter, gasket and fuel tubing of the fuel systems used in the diesel engine.
**Keywords:** Alternative fuel, biodiesel, corrosive characteristics, engine components

## INTRODUCTION

The economic growth of any country depends on the availability of the energy sources such as coal, petroleum and natural gas. The world is presently facing two major problems namely fossil fuel depletion and environmental degradation. Hence, it is necessary to find suitable renewable alternative fuel for better energy security and environmental protection. Among the available renewable alternative fuels, biodiesel is considered as a better substitute for the fossil diesel [1,2]. In recent years, India is a significant consumer of fossil fuels due to high economic growth rates and over 15% of the world's population. India does not have enough fossil fuels sources and hence imports crude petroleum oil from other countries to meet the local demand. However, Indian government encourages the use of biofuels produced from feedstocks available within the country as the substitute for the fossil fuels. In India's bio-fuel policy, ethanol and biodiesel derived from vegetable oils is being considered as substitute for the petroleum fuels because these bio-fuels can provide employment generation to rural people through plantation of vegetable oils and can be beneficial to sugarcane farmers through the ethanol program [3].

Jatropha curcas is a multipurpose, drought resistant, perennial plant belongs to Euphorbiaceae family. It grows in tropical and sub-tropical regions of the world and can be grown in low to high rainfall areas either in the farms as a commercial crop or on the boundaries as a hedge to protect fields from grazing animals and to prevent erosion. It has large green to pale-green leaves and can attain a height of upto eight or ten meters under favourable conditions. It starts yielding from the second year onwards and continues for 40 years [4,5].

Figure 1. a) Jatropha b) Jatropha Seeds

*Figure 1 shows the Jatropha and its seeds. In a combustion study of Jatropha oil, it is reported that the fatty acid burned in the first step and glycerol does in the second step [6]. The by-product of the oil extraction is seed cake which contains 24 to 28% protein on dry basis. It is reported that the seed cake protein showed most promising results on adhesive and emulsifying properties, which increase the value of the Jatropha.*

*Pere et al [7] studied the agronomic and economic viability and livelihood impacts of Jatropha curcas plantations on private farms in Tamil Nadu, India and they found that the crop impoverishes farmers, particularly the poorer and socially backward farmers. Simon et al [8] conducted a full life cycle assessment on Jatropha-based rural electrification and then compared with other electrification approaches such as photovoltaic, grid connection and a diesel-fuelled power generator. They reported that the Jatropha-based electrification reduces greenhouse gas emissions over the full life cycle by a factor of 7 compared to a diesel generator or grid connection.*

*Siddharth et al [9] reported that the Jatropha has potential for the production of biodiesel. Hence, in this work, biodiesel was produced from the Jatropha oil and studies were carried-out to study its effect on the engine components. If the acid value of the vegetable oil is high, then a two-step transesterfication is one of the ways of producing biodiesel from it [10,11]. The biodiesel produced from vegetable oil should satisfy the ASTM / EN Standards. It is reported in the literature that the engine performance with the biodiesel is similar to the diesel [12,13]. The properties of the biodiesel produced from different vegetable oils are shown in the Table 1.*

*Table 1. Properties of the biodiesel produced from different oils*

| Property | Honge Biodiesel [11] | Sunflower Biodiesel [12] | Cotton seed oil Biodiesel [13] |
|---|---|---|---|
| Kinematic viscosity ($mm^2/s$) (40 °C) | 4.33 | 4.439 | 6.0 |
| Acid Value (mg KOH/g-oil) | 0.23 | -- | -- |
| Density ($kg/m^3$) | -- | -- | 850 |
| Flash point (°C) | 174 | 183 | -- |
| Cold filter plugging point (°C) | -- | -3 | -- |
| Cloud point (°C) | -- | 3.4 | -2 |

*From the literature review, it is observed that the no work has been carried out to study the effect of biodiesel on engine fuel system components such as fuel filter, fuel gasket and fuel lining tube and hence, this work was carriedout.*

## OBJECTIVES

*The objective of this research work was to produce biodiesel from Jatropha oil and to study the effect of Jatropha biodiesel on the fuel injection components such as fuel filter, fuel gasket and fuel lining tube. Also, the variation in the important properties of the biodiesel during the storage period was studied. In addition, a review work was carried-out and to provide details of effect of biodiesel on the engine components.*

## MATERIALS AND METHODS

*The Jatropha oil was collected from university of agricultural sciences, Bangalore, India. This oil was filtered and refined and used for the production of biodiesel. The acid value of the Jatropha oil was 1.3 mg of KOH/ g of oil, and hence a single step transesterification reaction was followed to produce the biodiesel. Alkaline catalyst, potassium hydroxide was used as catalyst. Compared to other alcohols, methanol is cheaper and has better physical and chemical advantages (polar and shortest chain alcohol) and was used as the reactant. The potassium hydroxide and methanol were purchased from Merck Company, India. All the chemicals used for the transesterification were of analytical reagent grade.*

## BIODIESEL PRODUCTION

*In this work, biodiesel was prepared from the non-edible jatropha oil using 25 lt capacity biodiesel plant. The Jatropha oil was filtered and refined. The sodium hydroxide pellets (1% wt of the oil) were added to the vessel containing methanol (25% wt of the oil) and mixed thoroughly until a homogenous mixture was produced. After that this homogenous mixture was added to the reactor vessel containing the Jatropha oil. An electrical heater and a mechanical stirrer provided in the reactor vessel was switched-on and the reaction temperature was maintained between 55 to 60°C, below the boiling point of the methanol and the stirrer speed was maintained at 200 rpm. The reaction was carriedout for two hour and the sample was taken to check for the phase separation.*

*After the confirmation of phase separation, the products of transesterification were heated above 70°C, to remove the excess methanol and then products were transferred to the settling tank. Then the products were allowed to settle for 8 hour and two layers were observed. The top layer containing biodiesel was removed and the washed with warm distilled water to remove the soap, catalyst etc. Figure 2 shows the biodiesel plant. The biodiesel properties were determined as per ASTM standards*

*Figure 2. Biodiesel plant*

## STATIC IMMERSION STUDY

*A few automobile manufacturers extended their warranty only to lower blends of biodiesel (e.g. B5). But the higher blends (e.g. B50 or B100) are still not covered by warranty. In India's biofuels policy, Jatropha biodiesel is considered as an alternative substitute for the diesel. But many researches on Jatropha biodiesel have concerned the engine gas emissions and engine performances and not any significant work has been carriedout to study the effect of Jatropha biodiesel on the engine fuel injection components such as fuel filter, gasket and fuel tubing. Hence, this work has been carried out to study the effect of Jatropha biodiesel on the engine components by static immersion study and also to study the variation in the fuel property during long storage period. In static immersion study, the engine fuel filter, gasket and fuel rubber tubing were immersed in the fuel samples kept in the 500 ml beakers. The beaker top end was closed with the aluminum foil and the arrangements were shown in the Figure 3. The static immersion study was carriedout for the 12 month.*


*Figure 3. Fuel injection components in the biodiesel*

## RESULTS AND DISCUSSION

*The biodiesel yield obtained by the biodiesel plant was 89.2%. The properties of the biodiesel were determined as per the ASTM standards. Table 2 shows the properties of the biodiesel and diesel.*

*Table 2. Properties of the Jatropha biodiesel and diesel*

| Property | Jatropha Biodiesel | Diesel |
|---|---|---|
| Kinematic viscosity ($mm^2/s$) (40 °C) | 4.1 | 2.8 |
| Acid Value (mg KOH/g-oil) | 0.39 | 0.08 |
| Density ($kg/m^3$) | 0.88 | 0.84 |
| Flash point (°C) | 164 | 61 |
| Calorific value (MJ/kg) | 36.8 | 42.8 |
| Ash Content (%) | 0.01 | 0.01 |
| Copper Corrosion, 3hr/50°C | 1 | 1 |
| Pour point (°C) | 6 | -19 |

*From the Table 2, it is observed that the acid value, kinematic viscosity, flash point, pour point and density of the biodiesel are higher than the diesel. But the calorific value is lower than the diesel due to presence oxygen in its molecular structure. The ash content and copper corrosion values are remains same for both biodiesel and diesel. If any variation in the property of the fuel, then it may significantly affects the engine components.*

*The static immersion studies were carriedout for one year and after that the variation in the properties of the biodiesel were determined and is shown in Table 3. From the table, it is observed that the properties of the biodiesel vary significantly during the storage period.*

*Table 3 Properties of the biodiesel after one year storage study*

| Property | Jatropha biodiesel | Stored Jatropha Biodiesel |
|---|---|---|
| Viscosity ($mm^2/s$ at 40°C) | 4.1 | 5.3 |
| Acid Value (mg KOH/g) | 0.39 | 0.68 |
| Iodine Value (g $I_2$/100 g) | 124 | 116 |

*From the table, it is observed that the important properties of the biodiesel such as viscosity, acid value and iodine value varies significantly during the storage period. The increase in acid value of the biodiesel increase corrosive nature of the biodiesel. The increase in the viscosity value of the biodiesel significantly affects the fuel atomization, spray formation and combustion.*

## *EFFECT OF BIODIESEL ON ENGINE COMPONENTS*

*The engine fuel injection components such as fuel filter, gasket and fuel lining tube were taken out from the beakers containing biodiesel (B100), B5 and diesel. These components were observed for the corrosion and sediment deposition. The size of the fuel filter was enlarged during the storage period as compared to the B5 and diesel. Figure 4 compares the fuel filter which was kept in the B5 and B100 samples. A thin layer of deposition was observed at the metal holder of the fuel filter which was kept in the Jatropha Biodiesel (B100) sample. The deposition in the fuel filter holder was removed and is shown in the Figure 5. Figure 6 shows the microscopic image of this deposition. This is due to the autooxidation, hygroscopic nature, polarity, higher unsaturated components and solvency properties of the Jatropha biodiesel. It also causes degradation elastomers. The metal holder exposed to B5 and diesel does not have any deposition. Hence, B5 use will not affect the fuel components which are used in the diesel engine components. If Jatropha Biodiesel (B100) is used as fuel in the diesel engine, then it will affect the fuel injection components which may leads to clogging of the injection pumps and filters, poor engine performance and early replacement of few fuel injection components.*


*Figure 4. Fuel filters which were kept in the B100 and B5*

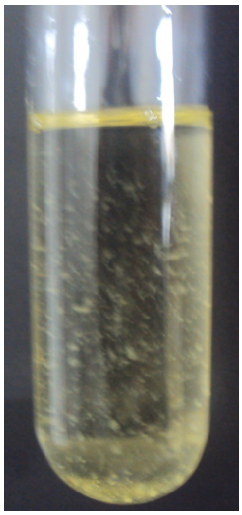

*Figure 5. Deposition on the holder of the fuel filter*

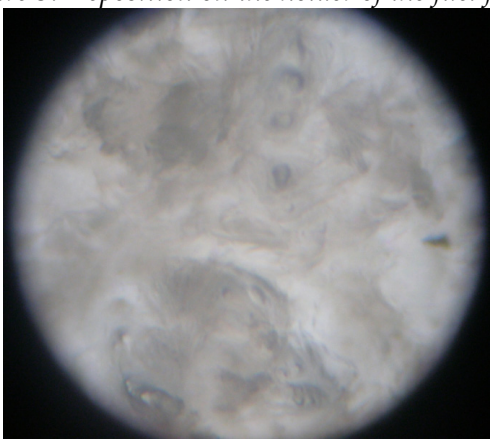

*Figure 6. Microscopic View of the Deposition*

## *REVIEW OF LITERATURE ABOUT BIODIESEL OXIDATION*

*The fuel properties of the brassica carinata biodiesel such as acid value, peroxide value and viscosity increases with the increase in storage period. However, the iodine value decreases with the increase in storage time [14]. María et al [15] reported that the fuel properties can be strongly affected if the biodiesel has been improperly stored or transported. The biodiesel quality is harmed by the oxidation products, which are corrosive to engine chambers. The oxidized biodiesel significantly affect the exhaust emissions such as CO and HC and there is no significant difference in smoke and NOx emissions of the oxidized and unoxidized biodiesel [16].*

*Amit et al [17] observed that small concentrations of metal contaminants showed nearly same influence on oxidation stability as large amounts. They reported that the copper has strongest detrimental and catalytic effect on biodiesel oxidation.*

*Agarwal et al. [18] studied the effect of 20 percent linseed oil methyl ester blend and diesel oil on the engine wear. They reported that the physical wear of various vital parts, injector coking, carbon deposits on piston and ring sticking were found to be substantially lower in case of B20 blend as compared to the diesel. From the atomic absorption spectroscopy tests they confirmed substantially lower engine wear and concluded that the B20 blend improves the life of biodiesel operated engines. Few researchers reported that the biodiesel significantly affect the components of an engine [19,20] as metallic materials of an automobile fuel system, like ferrous alloy and non-ferrous alloys and elastomers come in contact with fuel.*

*Fazal et al. [21] compared the corrosion behavior of aluminum, copper and stainless steel in both petroleum diesel and palm biodiesel by immersion tests in biodiesel (B100) and diesel (B0) at 80 °C for 1200 h. Their results show that the extent of corrosion and change in fuel properties upon exposure to metals are more in biodiesel than that in diesel. Copper and aluminum were susceptible to attack by biodiesel whereas stainless steel was not. Fazal et al [22] study aims to investigate the corrosion behavior of mild steel at three different temperatures such as room temperature, 50 and 80 °C. They carriedout static immersion tests in B0 (diesel), B50 (50% biodiesel in diesel), B100 (biodiesel) were carried out for 1200 h. Their results showed that the corrosion of mild steel increases with increase of temperature. They also observed that the water content and oxidation products are increased when exposure of biodiesel to mild steel at high temperature.*

*Fazal et al [23] reported that biodiesel from different origins is always seen to provide better lubricity than that of diesel fuel. However, in long term test it loses its lubricity due to its corrosive and oxidative nature.*

*Savita [24] studied the synthesis and characterization of biodiesel from non-edible oils like pongamia glabra, madhuca indica and salvadora oleoides and carriedout long duration static immersion test method corrosion studies on engine parts like piston metal and piston liner with neat diesel and biodiesel synthesized from these non-edible oils. From their study, they observed that the salvadora biodiesel showed significant corrosion on both metal parts of diesel engine whereas biodiesel from other oils showed little or/no corrosion as compared to neat diesel.*

## *CONCLUSION*

*From this work, it is concluded that the properties of the Jatropha biodiesel vary significantly during the long storage period. Also the Jatropha biodiesel significantly affects the filter and filter holder material as compared to the B5 and diesel. Hence, it is recommended to use B5 blend as compared to the B100, as it may damage the fuel injection system. From literature review, it is observed that the corrosive chemical characteristics of the biodiesel may cause corrosive and tribological attack on metallic components and degrade elastomer parts of the internal combustion engine components. Hence, it is recommended to use B5 blend instead of using higher blends and B100.*

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***References***

*[1.] A. Demirbas, Present and Future Transportation Fuels, Energy Sources, Part A, Volume 30, 2008, pp 1473–1483.*

*[2.] Ayhan Demirbas, Progress and recent trends in biodiesel fuels, Energy Conversion and Management, Volume 50, Issue 1, 2009, pp.14-34.*

*[3.] Report of the committee on the development of bio-fuel, Planning Commission, Government of India, 2003.*

*[4.] http://en.wikipedia.org/wiki/Jatropha (browsed on June, 15, 2010).*

*[5.] http://www.svlele.com/fattyacids.htm (browsed on June, 15, 2010).*

*[6.] I.N.G. Wardana, Combustion characteristics of jatropha oil droplet at various oil temperatures, Fuel, Volume 89, Issue 3, March 2010, Pages 659-664*

*[7.] Pere Ariza-Montobbio, Sharachchandra Lele, Jatropha plantations for biodiesel in Tamil Nadu, India: Viability, livelihood trade-offs, and latent conflict, Ecological Economics, 70(2), 2010, pp 189-195.*

*[8.] Simon Michael Gmünder, Rainer Zah, Somnath Bhatacharjee, Mischa Classen, Prodyut Mukherjee, Rolf Widmer, Life cycle assessment of village electrification based on straight jatropha oil in*

*Chhattisgarh, India, Biomass and Bioenergy, 34(3), 2010, pp347-355.*

*[9.] Siddharth Jain, M.P. Sharma, Prospects of biodiesel from Jatropha in India: A review, Renewable and Sustainable Energy Reviews, 14(2), 2010, pp 763-771.*

*[10.] Houfang Lu, Yingying Liu, Hui Zhou, Ying Yang, Mingyan Chen, Bin Liang, Production of biodiesel from Jatropha curcas L. oil, Computers and Chemical Engineering, 33 (2009) 1091–1096.*

*[11.] Malaya Naik, L.C. Meher, S.N. Naik, L.M. Das, Production of biodiesel from high free fatty acid Karanja (Pongamia pinnata) oil, Biomass and Bioenergy, 32 ( 2008 ) 354 – 357*

*[12.] Aninidita Karmakar, Subrata Karmakar, Souti Mukherjee, Properties of various plants and animals feedstocks for biodiesel production, Bioresource Technology 101 (2010) 7201–7210*

*[13.] Md. Nurun Nabi, Md. Mustafizur Rahman, Md. Shamim Akhter, Biodiesel from cotton seed oil and its effect on engine performance and exhaust emissions, Applied Thermal Engineering, 29 (2009) 2265–2270.*

*[14.] Abderrahim Bouaid, Mercedes Martinez, Jose Aracil, (2009). Production of biodiesel from bioethanol and Brassica carinata oil: Oxidation stability study, Journal of Bioresource Technology, 100 (7), 2234-2239.*

*[15.] María Jesús Ramos, Carmen María Fernández, Abraham Casas, Lourdes Rodríguez, Ángel Pérez, Influence of fatty acid composition of raw materials on biodiesel properties, (2009). Journal of Bioresource Technology, 100(1), 261-268.*

*[16.] Abdul Monyem, Jon H. Van Gerpen, (2001). The effect of biodiesel oxidation on engine performance and emissions, Journal of Biomass and Bioenergy, 20(4), 317-325.*

*[17.] Amit Sarin, Rajneesh Arora, N.P. Singh, Meeta Sharma, R.K. Malhotra, Influence of metal contaminants on oxidation stability of Jatropha biodiesel, Energy, 34(9), 2009, pp 1271-1275.*

*[18.] A. K. Agarwal, J. Bijwe, L. M. Das, Effect of Biodiesel Utilization of Wear of Vital Parts in Compression Ignition Engine, J. Eng. Gas Turbines Power, 2003, 125(2), 604-612.*

*[19.] Ismet Celik, Cem Sensogut, Nuri Ceylan, The effects of biodiesel usage on the components of an engine, International Journal of Global Energy Issues 2008 – 29(3), pp. 303 – 313.*

*[20.] A.S.M.A. Haseeb, M.A. Fazal, M.I. Jahirul, H.H. Masjuki, Compatibility of automotive materials in biodiesel: A review , Fuel, 90(3), 2011, pp 922-931.*

*[21.] M.A. Fazal, A.S.M.A. Haseeb, H.H. Masjuki, Comparative corrosive characteristics of petroleum diesel and palm biodiesel for automotive materials, Fuel Processing Technology, 91(10), 2010, pp 1308-1315.*

*[22.] M.A. Fazal, A.S.M.A. Haseeb, H.H. Masjuki, Effect of temperature on the corrosion behavior of mild steel upon exposure to palm biodiesel, Energy, 36(5), 2011, pp 3328-3334.*

*[23.] M.A. Fazal, A.S.M.A. Haseeb, H.H. Masjuki, Biodiesel feasibility study: An evaluation of material compatibility; performance; emission and engine durability, Renewable and Sustainable Energy Reviews, 15 (2), 2011, pp 1314-1324.*

*[24.] Savita Kaul, R.C. Saxena, Ajay Kumar, M.S. Negi, A.K. Bhatnagar, H.B. Goyal, A.K. Gupta, Corrosion behavior of biodiesel from seed oils of Indian origin on diesel engine parts , Fuel Processing Technology, 88(3), 2007, pp 303-307.*


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# MODELLING OF MANUFACTURING SYSTEMS BY RAPID PROTOTYPING TECHNOLOGY APPLICATION

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***Abstract:*** *Technologies of Rapid Prototyping (RP) represents the rapid production of 3D physical parts using by additive manufacturing technology. The start these techniques became available in the late 1980s and were used to produce 3D models and prototype parts. Today they are used for a much wider range of applications and are even used to manufacture production-quality parts in relatively small numbers. Rapid Prototyping is widely used in the automotive, aerospace, medical, and consumer products industries. In paper is presented application of Fused Deposition Modelling rapid prototyping technology for realization of models of manufacturing systems components represent by industrial robot.*

***Keywords:*** *modelling, manufacturing systems, rapid prototyping*

## INTRODUCTION

*Technology of Rapid Prototyping (RP) represents new type of manufacturing technology that is used for production of the rapid building of physical objects using additive principle. Beginnings of Rapid Prototyping technology are dated in the late 1980's when Stereolithography technology was defined as a method and device was built for making solid objects by successive "printing" of thin layers of the ultraviolet curable material one on top of the other, what led to production of models and prototype parts. In 1986 the first company was founded which generalized and commercialized such procedure, 3D Systems Inc. Today, there is much wider range of Rapid Prototyping methods that are used to manufacture the models, parts or final products. Before application of Rapid Prototyping technology operator must to handle the models of future parts while using Computer Aided Design (CAD) systems, then to transform them into STL format that is further used in Rapid Prototyping devices for parts production [1].*

*There are a multitude of experimental Rapid Prototyping methods either in development or used by small groups of individuals. This paper is focused on application of Rapid Prototyping technique that is currently commercially available, Fused Deposition Modelling (FDM) technique.*

## DESCRIPTION OF FUSED DEPOSITION MODELLING METHOD

*Fused Deposition Modelling (FDM) was developed by Stratasys in Eden Prairie, Minnesota. In this process, a plastic or wax material is extruded through a nozzle that traces the part's cross sectional geometry layer by layer. The build material is usually supplied in filament form, but some setups utilize plastic pellets fed from a hopper instead. The nozzle contains resistive heaters that keep the plastic at a temperature just above its melting point so that it flows easily through the nozzle and forms the layer. The plastic hardens immediately after flowing from the nozzle and bonds to the layer below. Once a layer is built, the platform lowers, and the extrusion nozzle deposits another layer. The layer thickness and vertical dimensional accuracy is determined by the extruder die diameter, which ranges from 0.013 to 0.005 inches. In the X-Y plane, 0.001 inch resolution is achievable. A range of materials are available including ABS, polyamide, polycarbonate, polyethylene, polypropylene, and investment casting wax [1].*

*For better orientation of user in process of setting of suitable parameters during the preparation of printing there was algorithm elaborated which accumulates all factors and steps that lead to selection of most suitable variant. All the attempts were realized as a part of preparation stage for*

printing on UPrint machine that utilize FDM technology to build the prototype. This technology, developed by Stratasys, uses the software program to orient the model and generate building slices. Printer dispenses with basic building material and support material. Each material has its own nozzle. Creation of particular prototype layers with use FDM method is shown in Figure 1.

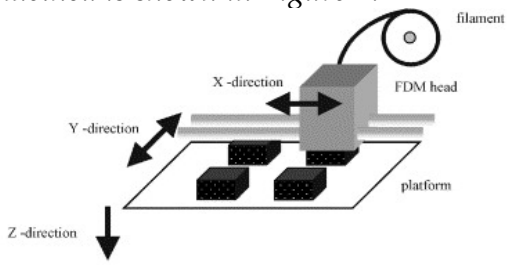


Figure 1. Principle of Fused Deposition modelling method

## INDUSTRIAL ROBOT IRB 140 FOR APPLICATION IN MANUFACTURING SYSTEMS

Industrial robot IRB 140 from ABB Company (Figure 2) is compact and powerful device. It disposes with six motion axis and belongs to the class of small robots. Producer makes only one smaller 6-axial model than IRB 140 which is IRB 120. It can handle relatively high weight and considering it dimensions it has also a good reach (up to 810 mm). IRB 140 was introduced to the market in 1999 as a robot with high average period of failure-free operation (MTBF), low demands for maintenance and short reparation times. The speed which can be reached makes it the fastest in its category. When using IRB 140T, the cycles periods are significantly shorter thanks to the maximum approach speed and acceleration option together with the motion control - Quick Move from ABB. Movements according to trajectories are executed with high accuracy. Repeated returns to the given positions can be realized also accurate (± 0.03 mm). Robot can manipulate with objects up to 6 kg of weight.

Final part of robotic arm can turn around six axis of rotation and the controller allows the connection with other additive devices with possibility to control another 6 axis. Turning around the axis is realized thanks to the servomotors, which can execute also other types of motions. In combination of servomotor with gearing and gear track it is possible to create the control of linear motion. Such a connection can be used for track motion systems, while having this device programmed and controlled with use of single controller [2].

Compact dimensions of robotic arm IRB 140 can present its main advantage in some applications. On the other hand, rather low load capacity and small range can limit the possibilities of its use in some cases. Most typical application areas of this robotic device are: welding and linking, assembly, cutting and finishing, die casting, bonding and batching, injection of plastics, manipulation tasks, removing and packaging.


Figure 2. Industrial robot ABB IRB 140

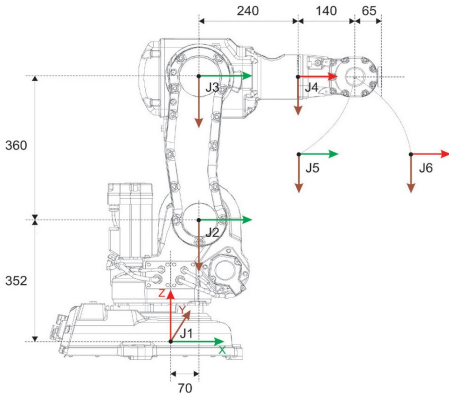


Figure 3. IRB140 - dimensions and degrees of freedom

## PRODUCTION OF INDUSTRIAL ROBOT MODEL BY FUSED DEPOSITION MODELLING APPLICATION

Rapid Prototyping methods are one of methods that uses special computer format STL (also called STereoLitography). From historical point of view it is the work of developers who establish this format as output data form obtained after digitalization with 3D scanner. Polygon surfaces also known as facets represents areas for volume description. Model in STL format created in some three dimensional CAD software has surface constituted from number of triangles. Number and size of triangles defines the preciseness of curvature of particular model surfaces. STL format can be used in two different forms: ASCII and binary form.

*Size and number of triangles defines the preciseness of curvature of surfaces [3].*

*Currently in industrial practice there is huge number of CAD software that allows constructors and designers to design the product models according to their ideas that are used with addition of third dimension. Nowadays all CAD software products provide functions and tools necessary for export of created models in STL format that is further used in Rapid Prototyping process. User of 3D technology can change spatial orientation according to his requirements. They should be based on functionality and corresponding quality of complicated surfaces (complex surfaces, planar surfaces under angle, cavities, holes) and also on expected proportion of used basic and support material with focus on economical matters. In most cases automatic mode can be chosen for definition of model position but in that case it is barely justified or explained on the base of functionality of some part surfaces. Next parameter that is important from the viewpoint of final quality and price is definition of thickness of single printed layer. With this parameter there is also related style of model and support material addition as two basic building substances used for prototype production. Material can be build as one unit or particular layers can be printed in grid with lower density what reduces the printing price. Factor of input data quality, factor of suitable software and physical part orientation and factor of relevant density and building layers style are most problematic aspects in process of realization of rapid prototyping technology [3].*

*For better orientation of user in process of setting of suitable parameters during the preparation of printing there was algorithm elaborated which accumulates all factors and steps that lead to selection of most suitable variant. All the attempts were realized as a part of preparation stage for printing on UPrint machine that utilize FDM technology to build the prototype. This technology, developed by Stratasys, uses the software program to orient the model and generate building slices. Printer dispenses with basic building material and support material which is used if necessary for creation of holes, cavities, drafts, etc. Each material has its own nozzle.*

*Fused Deposition Modelling is very often in practice used RP process that provides parts mainly from ABS plastic. FDM produces the quality parts in Acrylonitrile Butadiene Styrene (ABS) which is a common end-use industrial material allowed to perform operational tests on produced parts. Real production thermoplastics are stable and have no appreciable warpage, shrinkage, or moisture absorption, like the resins in competitive processes.*

*To prototype successfully, first select an appropriate rapid prototyping tool. There are hundreds of rapid prototyping tools available. They range from simple graphics packages that allow you to draw screens to complex systems that allow you to create animation. Each tool is better for some functions than for others. Although several rapid prototyping techniques exist, all employ the same basic five-step process. The steps are [4]:*

*1. Creation of CAD models of the product parts.*
*2. Conversion of CAD models into STL formats.*
*3. Use of STL files in Rapid Prototyping devices.*
*4. Production of the parts by one layer atop another.*
*5. Cleaning of parts and assembly of the product.*

*Model of industrial robot IRB 140 was created and subsequently modified in CAD/CAM/CAE system Pro/Engineer. Transfer of models between Pro/Engineer and another CA systems was implemented using the exchange format IGES where they were treated. On Figure 4 is example of CAD model of industrial robot in Pro/Engineer. On the start of the production process are generated STL data in the Pro/Engineer system and these STL data are next loaded to the Catalyst program for layered rendering of the model (Figure 5).*

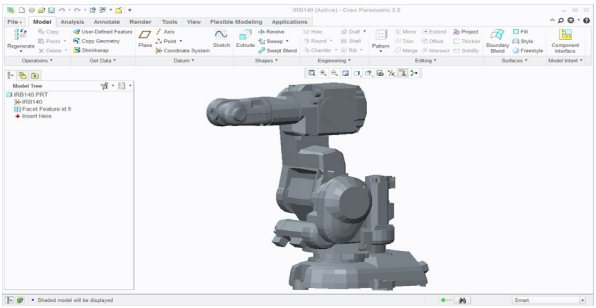

*Figure 4. Model of the robot in CAD system*

*For RP methods there are specific production devices (3D printers) that use their own software based on principle of reading and processing of*

*input STL data. In spite of different manufacturers, such programs have the same characteristic features: settings for single layer resolution, settings for density of model material, settings for density of support material, STL processing to layer mode.*

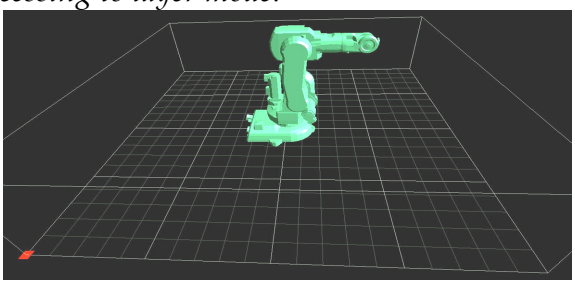

*Figure 5. Model in Catalyst software*

*All these software solutions allow their user to change large number of different settings. Changes are made by user himself. Programs for preparation of FDM production make many actions easier and more automatic, but deciding process about particular parameters is still up to user. In case of using the automatic mode these decisions are made by program without explanation, so there is space for optimization of setting contrary to user criteria. Solution could be realized in implementation of deciding steps or automatic decision with actual information about reasons running on background, eventually together with information about parts already produced. Higher parameters of quality mean longer printing times and higher energy consumption, but utilization possibility of such models is much higher as they can be used instead of real functional parts. On Figure 6 is view of workplace of 3D FDM printer UPrint with printed part [5].*

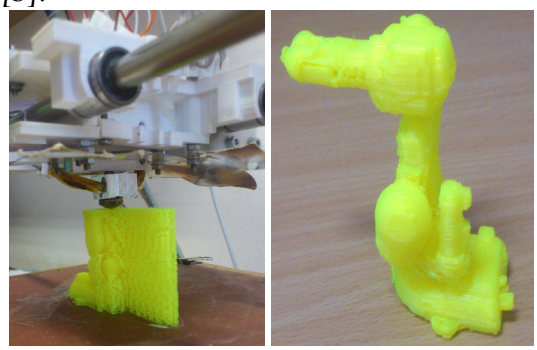

*Figure 4. Printed model of industrial robot IRB 140 by FDM method*

## CONCLUSION

*In industrial practice there are currently more than 20 vendors for RP systems, the method employed by each vendor can be generally classified into the following categories: photo-curing, cutting and glueing/joining, melting and solidifying/fusing and joining/binding. Photo-curing can be further divided into categories of single laser beam, double laser beams and masked lamp. The initial state of material in Rapid Prototyping technologies can come in either solid, liquid or powder state. In solid state, it can come in various forms such as pellets, wire or laminates. The current range materials include paper, nylon, wax, resins, metals and ceramics. Most of the RP parts are finished or touched up before they are used for their intended applications. Applications can be grouped into design engineering, analysis and planning and tooling and manufacturing. A wide range of industries can benefit from RP and these include automotive, aerospace, biomedical, consumer, electrical and electronic products.*

## References

[1.] *C. K. Chua, K. F Leong, C. S. Lim, Rapid Prototyping: Principles and Applications. World Scientific Publishing, Singapore, 2004.*

[2.] *ABB IRBT X004, Data sheet. Available on: http://www.abb.sk/product/seitp327/569910ed39487cb6c12574360040afa9.aspx?productLanguage=sk&country=SK.*

[3.] *J. Novak-Marcincin, J. Barna, L. Novakova-Marcincinova, V. Fecova, Analyses and Solutions on Technical and Economical Aspects of Rapid Prototyping Technology. Tehnicki vjesnik, Vol. 18, No. 4, 2011, pp. 657-661, ISSN 1330-3651.*

[4.] *J. Novak-Marcincin, L. Novakova-Marcincinova, J. Barna and M. Janak: Application of FDM rapid prototyping technology in experimental gearbox development process. Tehnicki Vjesnik, Vol. 19, No. 3, 2012, p. 689-694, ISSN 1330-3651.*

[5.] *J. Novak-Marcincin, M. Janak and L. Novakova-Marcincinova: Increasing of product quality produced by rapid prototyping technology. Manufacturing Technology, Vol. 12, No. 12, 2012, p. 71-75, ISSN 1213-2489.*

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# GREEN TECHNOLOGIES FOR SUSTAINABLE BUILDING

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**Abstract:** *Nowadays, there are so much pollution and problem to the earth which make the human realize to work on something in order to save the world holistically.. Meeting made by United Nation (UN) to take this issue as a main agenda is being use by all country around the world. It might take a long time to make sure the process of agenda being using around the world. Green Building Index (GBI) indicator and Agenda 21 for sustainable development have been introduced to decrease the effect of pollution during the development and surrounding. Since the industrial Revolution, the world has witnessed incalculable technological achievements, population growth, and corresponding increases in resource use. We are recognizing the side effects of human activities like population landfills at capacity, toxic waste, global warming, resource and ozone depletion, and deforestation. These efforts are straining the limits of the Earth's carrying capacity and its ability to provide the resources and required to sustain life while retaining the capacity to generate and remain viable. As the world's population continues to expand around the world, the implementation of resource-efficient measures in all areas of human activity is imperative and the build environment is one clear example of the impact of human activity on resources. Buildings have a significant impact on the environment, accounting for one-sixth of the world's freshwater withdrawals, one-quarter of its wood harvest and energy flow.*
**Keywords:** *green technology, green building, sustainable development, global warming*

## INTRODUCTION

*Green technology is a technology whose use is intended to mitigate or reverse the effects of human activity on the environment. Green Technology is the development and application of products, equipment and systems used to conserve the natural environment and resources, which minimizes and reduces the negative impact of human activities.*

*The green technology definition explained here basically gives you an idea about the messing up of the environment due to human intrusion and the important need to slow down and adopting healthier ways towards life. By adopting green technology wisely, the earth can be protected against environmental pollution (Ahmad and Abughres, 1985).*

*Green Technology is the development and application of products, equipment and systems used to conserve the natural environment and resources, which reduce the negative impact of human activities. It is believed to overcome environmental degradation and natural resources, improve health and lives, protect ecosystems, costs to the government in its efforts to migrate the impact of development and serve as an alternative in order to boost the economy. There are some criteria of the green technology (Carpenter, 1994):*

i. *Minimizes the degradation of the environment*
ii. *Zero or low green house gas emission to the surrounding.*
iii. *Safe for use and promotes healthy and improved environment for all forms of life.*
iv. *Conserves the use of energy and natural resources*
v. *Promote the use of renewable resources or energy like solar energy and rainwater)*

*The green technology nowadays is use not only save the cost for long term, but also friendly to the earth and renewable energy that being less maintenance. There are examples of the green technology:*

1) *Solar panel or solar tube- Solar panel and solar tube is using to decrease using an electricity supply by TNB and it also save the cost for the long term.*
2) *Natural Ventilation-Nowadays, air-conditioning is most famous useful for ventilation. However, the cost for the electricity is expensive. By using natural ventilation, it can decrease the electricity cost (Ahmad and Abughres, 1985)..*
3) *Rainwater Harvesting-This is an old technology but not practice by all designer and people. Rainwater can be used for daily purpose. However, It need a some system to make sure the water is clean.*

## *TECHNOLOGIES FOR SUSTAINABLE BUILDING*

*In order to discuss the technologies for sustainable building, it will be discussed on the following main areas:*

*i. Energy*
*ii. Water Technology*
*iii. Natural Lighting*
*iv. Natural Ventilation*

### *Energy*

#### ✓ *Passive Solar*

*In passive solar building design, windows, walls, and floors are made to collect, store, and distribute solar energy in the form of heat in the winter and reject solar heat in the summer. This is called passive solar design or climatic design because, unlike active solar heating systems, it doesn't involve the use of mechanical and electrical devices. The key to designing a passive solar building is to best take advantage of the local climate. Elements to be considered include window placement and glazing type, thermal insulation, thermal mass, and shading. Passive solar building design not only suitable in tropical country but also four seasons country since it is based on the building design not the climate. For example its stressed more on the openings like the degree window (Labs, 1988).*

*Figure 1 shows how the opening can have a direct lighting into the building. It does not use any technology, its by playing around with the windows door and louvers. It not only for lighting it also suitable for ventilation.*

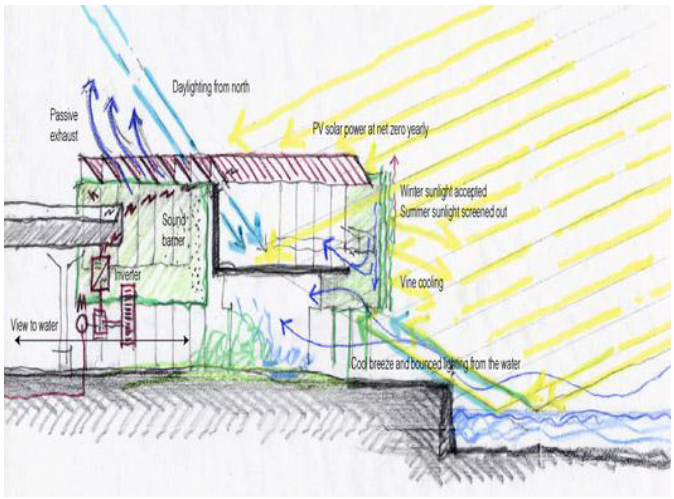


*Figure 1. Function of opening to direct natural lighting into the building*

#### ✓ *Heat Pumps*

*Heat pumps use the time proven refrigeration cycle to transfer heat from a source such as the ground, the ambient air or water through a heat distribution circuit to an internal space. A working fluid (or refrigerant) is driven around a circuit, comprising an evaporator, compressor , condenser and an expansion valve. The heat source transfers heat to liquid refrigerant, which causes it to evaporate. The refrigerant is now at a low temperature and pressure it then enters the compressor where the temperature and pressure are increased, as a result of work done by the compressor (Golany, 1983).*

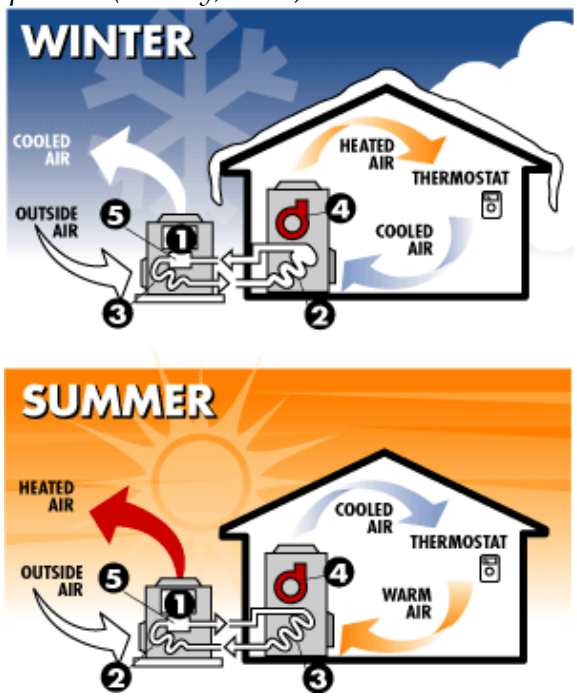


*Figure 2. Heat Pump mode of operation during winter and summer*

*The refrigerant gas enters the condenser, where the heat absorbed by the refrigerant in the evaporator, is released to be used in the building, via low a low temperature distribution system, such as underfloor heating or low temperature radiators. The refrigerant, which is still in the form of a gas but reduced in pressure and temperature, is throttled back further in the expansion valve before the cycle starts again (Ahmad and Abughres, 1985).*

*Heat pumps will consume electricity, since it is requires by the compressor. However, for every one units of heat energy is produced. The total amount of heat energy delivered to the building is equal to the energy input through the compressor, plus the energy extracted from the heat source.*

*Figure 2 shows how heat pumps works. During summer time it will pumps cooled air into the house while during winter it will pump hot air into the house to heat the house. Usually heat pumps is used at 4 season country since they will faced high temperature during summer and low temperature during winter (Golany, 1983).*

✓ ***Solar Energy***

*Solar photovoltaic cells (PVs) offer a clean way to produce electricity for use in our buildings. whilst a solar cell will produce the largest amount of power on a clear, bright sunny day, even on comparatively dull days, a solar array will still be providing cheap, green electricity.*

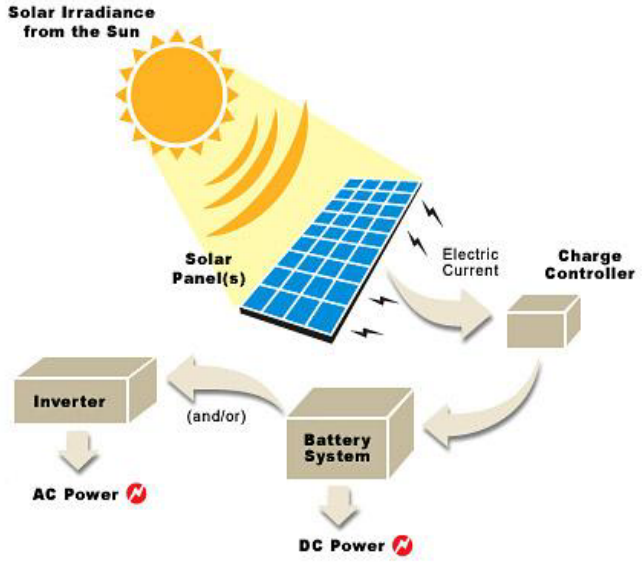


*Figure 3. Energy generated from solar irradiance through solar panels*

*The amount of power a solar cell produces is proportionate to the amount of light that it receives. The more light the more power. The building must be placed in an area with maximise sun and minimise obstruction. Figure 3 shows how energy is generated from solar irradiance through solar panels (Golany, 1983).*

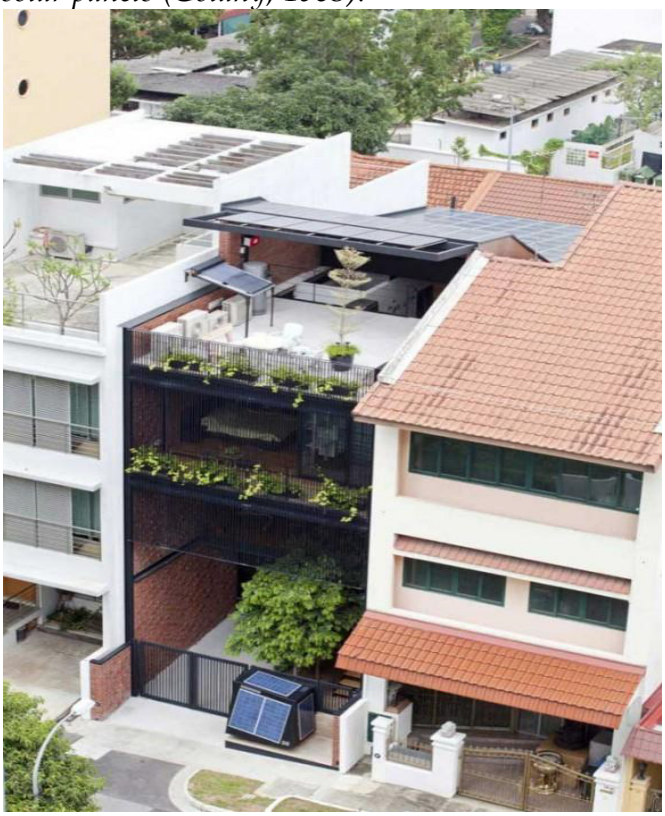

*Figure 4. Building fixed with photovoltaic panels*

*Figure 4 shows a building that has been fixed with photovoltaic panels which generate the Hybrid DC air-conditioner. To power a DC hot water heater for a zero to low energy system, the solar thermal collectors are also installed. Building Integrated Photovoltaic (BIPV) panels clad entire roof (Golany, 1983).. An innovative BIPV and ceiling composite design integrates ventilation slots, water, and heat and noise insulation so that the BIPV ceiling composite roof replaces the need for the conventional roof. PV external landscape lighting is also installed. And to achieve a zero to low energy residence, all artificial lights are energy efficient LEDs (Goldfinger, 1969). To further promote a green lifestyle, a solar charging unit integrated with the external metering compartment has been fitted for charging of electronics and solar bicycle.*

***Water Technology***

✓ ***Water Harvesting***

*The principle of collecting and storing rainwater are fairly simple and easy to follow. The water*

*must be stored in the dark below 18°C, and then the system will supply clean, perfectly usable water for most purposes other than drinking (Kumar et' al., 2007). The water is collected by normal roof gutters and is directed to the rainwater filter where the water is separated from leaves and other debris at the bottom of the rainwater downpipes (Figure 5).*

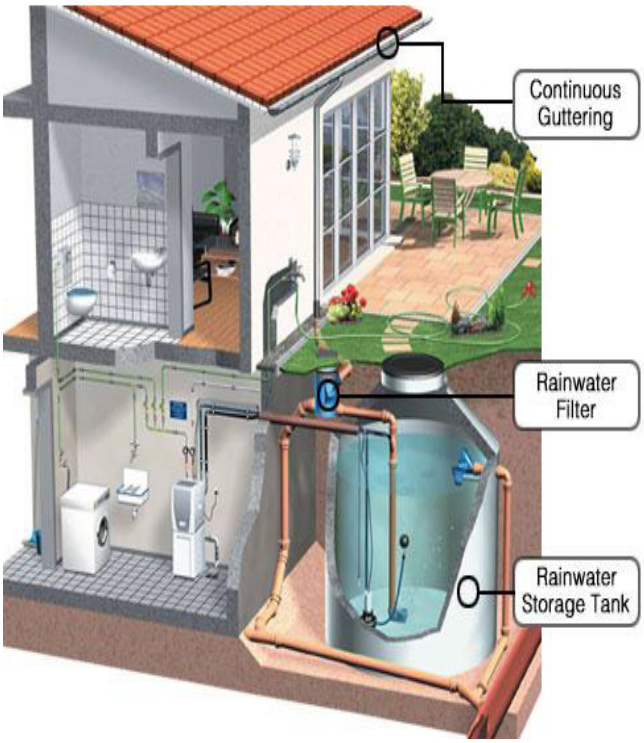


*Figure 5. Principle of water harvesting*

✓ ***Aqueduct System***

*An aqueduct is system that water supply or navigable channel constructed to convey water. The term of engineer is used for any system of pipes, ditches, canals, tunnels, and other structures used for this purpose. The word is derived from the Latin aqua (water) and ducere (to lead).*

*In a more restricted use, aqueduct (occasionally Water Bridge) applies to any bridge or viaduct that transports water instead of a path, road or railway across a gap. Large navigable aqueducts are used as transport links for boats or ships. Aqueducts must span a crossing at the same level as the watercourses on each end (Goldfinger, 1969). Figure 6 shows and example of house in India that use aqueduct irrigation system with water harvested from four on-site wells, which also provide water for the house. Locally quarried black basalt stone was used to construct aqueducts, boundary walls, plinths, and paving. Four wells on the site supply the house with water as well as irrigating the plantation via aqueducts, which are typical of the area (Schoenauer, 1981).*

*Figure 6. Palmyra house in India that utilizes a local aqueduct irrigation system with water harvested from four on-site wells*

***Natural Lighting***

*Natural light occurs as a by product of natural chemical processes. This is because when electrons get excited enough to jump an energy level and then return to their original energy level, the extra energy is released as photons, which are light. Light originates from stars like the sun, so solar light is the form of natural light with which people are most familiar and use most. It also can occur as a result of chemical processes on or in the earth (Goldfinger, 1969).*

*Natural light has several benefits when compared to artificial light. The production of artificial light requires the consumption of some kind of fuel, such as coal or petroleum, to produce electricity. The consumption of these fuels produces emissions and other waste products. In contrast, no fuel is needed to produce natural light, since the light is a by product of natural reactions. Also, natural light because it doesn't require fuel is free. Resources for artificial light production are limited when compared to the chemical reactions that produce natural light (Carmody and Sterling, 1984)*

*Light sources can be either natural or artificial. Sun is the primary source of natural light, and lightbulbs or lamps are the artificial sources. Light is a form of electromagnetic energy that, in the case of natural light, comes from the sun as the source and, in case of artificial light, illuminates via*

*energy from another source. No matter what the source, light has an impact on life on earth as a whole*

*Natural light is self-generated and comes in a spectrum of colors the visible colors of the rays we experience. The colour spectrum contains light with shorter wavelengths near the violet on one end and light with higher wavelength near the red (Carmody and Sterling, 1984). Called ultraviolet and infrared rays respectively, these rays are not visible to us. The complete spectrum of light from the natural source is ideal for plant and animal life on earth. Plants and animals thrive on natural light. The darkness that follows photo activity in organisms helps rejuvenate and repair life forms at the cellular level. A moderate amount of exposure to the healthy sunlight benefits humans, as it increases one's energy and metabolism, boosts the immune system and helps build vitamin D --- all of which are essential for the body. Overexposure, on the other hand, has detrimental effects on living organism. The harmful ultraviolet rays can cause conditions such as skin cancer and cataracts while also damaging the texture of the skin. For plants, the need for light and dark periods helps balance the cell activity in terms of growth and repair. Sunlight is also harmful since we cannot alter or control it to suit our condition (Carmody and Sterling, 1984).*

*Artificial light is man-made light generated from another energy source. Most of our activities would come to a halt if we didn't have an alternate source of light. The advantage with this light lies in the fact that we can control it at our own will. We can monitor the intensity, quantity and quality of light to suit each situation. Artificial light does not have as broad a spectrum of colors and wavelengths as natural light; hence, it is not as beneficial. Since the light has comparatively poorer quality, its effect on plant and animal life is also not as beneficial. Plants and animals exposed for prolonged periods to artificial light tend to yield poorer quality of life forms in plants and cause cellular degeneration or death in living beings.*

✓ ***Design with Retractable Awnings***

*Design isn't an item. Design is a strategy. Retractable awnings can improve the lighting of a room or save cash just by being installed. But you can actually maximize your investment and get genuinely spectacular results with a small bit of planning (Schoenauer, 1981).*

*First and most important: look at the fabric. High-good quality retractable awnings (even in budget lines) use solution-dyed acrylic. It is a durable, stain-resistant, fade-resistant fabric with excellent color top quality. Even better, it is approved by the American Skin Cancer Association for its UV protection (Schoenauer, 1981). Simply because solution-dyed acrylic is synthetic, it is accessible in an astonishing array of colours and patterns. For maximum impact on natural lighting designs, think about retractable awnings fabrics in warm, honey-coloured tones like dark yellows, beige, orange, or cream. That palette provides really soft colour that reduces glare although still being bright and cheerful.*

*Another significant factor are accessories for the retractable awning. Motors are a cinch motorized retractable awnings are used four times much more usually than manual retractable awnings according to business research. Other features like remote controls or switches permit awnings to be installed in otherwise inaccessible areas – over really high windows, sides of buildings, or over walkways – and be opened and closed easily. Other attributes like timers, wind sensors, and rain sensors can protect the retractable awning in threatening weather (and times with lowlight, when any natural light should be maximized).*

*And constantly keep in mind to look at the frame. Virtually all of the function of a retractable awning comes from what it offers indoors (light control, energy efficiency) but its beauty comes from how it looks outside. There are numerous frame styles, and high-end assemblers can custom-size retractable awnings to the inch. Strategies where you require an awning based on your lighting and energy needs inside – but match the style to the outside for the greatest curb appeal (Carmody and Sterling, 1984).*

*Lighting accounts for around 15% of the energy bill in most homes, and around 25% in commercial buildings. It is supplied by electrical power plants using fossil fuels, and is responsible for a significant percentage of carbon dioxide emissions, a leading cause of global climate change*

*(Schoenauer, 1981). Because of this, the building industry has targeted lighting as a key element in sustainable design, and there is now a global movement to develop and implement lighting solutions that meet people's needs and concerns, and address environmental regulations*

✓ ***Daylighting Design***

*The most sustainable lighting is natural daylight. It is not only a free renewable resource but it also has well-documented health benefits. Careful architectural design is required to maximise natural light in a building while maintaining indoor temperature regulation and reducing direct light glare. The strategic placement of windows, skylights, light shafts, atriums and translucent panels in harmony with other building components, such that light is reflected evenly throughout internal spaces, is known as daylighting design.*

***i. Sunlight Transportation Systems***

*An emerging new technology is that of sunlight transportation. Natural sunlight is collected on roof panels and transported into a building via fibre optic cables for distances up to 15 metres. These sunlight-piping systems can be used in combination with solar panels to integrate natural and artificial light systems, so that there is always light in the home.*

***ii. Energy Efficient Light Bulbs***

*The sustainable building industry is primarily focused on energy efficient lighting solutions. Standard light bulbs, known as incandescent bulbs, are known to be highly inefficient. Electricity is passed through a metal (tungsten) filament that heats to over 2000º Celsius and glows to give off light. Only 10% of the electrical energy is converted to light; 90% is wasted as heat. Halogen bulbs are similar but instead have a small pocket of halogen gas that reacts with tungsten to produce light. They burn brighter, use less electricity and last twice as long as a standard bulb, but are still inefficient compared with other forms of bulbs (Schoenauer, 1981).*

*Energy efficient light bulbs use significantly less energy than incandescent bulbs, and also last longer. There are two main kinds: Compact Fluorescent Lights and Light Emitting Diodes.*

***iii. Compact Fluorescent Lights (CFL)***

*These are small versions of full fluorescent lights, and consist of a glass tube coated with phosphor, filled with gas and a small amount of mercury. Electricity jumps off electrodes on the end of each tube, and excites the mercury molecules to emit ultraviolet light. This excites the phosphor coating, which emits visible light that shines out of the tube. CFLs give off the same amount of light as incandescent bulbs, but they are up to 80% cooler, are 4 times more energy efficient (to replace a 60-watt incandescent, you only need a 15-watt CFL), last 10 times longer (up to 20,000 hours), and are responsible for the emission of 70% less carbon dioxide (Schoenauer, 1981).*

*CFLs come in many different configurations and wattages, and are suitable for all lighting purposes. Although more expensive to buy than a standard bulb, they easily recover their costs in energy savings. On the downside, they contain trace amounts of mercury, which is hazardous to health and the environment. Care needs to be taken to ensure the glass tube doesn't break and that the bulbs are disposed of safely (Schoenauer, 1981).*

***iv. Light Emitting Diodes (LED)***

*LEDs are small, solid light bulbs that are lit by the movement of electrons in a solid semi-conductor material as electricity is passed through it. This is also called 'solid state lighting', because it uses a solid material, as opposed to gas (CFL) or filament (incandescent). LEDs are extremely energy efficient, lasting over 100 times longer than incandescent bulbs, and up to 10 times longer than CFLs. They have low heat generation, low power requirements, and are highly durable because there is no filament or tube to break.*

*LED is a relatively new technology, and currently the bulbs are most suitable for track and recessed lighting, where a pointed light is required rather than radiated light. They are more expensive than CFLs, but energy savings over their lifetime means their cost is soon recouped. Because their power inputs are minimal, LEDs are readily combined with solar panels to provide reliable, energy efficient lighting day and night.*

***v. The Future is Bright***

*Along with technological solutions like energy efficient light bulbs, and using renewable energies*

*for their electricity source, simple practices such as turning lights off, using dimmers and timing switches can all help to make lighting more environmentally friendly. Unfortunately these practices are not yet available with all energy efficient bulbs. Furthermore manufacturers still need to address issues of waste, pollution and energy in their products' life cycle. The building industry is committed to reducing the environmental impact of lighting, and new buildings now include lighting design issues from the outset. While there is still a long way to go before lighting can be said to be truly sustainable, the future of sustainable lighting looks bright*

***vi. Sustainable Lighting***

*Sustainable lighting plays an important role in green building and energy efficiency. Designers in this field select fixtures and lighting technologies that balance current needs with the needs of future generations. Sustainable lighting design allows current occupants to perform tasks with ease and comfort while minimizing short- and long-term environmental damage (Schoenauer, 1981).*

*Natural lighting and passive solar design play an important role in sustainable lighting, according to "Architectural Lighting Magazine Online." Designers position the building to maximize daylight and reduce the need for electric lights. Buildings designed with sustainability in mind often feature a large number of windows and skylights, which are strategically located to provide light where it's most needed. Instead of complex overhead lighting systems, these buildings utilize appropriate task lighting and energy-efficient technologies. Many also include motion sensors and timers to switch lights off automatically and minimize wasted energy.*

***Natural Ventilation***

*Natural ventilation is the process of supplying and removing air by means of purpose-provided aperture (such as openable windows, ventilators and shafts) and the natural forces of wind and temperature-difference pressures. Natural ventilation may be divided into two categories:*

*i. Controlled natural ventilation is intentional displacement of air through specified openings such as windows, doors, and ventilations by using natural forces (usually by pressures from wind and/or indoor-outdoor temperature differences). It is usually controlled to some extent by the occupant (Aughenbaugh, 1980).*

*ii. Infiltration is the uncontrolled random flow of air through unintentional openings driven by wind, temperature-difference pressures and/or appliance-induced pressures across the building envelope. In contrast to controlled natural ventilation, infiltration cannot be so controlled and is less desirable than other ventilation strategies, but it is a main source of ventilation in envelope-dominated buildings.*

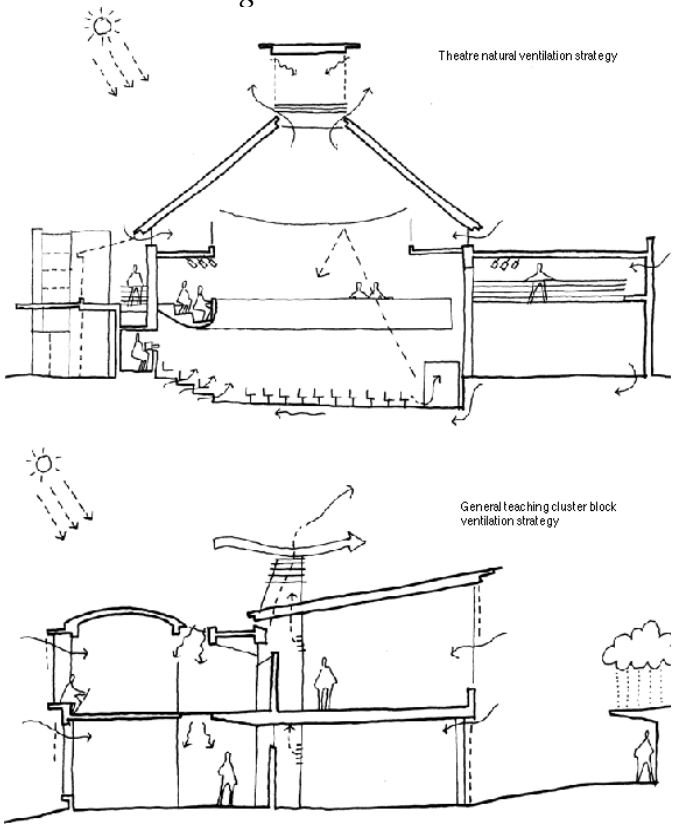


*Figure 7. Natural ventilation strategy*

*Figure 7 shows the natural ventilation strategy. For air to move into and out of a building, a pressure difference between the inside and outside of the building is required. The resistance to flow of air through the building will affect the actual air flow rate. In general, controlled natural ventilation and infiltration are driven by pressure difference across the building envelope. The pressure difference is caused by:*

- *wind (or wind effect);*
- *difference in air density due to temperature difference between indoor and outdoor air (stack or chimney effect); or*
- *combination of both wind and stack effects.*

## CONCLUSIONS

*Future building design should aim to cause the minimum possible harm to both users and the environment. This philosophy should be incorporated throughout the design, construction, use, repair and eventual end of life recycling of the building. Green building, as a concept, is straightforward and makes perfect sense. It means making thoughtful design choices and using ecological materials in ways that create quality, long-lasting environments with minimum damage to the planet. Natural ambient resources (sunshine, light, wind and rain) can and should be used for services such as energy, heating, cooling and water.*

*Solar and wind energy can be utilised at many sites and we should make better use at many sites and we should make better use of these independent, renewable resources. Using renewable energy makes us more dependent on climate and reduces or vulnerability to scarce, imported and increasingly costly fossil fuels.*

*The natural daylight can be used to displace the need for artificial lighting. However, glazed openings are often associated with excessive heat loss in winter and gains in summer and should be designed carefully. Artificial lighting is needed when there is insufficient daylight and lighting system and their control to maximise efficiency. In the heating section, passive solar heating can be used to displace the use of fossil fuel.*

*The availability of water depends on the amount of rainfall, the catchment area, the quality and extent of the treatment and distribution infrastructure. System of rainwater harvesting is collect rainwater from a down sprout draining the roof. Rainwater harvesting needs to be considered as a part of long term and overall environmental plan towards more sustainable development.*

**References**


[1.] *Ahmad, I., Khetrish, E., and Abughres, M.S., (1985), "Thermal analysis of the architecture of old and new houses at Ghadames". Building and Environment, Vol. 20 (1), pp. 39- 42.*

[2.] *Aughenbaugh, N.B., (1980)," Underground houses:, Design and Planning", Architectural Press, London, pp. 151–158.*

[3.] *Carmody, J., Sterling, R., (1984), "Design considerations for underground buildings", Underground Space. Vol. 8, pp. 352–362.*

[4.] *Carpenter , P., (1994), "An Introduction to Earth Sheltered Development in England and Wales", Coventry University, Coventry.*

[5.] *Golany, G.S., (1983), "Earth-Sheltered Habitat: History", Architecture and Urban Design, Van Nostrand Reinhold, New York.*

[6.] *Goldfinger, M., (1969), "Villages in the Sun", Lend Humphries, London.*

[7.] *Kumar, R., Sachdevab, S., Kaushik, S.C., (2007), "Dynamic earth-contact building: "a sustainable low-energy technology", Building and Environment, Vol. 42, pp. 2450–2460.*

[8.] *Labs K., (1988), "Passive Cooling", MIT Press, Cambridge, MA, pp. 197–322.*

[9.] *Schoenauer, N., (1981), "6000 Years of Housing", NY: Garland STPM Press.*



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# POWERS AND TORQUE RIPPLE MINIMIZATION OF DOUBLY FED INDUCTION GENERATOR IN WECS USING SPACE VECTOR MODULATION

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**Abstract:** *Space Vector Pulse Width Modulation SVPWM Is the best modulation techniques to generate sinusoidal voltage and current due to its facility and efficiency with low harmonics distortion. In this paper we presents the study and power control of a variable speed wind energy conversion system based on a doubly Fed Induction Generator (DFIG) using space vector modulation to achieve control of active and reactive powers exchanged between the stator of the DFIG and the grid to ensure a Maximum Power Point Tracking (MPPT) of a wind energy conversion system and to reduce significantly Powers and Torque ripples. The Simulation results have shown good performances of the system under these proposed control Compared to PWM control strategies.*
**Keywords:** *Doubly fed induction generator, Space Vector PWM (SV-PWM), wind turbine, MPPT, WECS, pitch control*

## INTRODUCTION

*Nowadays wind energy has turned out to be one of the most important and promising sources of renewable energy after its progress during the last three decades. It has been the subject of much recent research and development; and he drawing the most attention from government, utilities and industry all over the world[2] due its smaller environmental impact and its renewable characteristic that contribute for a sustainable development [3].*

*The advances in wind turbine technology and the rapid development of power electronic devices and thus decreasing equipment costs, let a lot of researchers in wind power generation technologies to made necessary the design of powerful control systems in order to bring down the cost of electrical energy produced by the WECS to be competitive in the electricity market, and improved the dynamic behavior, resulting in the reduction of the mechanical Stress, fluctuation of the electrical power, the increase of the power capture[3]. The major part of the existing research works concerning variable speed wind turbines control is not only to capture the maximum power from the wind but, also, to improve the quality of power [4] and to converge the system for operating at unity power factor. The doubly fed induction generator (DFIG) which its stator winding is directly connected to the grid and its rotor winding is connected to the grid through a frequency converter introduces itself as one of the most important generators for wind energy conversion systems because of the following reasons: a higher energy yield, a reduction of mechanical loads, an extensive controllability of both active and reactive powers, less fluctuation in output power and a simpler pitch control.*

*However, the performance of a DFIG depends not only on the induction machine but also on the two PWM converters as well as how they are controlled. In order to comprehend DFIG power generation characteristics under different control conditions, this paper presents a detailed analysis of the comparative advantage of PWM and space vector pulse width modulation (SVPWM) control technique.*

## SVM CONTROL STRATEGY

### Diagram of voltage space vectors

*Space vector pulse width modulation (SVPWM) is a modulation technique that involves the generation of a reference vector $V_{ref}$ representing a three phase sinusoidal voltage realized by switching between two nearest active vectors and*

*one zero vector switching sequence of a given power converter[6]. The desired output assigned $V_{ref}$ will rotate in angular velocity equal to desired output converter frequency. The magnitude of this vector is related to the magnitude of the output voltage (SVM) and the time this vector takes to complete one revolution is egal as the fundamental time period of the output voltage [12]. Rotating to each active vector corresponds a switch sequence. There are eight possible output voltage vectors, or $V_1$, $V_6$ represented active switching ([011] [001] [101] [100] [110] [010]), and two zero voltage vectors, i.e. $V_0$ and $V_7$, corresponding to switching states ([000] and [111]) These two vectors allocate in the center of the circle. Figure 1 shows reference voltage vector $V_{ref}$ and eight voltage vectors, which corresponds to the possible states of the inverter.*

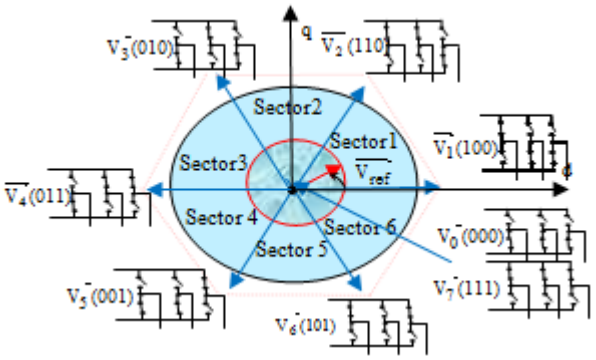


*Figure1. Diagram of voltage space vectors*

## *Implementation of the SVM Bloc*

*The vector $V_{ref}$ is given by two components $V_d$ ,$v_q$ and angle(a). From Figure 2 the $V_d$, $V_q$, $V_{ref}$, and angle (a) can be determined as follows:*

$$\begin{bmatrix} V_d \\ V_q \end{bmatrix} = \frac{2}{3}\begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix}\begin{bmatrix} V_{an} \\ V_{bn} \\ V_{cn} \end{bmatrix} \quad (1)$$

$$\left[\overline{V_{ref}}\right] = \sqrt{V_d^2 + V_q^2} \quad (2)$$

*where:*

$$a = tan\left(\frac{V_q}{V_d}\right) \quad (3)$$

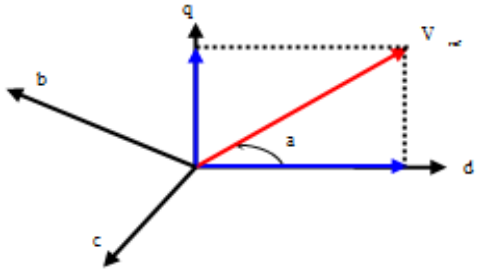


*Figure 2. Voltage space vector and its components in (d, q).*

*An algorithm for Research angular sector is used to determine the sector (k= 1, 2, 3 ....6) as shown in Figure (3).*

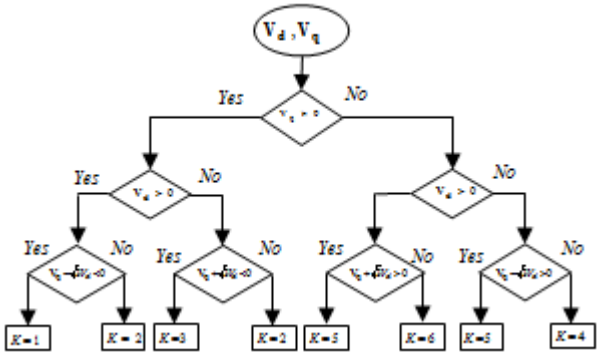


*Figure 3. Algorithm for determining Sector K*

*In every sector, each voltage vector is synthesized by basic space voltage vector of the two side of sector and one zero vector. For example, in the first sector, $V_{ref}$ is a synthesized voltage space vector and expressed by:*

$$\int_0^{T_Z} \overline{V_{ref}} = \int_0^{T_1} \overline{V_1}dt + \int_{T_1}^{T_1+T_2} \overline{V_2}dt + \int_{T_1+T_2}^{T_1} \overline{V_0} \quad (4)$$

$$T_Z.\overline{V_{ref}} = (T_1.V_1 + T_1.V_2 + T_0.V_0) \quad (5)$$

$$T_Z = \frac{1}{f_Z} \text{ and } H = \frac{\overline{V_{ref}}}{2/3.V_{dc}} \quad (6)$$

*where, $T_0$, $T_1$ and $T_2$ are the work times of basic space voltage vectors $v_o$, $v_1$ and $v_2$ respectively [8].*

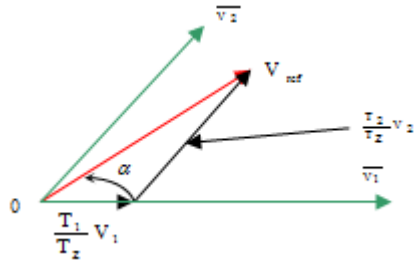


*Figure 4. Reference vector as a combination of adjacent vectors at Sector 1.*

*The determination of the amount of times $T_1$ and $T_2$ is given by:*

$$T_1 = \frac{\sqrt{3}T_Z\left|\overline{V_{ref}}\right|}{V_{dc}}\left(\sin\left(\frac{\pi}{3} - a + \frac{(n-1)}{3}\pi\right)\right) \quad (7)$$

$$T_1 = \frac{\sqrt{3}T_Z\left|\overline{V_{ref}}\right|}{V_{dc}}\left(\sin\left(\frac{n}{3}\pi\cos a - \cos\frac{n}{3}\pi\sin a\right)\right)$$

$$T_2 = \frac{\sqrt{3}T_Z\left|\overline{V_{ref}}\right|}{V_{dc}}\left(\sin\left(a - \frac{(n-1)}{3}\pi\right)\right) \quad (8)$$

$$T_2 = \frac{\sqrt{3}T_Z\left|\overline{V_{ref}}\right|}{V_{dc}}\left(\sin a\sin\frac{(n-1)}{3}\pi - \cos a\sin\frac{(n-1)}{3}\pi\right)$$

$$T_0 = (T_Z - T_2 - T_2) \quad (9)$$

*where, the sector (n) = 1 through 6.*
*The switching time at each sector is summarized in the following Table [8].*

*Table 1. The switching time*

| sector | Switches($s_1$, $s_3$, $s_5$) | Switches($s_4$, $s_6$, $s_2$) |
|---|---|---|
| 1 | $s_1=T_1+T_2+T_0/2$<br>$s_3=T_2+T_0/2$<br>$s_5=T_0/2$ | $s_4=T_0/2$<br>$s_6=T_1+T_0/2$<br>$s_2=T_1+T_2+T_0/2$ |
| 2 | $s_1=T_1+T_0/2$<br>$s_3=T_1+T_2+T_0/2$<br>$s5=T_0/2$ | $s_4=T_2+T_0/2$<br>$s_6=T_0/2$<br>$s_2= T_1+T_2+T_0/2$ |
| 3 | $s_1=T_0/2$<br>$s_3= T_1+ T_2+ T_0/2$<br>$s_5= T_2+ T_0/2$ | $s_4= T_1+ T_2+T0/2$<br>$s_6= T_0/2$<br>$s2= T_1+ T_0/2$ |
| 4 | $s_1= T_0/2$<br>$s_3= T_1+ T_0/2$<br>$s_5= T_1+ T_2+ T_0/2$ | $s_4= T_1+T2+T0/2$<br>$s_6= T_2+ T_0/2$<br>$s_2= T_0/2$ |
| 5 | $s_1= T_2+ T_0/2$<br>$s_3= T_0/2$<br>$s_5= T_1+ T_2+ T_0/2$ | $s_4= T_1+ T_0/2$<br>$s_6= T_1+ T_2+ T_0/2$<br>$s_2= T_0/2$ |
| 6 | $s_1= T_1+ T_2+ T_0/2$<br>$s_3= T_0/2$<br>$s_5= T_1+ T_0/2$ | $s_4= T_0/2$<br>$s_6= T_1+ T_2+T0/2$<br>$s_2= T_2+ T_0/2$ |

## WECS Modeling

*The general turbine model with doubly fed induction generator is shown in Figure 5.*

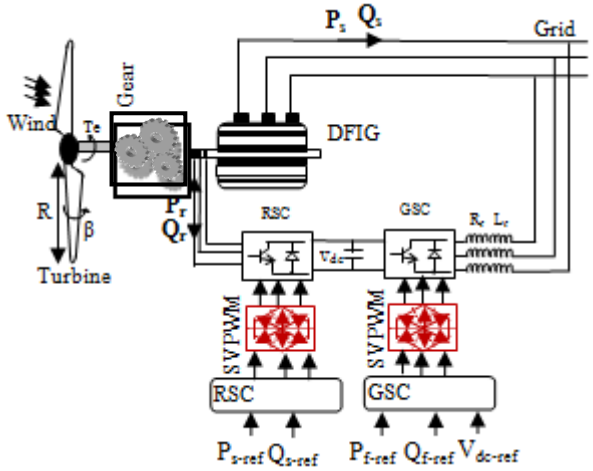


*Figure 5. Wind turbine system with DFIG*

## Wind Turbine Model

*The wind turbine is modeled in terms of optimal tracking, to provide maximum energy capture from the wind. The aerodynamic model of the wind turbine gives a coupling between the wind speed and the mechanical torque produced by the wind turbine. The mechanical power Pt produced by the wind turbine rotor can be defined as [11]:*

$$p_t = \frac{1}{2} c_p(\lambda, \beta).\rho. \quad s.v^3 \qquad (10)$$

*with :*

$$\lambda = \frac{\Omega_t}{v}.R \qquad (11)$$

*where $P_t$ (w) the aerodynamic power; $P_v$ (w) wind power available in the rotor swept area; ρ (kg/m³) the air density; S (m²) the rotor disk area, R (m) the rotor radius; ν (m/s) the wind speed; and Cp the power coefficient which is a function of the tip speed ratio λ (ratio between blade tip speed and wind speed) and β the pitch angle of rotor blades.*

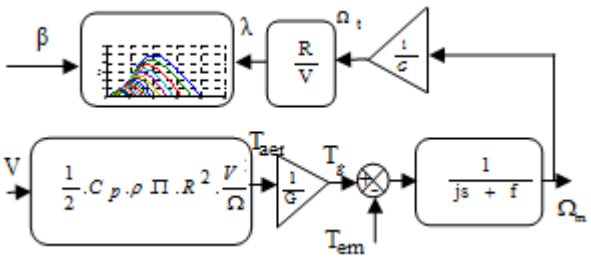


*Figure 6. Wind turbine model*

*The power coefficient is defined by:*

$$C_p(\lambda,\beta) = C_1\left(\frac{C_2}{\lambda_i} - C_3.\beta - C_4\right)e^{\frac{-C_5}{\lambda_i}} + C_6\lambda \qquad (12)$$

*where*

$$\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.08.\beta} - \frac{0.035}{1+\beta^3} \qquad (13)$$

*with: $c_1 = 0.5176$, $c_2 = 116$, $c_3 = 0.4$, $c_4 = 5$, $c_5 = 21$, $c_6 = 0.0068$*

*On Figure 8 is represented this coefficient in function of λ and for different values of pitch angle β of the blades. This curve is characterized by the optimal point (λopt=9, Cp-max=0.5, β=2°) corresponding to the maximum power coefficient Cp and therefore the maximum mechanical power recovered*

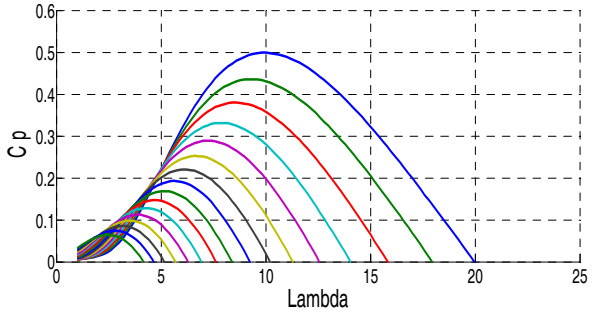


*Figure 7. Characteristic $C_p = f(\lambda_{opt})$*

$$\Omega_t = \frac{\lambda_{opt}}{R}.v \qquad (14)$$

*The torque at the shaft neglecting losses in the drive-train is given by:*

$$T_t = \frac{P_t}{\Omega_t} = \frac{R.P_t}{\lambda.v} = \frac{C_p \rho \pi^2 R_t^3 v^2}{2\lambda} \qquad (15)$$

and $$C_t = \frac{C_p}{\lambda} \quad (16)$$

For our model we'll assume the stiffness and damping are neglected, and then the dynamic equations of the drive-train can be obtained with a model to a mass in this case described by:

$$T_g - T_{em} = J \frac{d\Omega_m}{dt} \quad (17)$$

The equivalent moment of inertia is:

$$J = J_g + \frac{J_t}{G^2} \quad (18)$$

the gear ratio between the turbine and the generator:

$$G = \frac{\Omega_t}{\Omega_g} \quad (19)$$

### Doubly-Fed Induction Generator

The DFIG voltage and flux equations, expressed in the Park reference frame, are given by.

$$\begin{aligned} V_{sd} &= R_s I_{sd} + \frac{d}{dt}\varphi_{sd} - \omega_s \varphi_{sq} \\ V_{sq} &= R_s I_{sq} + \frac{d}{dt}\varphi_{sq} + \omega_s \varphi_{sd} \end{aligned} \quad (20)$$

$$\begin{aligned} \varphi_{sd} &= L_s I_{sd} + M I_{rd} \\ \varphi_{sq} &= L_s I_{sq} + M I_{rq} \\ \varphi_{rd} &= L_r I_{rd} + M I_{sd} \\ \varphi_{rq} &= L_r I_{rq} + M I_{sq} \end{aligned} \quad (21)$$

Moreover, the electromagnetic torque is given by:

$$C_e = p\frac{M}{L_s}\left(I_{rq}\varphi_{sd} - I_{rd}\varphi_{sq}\right) \quad (22)$$

The stator resistance of the DFIG is neglected and the stator flux $\varphi_s$ is set aligned with the d axis and assumed to be constant (it is the case of a powerful and stable grid) [12]. Then, we can write $\varphi_{sd} = \varphi_s, \varphi_{sq} = 0$

Consequently, the stator voltages and fluxes can be rewritten as follows:

$$\begin{aligned} V_{sd} &= \frac{d}{dt}\varphi_s = 0 \\ V_{sq} &= \omega_s \varphi_s \end{aligned} \quad (23)$$

$$\begin{aligned} \varphi_{sd} &= L_s I_{sd} + M I_{rd} \\ 0 &= L_s I_{sq} + M I_{rq} \end{aligned} \quad (24)$$

Hence, the torque equation can be written as follow

$$T_{em} = p\frac{M}{L_s} I_{rq}\varphi_{sd} \quad (25)$$

The stator active and reactive power and voltages are given by:

$$\begin{aligned} P &= V_{sd} I_{sd} + V_{sq} I_{sq} \\ Q &= V_{sq} I_{sd} - V_{sd} I_{sq} \end{aligned} \quad (26)$$

From equation (16), we obtain:

$$\begin{aligned} P &= -V_s \frac{M}{L_s} I_{rq} \\ Q &= -V_s \frac{M}{L_s} I_{rd} + V_s \frac{\varphi_s}{L_s} \end{aligned} \quad (27)$$

From the last equation, we can see that the electromagnetic torque and the active power will only depend on the q-axis rotor current, while the reactive power may be controlled through the rotor current $I_{rd}$.

the rotor voltage equations can be defined as:

$$\begin{aligned} V_{rd} &= R_r I_{rd} + (L_r - \frac{M^2}{L_s})\frac{dI_{rd}}{dt} - g\omega_s(L_r - \frac{M^2}{L_s})I_{rq} \\ V_{rq} &= R_r I_{rq} + (L_r - \frac{M^2}{L_s})\frac{dI_{rq}}{dt} + g\omega_s(L_r - \frac{M^2}{L_s})I_{rd} + g\frac{MV_s}{L_s} \end{aligned} \quad (28)$$

### Rotor Side Converter

This converter controls the active and reactive powers generated by the stator of the DFIG and delivered to the grid by controlling the rotor currents of the DFIG (Figure 8). The real active and reactive powers are compared to their references, and then two PI controllers are used. The outputs of these controllers represent the direct and quadrature components of the current references [14]

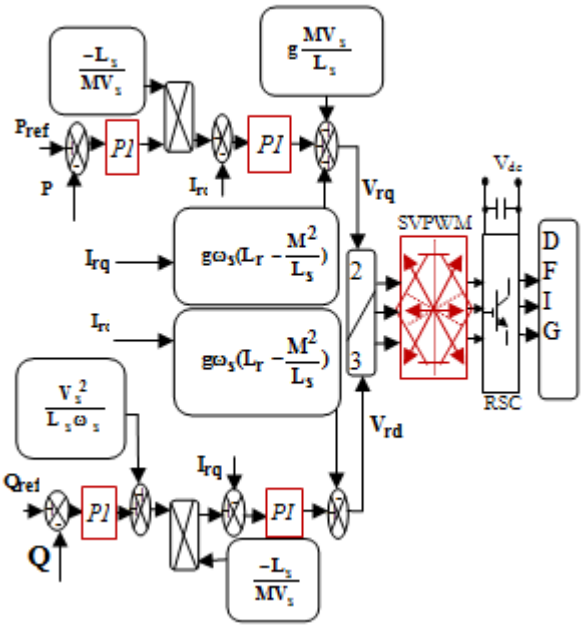


Figure 8. Control of the RSC

### Grid Side Converter

The objective of the grid side converter is to regulate the DC-link voltage and to set a unit

*power factor. The topology of grid-side converter is shown in Figure 9.*

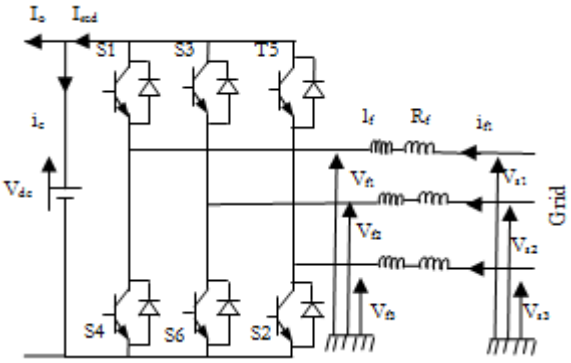


*Figure 9. Grid side converter*

*Based on the circuit topology, the mathematical model of inverter in three-phase static abc coordinates can be drawn as follows:*

$$\begin{aligned} V_{f1} &= -R_f i_{f1} - l_f \frac{di_{f1}}{dt} + v_{s1} \\ V_{f2} &= -R_f i_{f2} - l_f \frac{di_{f2}}{dt} + v_{s2} \\ V_{f3} &= -R_f i_{f3} - l_f \frac{di_{f3}}{dt} + v_{s3} \end{aligned} \quad (29)$$

*In the d, q reference frame:*

$$\begin{aligned} V_{fd} &= -R_f i_{fd} - l_f \frac{di_{fd}}{dt} + \omega_s l_f i_{fq} + v_{sd} \\ V_{fq} &= -R_f i_{fq} - l_f \frac{di_{fq}}{dt} + \omega_s l_f i_{fd} + v_{sq} \end{aligned} \quad (30)$$

*The active and reactive powers ($P_f$ and $Q_f$) can be both expressed by using Park components of supply voltage($v_{fd}$ and $v_{fq}$) and line current($i_{fd}$ and $i_{fq}$) as follows:*

$$\begin{aligned} P_f &= v_{fd} i_{fd} + v_q i_{fq} \\ Q_f &= v_{fq} i_{fd} - v_d i_{fq} \end{aligned} \quad (31)$$

*we can find the reference currents ($i_{fd\text{-}ref}$, $i_{fq\text{-}ref}$), which allows setting the desired reference active and reactive powers ($P_{f\text{-}ref}$, $Q_{f\text{-}ref}$), as follows:*

$$\begin{aligned} i_{fd\text{-}ref} &= \frac{Q_{f\text{-}ref}}{v_{sq}} \\ i_{fq\text{-}ref} &= \frac{P_{f\text{-}ref}}{v_{sq}} \end{aligned} \quad (32)$$

*The unity power factor is obtained simply by setting the reactive power reference null. The DC reference voltage $V_{dc\text{-}ref}$ is compared to the measured DC voltage across the capacitor $V_{dc}$. The DC voltage corrector regulates the DC bus and sets the active power $P_{c\text{-}ref}$ which is necessary to charge the capacitor to the desired value. The reference active power Pf- ref is obtained after being calculated the Pc-ref. The evolution of the DC voltage $V_{dc}$ is given by the following equation:*

$$\begin{aligned} C.\frac{dv_{dc}}{dt} &= (i_{red} - i_o) \\ i_c &= i_{red} - i_o \end{aligned} \quad (33)$$

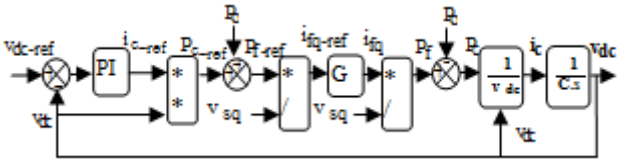


*Figure 10. Bloc Diagram of the DC Bus Control*

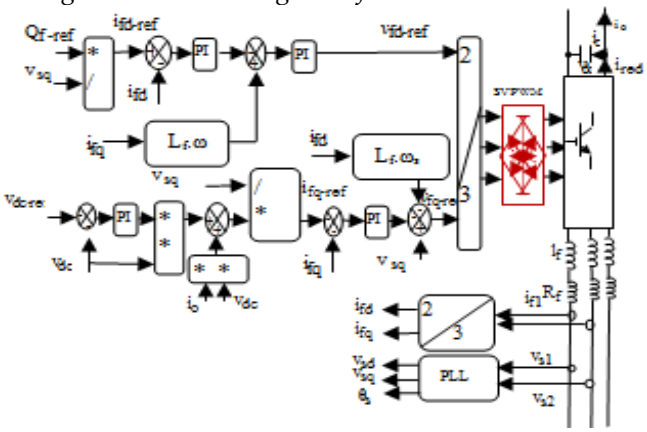


*Figure 11. Grid side converter control*

## *SIMULATION RESULTS*

*In order to made a comparison between the proposed control strategies PWM (SV-PWM) for a doubly fed induction generator (DFIG)-based wind energy conversion system shown in Figure (5), all the matlab simulations are carried out in the same operation conditions.*

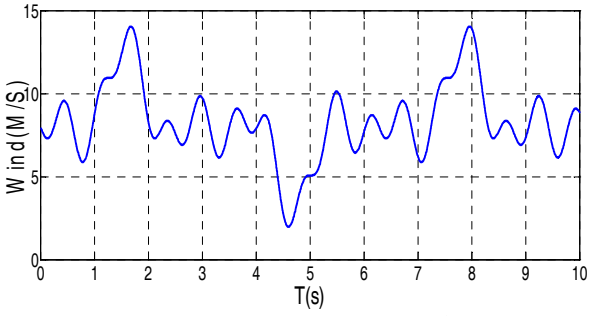


*Figure 12. Wind speed profile*

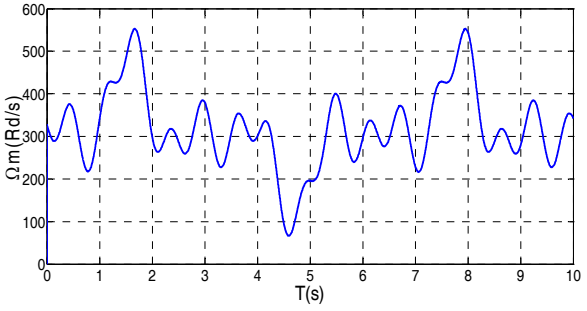


*Figure 13. Mechanical speed*

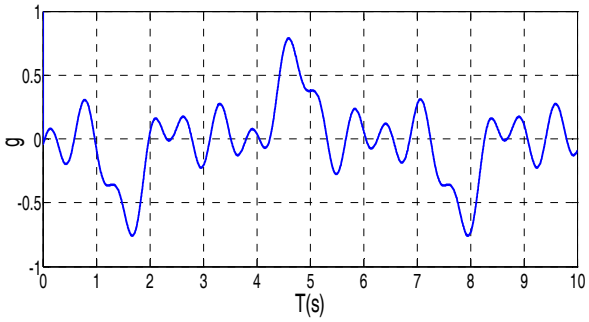


*Figure 14. Slip variation of the grid-connected DFIG*

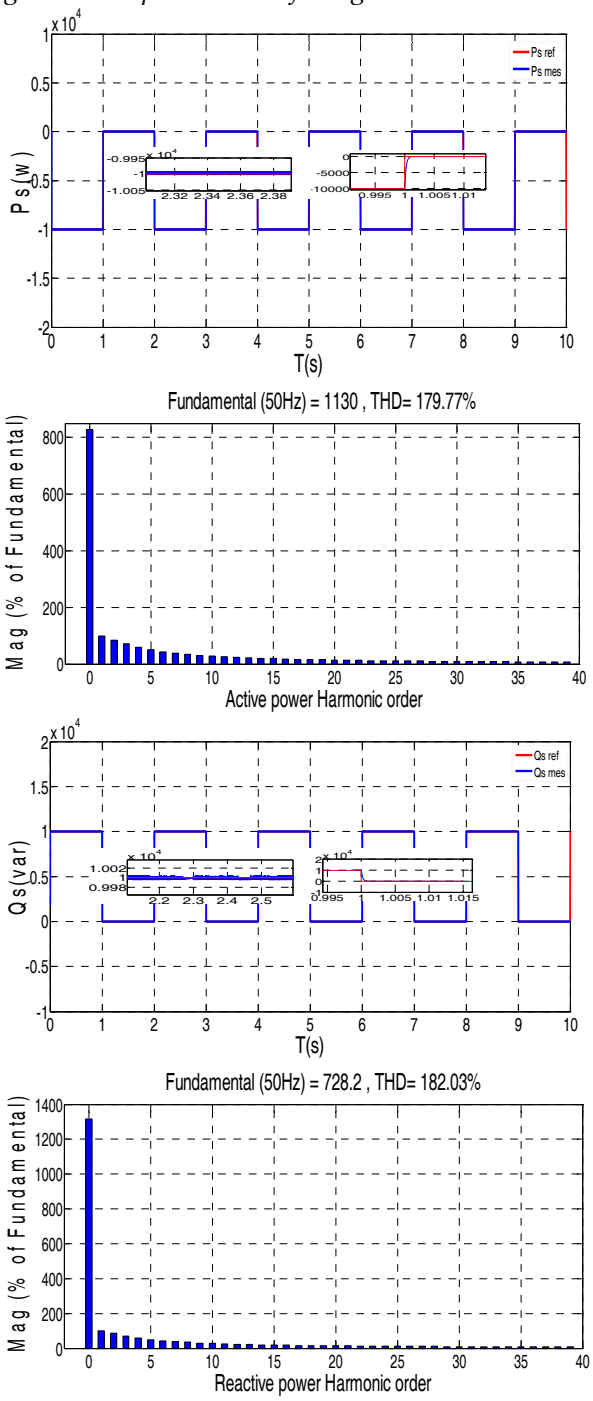


*Figure 15. (a) Stator active and reactive powers with SVM*

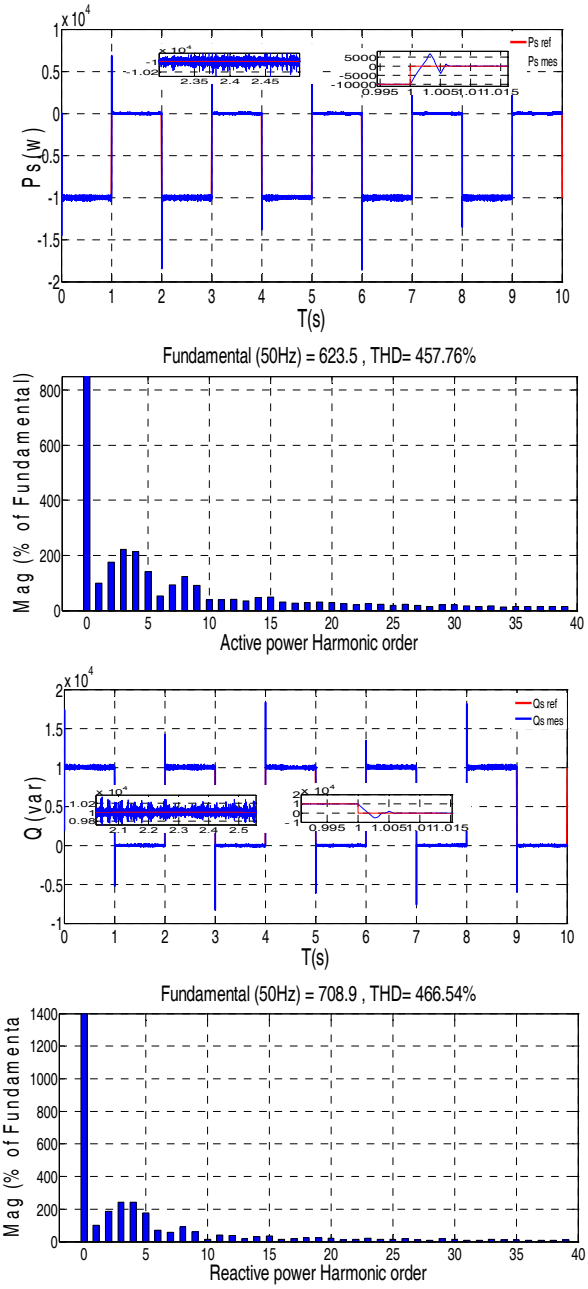


*Figure 15. (b) Stator active and reactive powers with PWM*

*Variable speed operation in the DFIG tracking curve effects higher power output from the wind. The direction of the power flow through the converters depends on the operating point of the generator.*

*In the sub-synchronous operation mode, the stator of DFIG supplies power to the grid and also the slip power to the rotor via the slip rings and the power converter. In the super-synchronous operation mode, both the stator output power and the rotor slip power are fed into the grid. In all simulation results presented, by comparing the current, torque, active and reactive power THD*

*between the proposed control strategies it can be observed a much better behavior of the SV-PWM performance as compared to PWM, achieving the objectives of the present work, which was to reduce the torque and power ripple and consequently improve the power exchanged between the stator of the DFIG and the power network.*

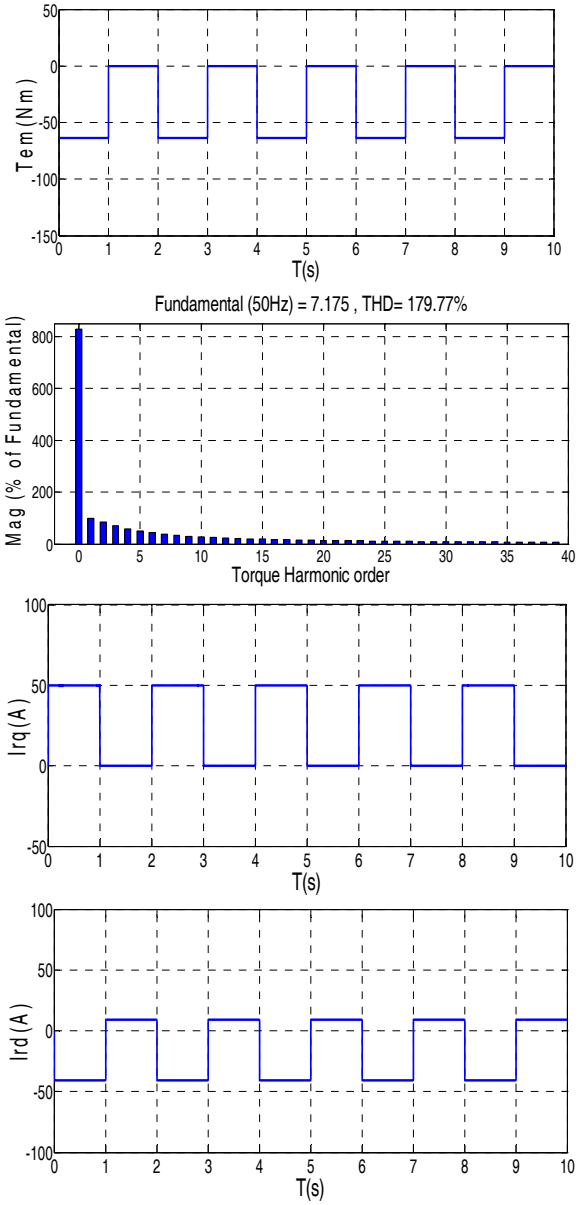


*Figure 16(a). Torque and rotor currents with SVM*

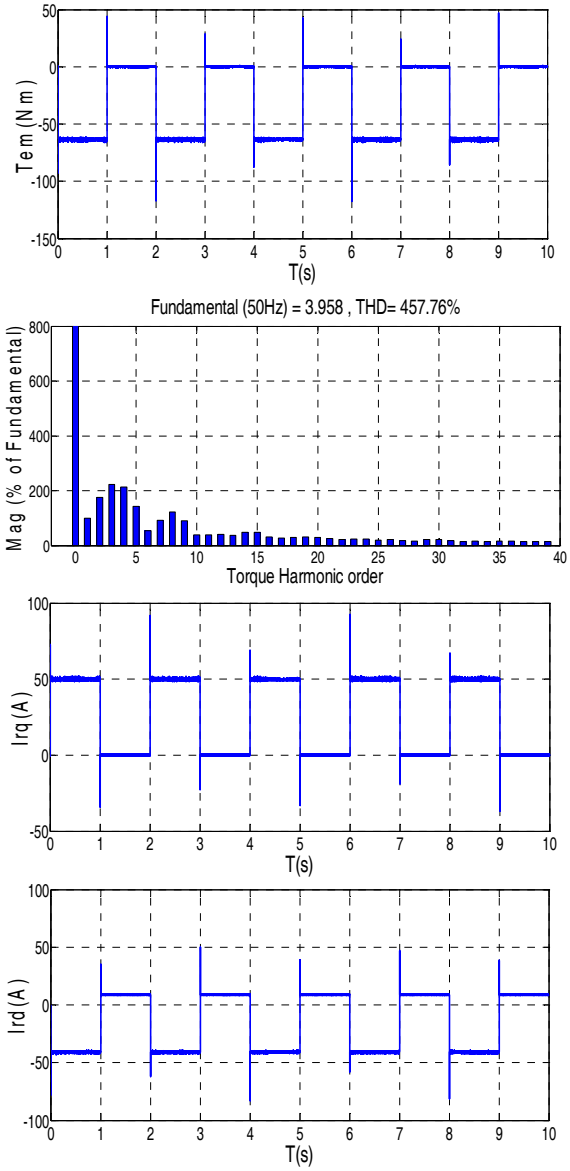


*Figure 16(b). Torque and rotor currents with PWM*

*Simulation results show good decoupling between stator active and reactive power and proven that both control strategies are able to offer convergence of the dynamic response of the system to the reference values despite wind variations. The proposed scheme ensures perfect tracking of maximum captured power and improves good dynamics and provides less harmonics in rotor currents.*

## CONCLUSION

*The paper has presented a model for a wind turbine generation system based on a doubly fed induction generator with a stator directly connected to the grid and a rotor connected to the grid through SVPWM converte.*

*A detailed modeling of the mechanical dynamics, the wind turbine electrical system, and the converter been presented.*

*The obtained results demonstrate that the proposed DFIG system control operating at the variable speed may be considered as an interesting way for problems solution in renewable energy area.*

## References

*[1.] W. Yu, J. Lai and S.Y. Park, «An Improved Zero-Voltage Switching Inverter Using Two Coupled Magnetic in One Resonant Pole» IEEE Trans. on*

*Power Electron., Vol.25, No.4, pp.952-961, April.2010.*

[2.] *J. Hua, Y. Hea and L Xub, «Improved rotor current control of wind turbine driven doubly-fed induction generators during network voltage unbalance»,Electric Power Systems Research 80 (2010) 847–856*

[3.] *A. K. Mishra, L. Ramesh, S.P. Chowdhury, S.Chowdhury, «Review of Wind Turbine System and its Impact for Grid Stability», Journal of Electrical Engineering. Vol.11, Issue 1. 2011. pp. 153–165.*

[4.] *L. Shuhui, T.A. Haskew, «Analysis of Decoupled d-q Vector Control in DFIG Back-to-Back PWM Converter», IEEE CNF Power Engineering. June 2007. pp.1-7.*

[5.] *Y. Bekakra, D. B. attous, «Active and Reactive Power Control of a DFIG with MPPT for Variable Speed Wind Energy Conversion using Sliding Mode Control», World Academy of Science, Engineering and Technology 60 2011.*

[6.] *H.Karimi-Davijani, A.Sheikholeslami, R. Ahmadi, and H. Livani, «Active and reactive power control of DFIG using SVPWM converter», in Proc.of IEEE UPEC, pp.1-5, 2008.*

[7.] *Badrul H. Chowdhury, and Srinivas Chellapilla, «Double-fed induction generator control for variable speed wind power generation», Electric Power Systems Research, Volume 76, Issues 9-10, June 2006, pp.786-800.*

[8.] *J.W Jung, A. Keyhani, «Space Vector PWM Inverter», Departement of Electrical and Computer the Ohio State University, 2005.*

[9.] *R. Penaa, R. Cardenasb, E. Escobarb, J. Clarec, P. Wheelerc, « Control strategy for a doubly-fed induction generator feeding an unbalanced grid or stand-alone load, Electric Power Systems Research, Vol. 79, pp. 355- 364, 2009.*

[10.] *A. M. Eltamaly, A. I. Alolah, M. H. Abdel-Rahman, « Modified DFIG control strategy for wind energy applications», SPEEDAM 2010, International Symposium on Power Electronics, Electrical Drives, Automation and Motion, 2010 IEEE, pp. 659-653, 2010.*

[11.] *M. Machmoum, F. Poitiers, «Sliding mode control of a variable speed wind energy conversion system with DFIG», International Conference and Exhibition on Ecologic Vehicles and Renewable Energies, MONACO, March 26-29 (2009).*

[12.] *M. Saeedifard, H. Nikkhajoei, R. Iravani and A. Bakhshai, «A Space Vector Modulation Approach For A Multi- Module HVDC Converter System», IEEE Transactions on Power Delivery, Vol.22, No.3, PP.1643-1654, July, 2007.*

[13.] *Choon Yik Tang, Yi Guo, John N. Jiang, «Nonlinear Dual-Mode Control of Variable-Speed Wind Turbines with Doubly Fed Induction generators»,IEEE,Transactions on Control Systems Technology, July 2011, 19 (4), pp. 744-756*

[14.] *Yao Xing-jia, Liu Zhong-liang, Cui Guo-sheng, «Decoupling control of Doubly-Fed Induction Generator based on Fuzzy-PI Controller», IEEE Trans. Mechanical and Electrical Technology (ICMET 2010) , pp 226-230 ,2010.*

[15.] *Md. Rabiul Islam1, Youguang Guo, Jian Guo Zhu, «Steady State Characteristic Simulation of DFIG for Wind Power System», IEEE Trans. Electrical and Computer Engineering (ICECE), pp. 151-154, 2011.*

[16.] *T. Luu, A. Nasiri, «Power Smoothing of Doubly Fed Induction Generator for Wind Turbine Using Ultra capacitors», IEEE Trans. IECON 2010 - 36th Annual Conference., pp. 3293-3298, 2010.*

[17.] *C.O. Omeje, D.B. Nnadi, and C.I. Odeh, «Comparative Analysis of Space Vector Pulse-Width Modulation and Third Harmonic Injected Modulation on Industrial Drives», The Pacific Journal of Science and Technology, Volume 13. Number 1. May 2012 (Spring).*

[18.] *H. Zhang, Q. Wang, E. Chu, Xi. Liu, and L. Hou, «Analysis and Implementation of A Passive Lossless Soft-Switching Snubber for PWM Inverters», IEEE Trans. on Power Electron. Vol. 26, No.2, pp. 411- 426, Feb.201.1*

[19.] *R. Huang and S. K. Mazumder, «A Soft Switching Scheme for Multiphase DC/Pulsating-DC Converter for Three-Phase High-Frequency-Link Pulse width Modulation (PWM) Inverter», IEEE Trans. on Power Electron.,Vol.25,No.7,pp.1761-1774,July.2010. Renewable Energy, Vol. 35, pp. 1033-1042, 2010*


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# STUDIES ABOUT INFLUENCE OF THE PSEUDO-RANDOM NUMBER GENERATORS IN SIMULATION MODELS FOR MAGNETODIELECTRIC NANOCOMPOSITES

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**Abstract:** *Interest for magneto-dielectric nanocomposites is motivated by their interesting properties [1]: high electrical resistivities, low losses in turbionar currents and hysteresis, endurance at high temperature, chemical stability. Such materials offer many appealing technological properties: can easily be fabricated in various shapes and dimensions with low technological losses and at low prices. These properties open the possibility of using these materials instead common magnetic materials for electric machines and other electromagnetic devices. In this context the simulation problems of this materials behaviour in electromagnetic fields is very important. This paper proposes a study on how the PRNG type influences the results obtained through a simulation models for magnetodielectric nanocomposites behavior in electromagnetic fields. The case study model allows the calculation of the Néel time in nanoparticles systems with magnetic dipole interactions.*

**Keywords:** *superparamagnetism, magnetic nanoparticles system, stochastic model, pseudo-random number generator, simulation model, nanoparticle system*

## INTRODUCTION

*Nowadays, in nanomagnetism the effort is becoming greater for understanding the phenomena at nanoscopic scale. For this purpose, the modelling and simulation, especially the stochastic modelling and simulation play a major role. So, random numbers are being used more and more in computational nanomagnetism. To simulate the random components, we use random numbers, with theoretical or empirical distributions. For generating these numbers through algorithms, we use random numbers uniformly distributed in the range (0, 1) generated by computer. The algorithm used for generating is called pseudo-random number generator (PRNG).*

*The pseudorandom numbers are generated by deterministic algorithms, PRNG. An acceptable PRNG must yield sequences of numbers that are uniformly distributed, statistically independent, reproductible and non-repeating for any desired length. Thus, they are subjected to empirical and statistical tests, as follows: frequency test, serial test, autocorrelation test, run test, and chi-square test for goodness of fit [2]*

*The quality requirements for a PRNG include a huge period length, good statistical properties, high speed, low memory usage, repeatability of jumping ahead and splitting facilities [2].*

*The pseudorandom numbers used in simulation algorithms in science and engineering [3], [4], [5], [6].*

*The random number generators (RNGs), like those in MATLAB, are algorithms for generating pseudorandom numbers with a specified distribution [2]. A given number may be repeated many times during the sequence, but the entire sequence is not repeated.*

*A pseudorandom sequence is described by several properties [7]. A random stream is the sequence of values that are returned by a generator. The period of a sequence is its length, which is the number of values that it generates before the entire sequence is repeated. The state is the information that the generator keeps internally in order to create*

*successive values in the stream. The seed of a sequence is a single value defining its starting point.*

*The MATLAB software offers six generator algorithms [7]. Table 1 summarizes the key properties of the available generator algorithms and the keywords used to create them [3].*

*Table 1. Generator algorithms in Matlab [7]*

| Keyword | Generator | Multiple Stream and Substream Support | Approximate Period In Full Precision |
|---|---|---|---|
| mt19937ar | Mersenne twister (used by default stream at MATLAB startup) | No | $2^{19936}-1$ |
| mcg16807 | Multiplicative congruential generator | No | $2^{31}-2$ |
| mlfg6331_64 | Multiplicative lagged Fibonacci generator | Yes | $2^{124}$ |
| mrg32k3a | Combined multiple recursive generator | Yes | $2^{127}$ |
| shr3cong | Shift-register generator summed with linear congruential generator | No | $2^{64}$ |
| swb2712 | Modified subtract with borrow generator | No | $2^{1492}$ |

*Some of the generators (mcg16807, shr3cong, swb2712) provide for backwards compatibility with earlier versions of MATLAB [7]. Two generators (mrg32k3a, mlfg6331_64) provide explicit support for parallel random number generation. The remaining generator (mt19937ar) is primarily designed for sequential applications. Depending on the application, some generators may be faster, or return the values with more precision.*

## THE CASE STUDY SIMULATION MODEL

*The case study simulation model is a 3D model (arrangement of the nanoparticle in the system), phenomenological-stochastic, that allows the simulation of the average Néel relaxation time in a system of nanoparticles dispersed in dielectric matrix.*

*In this model [10], we consider a superposition of the nanoparticle size distributions, of the effective anisotropy constant distributions, and the nanoparticle disposal distributions in the sample. We take into account the dipolar magnetic interaction between the nanoparticles. With this model, we will realize advanced studies on understanding the phenomena at nanoscopic level and their implications in nanoparticles system applications, especially in electromagnetic devices.*

*Our model [10] is reported to the display of the nanoparticles in a given quantity, and we assume that it is aleatory (Gaussian distribution). We consider a statistical angular distribution for the angles made at a given moment by the other j nanoparticles with the uniaxial anisotropy axis, and we are going to simulate a 3D initial geometrical state after the dispersion of the nanonanoparticles in the basic matrix. These distributions will be simulates by stochastic methods.*

*So, for the N nanoparticles of the system, we simulate the distribution of diameters and anisotropy constants. The nanoparticle diameters are simulated as aleatory variables generated by a lognormal repartition law. The effective magnetic anisotropy constants of the nanoparticles, due to the surface effects, can be also simulated using a lognormal distribution. The variation of the anisotropy constants is justified [8] by the appearance of a surface anisotropy of the nanoparticles (a structural anisotropy resulted from the discontinuity of the magnetic interactions between individual spins found on the particle surface).*

*The distributions related to the nanoparticle geometrical arrangements and magnetic moment orientations are Gaussian distributions simulated through the Box Mueller method [9].*

*The model [10] starts from the idea of an Ising two-level model [11] of a spherical nanonanoparticle system with distribution of diameters and effective magnetic anisotropy effects. The energy of an i nanoparticle of the system in the* $\vec{H}_i$ *local magnetic field, oriented along its easy-magnetisation axis, is a function of* $\theta_i$, $E_i = f(\theta_i)$, *where* $\theta_i$ *is the angle between the direction of the i nanoparticle magnetic moment and the direction of the easy-magnetisation axis, along which the external magnetic field acts. In the* $E_i$ *expression [6], we find the* $M_{pi}$ *- i nanoparticle magnetic moment,* $v_i$ *- volume of the i nanoparticle,* $K_{ieff}$ *- the effective anisotropy constant of the nanoparticle, and* $H_i$*, local magnetic field in direction of easy magnetisation axis of nanoparticle. If we take into account the interactions of nanoparticles, we can consider that the* $H_i$ *field is made of two contributions: the external magnetic field H that acts along the easy-magnetisation direction, and the projection along the external field of the dipolar magnetic field created on the i nanoparticle, due to the dipolar magnetic interactions of the nanonanoparticles.*

$$H_i = H + H_{di} \qquad (1)$$

The magnetic behaviour of the nanoparticles in a dielectric matrix is determined by the Néel relaxation processes (nanoparticle magnetic moment rotation), characterised by the Néel relaxation time $\tau_N$, whose expression for the non-interactive case is given, for example, in [12], because the Brown relaxation processes (nanoparticle rotation in the solid dielectric matrix), characterised by Brown relaxation time $\tau_B$ [12] in blocked.

In these conditions, the $M_{pi}$ magnetic moment of a given i nanoparticle can be in one of the two equilibrium states, with the minimum energies $E^i_{min1}$ and $E^i_{min2}$ determined by $\theta_i = 0$ and $\theta_i = \pi$. These minimums are separated by the maximum energy $E^i_{max}$.

In the presence of thermal fluctuations, the magnetic moment of an i nanoparticle in steady state, with minimal energy $E^i_{min1}$, can spontaneously change its direction in the minimum energy state $E^i_{min2}$. The energy barriers for these re-orientations are $E^i_{b12}$ and $E^i_{b21}$.

We consider that the system is in thermal equilibrium. The average number of nanoparticles that pass in time unit from a minimum to another minimum is proportional with $N_k \exp\left(-\frac{E_{bk}}{k_B T}\right)$, where $k_B$ is the Boltzmann constant, and T is the temperature. If $N_1$ is the average number of nanoparticles in the state with minimum average energy $<E_{min1}>$, $N_2$ is the number of nanoparticles in the minimum average energy $<E_{min2}>$, the average energy barriers $\langle E_{b12}\rangle = < E_{max} > - < E_{min1} >$ and $\langle E_{21}\rangle = <E_{max}> - <E_{min2}>$, then the equilibrium condition shall be:

$$N_1 \exp\left(-\frac{<E_{b12}>}{k_B T}\right) = N_2 \exp\left(-\frac{<E_{b21}>}{k_B T}\right) \qquad (2)$$

$<x>$ is the notation for the statistical average for x. For a very large number N of nanoparticles, the arithmetical average estimator of x tends to the statistical average of x.

If N is the total number of nanoparticles of the system:

$$N = N_1\left[1 + \exp\left(-\frac{<E_{b12}> - <E_{b21}>}{k_B T}\right)\right] \qquad (3)$$

The difference $n = N_1 - N_2$ determines the resultant magnetic moment of the system. The total magnetic moment of the system in a given moment is proportional with n. Within an infinitesimal time period, the n difference becomes:

$$\frac{\partial n}{\partial t} = f\left[N_1 \exp\left(-\frac{<E_{b12}>}{k_B T}\right) - N_2 \exp\left(-\frac{<E_{b21}>}{k_B T}\right)\right] \qquad (4)$$

where f is a factor measured in $s^{-1}$.

Having in view the relations between $N_1$, $N_2$ and n, and applying a simple calculation artifice, we can write:

$$\frac{\partial n}{\partial t} = -f \cdot \exp\left(-\frac{<E_{b12}> + <E_{b21}>}{2k_B T}\right) \cdot \left[nch\left(\frac{<E_{b12}> - <E_{b21}>}{2k_B T}\right) + Nsh\left(\frac{<E_{b12}> - <E_{b21}>}{2k_B T}\right)\right] \qquad (5)$$

Starting from the equation (5), at usual temperatures much higher than the blocking temperature and very close to the equilibrium, the magnetic relaxation process of the system is governed by a differential equation which offers the solution that represents the exponential evolution in time of the residual magnetisation of the system with the Néel relaxation time:

$$\tau_N = \frac{\exp\left(\frac{<E_b>}{k_B T}\right)}{f_0 \cdot ch\left(\frac{<E_{b12}> - <E_{b21}>}{2k_B T}\right)} \qquad (6)$$

where $<E_b>$ is the average energy barrier and $f_0 = 2f$.

In the expression of energy barriers for the magnetic moments, we find re-orientations of the dipolar field of the nanoparticle $H_{di}$. To calculate the $H_{di}$ and the average dipolar field $<H_d>$, we use a stochastic method [13].

Using this model, we will perform a series of advanced studies to understand the effects of the distribution of particle sizes, the surface anisotropy and the anisotropy distribution, as well as the role of the dipole interaction on the magnetic properties. These studies will enhance our understanding of the magnetic properties of the nanoparticle systems, which is now far from being complete.

## RESULTS AND INTERPRETATIONS

The simulations were made for a system of 14 335 spherical nanoparticles of magnetite, with the spontaneous magnetization $M_s = 4.46 \cdot 10^5\ A/m$,

*dispersed in solid dielectric matrix, with average diameter of 10 nm, dispersion of the aleatory variable lnd 0.0625, average effective magnetic anisotropy constant of 10000 J/m$^3$, and dispersion of the aleatory variable ln $K_{eff}$ 1.21. The spatial distribution is simulated with Box Muller transformation [13], [14]. The spatial distribution parameters are: angular distribution dispersion for magnetic moments orientation: 0.25, dispersion of the spatial distribution of the nanoparticles: 0.01 (uniform arrangement of the nanoparticles in solution).*

*To generate series of random numbers with various distributions (lognormal, Gaussian) used in the model, we applied stochastic methods, and we checked the generated series of numbers with the concordance statistical criterion Kolmogorov-Smirnov [9], using from Matlab the function kstest. In case the series passes the test, the parameter H of this function returns the value 0; otherwise, the value is 1.*

*For simulations, we used 3 types of pseudo-random number generators: Mersenne Twister (mt19937ar), multiplicative congruential generator (mcg16807) and shift-register generator summed with linear congruential generator. Thus, we simulated the average Néel relaxation time for the nanoparticle system and the average effective magnetic relaxation time at various volume fractions of nanoparticles in solution, for seed=5. The graphical results are presented in Figure 1.*

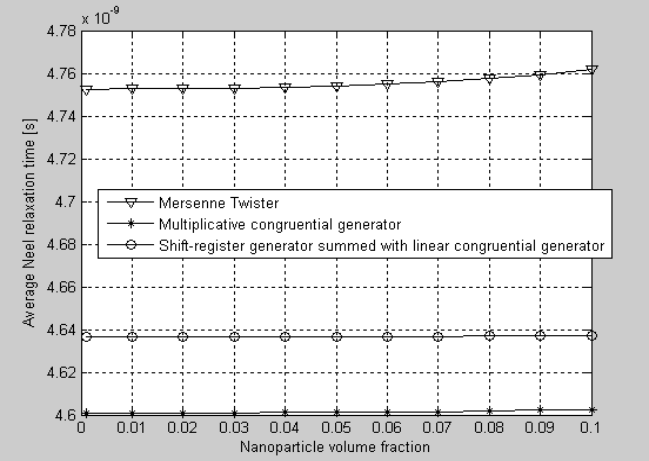


*Figure 1. The average Néel relaxation time versus the nanoparticle volume fraction, for generator seed=5*

*In the Figure 1 can be seen that the type of pseudo-random number generators influences the average value of the Néel relaxation time and the average effective magnetic relaxation time of the nanoparticles. Closer to reality are the results simulated with the Mersenne Twister generator. Most of the literature in the field [16], [17] claims an increase of the magnetic relaxation time with increasing the concentration of nanoparticles, at low concentrations.*

## CONCLUSIONS

*A way to check the results of a stochastic simulation is to rerun the simulation with two or more different generator algorithms, and the MATLAB software's generator choice provides you with the means to do that. It can be seen that the results do not differ greatly in case we work with different PRNGs, but a more realistic dependence can be seen when working with the Mersenee Twister generator.*

*According to the literature [see the References] and the researchers in the field, the current PRNG's state-of-the-art for simulation work is the so-called "Mersenne Twister" (MT).*

*It's hard to imagine any scientific application failing with this generator, although it has a huge period. It has also been adapted to many languages, and it is the default RNG in research.*

## References

[1.] *M. Osaci, M. Panoiu, I. Muscalagiu, Comparative study of the models for simulating the behavior of the ferritic nanocomposites within radiofrequency magnetic fields, Romanian Journal of Physics, vol. 49, nr. 9-10, 2004*

[2.] *H. Perros, Computer Simulation Techniques: The definitive introduction, 2009, http://www4.ncsu.edu/~hp/simulation.pdf*

[3.] *M. Panoiu, C. Panoiu, I. Sora, M. Osaci, About the Possibility of Power Controlling in the Three-Phase Electric Arc Furnaces Using PSCAD EMTDC Simulation Program, Advanced in Electrical and Computer Engineering, 7(1), pp.201-207, 2007*

[4.] *M. Pănoiu,C. Pănoiu, M. Osaci, I. Muscalagiu, Simulation Result about Harmonics Filtering for Improving the Functioning Regime of the UHP EAF, Proceedings of tha 7th WSEAS International Conference on Signal Processing, Computational Geometry & Artificial Vision, pp.75-80, 2007*

[5.] *M. Pănoiu, C. Pănoiu, M. Osaci, I. Muscalagiu, Simulation Results for Modeling the AC Electric Arc as Nonlinear Element Using PSCAD*

EMTDC, WSEAS Transactions on Circuits and Systems, 6(1), pp. 149-156,

[6.] M. Pănoiu, C. Pănoiu, I. Şora, M. Osaci, Simulation Results on the Reactive Power Compensation Process on Electric Arc Furnance Using PSCAD-EMTDC, International Journal of Modelling, Identification and Control, 2(3), pp. 250-257, 2007

[7.] http://www.mathworks.com/help/techdoc/ref/randstream.list.html

[8.] M. Knobel, W.C. Nunes, L.M. Socolovsky, E. De Biasi, J.M. Vargas, J.C. Denardin, Superparamagnetism and other Magnetic Features in Granular Materials: A Review on Ideal and Real Systems, Journal of Nanoscience and Nanotechnology, vol. 8, 2836-2857, 2008.

[9.] E. Petrisor, Simulare Monte Carlo, Politehnica Publishing House, Timisoara, 2006, pp. 67.

[10.]M. Osaci, Study about the possibility to control the superparamagnetism-superferromagnetism transition in magnetic nanoparticle systems, Journal of Magnetism and Magnetic Materials, 343, 189-193, 2013

[11.]R. Prozorov, Y. Yeshurun, Magnetic irreversibility and relaxation in assembly of ferromagnetic nanoparticles, Physical Review B, vol. 59, issue 10, pp. 6959-6965

[12.]R.E. Rosensweig, Journal of Magnetism and Magnetic Materials, 252 (2002) 370–374.

[13.]Manuela Pănoiu, Caius Pănoiu, Mihaela Osaci, Ionel Muscalagiu, Modeling and Simulating the AC Electric Arc Using PSCAD EMTDC, Proceedings of the 5th WSEAS Int. Conf. on System Science and Simulation in Engineering, Tenerife, Canary Islands, Spain, December 16-18, 2006

[14.]Manuela Pănoiu, Caius Pănoiu, Mihaela Osaci, Ionel Muscalagiu, Simulation Results for Modeling the AC Electric Arc as Nonlinear Element Using PSCAD EMTDC, WSEAS Transactions on Circuits and Systems,Vol 6, 2007, Pp 149-157

[15.]Mihaela Osaci, Manuela Pănoiu, Adela Diana Berdie, Stela Rusu-Anghel, Three-dimensional stochastic model for simulation of the nanoparticles geometry in nanoparticles dispersed magnetic media, Proceeding ICCOMP'09, Proceedings of the WSEAS 13th International Conference on Computers, 2009, pp. 179-183.

[16.]Ainhoa Urtizberea, Eva Natividad, Ana Arizaga, Miguel Castro and Arturo Mediano, J. Phys. Chem. C, 2010, 114 (11), pp 4916–4922

[17.]J.L. Dormann, L. Bessais, D. Fiorani, J. Phys. C: Solid State Phys, 21, (1988), 2015


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BULLETIN OF ENGINEERING
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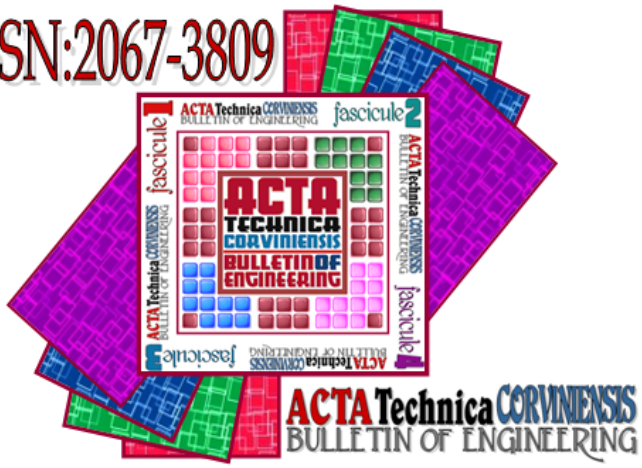


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ACTA TECHNICA CORVINIENSIS – BULLETIN OF ENGINEERING. Fascicule 2 [APRIL–JUNE]
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# RELATIONSHIP BEETWEN SUSTAINABLE AGRICULTURE AND RURAL DEVELOPMENT IN HUNGARY

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**Abstract:** Decades ago, agriculture and rural areas primarily focussed on producing industrial raw material as well as foodstuffs of appropriate quality and substantial quantity, which entailed the employment of a big chunk of rural labour in the agricultural sector. Later a trend emerged requiring the reduction of agricultural pressure on the environment, primarily by minimizing the use of chemicals. This trend then evolved into organic agricultural production and ecological farming, which both have been enjoying wide success in the develop world (see HOLLÓ et al., 2009) and have significantly risen in importance over the past few years as key factors of sustainable agriculture both in Hungary and across the globe. A shift from industrial agriculture to ecological agricultural production is evidently in progress both in the European Union and in Hungary (KISSNÉ, 2000).
**Keywords:** sustainable agriculture, rural development

## INTRODUCTION

While rural space has been drastically shrinking in the West, rural values are still well detectable in Hungary, thus bearing the potential of the revitalisation of segments of the economy which rely on rural resource systems. This revitalisation should be based on the principles of local sustainability as the current ecological situation is unsustainable both in Hungary and across the globe (MAGDA- MARSELEK, 2010).

I decided on the investigation of the relationship between rural development and sustainable agriculture as the subject of my research as the past few years have seen an emerging interest in sustainable agricultural solutions, with a special focus on natural, organic and ecological crop cultivation as well as livestock production methods. I believe that ecological farming could largely contribute to rural sustainability and development, and subsequently to the retention of the current rural population and triggering further population growth.

The above-mentioned factors are emphatic in both the Hungarian and European Union (EU) environmental and rural development policies. Organic production is the sole production system that has been clearly defined on EU level. This system aims at creating a sustainable management system that respects natural biological processes and cycles and at the same time produces high quality foodstuffs without posing a threat to the environment as well as to the health and well-being of humans, animals and plants alike (IFOAM EU GROUP, 2010).

Thomas Mal thus was the first to touch upon the issue of agricultural sustainability, arguing that population growth, if unchecked, could lead to starvation and wars due to an insatiable demand for food; consequently, the law of diminishing returns rules in the agriculture (LISÁNYINÉ, 2011).

The interpretation of agricultural sustainability as well as the role agriculture plays in rural sustainability recurrently raises professional debates. The lack of consensus results from the different approaches to the definition of sustainable agriculture, which consequently entails that the relationship between the rural areas and agriculture is not clearly identified yet.

I agree with Laki (2006), who claims that on the one hand, a vigorous rural area is based on vigorous agriculture but on the other hand rural

*development cannot be fully resolved solely via agricultural development. This also serves as proof that it is not realistic to expect agriculture to remedy the problems of rural areas.*

## *MATERIAL AND METHOD*

*Primarily I relied on the available scientific literature, research data, statistics databases as well as academic articles published in journals for my research purposes. I collected the statistical data with the assistance of the Hungarian Central Statistical Office (KSH), National Employment Service, Biokontroll Hungária Nonprofit Ltd, Hungarian Bioculture Association and EUROSTAT, the statistics database of the European Union.*

*My research explores the viability of ecological farming, a frequently emphasized production method these days, as a means of economic take-off in Bács-Kiskun County, a Hungarian region with deep and significant agricultural traditions.*

*I conducted in-depth interview with ecological farmers from Bács-Kiskun County, the majority of whom I randomly selected from a list of ecological farmers which is publicly available on the Hungarian Bioculture Association website. During visits at ecological farms, I was provided with contacts to further ecological farmers. Controlled ecological farms, farms converting to ecological cultivation as well as farms that had abandoned ecological cultivation were equally interviewed as I aimed at investigating the reasons for the drastic decline in the number of ecological farms after 2005.*

## *RESULTS*

*Ecological farming in Hungary is primarily engaged in crop cultivation but the overwhelming majority of the land is used as pasture or field while the cultivation of cereals is also significant (Figure 1).*

*Radics argues that the ideal land size for ecological farming would be ha 600,000 under the current conditions in Hungary but he disapproves the current administrative practices that classify many fields as ecological landing area although there is no actual cultivation performed – what actually happens on these areas is "taken care by Nature itself" (RADICS, quoting HAJTUN, 2012).*

*In the field of animal husbandry, cattle rearing and poultry farming are the most significant sectors (Figure 2).*

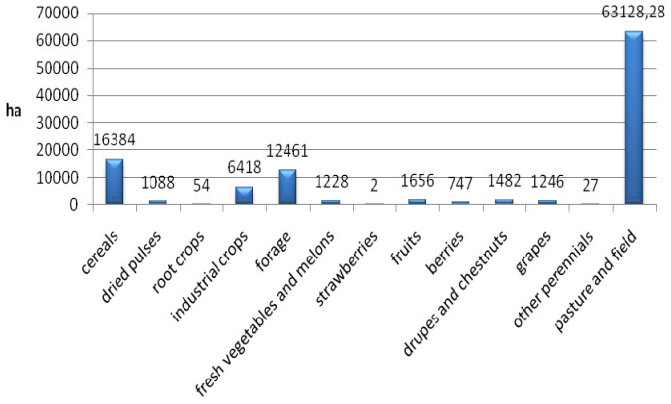


*Figure 1: Controlled areas in Hungary (2010)*
*Source: Biokontroll Hungária, 2011*

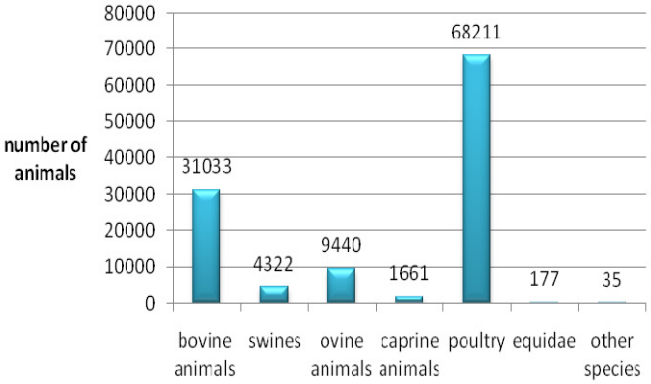


*Figure 2: Controlled livestock in Hungary (2010)*
*Source: Biokontroll Hungária, 2011*

*The farms participating in my research produce a variety of animal and plant species including cereals, corn, leguminous plants; fruits, grapes; vegetables; animals: grey cattle, racka (Hungarian sheep breed), Mangalitsa, caprine animals, poultry, Kisber Felver horses (Hungarian horse breed).*

*The range of plants produced varies from year to year depending on crop rotation.*

*Regarding the age group of the interviewees, the majority is aged 45 to 60. 40 percent of the farmers have completed higher education. In his research, Szente refers to the findings of the Agricultural Census of 2002, i.e. that the educational attainment of the controlled and uncontrolled ecological farmers is above the average. The ratio of controlled ecological farmers with tertiary attainment is 20 percent higher than the ratio of farmers on family-run farms generally; while the comparison of the ratio of tertiary attainment of uncontrolled ecological farmers and their*

*colleagues working on family-run farms reveals 11 percent difference (SZENTE, 2005). Figure 3 presents the educational attainment of the interviewees.*

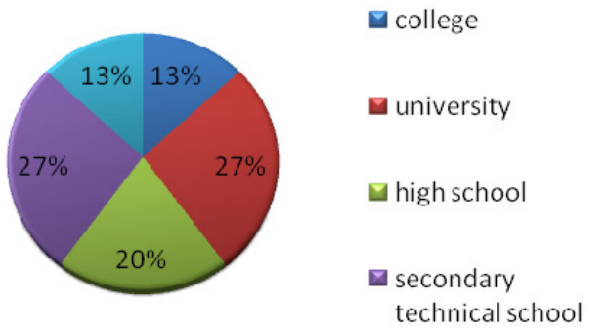


*Figure 3: The educational attainment of the interviewed ecological farmers*
*Source: Researcher's own research and editing, 2013*

*Most of the interviewed farmers used to work in the agricultural sector prior to switching to ecological farming, hence they have gained solid agricultural skills and relevant experience over the years. The majority of them is primary agricultural producers and has been working on family-run farms.*

*The in-depth interviews reveal that the majority of the interviewed farmers have started up in ecological farming out of commitment to the protection of the environment, non-chemical agricultural practices as well as healthy lifestyle. One of the interviewed farmers, who has quit ecological farming, claims that he decided to start up in this business due to the money-making and career-building potential that he believed ecological farming might have. I think this case exemplifies well that farmers who solely start up in ecological farming in the hope of financial gains will not get far in this business because in many cases they simply cannot cope with efficient weed management, ruined harvest or farming related administrative tasks – or they lack the willingness to cope with the latter as they regard it as a waste of time. I am of the opinion that ecological farming is a way of life, a world view and Attila Kocsis, the former Deputy Director of Hortobágyi Nonprofit Ltd also shares this view: "This is not simply a job but this is a mission in life that you do not only practise on the farm but it has got to be in your heart, in your soul" (ILONKA, 2010: p. 7).*

*Two of the interviewed farmers are converting part of their land, which are actually both vineyards, from conventional to ecological production. I think they are doing so in an attempt to find new market opportunities. The farmers have already faced several difficulties during the shift, therefore they are not sure yet whether they do not return to conventional agricultural production, especially because they can market wine grapes only as conventional products in the region where they live State bodies are paying an increasing amount of attention to ecological farming, for example its support plays a significant role in the Hungarian National Agri-Environmental Program, dated 1999. Aid is granted for ecological arable and pasture lands and plantations in the framework of Agri-Environmental Program (AKG) as well as area aid is also eligible for ecological farmers.*

*Szente (2005) points out in his research that the integration of agricultural lands of poorer soil into ecological production is given special attention in the Hungarian National Agri-Environmental Program. In Germany, farmers working on scattered lands of poorer soil and lower yield have had a higher tendency to convert to ecological farming. Of all the farmers I interviewed, only one claims that his possessing a poorer quality sand soil land played a role in his decision to convert to ecological farming.*

*The interviewees state that qualification as ecological producers does not bring high pecuniary gain, they rather use it to demonstrate instead that they stand up for high quality standards both in ecological farming and food production.*

*Most of the farmers agree that there is a raising demand for organic products on the side of Hungarian population, consumers are interested in these products and hopefully the number of consumers of organic products will further increase in the future. I think that this is partly owing to the health issues that the population struggles with and partly to the gravity that healthy lifestyle is present with in our everyday life; the youth increasingly pays attention to healthy diet while the older generation intends to protect and improve their health condition by consuming organic products.*

*In comparison to conventional products, the ratio of organic products available on the market is relatively small in Hungary, the overall supply is smaller than in the surrounding countries, for instance in Austria, where ten percent of the total territory used for agricultural production is subject to ecological farming. The consumers' potential reluctance to go for organic products is partly owing to financial considerations and partly to the mistrust towards organic products.*

*Direct sales plays a crucial role in the management of the majority of the farms in this research and this trend has led to the emergence of the so-called "Pantry Tour Network" which now has its own logo (Figure 4) and website (visit www.kamra-tura.hu). Pantry Tour is no webstore, no purchase can be done on the website, products can instead be purchased right on the spot from the farmers.*


*Figure 4: The official Pantry Tour logo*
*Source: Bács-Kiskun County Chamber of Agriculture*

*Ecological farmers in the surroundings of Kecskemét founded the so-called Szatyor Association. The Association operates a webstore, hence their products are purchasable online; orders can be placed on their website (szatyor.org), then these individual orders are gathered and forwarded collectively to the farmers on weekly bases. These farmers then deliver the ordered goods to the pick-up points on the days of taking over and in turn the members of the association who are in charge of picking up the delivered goods hand over the new orders designated to the individual farmers. The farmers are accountable for the quality and freshness of the goods they produce.*

*The stock-farmers I interviewed mainly raise indigenous Hungarian breeds which are highly resistant and have a high tolerance of extensive conditions.*

*The existence of controlled ecological farming in Hungary can be traced back to 1993-4. All the farms covered in my research, just like 95 percent of all the Hungarian ecological farms, are controlled by Biokontroll Hungária Nonprofit Ltd.*

*The interviewed farmers consciously select highly resistant local breeds that are fully suitable for the conditions of the given agricultural area. The adequate adaptability of the selected breeds to the specific conditions of the agricultural area is a minimum requirement on ecological farms because this is a prerequisite for the creation and preservation of the balance between the plant breed and the ecological as well as growing conditions, which harmony in yields successful production and high quality products (MÁRAI, 2010).*

*The in-depth interviews I conducted reveal that some of the farmers and their products are both domestically and internationally acknowledged. The Rendeks were rewarded with the Henry Ford European Conservation Awards for their achievements in the fields of eco-friendly farming and the preservation of folk culture; they received the awards at the Hungarian Academy of Sciences. They also joined the Slow Food[1] movement and they successfully present the Hungarian Mangalitsa sausage at the international food fair in Torino from year to year, where they represent Kiskunsági Traditionalist Association.*

*iPOPY (innovative Public Organic food Procurement for Youth) was launched as a research project in the European CORE Organic program in 2007 with the objective to provide the youth with organic food at school and other public serving outlets, thus increasing young people's consumption of organic food in Europe. Fourteen researches from Denmark, Finland, Italy, Norway and Germany participate in the project. The introduction of organic food into public food serving outlets is implemented step by step, in conjunction with political measures (NAGY, 2010).*

[1] *Slow Food is an international movement founded by Italian Journalist Carlo Petrini to resist the fast food phenomenon and particularly the opening of a fast food restaurant near Piazza de Spagna. The objectives of the movement are to promote and protect regional products from the wrongs of globalization and homogenization; hence their logo is the snail. Small producers have been awarded since 2000 for protecting biodiversity. Numerous products enjoy national and product protection in Europe but the sole Hungarian product to enjoy this protection is the Rendeks' Mangalitsa sausage.*

*The interviewees agree that ecological farming could contribute to the decrease of unemployment, related processing industry and trade could take on labour as well. Farmers face a severe shortage of agricultural labour with a willingness to work hard. Despite the high rate of unemployment, many unemployed are disinclined to take on hard agricultural jobs and it is more challenging to find reliable and properly skilled labour.*

*The majority of the interviewees do not plan to quit ecological farming but in the future they prefer focussing on processing to expanding the land they cultivate.*

*However, the future development of these farms heavily depends on aid from the government. A recently launched comprehensive agricultural program which covers agricultural and rural development and operates as the implementation framework of the Hungarian National Rural Strategy favours high quality agriculture, land and environmental management. The ruling government has set it as its objective to foster the production of high quality, healthy, safe and GMO-free foodstuffs in Hungary and the simultaneous protection of the natural resources, soil, drinking water, wildlife, landscape along with the humans, their communities and culture. The creation of job opportunities and the expansion of employment in rural areas are prioritized.*

*During his lecture at "The Current Situation of Domestic Ecological Farming in Hungary – Trends and Take-Off" event at Szent István University held on 2 February 2012, Lehota (2012) voiced his opinion that the domestic organic foodstuffs sector can succeed only if its competitiveness improves. A prerequisite to this end is the development and implementation of a strategy drawn up on the bases of proper and reliable research work.*

## *CONCLUSIONS*

*The in-depth interviews have brought me to the conclusion that only those farmers can succeed in ecological farming who have adopted the organic life style and world view in their lives, who truly believe that organic products are healthier, tastier than the conventional ones, who believe that they really contribute to the protection of the environment and natural assets and who want an alternative to the conventional chemicals-based agriculture. The pressure to maximize profit should be curtailed while drawing up the ecological policy; the farmers should accept (in theory) that the establishment of quality environment (including animal welfare, pleasant landscape and safe foodstuffs) is to prevail over profit and to meet this end, they bows to lower profitability. Profit is just a means here to the end of enhancing life quality. However, I agree with Farkas' opinion (2010) that farmers who put ecological production first and cut back on productivity and profitability would like to consolidate their finances which they see shaking in the absence of direct financial aids.*

*I think the biggest issue for ecological farming lies in the shortage of appropriate processing facilities and slaughterhouses. Slaughterhouses and processing facilities could take on significant labour, hence they could potentially decrease unemployment. The advancement of ecological farming could foster the expansion of organic product portfolios, which would bring Hungarian ecological farmers more consumers, hence the number of farmers who can solely conventionally market the majority of their products would decrease. The growth of ecological livestock rearing farms could help resolve the soil fertilization issue of plant production.*

## *REFERENCES*


*[1.] Magda R. – Marselek S. (2010): Vidékgazdaságtan I. A vidékfejlesztés gazdasági folyamatai. Szaktudás Kiadó Ház, Budapest. 297. o.*

*[2.] Holló M. – Bálint J. – Gál-Berey T. – Juhász M. (2009): Környezeti és társadalmi felelősségvállalás az agráriumban. Gazdálkodás. LIII. évf. 1. szám 46-56 o.*

*[3.] IFOAM EU GROUP (2010): A mezőgazdaságnak és az élelmiszertermelésnek meg kell felelnie a jövő kihívásainak. Hogyan profitálhat az EU az ökológiai gazdálkodási rendszerekből összetett szakpolitikai céljainak elérésében? Brüsszel. 53.o.*

*[4.] Kissné Bársony E. (2000): Az ökogazdálkodás szabályozási rendszerének EU- konform továbbfejlesztése az AGENDA 2000 tükrében. Agrárgazdasági tanulmányok. Budapest, AKII, 2. szám.*

[5.] Laki G. (2006): A mezőgazdaság fenntarhatóságának és mérési lehetőséginek vizsgálata. In. Biokultúra XIX. évf. 4. sz.
[6.] Lisányi E-né Beke J. (2011): A fenntartható mezőgazdaság kritériumrendszere és eredményei Dániában és Magyarországon. Gödöllő, Doktori (PhD) értekezés, 150. o.
[7.] Hajtun Gy. (2012): Az ökogazdálkodás lehetőségei. Magyar Mezőgazdaság, LXVII. évf. 7. sz. 24-25. o.
[8.] Szente V. (2005): Az ökoélelmiszerek termelésének, kereskedelmének gazdasági és piaci összefüggései. Kaposvár, Kaposvári Egyetem Gazdaságtudományi Kar, PhD. értekezés, 154. o.
[9.] Ilonka M. (2010): Pro Biokultúra 2010. Biokultúra. XXI. évf. 6. sz. 7. o.
[10.] Márai G. (2010): Tájfajták az ökológiai gazdálkodásban. Biokultúra XXI. Évf. 3. szám 31.o.
[11.] Nagy J. (2010): Öko ételek a gyermekétkeztetésben – tapasztalatok Nyugat-Európából. Biokultúra. XXI. évf. 3. szám 30.o.
[12.] Farkas J. Zs. (2010): Agrár- és vidékföldrajzi kutatások Bács-Kiskun megyei példákkal. Szeged, SZTE Doktori (PhD) Disszertáció, 180. o.
[13.] Lehota J. (2012): Biotermékek marketingje, kutatási eredmények és kitörési pontok. In: Az ökológiai gazdálkodás hazai helyzete- Trendek és kitörési pontok c. konferencia. Gödöllő, Szent István Egyetem 21-27. o.


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# SOLAR INTEGRATED ENERGY SYSTEM FOR GREEN BUILDING

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**Abstract:** *Green building is a kind of sustainable development and energy-saving building, has a very important significance for alleviating strained resources, protecting the environment to reduce pollution. And the solar energy is not only an energy, and a renewable energy, but which rich in resources. It not only free use of, but also not to be transported, and it produces no pollution to environment and more widely using in the green building. Early, solar building just passed the light and heat of the Sun in order to light up and heat the building. But now, the green building obtains solar energy by adopting 'active'. This 'active' green building is a kind of heating system consists of solar energy collector, radiator, pump and fan, or air conditioning-building combined with absorption chiller. One of the green building which is Shanghai Research Institute of Building Science contain multiple green energy technologies, such as solar thermal technology, solar photovoltaic, natural ventilation, natural lighting, and indoor virescence. Here, there an example of solar integrated energy system including heating, air conditioning, natural ventilation and hot water supplied which applied in the green building*
**Keywords:** *sustainability, thermal, solar, photovoltaic, renewable energy*

## *Introduction*

*The field of „green technology" encompasses a continuously evolving group of methods and materials, from techniques for generating energy to non-toxic cleaning products [1]. The present expectation is that this field will bring innovation and changes in daily life of similar magnitude to the „information technology" explosion over the last two decades. In these early stages, it is impossible to predict what „green technology" may eventually encompass. The goals that inform developments in this rapidly growing field include [2]:*

- *Sustainability - meeting the needs of society in ways that can continue indefinitely into the future without damaging or depleting natural resources. In short, meeting present needs without compromising the ability of future generations to meet their own needs.*
- *„Cradle to cradle" design - ending the „cradle to grave" cycle of manufactured products, by creating products that can be fully reclaimed or re-used.*
- *Source reduction - reducing waste and pollution by changing patterns of production and consumption.*
- *Innovation - developing alternatives to technologies - whether fossil fuel or chemical intensive agriculture - that have been demonstrated to damage health and the environment.*
- *Viability - creating a center of economic activity around technologies and products that benefit the environment, speeding their implementation and creating new careers that truly protect the planet.*

*Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs this is a common definition of the sustainable that been use all wide world [2]. In other word sustainability is the approach in which development that provide to ensure the need of today generation but not forgetting the need of future generation. The benefit of sustainability and green technologies is divided to three components, which are environment, social and economic.*

*The **environmental** benefits of sustainability and green technologies are as follows:*

- ***Lower Air Pollutant and Greenhouse Gas Emissions***

*One of the benefit of sustainability and green technologies is it reduce emission of CO2 this reduce by decreasing energy use through energy-efficient design, use of renewable energy, and building commissioning. When the CO2 is reduced it will lower the greenhouse gas emissions as CO2 is one of the gases that produce greenhouse effect [1].*

- ***Reduced Volumes of Solid Waste***

*Green construction practice such as using recycle material, waste prevention, storage and collection of recyclables will reduce the volume of solid waste that can contribute to pollution.*

- ***Decreased Use of Natural Resources and Lower Ecosystem Impacts***

*Sustainable design principle also assists in lessening the impacts on natural resources and ecosystems. One of the principles is sustainable sitting approach. It avoids built building on prime agricultural land, floodplains, and habitats for threatened species or near wetlands, parklands, and cultural or scenic areas. This will reduce the impact of the building to the ecosystem. Other than that; the use of rapidly renewable material such as bamboo will help reduce the use not renewable materials and help maintaining the forest and biodiversity.*

*The **social** benefits is of sustainability and green technologies*

- ***Better health of building occupants***

*The benefit of sustainability and green technologies in health is focus on the indoor environment and specially put in intention on the air quality. The indoor air quality is very important in maintaining the health of the occupant this is because usually the diseases are transmitted through the air. So, enough air ventilation is needed to remove harmful air outside and allow fresh air to the building through a sustainable site orientation and planning this can be achieved.*

*Usually sustainable building is design with many opening or louvered to allow the movement of air [2].*

- ***Improved comfort, satisfaction, and Well-being of building occupant***

*Psychological effects (e.g., comfort, satisfaction and well-being) are generated through perceptual and sensory processes that interpret environmental information in terms of its effect on current needs, activities, and preferences. Some of the sustainable feature like natural daylight, views, connection to nature, and spaces for social interaction, appear to have positive psychological and social benefits.*

- ***Community and societal benefit***

*Sustainable construction practices tend to generate lower amounts of dust, pollution, noise, traffic congestion, and other community disturbances. These improvements will likely contribute to improved public health, safety, and well-being. Construction practices and building operation practices that foster recycling and reduce waste generation will decrease the public nuisance this is because it will reduce the will demand for new landfills, electric utility plants, transmission and gas pipelines, and wastewater treatment. Furthermore, the use of local product in sustainable building will increase the local economy and provide job for community [2].*

*The **economic** benefit of sustainability and green technologies*

- ***Reduce First Cost***

*Sustainability and green technologies provide financial rewards for building owner's. This is because it lower the first costs. this can be seen when it use recycle material instead of other virgin material. the sustainable approach to site orientation will ensure the building capture enough sunlight and balancing the sunlight penetration with vegetation reduce the use of HVAC system which then reduce the first cost [2].*

- ***annual energy cost saving***

*Sustainable design approach will lead to annual energy saving. For example, reducing the use of HVAC system because of the sustainable design approach like good building orientation and good site planning may reduce the use of energy.*

- ***annual water cost saving***

*the annual water is save by using green technologies such as rain water harvesting. the rain water is use for the domestic use and lead to water cost saving. Some of the technologies such as*

*ultra-low-flow showerheads, no-water urinals, and dual-flush toilets will lower indoor water consumption [1].*

- ***lower costs of facility Maintenance and repair***

*Sustainable design aims to increase durability and ease of maintenance which will reduce the maintenance cost and repair cost. Some of the sustainable design approach is using local material to reduce the maintenance cost this is because the material is easy to get and the material is cheap.*

## *SOLAR INTEGRATED ENERGY SYSTEM FOR BUILDING*

*In the era where the energy future is uncertain. The amount of fossil fuel is no longer enough for the future. This cause the improvement of technologies in renewable energy sources. There are several of renewable energy sources available today. Some of the renewable energy sources is wind, biomass, and hydroelectricity and solar which now becomes a trend for the green building [3].*

*Solar energy is radiant light and heat from the sun. The technology enable the sun radiant light to be transform into electrical energy that can be used for the daily purposed. Some of the solar technologies are solar heating, solar photovoltaic, solar thermal electricity and solar architecture.*

*Solar technologies are basically divided into two which are active solar energy system or passive solar energy system depend on the way they capture, convert and distribute solar energy. Active solar energy system is the use of photovoltaic panel and solar thermal collectors to harness the energy. While, passive solar energy system is the technique to harness the solar energy passively. For example, by adjusting the building orientation to capture natural sunlight and to capture the heat from the sun to provide comfortable environment in the building [4].*

*It has become a trend for the large firms, and some of the famous architect to joining the forces with energy specialist to design the building based on the solar integrated energy system. Solar integrated energy system is no longer a system that only provides renewable energy either provide the passive solar energy system or active solar energy system. This is because it is a combination of all the technologies such as solar heated and cooled, photovoltaic powered building. Solar integrated energy system is also can be called as "solar building".*

*The word integrated in the solar integrated energy system is solar system become one of the part of the general building design. It cannot be separated or added after the building is completed. In fact, it becomes one of the building elements. Solar integrated energy system is sustainable system that combining all the solar technologies system that integrated with the building to make the building more energy efficient and reduce the use of depleting energy sources [3].*

## *ACTIVE SOLAR ENERGY vs PASSIVE SOLAR ENERGY*

*Active Solar Energy uses of mechanical devices in the collection, storage, and distribution of solar energy for building. An example is in active solar energy water heating systems a pump is used to circulate water through the system. There are a numerous solar applications that acan use to take full advantage of active solar energy. These include [5]:*

- *Active Solar Heating is a method of heating the air inside of the building. This method uses mechanical equipment including: pumps, fans and blowers to help collect, store and distribute heat throughout the building.*
- *Active Solar Heating is a method of heating the building with water using the sun and pumps to circulate the water or heat-transfer fluid through the system.*
- *Passive Solar Energy refers to the harnessing of the sun's energy without the use of mechanical devices. Using south-facing windows to provide natural lighting and heat for home are examples of passive solar energy.*

*There are a variety of solar applications that a homeowner can use to take full advantage of passive solar energy. These include:*

*Passive Solar Heating is a type of solar space heating that can be accomplished by the following methods:*

- *Orienting the building so that the majority of it's windows face south.*
- *Sizing windows for optimal heat gain and making sure have the right type of windows.*

– *Utilizing thermal mass to absorb the solar energy entering the windows for release during the night. Thermal mass is simply a solid or liquid material that will absorb and store warmth and coolness until it is needed. Examples of thermal mass include: brick, stone, concrete and water.*
– *Insulating the building to minimize heat loss.*

*Passive Solar Cooling utilizes many of the methods listed below to minimize the impact the summer sun has on the building and thereby reduce or eliminate building need for mechanical cooling systems. Passive Solar Cooling techniques include [5]:*

– *Orienting building and landscape so that it can take advantage of cooling breezes.*
– *Designing building to minimize barriers to air paths through the buildng to allow for natural ventilation.*
– *Using the right size and type of windows in order to minimize the heat gain in the summer and that enable ventilation by opening.*
– *Using both structural features and landscaping to create shading.*
– *Insulating the building to maintain a comfortable temperature.*

*Solar energy is receiving much attention in green building energy system because of its abundant and clean being. Generally, the newer green buildings combine several of solar technologies. As for example, they may be both energy efficient, solar heated and cooled, and PV powered in one building. They are simply just solar buildings. Solar integrated energy system is the combination of different solar-related technologies. Solar energy is a renewable resource that can be used in many ways for water heating, space heating and cooling in buildings [2].*

*An integrated energy system based on solar thermal technologies are:*

***a) Solar Water Heating System***

*The beauty of a solar hot water system is its relative simplicity and durability. There are two types of collectors used in a solar hot water service as been shown in Figure 1:*

– *flat plate collectors (suitable where tank roof mounting is required)*
– *evacuated tubes (more efficient and great for frost prone areas)*

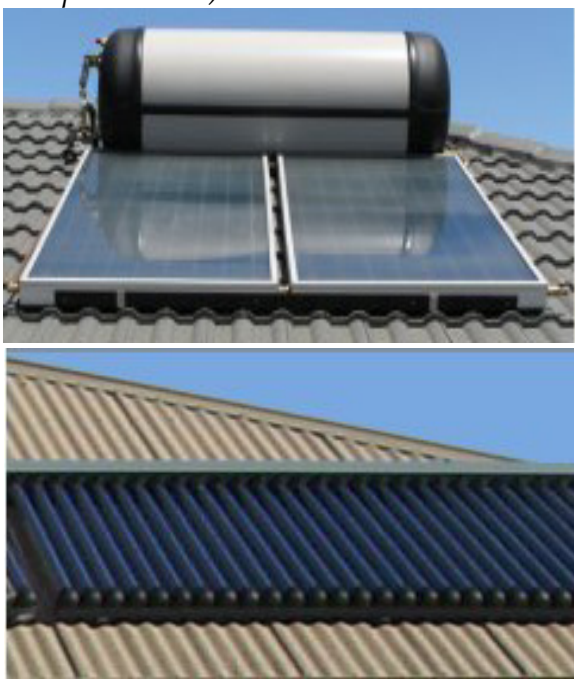

*Figure 1. Flat panel (left) and evacuated tube collectors*

***i. Flat plate solar collectors***

*Flat plate collectors' work on copper pipes running through a glass covered collector, often connected to a water storage tank on the roof. The hot water can then thermo-siphon itself in and out of the tank, thus heating the water [5].*

***ii. Evacuated tube solar collectors***

*Evacuated tubes use a glass tube with a vacuum inside and copper pipes running through the centre. The copper pipes are all connected to a common manifold which is then connected to a slow flow circulation pump that pumps water to a storage tank below, thus heating the hot water during the day. The hot water can be used at night or the next day due to the insulation of the tank [4].*

*The evacuation tube systems are superior as they can extract the heat out of the air on a humid day and don't need direct sunlight. Due to the vacuum inside the glass tube, the total efficiency in all areas is higher and there's better performance when the sun is not at an optimum angle - such as when it's early in the morning or in the late afternoon.*

***b) Integrated solar Energy System***

*The integrated solar energy system mainly includes two adsorption chillers, floor heating pipes, finned tube heat exchangers, circulating pumps and a cooling tower. Hot water storage tank*

*is employed to collect solar heat, thereby providing hot water for the integrated solar energy system. The integrated solar energy system can be switched to different operating modes through valves located on the pipes according to different seasons [5].*

*This silica gel-water adsorption chiller is composed of three working vacuum chambers including two desorption/ adsorption chambers and one heat pipe working chamber. In the adsorption chamber, water is taken as the refrigerant, while in the heat pipe working chamber; methanol is used as the working substance. The evaporation cooling in evaporator 1 or 2 is transferred to the methanol chamber via heat pipe evaporation/condensation process. Chilled water is cooled down in the methanol chamber directly. This design idea has made two water evaporators (Evaporator 1, Evaporator 2) integrated into one methanol evaporator.*

*Generally, the supply water temperature of floor heating system is relatively lower, which leads to the feasibility of low-grade heat source. As a result, solar energy is suitable for floor heating system. The floor heating coil pipes are made of high-quality pure copper with the dimension of F12 _ 0.7 mm, fixed on the 30-mm thick polystyrene insulation layer with spacing interval 200 mm. And then crushed stone concrete was poured with the thickness of 70 mm. Figure 2 shows the arrangement of floor heating coil pipe [5].*

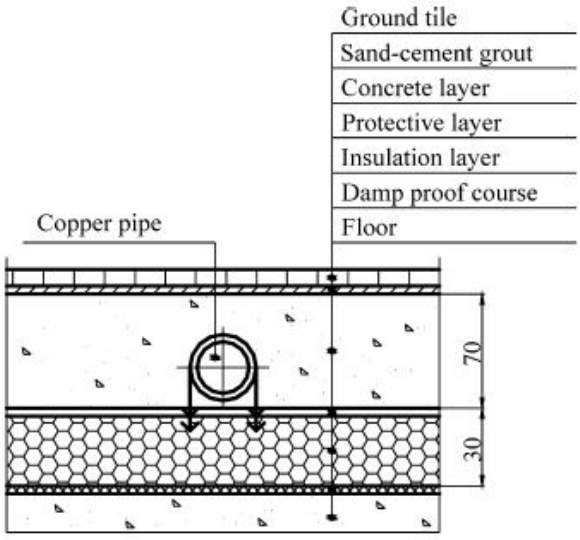


*Figure 2. Arrangement of floor heating coil pipe*

### *c) Natural Ventilation Enhance*

*There is an air channel under the roof of the green building, which is designed for indoor air exhaust through natural ventilation. In order to enhance natural ventilation by stack pressure, we installed seven groups of heat exchange elements inside the air channel. Each group consists of three parallel finned tube heat exchangers as shown in Fig. 8. The finned tube heat exchanger is made of a 3-m long copper tube with 540 square fins. The diameter of the tube is 20 mm and the sectional dimension of the square fins is 102 mm [3].*

## *SOLAR INTEGRATED SYSTEM APPLIED IN GREEN BUILDING*

*The green buildings of Shanghai Research Institute of Building Science include an office building for the demonstration of public building and two residential buildings which are for the demonstration of flat and villa, respectively. As demonstration projects, they contain multiple green energy technologies, such as solar thermal technology, solar photovoltaic, natural ventilation, and natural lighting [6]. Here, we designed a solar-powered integrated energy system including heating, air-conditioning, natural ventilation and hot water supply for the office building. However, only solar hot-water systems were designed for the flat and villa. All the three systems have continuously run for 2 years.*

### *i. Integration of solar hot-water system with flat*

*A three-storey green building was built for the demonstration of flat, where the first floor is for ordinary single-storied flat and the upper two floors are for duplex flat. The solar collectors were installed on the sideboards of balconies. According to the dimension of balconies, we customized evacuated tubular solar collectors with CPC, and placed solar collectors at the first floor, second floor and third floor. Figure below shows the effect of integration of solar collectors and the flat. Here, solar collectors act as not only the heat source of hot-water system, but also the decoration of balconies [4]. This demonstration project serves as a good example of both building integration and of a sensible combination of functions. Moreover, it provides a feasible design method for multi-story buildings and high-rise buildings especially for residential buildings. Besides solar collector arrays, the solar hot-water system of the single-storied flat is mainly composed of a solar collecting pump, a*

*constant pressure tank and a heat storage water tank. They are connected through copper pipes and valves to form a closed circulating system [5]. The domestic hot water is heated by the heat exchanger inside the heat storage water tank. Similar solar hot-water system was constructed for the duplex flat by the parallel connection of solar collector arrays on the second floor and the third floor.*

***ii. Integration of solar hot-water system with villa***

*In the villa, because the whole roof is occupied by technologies of solar photovoltaic then U-type evacuated tubular solar collected is customized with CPC in terms of the dimension of awning, as shown in below. Such design provides another example of how a solar element could be used in the original design in a logical manner, especially for those without enough roof area. The solar hot-water system in the villa is similar with those of flat (Figure 3).*


*Figure 3. Solar hot-water system in villa*

***iii. Integration of solar collectors and green office building***

*As the power to drive adsorption chillers and the heat source for the floor heating and natural ventilation, the solar collectors are the most important parts. We installed solar collectors on the roof of the green building, wherein U-type evacuated tubular solar collectors with CPC of area were placed on the west side (SCW), and the other heat pipe evacuated tubular solar collectors on the east side (SCE). For the purpose of efficient utilization of solar energy, the architects designed a steel structure roof, facing due south and tilted at an angle of 40° to the ground surface, on which the solar collectors were mounted and integrated with the building perfectly [6].*

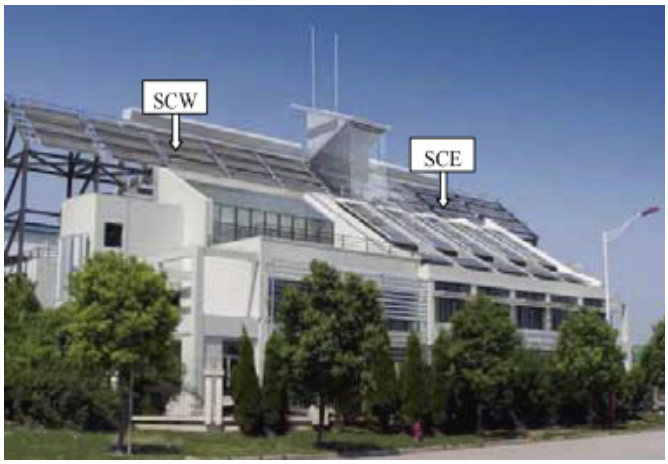


*Figure 4. Appearance of the green office building integrated with solar collectors*

*Figure 4 shows the appearance of the green office building integrated with solar collectors. All solar collectors of both sides were divided into three parallel rows. The collector units in each row were connected in a series arrangement for the purpose of obtaining hot water with relatively high temperature, which plays an important role in improving performance of the solar energy system. Such an arrangement of solar collectors not only guarantees high system performance but also enhances the architectural expression of the building. Besides, it provides a feasible idea for integration of solar collectors and civil buildings especially for public buildings [3].*

***iv. Design of solar-powered integrated energy system***

*An integrated energy system based on solar thermal technologies was designed and set up for building area of 460 m². As an office building, the hot water demand is not as significant as that in residential buildings. So, the solar-powered integrated system design of the green building is mainly focused on floor heating in winter and air-conditioning in summer. Another design is natural ventilation enhanced by solar hot water, which is effective and necessary to solve the problem of surplus hot water in transitional seasons. Moreover, it provides a new method for the design of solar-enhanced natural ventilation [4].*

*Except for solar collectors, the solar-powered integrated energy system mainly includes two adsorption chillers, floor heating pipes, finned tube heat exchangers, circulating pumps, and a cooling tower. Besides, a hot water storage tank is employed to collect solar heat, thereby providing*

*hot water for the integrated solar energy system. All components are connected by tubes and valves to form the whole circulating system.*

***BENEFITS OF SOLAR INTEGRATED ENERGY SYSTEM***

*First of all advantages of solar energy is that Solar energy offers the highest energy density among all the renewable energy resources (a global average of 170 W/m$^2$). The amount of solar energy received by the Earth every minute is greater than the amount of energy from fossil fuels consumed each year worldwide.*

*In areas with a well-developed power grid, solar energy leads green energy in the network. In the case of grid-connected, photovoltaic energy can be stored and used at times of peak demand, reducing the network load. A solar energy system can generate electricity all year round, not just in the days of sunshine. Solar energy does not cause pollution, which is one of the most important advantages of solar energy. The maintenance, or structures, after an initial set-up, is minimal [7].*

*The solar energy connected to the network can be used locally minimizing in this way the losses related to transmission / distribution (approximately 7.2%). The grid-connected photovoltaic systems produce electricity from conventional clean and sustainable. Are environmentally friendly, the usual costs of transport and energy allow any user to become a producer of green energy in an easy and profitable.*

*Supported the initial cost of installing a solar power plant, operating and maintenance costs are minimal (<10% of revenues), as compared with existing technologies. The lifetime of a solar energy system over 20 years, this is also one of many important advantages of solar energy.Solar cells are long lasting sources of energy which can be used almost anywhere. They are particularly useful where there is no national grid and also where there are no people such as remote site water pumping or in space [5].*

*Solar cells provide cost effective solutions to energy problems in places where there is no mains electricity. Solar cells are also totally silent and non-polluting. As they have no moving parts they require little maintenance and have a long lifetime. Compared to other renewable sources they also possess many advantages; wind and water power rely on turbines which are noisy, expensive and liable to breaking down [6].*

*Rooftop power is a good way of supplying energy to a growing community. More cells can be added to homes and businesses as the community grows so that energy generation is in line with demand. Many large scale systems currently end up over generating to ensure that everyone has enough. Solar cells can also be installed in a distributed fashion, i.e. they don't need large scale installations. Solar cells can easily be installed on roofs which means no new space is needed and each user can quietly generate their own energy.*

*Solar Energy Advantages are often discussed in the news, the biggest advantage may be that this is an option to achieve energy independence on an individual basis and at your own speed [7]. You can add a solar powered attic fan or water heater or migrate a little faster with solar panels to supplement a portion of your electrical needs or get completely off the grid or somewhere in between. We took for granted that electricity would continue to be easy to acquire, relatively cheap to consume and reliable.*

*While it is still convenient, we know it is no longer easy to acquire or cheap to consume and in the past few years many of us have experienced rolling blackouts, power outages that lasted longer than a few days and these instances are happening multiple times and more regularly. Taking into consideration the environmental disasters of oil spills in just Alaska and in the Gulf, it's clear that oil companies have no backup plan in the case of mishap. Now maybe the best time to really explore the advantages of solar energy and how to transition to this source of energy for our homes and businesses.*

***CONCLUSIONS***

*In conclusion, solar technologies can be divided into two which are active solar energy system or passive solar energy system depended on the way they capture, convert and distribute solar energy. Active solar energy system is the use of photovoltaic panel and solar thermal collectors to harness the energy while, passive solar energy system is the technique to harness the solar energy passively. For example, by adjusting the building*

*orientation to capture natural sunlight and to capture the heat from the sun to provide comfortable environment in the building. Solar integrated energy system is sustainable system that combining all the solar technologies system that integrated with the building to make the building more energy efficient and reduce the use of depleting energy sources. Solar integrated energy system involves heating, air-conditioning, natural ventilation and hot water supplying was constructed for the green building, which realizes high integration of solar thermal technologies.*

***References***


[1.] *M. Green, Third Generation Photovoltaics: Advanced Solar Energy Conversion, Springer, Berlin, 2006.*

[2.] *G. Dennler, The value of values, Mater. Today 10 (2007) 56. [4] ASTM Standard G173, Standard Tables for Reference Solar Spectral Irradiances: Direct Normal and Hemispherical on 371 Tilted Surface, ASTM International, West Conshohocken, PA: /http://www.astm.*

[3.] *IEC Standard 60904-3, Photovoltaic Devices – Part 3: Measurement Principles for Terrestrial Photovoltaic (PV) Solar Devices with Reference Spectral Irradiance Data, International Electrotechnical Commission, Geneva, Switzerland*

[4.] *ASTM Standard E 927, Standard Specification for Solar Simulation for Photovoltaic Testing, ASTM International, West Conshohocken, PA, USA*

[5.] *IEC Standard 60904-9, Photovoltaic Devices – Part 9: Solar Simulator Performance Requirements, International Electrotechnical Commission, Geneva, Switzerland*

[6.] *V. Shrotriya, G. Li, Y. Yao, T. Moriarty, K. Emery, Y. Yang, Accurate measurement and characterization of organic solar cells, Adv. Funct. Mater. 16 (2006) 2016–2023.*

[7.] *W. Durisch, B. Bitnar, J.-C. Mayor, H. Kiess, K.-H. Lam, J. Close, Efficiency model for photovoltaic modules and demonstration of its application to energy yield estimation, Solar Energy Mater. Solar Cells 91 (2007) 79–84.*



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# RISK TREATING IN EARLY LIFECYCLE PHASES

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**Abstract:** Identification and treatment of risks in early phases of a product lifecycle are becoming more commonplaces nowadays. Since state-of-art companies that want to keep up with competitors have to consider all actions which might prevent loses or customer's dissatisfaction. This paper deals with a new risk management procedure concerning the early phases of a product lifecycle. Proper risk identification in early phases may result in mitigation or removal of an impact that might cause considerable property, health or the environment losses in late phases of a product lifecycle. Phases of conceive and design are considered as early phases in this study. It is always very complicated to assess risks in an early phase of a project since almost no data is available. Therefore, this procedure has been developed to help to manage such risks. Procedure combines so far known methods and adds new possible steps that may be taken advantage of.
**Keywords:** Risk Management, Product Lifecycle, Conceive, Design

## INTRODUCTION

Currently, risk management is an integral part of every state-of-art production enterprise because running enterprises always goes with various kinds of risks. Therefore, it is necessary to develop and improve ways of implementation of a risk management system into enterprise processes. Risks are supposed to be managed across all levels of organization and considered in terms of finance, environment and occupational safety. As far as production enterprises are concerned, it is also necessary to transfer the risk management to produced products. Every product has its product lifecycle where it is needful to consider various influences which enter the product lifecycle and manage risks here. The product lifecycle and its managing have become a present standard and a part of the information structure of modern enterprises. Due to comprehensibility and definiteness, it consists of several phases. This helps to make risk management easier because it is feasible to manage risks for each phase separately. This study deals with the phases of conceive and design that are considered to be the early phases of a product lifecycle. Managing risks at the beginning of a product lifecycle is very important because this action may be beneficial in the future phases and save a considerable amount of money, company's reputation or even human health.

## PRODUCT LIFECYCLE MANAGEMENT

The product lifecycle is based on the principle of a biological cycle, i.e. the process from birth to death. This theory is the same for a product and it can also be understood as a process which is one of the other enterprise processes. In risk management, all participating subjects must understand the relation between project management processes and the other enterprise processes. The project lifecycle is the natural framework for investigation of relations and processes in the field of project management. It is described as a means of defining of the beginning and end of a project and its phases. The form of life cycle definitions varies by industry areas but it is also various within the same industry for different organizations and businesses. In project management, the risk approach changes in various stages. This depends on how much information is available and what the extent of the project progress is. The most common lifecycle description covering all phases is seen in Figure 1.


Figure 1: Common lifecycle phases

*The product life cycle or PLM (Product Lifecycle Management) is a control process from conception through design and production to service and disposal. PLM includes people, data, processes, business systems and provides the main information flow for companies. Simultaneously, PLM systems help organizations in copying with an increasing complexity and engineering tasks of new products development for global competitive markets [1].*

*Low-quality data in the process of a product origin means a considerable problem of higher costs. Number of components of all today's products and its shape complexity are still increasing. This trend is clearly seen in all industries. It is not an exception when the number of product components is not just in the tens of thousands but hundreds of thousands or even in six figures (automotive, marine, aviation and aerospace industry) [2]. Therefore, it is necessary to prevent the risk of failures from the very beginning of the lifecycle of each product.*

## *RISKS IN THE PHASE OF CONCEIVE*

*At the beginning of each product's life cycle is always the customer who expresses its needs and these needs must be heard. There is no universal voice of the customer (VOC), each is unique and very diverse. Customers have many different requirements. Even within a single purchasing unit may appear different requirements [3]. All these voices must be considered and balanced in order to develop a truly successful product. For a better understanding of customer needs, a discussion with him should be held where it is important to identify the basic needs of the customer. First, his involvement is necessary to define requirements, answer questions of developers and then to advice and criticise the actual product development process or evaluation of a prototype design, etc.*

*General requirements should be divided into more specific details - the customer should be urged to thoroughly clarify and express its demands until they make a perfect sense. Such practices often lead engineers of highly technological products to fundamental findings that ease of use and durability are usually more important for the customer than the latest technology. Besides expressed needs of the customer, it is also needed to identify the unspoken ones. Needs considered as only a conjecture and therefore unmentioned, they can be identified through the preparation of a tree of functions. When all the needs of the customer are collected, it must be properly organized.*

*Voice of customer is usually the input for CTC. Critical to customer (CTC) are measurable standards of performance for a product or service that are essential in order for that product or service. Critical to Customer items are those which are particularly important to the customer, as defined through a process of assessing the Voice of the Customer by methods from survey to interview to focus groups. CTC provides a simple method for prioritizing and selecting appropriate input requirements for this process. CTC items are reflected internally in Critical to Quality (CTQ) criteria. Then, CTC and CTQ are inputs for further risk analysis as the Delphi method. The next input for the primary risk analysis of the entire product lifecycle is so-called Lessons learned. A recommendation, based on analysed experience, from which others can learn in order to improve their performance. It is necessary to consider whether a similar product was developed in the past and what risks occurred and how they were treated. Then, the same counter-measures must be applied to the current product or eventually with improvements.*

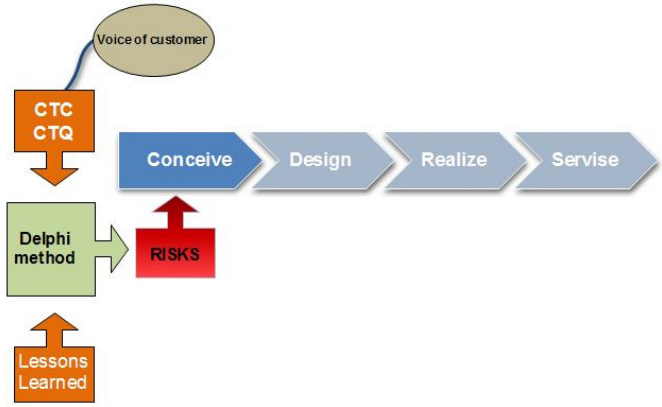


*Figure 2: Risk identification in the phase of conceive*

*As it was mentioned above, the input for primary risk analysis should be CTC, CTQ and Lessons Learned as it is seen in Figure 2. Since it is not possible to quantify risks in the first phase of the lifecycle, it is necessary to carry out only a qualitative estimate. For these purposes, it is*

*suitable to choose the Delphi method or some of methods according to [4]. Then, all identified risks will come through all phases. Before the single risk analysis, it is needed to define a terminology which will be used during the entire lifecycle.*

*In this phase, it is not difficult to carry out any changes. In consequent product phases, the possibility and ease of any change go down and a price of a change and a risk rapidly grows in time since the product is committed to technology, configuration and performance. Therefore, it is necessary to identify all risks in the first two phases when it is still possible to make changes and counter-measures with ease. Unidentified risks in the phases of realize and service may endanger the financial achievement of the whole project [5]. The level of ease of changes in single phases is seen in Figure 3.*

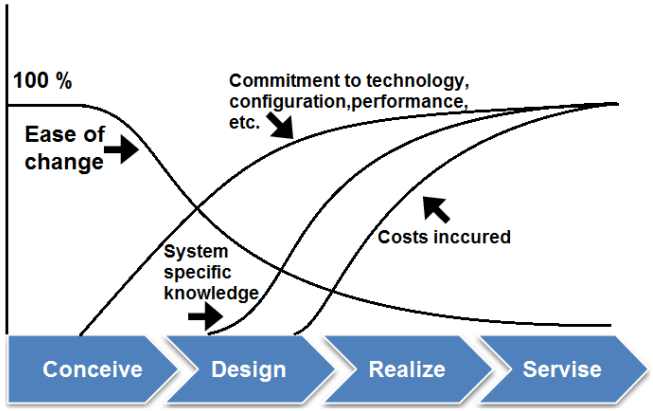


*Figure 3: Ease of change, commitment to technology and costs during the product lifecycle [4].*

## RISK IN THE PHASE OF DESIGN

*A design risk assessment is the act of determining potential risk in a design process, either in a detailed design, consequent analysis or simulation, validation and possible tool design [6]. It provides a broader evaluation of a design beyond just CTQs, and enables to eliminate possible failures and reduce the impact of potential failures. Risks from the conceive phase are transferred to the phase of design and new risks must be assessed after simulation and clarification as seen in Figure 4.*

*Making a prototype and simulations, it can considerably help in identification of product risk aspects. Also, a simulation of treating the product and its placing into the working environment are important. Here, it is possible to estimate the risk probability which is already quantitative. For the better understanding of customer's requirements, it is suitable to set an appointment with a customer and introduce the prototype. Then, it is possible to adjust it according to customer's needs. From the way of the customer's treating with the prototype, it is likely to observe other possible risks. For the risk assessment, the method from [7] was used.*

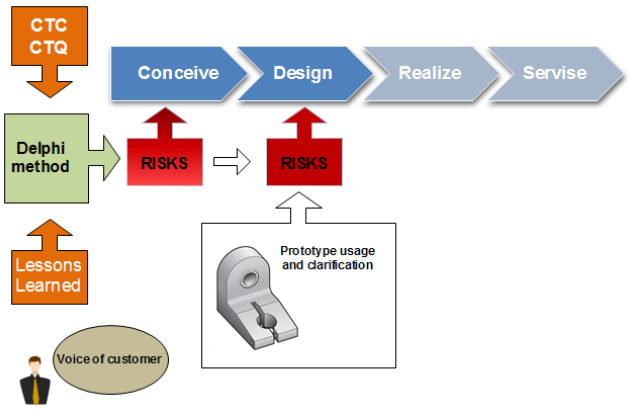


*Figure 4: Process of risk identification in the design phase*

*In this study, probability level is divided into five levels: very likely, likely, possible, unlikely and very unlikely. The relative description of probabilities is shown in Table 1. Further, the level of impacts of events is divided also into five levels: very serious, serious, moderate, minor and negligible. The exact criteria description depends on a certain product as seen in Table 2. The higher levels of both, the more serious issue may occur.*

*Table 1: Probability level*

| Level | Description | Probability [%] |
|---|---|---|
| 5 | Very likely | 1 – 0,1 |
| 4 | Likely | 0,1 – 0,01 |
| 3 | Possible | 0,01 – 0,001 |
| 2 | Unlikely | 0,001 – 0,0001 |
| 1 | Very unlikely | less than 0,0001 |

*Table 2: Impact level*

| Level | Description | Criterion |
|---|---|---|
| 5 | Very serious | |
| 4 | Serious | |
| 3 | Moderate | Depends on the event |
| 2 | Minor | |
| 1 | Negligible | |

*Table 3: Example of a table with assessed risks*

| Item | Event | Probability level | Impact level | Probability index | Impact index | Risk value |
|---|---|---|---|---|---|---|
| 1-... | Risk | 1-5 | 1-5 | 0-1 | 0-1 | 0-1,41 |

*After identification of all risk events, it is needed to determine the probability* $R_p$ *and impact* $R_I$ *index*

*of a given event and the consequent risk value R as it seen in Formula 1. Calculations of the probability and impact indexes are described in Formulas 2 and 3.*

$$R = \sqrt{R_I^2 + R_p^2} \quad (1)$$

*where,*

$$R_p = \frac{\mu_p - min}{R_{FP}} \quad (2)$$

$$R_I = \frac{\mu_I - min}{R_{FI}} \quad (3)$$

*From Formula 2, $\mu_p$ refers to the mean of probability level. From Formula 3, $\mu_I$ refers to the mean of impact level, min refers in both cases to the minimum of the k – level table, set to 1. $R_{FI}$ and $R_{FP}$ refer to the full distance of k – level table minus 1, both values are 4 ($R_{FP} = R_{FI} = 4$). All counted indexes and values are recorded in the table. An example is seen in Table 3.*

## BASEBALL FIELD DIAGRAM

*Risk value R is divided into five priority areas, from A to E, where A represents the area of the highest priority. Risk value R combines the probability index $R_p$ and the impact index $R_I$. With one index as horizontal axis and the other as the vertical axis, a diagram reminding of a sector of a baseball field can be drawn. Whose bottom left corner represents the lowest coordinates (0,0) and whose upper right corner is the largest coordinates (1,1) as seen in Figure 5.*

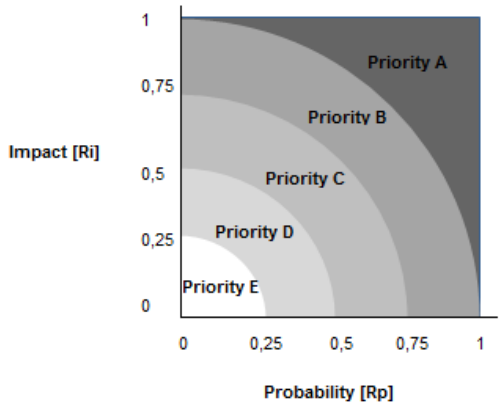


*Figure 5: Baseball field diagram*

*There are five priority areas in the diagram. The priority area A represents risks of the highest priority and it is necessary to carry out immediate counter-measures. The area of B represents risks of the high priority. It has the next highest priority for resources for management and control, and so on, down to the probability area E where risks may be neglected.*

## CASE STUDY

*For instance, this may be applicable for a new printed circuit boards (PCB) development or for custom made PCBs. When a customer requires special treatment or PCBs determined for special environmental conditions. Practical examples of treating risks and the Baseball field diagram are shown below.*

### Conceive

*A customer requires a product line of printed circuit boards with a perfect level of cleanliness, accuracy and all PCBs must be perfectly soldered. This may be considered as a Voice of Customer and these three drivers are critical to quality of a product. It is seen in Figure 6 and this is the input for the phase of conceive. It is always necessary to listen to the customer's voice and his wishes from which drivers for CTQ may be deduced. When a similar product was produced in the past, all issues concerning its quality should be counted on and considered for the new product. This is called Lessons Learned as also seen in Figure 6.*

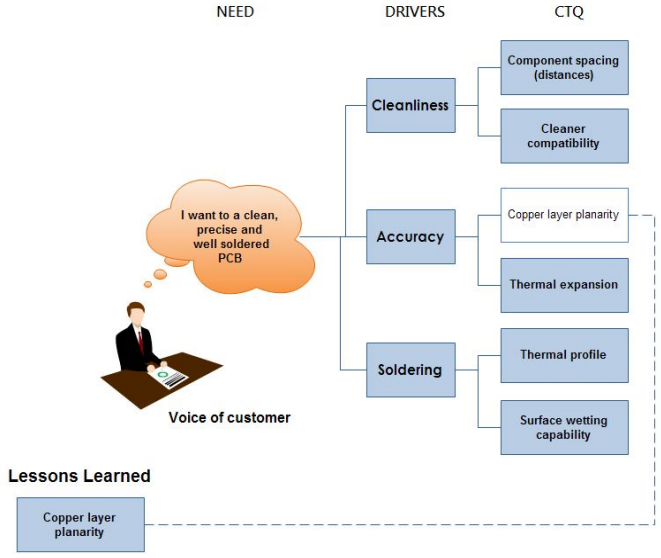


*Figure 6: Critical to quality diagram*

*Methods such Delphi may be also used for further risk identification. Then, all these identified risks are taken into consideration and become the input for the next phase, the phase of design.*

### Design

*In the phase of design, it is required to assess identified risks and find out their risk values, if applicable. The aim of this is to prioritize risks and initiate countermeasures according to priorities. In*

Table 4, assessed risks are seen with their risk values. Items including the issue of accuracy are named A, the issue of cleanliness C and the issue of soldering S. The risks concerning customer's requirements are seen and evaluated. Probability values should be based on real observation and simulation data or when we consider Lessons Learned cases, there it is possible to use the data from a real production and adjust it to the new product. Impact relies on the certain event or importance of a customer's requirement. The more important to the customer the bigger value is required.

Table 4: Risk value

| Item | Risk | Probability grade | Severity Grade | Probability | Severity | Risk value |
|---|---|---|---|---|---|---|
| 1A | Thick copper design may cause lack of planarity | 4 | 3 | 0,75 | 0,5 | 0,90 |
| 2A | Shrinkage, some materials do not shrink uniformly | 2 | 2 | 0,25 | 0,25 | 0,35 |
| 1C | Spacing | 3 | 2 | 0,5 | 0,25 | 0,56 |
| 2C | Compatibility with greater diversity of materials | 2 | 2 | 0,25 | 0,25 | 0,35 |
| 1S | Thermal profile issue | 3 | 4 | 0,5 | 0,75 | 0,90 |
| 2S | Surface wetting capability | 4 | 4 | 0,75 | 0,75 | 1,06 |

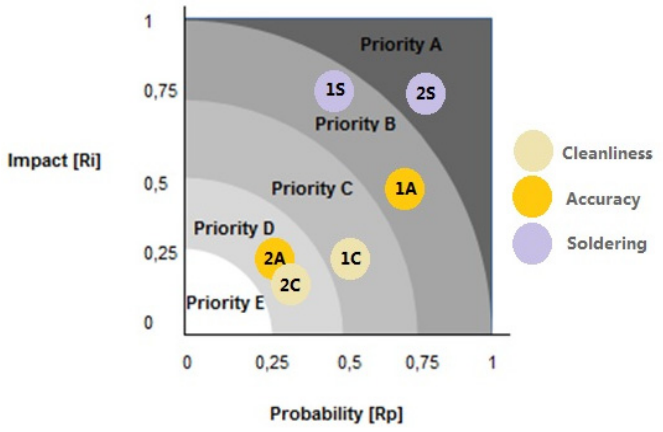


Figure 7: Application of the Baseball field diagram

From these values, it is counted the risk value and the treatment priority from the baseball field diagram, as seen in Figure 7. In this case, the most serious issue seems to be surface wetting capability concerning proper soldering. This item gets the highest priority. The other items are treated consequently according to priority ranking such thermal profile issue, thick copper design ect.

## CONCLUSION

Ever-increasing financial, time and qualitative demands force current companies and project teams to consider all possible risks and their consequences which might have fatal impacts. Right awareness, considering and consequent risk management at the beginning of the project can mean a multiple saving at its progression or end. Risk management throughout the entire product lifecycle is slowly becoming a standard practice, but appropriate methods and procedures are not always used. This study offers a possible way how to treat risk in the first phases of the product lifecycle where is still possible to make significant changes without incurred costs that would considerably endanger the financial achievement. Identified risks can be used for a decision whether to continue the production of a product or make significant changes. Performing this analysis can result in mitigation of property, health or the environment losses. This case study enables a better view of the issue of risk management of the product lifecycle and shows a possible way of usage. Further research will be devoted to next product lifecycle phases in order to create a unique methodology.

## REFERENCES

[1.] IMMONEN A.; SAAKSVUORI A.: Product Lifecycle Management, Berlin, Springer, 2008.

[2.] GECEVSKA, V.; STOJANOVA, T. and JOVANOVSKI, B.: Product Lifecycle Management Tools, Annals of Faculty Engineering Hunedoara, Vol.1, 219-222, 2013.

[3.] POL, G., MERLO, C., LEGARDEUR, J.: Implementation of collaborative design processes into PLM systems, International Journal of Product Lifecycle Management, Inder-science, Vol.3, 279-294, 2008.

[4.] MACHAČ, J.; STEINER F.: Řízení rizik v etapě vývoje technologického procesu, Electroscope, 2012, vol. 2.

[5.] MACHAČ, J., STEINER, F. Risk Management Methodology Covering the Entire Product Lifecycle. In Advances in Suistainble and Competitive Manufacturing Systems. Heidelberg: Springer, 2013. s. 59-64. ISBN: 978-3-319-00556-0 , ISSN: 2195-4356

[6.] MARKESET, T.; KUMAR U.: R&M and Risk-Analysis Tools in Product Design to Reduce Life-Cycle Cost and Improve Attractiveness, PROCEEDINGS Annual RELIABILITY and MAINTAINABILITY Symposium: IEEE, 1-7, 2001.

[7.] HSIA, T.C.; CHEN, S.C.; TSAI, R.K. and HUANG, S.C..: Using Systematic Innovation Process (TRIZ Method) to Improve the Manufacturing Technology of Platelet Agitators, 21st International Conference on Flexible Automation and Intelligent Manufacturing: FAIM 2011, Taiwan, 5, 2011.


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# COMPARISON OF RHEOLOGICAL PARAMETERS OF SELECTED POLYMER MODIFIED BITUMINOUS BINDERS

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**Abstract:** *Bituminous binders are broadly used for asphalt mixtures in construction of roads. They are often modified by synthetic polymers to improve their physical properties (to increase their softening point and decrease their breaking point). This paper deals with comparison of rheological parameters η*, G', G'' of selected polymer modified bituminous binders at the temperatures of 60 and 80 °C.*
**Keywords:** *polymer modified bituminous binders, rheological properties, oscillatory rheometer, complex viscosity, complex shear modulus*

## INTRODUCTION

*Bitumen is generally material obtained as the residue of vacuum distillation process during the refining of crude oil [1]. It is broadly used as a binder in a construction of roads where it is mixed with aggregate to create asphalt mixture (Figure 1).*

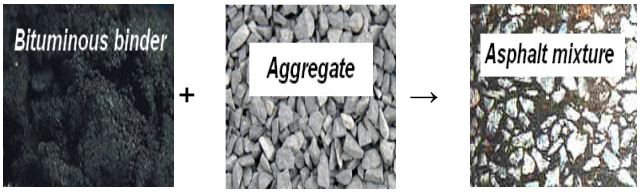


*Figure 1. Scheme of creating of asphalt mixture*

*Bituminous binders are semi-solid at ordinary temperatures but they can be liquefied by applying heat. They are highly waterproof, durable and act as the glue that holds the road together. Mechanical properties of asphalt mixture are mostly affected by the properties of applied bituminous binder. Bitumen binder must be fluid enough at high temperature (about 160 °C) to create homogenous coating of the aggregates upon mixing. Depending on the local climate, it has to become stiff enough at the highest pavement temperature to resist rutting deformation and it must remain soft enough at low temperatures [2].*

*In order to obtain appropriate properties, bituminous binders are used not only in the form of pure bitumen (unmodified bitumens = paving grade bitumens, PBS) but they are modified by synthetic polymers. Polymer modified bitumens (PMB) have higher softening point and lower breaking point than unmodified ones and therefore they are recommended for construction of highly loaded roads in climates with large temperature changes [3], [4], [5].*

*Bituminous binders are thermoplastic liquids which behave as viscoelastic materials [3]. Their deformation behavior can be determined by their rheological parameters. The changes of both viscous and elastic properties with temperature and time are measured as the response of the material to deformation by periodic forces (during forced vibration or small-amplitude oscillatory shear). Stress and strain are not in phase, the strain delays behind the stress by a phase angle. If the oscillatory*

shear is sinusoidal, shear stress τ is expressed [6], [7]:

$$\tau(t) = \tau_0 \cdot e^{i\omega t} = \tau_0(\cos\omega t + i \cdot \sin\omega t) \quad (1)$$

$\tau_0$ - stress amplitude, $\omega$ - angular frequency, $t$ - time and $i = \sqrt{-1}$.

The complex shear modulus $G^*$ [Pa] is defined as [6], [7]:

$$G^* = \frac{\tau(t)}{\gamma(t)} \quad (2)$$

Equation (2) can be resolved into two parts:

$$G^* = G' + i \cdot G'' = \frac{\tau_0}{\gamma_0}(\cos\delta + i \cdot \sin\delta) \quad (3)$$

The first G' is in phase with strain, and the second G" is out of phase with strain of angle δ. Therefore, two dynamic moduli are defined [6], [7]:

$$G' = \frac{\tau_0}{\gamma_0}\cos\delta \quad (4)$$

$$G'' = \frac{\tau_0}{\gamma_0}\sin\delta \quad (5)$$

G' is called storage modulus and its value is a measure of the deformation energy stored by the sample during the shear process. Thus, it represents the elastic behavior. Value of loss modulus G" is a measure of the deformation energy used up by the sample during the shear process and therefore it represents the viscous behavior of the material. A part of this energy heats the sample and the residue is released as heat to environment. Sample with high loss modulus exhibits irreversible deformation [6], [7].

The complex dynamic viscosity $\eta^*$ [Pa.s] is defined by the equation

$$\eta^* = \frac{\tau(t)}{\dot{\gamma}(t)} \quad (6)$$

$\dot{\gamma}$ [$s^{-1}$] presents the shear rate [6], [7].

This paper deals with the comparison of rheological parameters $\eta^*$, G', G" of selected polymer modified bituminous binders at the temperatures of 60 and 80 °C.

## EXPERIMENTAL MATERIAL

Rheological properties were determined and compared for three various polymer modified bituminous binders produced by different producers. Apollobit, Sealoflex and Kraton represent binders modified by synthetic polymer Styrene Butadiene Styrene [4], [5], [8], [9], [10]. Basic properties of tested materials are shown in Table 1.

Table 1. Basic properties of tested bituminous binders

| Type of binder | polymer modified binders | | |
|---|---|---|---|
| | Apollobit | Sealoflex | Kraton |
| Softening point [°C] | min. 70 | min. 90 | 83 |
| Penetration at 25°C [$10^{-1}$ mm] | 50 - 100 | 60 - 90 | 70 - 100 |

## EXPERIMENTAL METHOD AND CONDITIONS

Measurements were performed on the oscillatory Physica Rheometer MCR301 with convection heating device CTD 450. The applied method was Frequency Sweep test (FS). FS method uses parallel plate system (PP system: lower plate is stationary, upper one is shear, performing oscillatory motion). The distance between the plates (shearing interval) is well-defined (Figure 2).

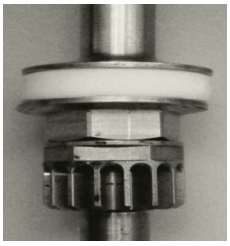

Figure 2. PP system, Physica Rheometer MCR301

FS test is run at a constant temperature. This measuring method enables simultaneous monitoring of rheological parameters G', G" and $\eta^*$ in the chosen interval of angular frequencies [6].

Each tested sample was placed between two parallel plates with diameter of 25 mm (PP25 system), in 1mm distance from each other (shearing interval = 1 mm). Measurements were carried out at the temperatures of 60 and 80 °C. Amplitude of γ was 5%, applied angular frequency ω was 30 – 600 $s^{-1}$.

## RESULTS AND DISCUSSION OF EXPERIMENTS

The course of monitored rheological parameters G', G", $\eta^*$ in dependence on angular frequency is linear except for high angular frequencies 400 – 600 $s^{-1}$ at both temperatures (Figures 3 – 5). The curves G' and G" have no intersection point in observed interval of angular frequencies and therefore degradation which would be shown by

*changes of molecular weight (as networking or macromolecular chains breaking) is not probable [6].*

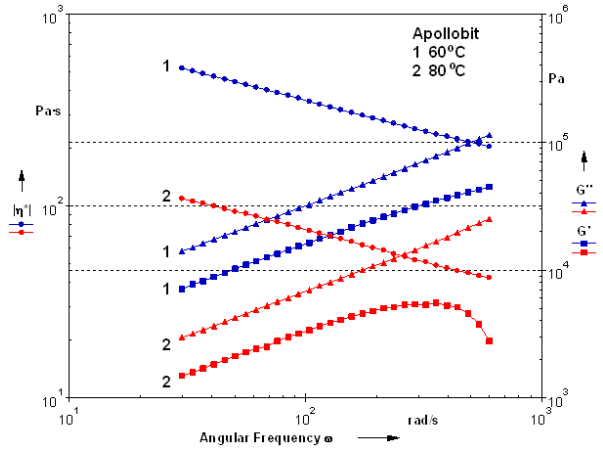


*Figure 3. Rheological parameters of Apollobit modified binder at 60 and 80°C*

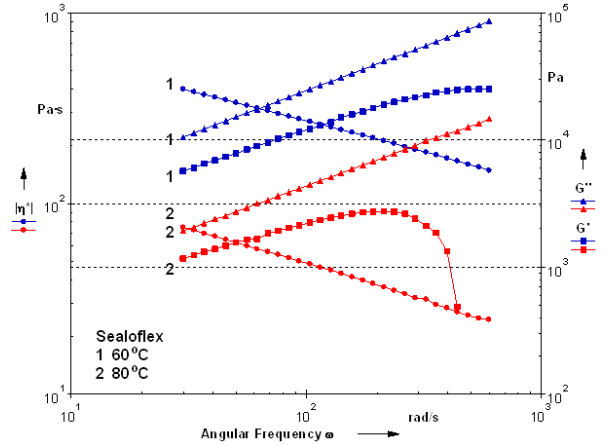


*Figure 4. Rheological parameters of Sealoflex modified binder at 60 and 80°C*

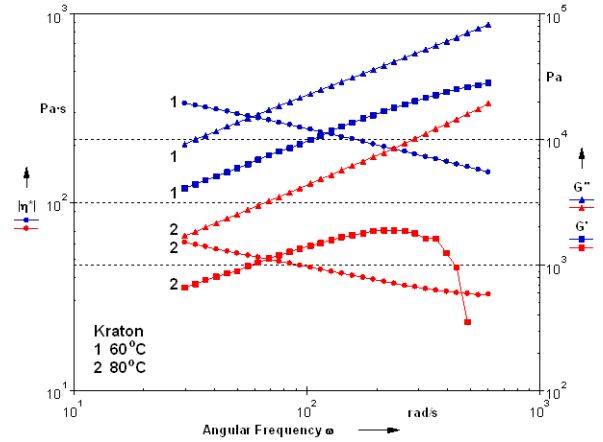


*Figure 5. Rheological parameters of Kraton modified binder at 60 and 80°C*

*As we can see in Figures 3 – 5, the increase of temperature from 60 °C to 80 °C caused strong loss of parameters G', G" and η*.*

*At 80 °C, the curves expressing storage modulus G' lose their linearity at the angular frequencies of 400 – 600 $s^{-1}$ (Figures 3 – 5). Sharp decrease of G' means higher ratio between loss modulus G'' and storage modulus G' (called damping factor) and it points to degradation connected with the loss of elasticity. This phenomenon is more pronounced for Sealoflex and Craton than for Apollobit modified binder.*

*Differences of complex viscosities of all tested samples in dependence on angular frequency ω can be seen in Figure 6 A, B. Apollobit modified binder reaches the highest values of complex viscosity at both temperatures and at both angular frequencies. All tested binders show sharp decrease of complex viscosity at higher angular frequency (ω = 600$s^{-1}$) at lower temperature. This decrease is the strongest for Apollobit binder. On the contrary, the viscosity of Kraton binder is least dependent on angular frequency.*

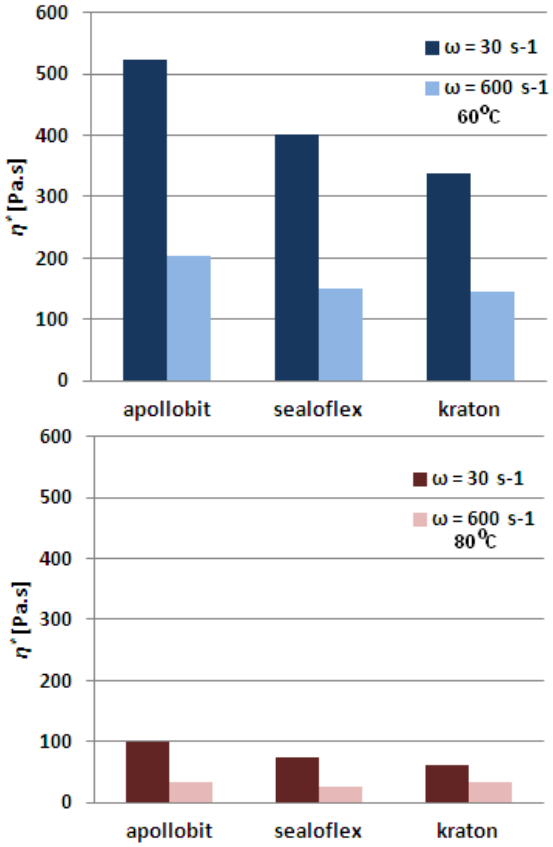


*Figure 6. Comparison of complex viscosities of tested modified binders in dependence on angular frequency ω. A –60°C, B - 80 °C*

## CONCLUSION

√ *Apollobit polymer modified binder achieves the highest values of evaluated rheological parameters G', G", η* in the considered interval of angular frequencies at the temperatures of 60 and 80 °C. The lowest values of rheological*

*parameters are achieved for Kraton modified binder.*

- √ *Tested modified binders show significant reduction in complex viscosity with the increase of angular frequency (Figure 6).*
- √ *According to obtained results, Apollobit seems to be the most suitable (from a set of tested binders) in asphalt mixtures for highly traffic loaded roads that will be resilient to prevent permanent deformation during hot weather.*

***ACKNOWLEDGEMENTS***

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***REFERENCES***

[1.] *Simanzhenkov, V., Idem, R.: Crude oil chemistry. CRC Press, 402 p., 2003.*

[2.] *Leseueur, D.: Letter to the Editor: On the Thermo-rheological Complexity and Relaxation of Asphalt Cements. Journal of Rheology, Vol. 43, pp. 1701 – 1704, 1999.*

[3.] *Goodrich, J. L.: Asphalt and polymere Modified Asphalt Properties related to the Performance of Asphalt Concrete Mixes. Procedings of the Association of Asphalt Paving Technologists, Vol. 57, pp. 116 – 175, 1988.*

[4.] *Airey, G. D.: Styrene Butadiene Styrene Polymer Modification of Road Bitumens. Journal of Materials Science, vol. 39, pp. 951 – 959, 2004.*

[5.] *Airey, G. D.: Rheological properties of Styrene Butadiene Styrene Polymer Modified Road Bitumens. Fuel, Vol. 82, pp. 1709 – 1719, 2003.*

[6.] *Mezger, T.G.: The rheology handbook. 2nd ed. Hannover: Vincentz Network, 276 p., 2006.*

[7.] *Kahovec J.: Rheology of Polymer Systems, Wiley-VCH, Praha, 182 p., 2000.*

[8.] *http://www.slovnaft.sk/sk/obchodni_partneri/vyrobky/asfalty/modifikovane_cestne_asfalty%20/ 11. 6. 2013*

[9.] *http://www.ooms.nl/en/7/245/sealoflex.aspx 11. 6. 2013*

[10.] *http://www.kraton.com/products/Kraton_D_SBS.php 11. 6. 2013*


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# TIME-FREQUENCY ANALYSIS OF DIESEL ENGINE NOISE

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**Abstract:** Combustion is the main type of noise radiated from diesel engines. Several methods have been devised to reduce the noise levels. Fourier tranformation methods along with block attenuation curves have been used to study the correlation between cylinder pressure and noise radiated from engines. In this work wavelet method has been used to study noisee mitted from a dual injection diesel engine. The results show high variation in cylinder pressure levels and noisee mitted which indicate non stationary nature of combustion process.
**Keywords:** Engine Noise, Vibrations, Condition Monitoring

## INTRODUCTION

The noise emitted from engines has been studied long time back. Signal processing is an important technique to separated various noise sources. FFT transformations have been used as an effective method of signal analysis [1]. These transformations have many transient parts, hence are unsuitable [2].

In recent years linear and bi linear time frequency distributions have been used as an alternatives[3]. Both of these methods have their own advantages and short comings. The former one has low resolutions while the latter one has low processing speed and is complex [4]. In this work time-frequency analysis have been done on signals acquired from a diesel engine test rig. Noise in an engine consists of several components like flow based noise, combustion noise, mechanical noise etc [5]. Combustion noise is produced due to rapid change in pressure which causes vibrations and resonance of combustion chamber. As the piston moves from TDC to BDC, the gap between liner and piston causes impact of piston with walls of cylinder which is known as piston slap [1]. Motion of rotary parts adds low frequency components to overall noise levels. Gears, injectors and valve motion also contribute towards transient components of noise. Injector noise depends upon stiffness of spring which holds needle tight to its seat[1]. Low spring stiffness may cause failure of needle to return back to seat[1]. This may cause needle to remain open even after injection events. Any faults in valves seats, cams, tappets orvalve springs may cause irregularity in valve operations. Flow induced inlet and exhaust noise also contribute high frequencies components towards overall noise levels [1].

Figure 1 shows a typical plot of noise signals obtained from a diesel engines. In diesel engines the mixing of fuel with air produces a sudden pressure rise known as knock [6]. Hence noise radiated is both due to combustion events as well as motion of parts is shown in Figure 3.

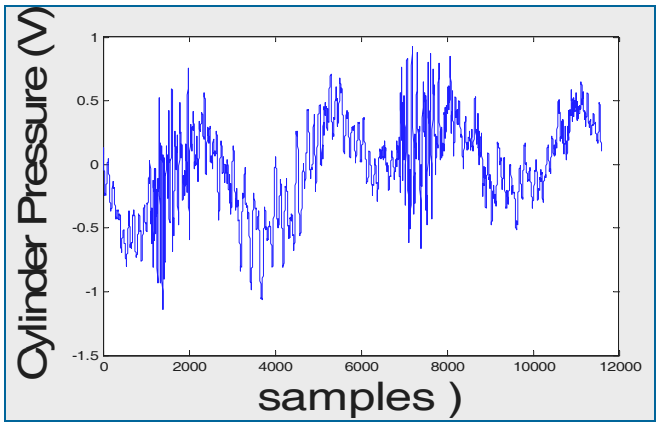


Figure 1 - Diesel engine Noise signal

This relationship both transient as well as harmonic components. The major harmonic content was removed by Fourier transformations and the results are seen in Figure 2.

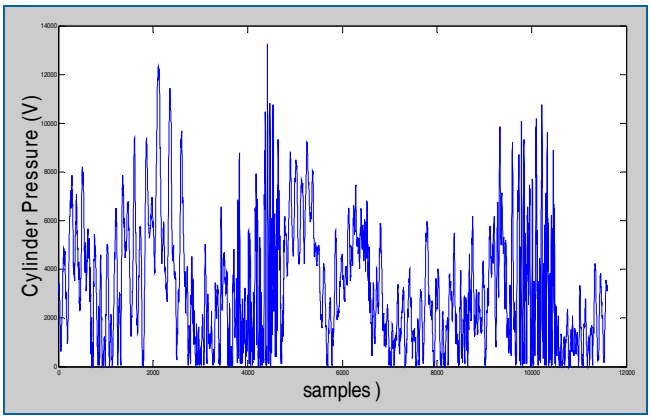


Figure 2 - Residual Noise signals

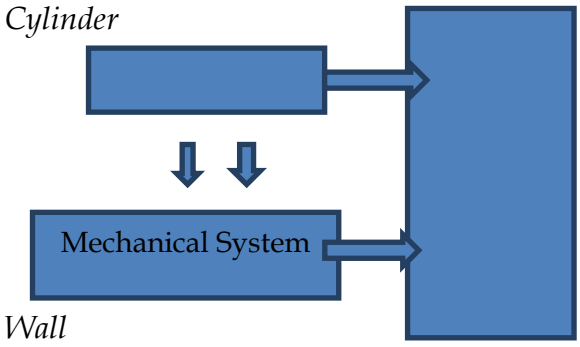


Figure 3 - Noiseprocess

*A high oscillation causes resonance of whole engine structure frequency of which is also dependent on temperature of gas inside. Due to increase in restrictions in limits of noise radiated from vehicles study has been focused on block attenuation and transfer function between noise radiated and cylinder pressure. With use of modern injection systems it has been possible to optimize the injection parameters e.g. engine speed, injection pressure etc.*

## TESTING SETUP

*A lombardini LDW442CRS common rail double direct injection engine system was used to conduct tests. This engine has specifications as given by Table 1. This engine test right as a piezoelectric type Kistler 6056A make pressure transducer for in cylinder pressure measurements and an optical crank angle encoder for detection of TDC position as well as engine speed. The signals data obtained from the tests were processed using B&K Nexus device which amplifies and filters data at 22.4 kHz. Experiments were carried out by varying the dwell time between pre and main injections keeping other parameters fixed. The data presented in Table 2 was obtained at a speed of 2000 RPM and at motored & 100% load conditions.*

Table 1 - Engine Features

| | |
|---|---|
| Type | Direct Injection |
| Number of cylinders | 2 |
| Bore | 68 mm |
| Stroke | 60.6 mm |
| Displaced Volume | 440cm³ |
| Compression Ratio | 20:1 |
| Maximum Power | 8.5k w@4400 RPM |
| Maximum Torque | 25N-m @2000 RPM |

Table 2 - Injection Features

| Condition | $P_{rail}$ (Bar) | $Q_{pre}$ (mm³/c) | $SOI_{pre}$ (°BTDC) | $SOI_{main}$ (°BTDC) |
|---|---|---|---|---|
| B3 | 700 | 1 | 13.2° | 6° |
| BASE | 720 | 1 | 16.2° | 6° |
| B1 | 700 | 2 | 17.1° | 6° |
| B2 | 700 | 1 | 20.1° | 6° |

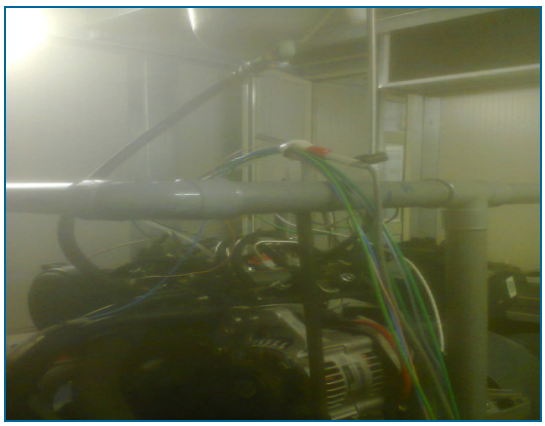

Figure 4 - Engine Test Rig showing Microphone

*In order to observe complex-non stationary phenomenon in diesel engines, time-frequency methods have been used to surpass limitations of classical time or frequency domains. In this work, mathematical models have been used to find the correlation between radiated noise and excitation forces. Spectrogram which is an extension of FFT is not an effective method to analyze the combustion process due to non-stationary effects. These signals are best analyzed by Wigner distribution, however this distribution has cross terms [7]. In contrast the wavelet method frequency information is obtained by widow dilation. This method is useful for assessment of phenomenon where there are sharp peaks in signals as in case of radiated noise and in cylinder pressure [8]. In this work following approach has been used for analysis study of incylinder pressure to identify various sources and contributions. Estimation of attenuation of engine block to check validity of*

*method. Time -frequency analysis of noise radiated from engine and determining any correlation between in cylinder pressure and noise radiated. The test cell used is large enough with noise absorbing walls to measure radiated noise at low frequency.*

**RESULTS AND DISCUSSIONS**

*The spectrum analysis is carried out by Discrete Fourier transformation (DFT) which gives energy distribution among frequency associated with any variable.In this section DFT of in cylinder pressure with and without motoring condition has been carried out. As seen from Figure 5, there is difference between energy levels at these conditions. At higher frequency low energy distribution can be observed in motored condition as compared to combustion conditions.*

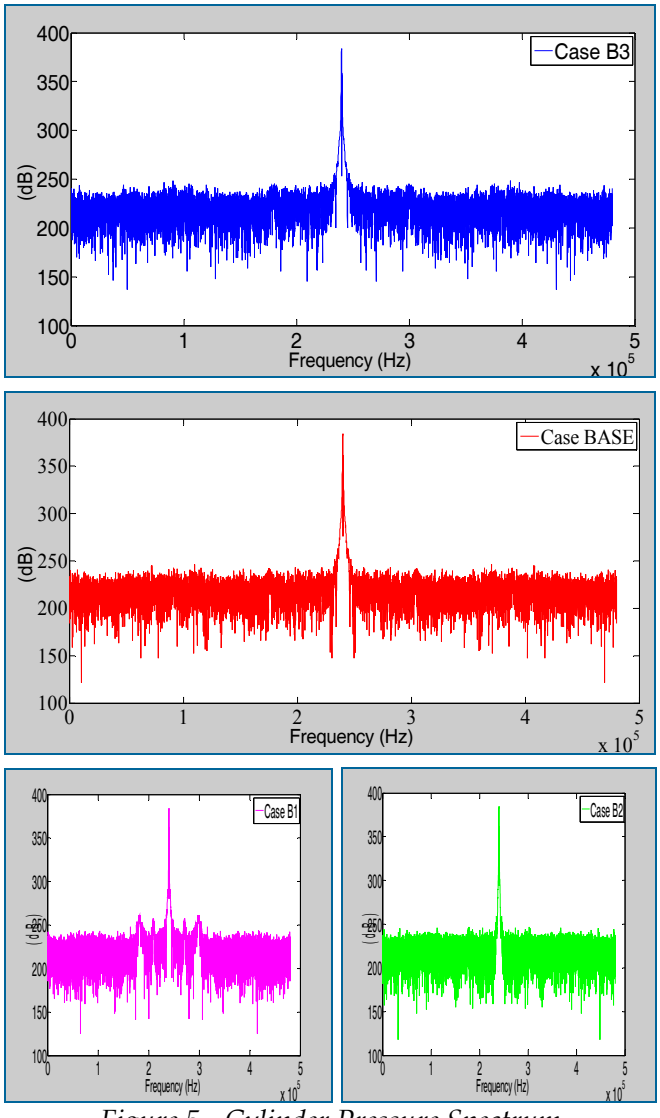


*Figure 5 - Cylinder Pressure Spectrum*

*A peak can be clearly seen at a frequency of 240KHz which denoted the resonant frequency related to combustion chamber. Further time frequency analysis has been done to obtain spectral energy distribution of combustion noise. This type of information is not available in DFT.*

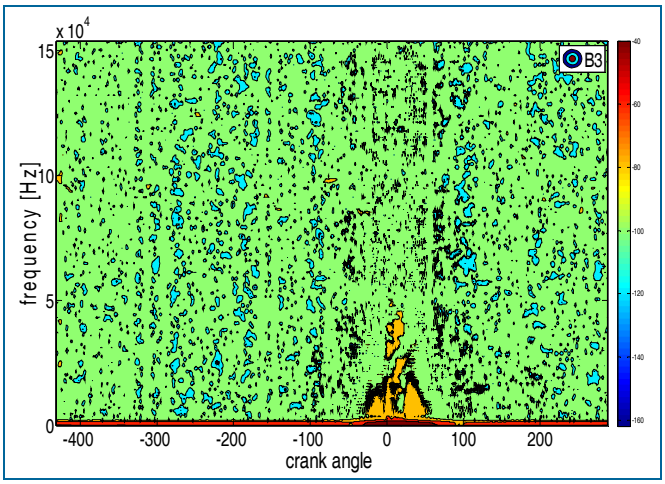


*Figure 6 - Cylinder Pressure STFT using Spectrogram –(B3)*

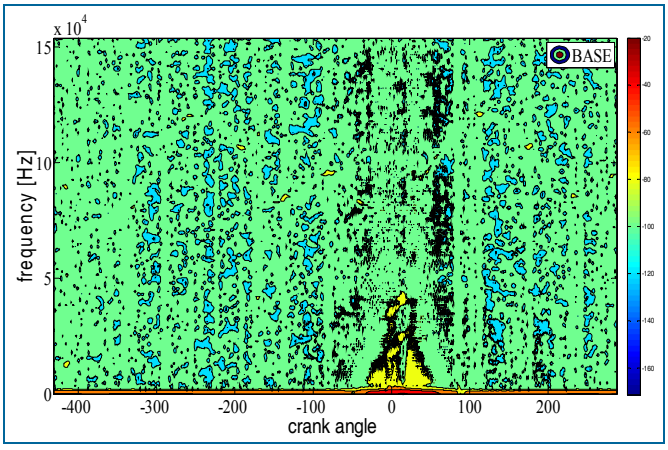


*Figure 8 - Cylinder Pressure STFT using Spectrogram –(BASE)*

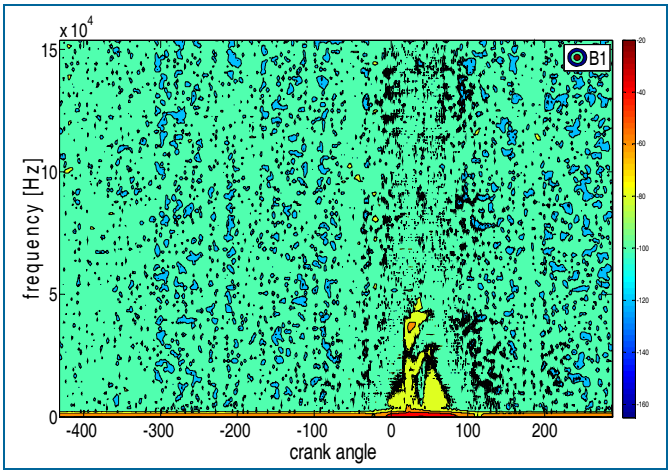


*Figure 9 - Cylinder Pressure STFT using Spectrogram –(B1)*

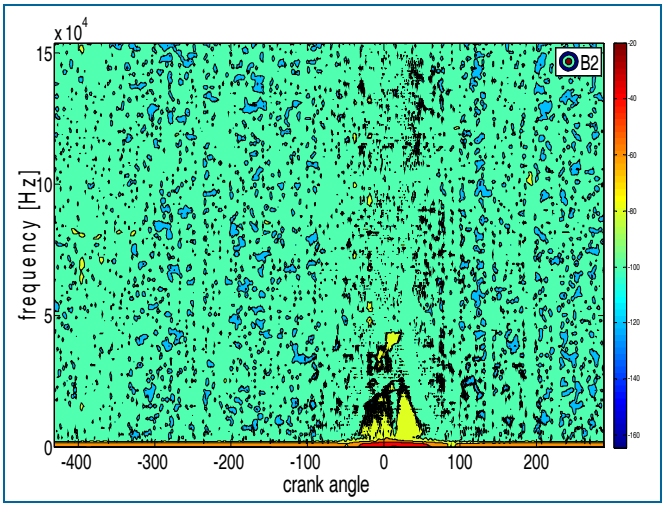


*Figure 10 - Cylinder Pressure STFT using Spectrogram –(B2)*

*In these plots the fluctuation of cylinder pressure of combustion chamber can be seen. A burst of energy havign frequency of around 1500 Hz is visible around TDC position in each case which corresponds to onset of combustion process. Combustion noise is also dependent upon the strutural attenuation of engine. Stankovic and Bhome have proposed a time variant transfer function of block attenuation [9]. From these observations it can be concluded that mechanical noise is concentrated in this range whereas sound power levels greater than Hz are associated with noise caused due to pressure forces. This is coincident with observations made by Usami et al during study of piston slap [10].*

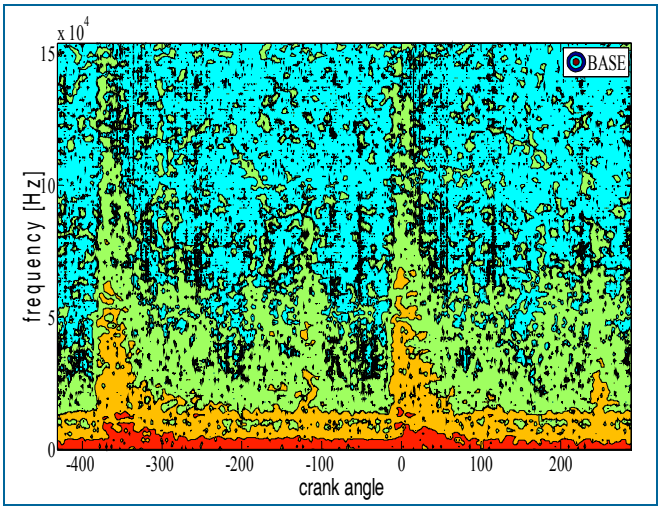


*Figure 11 - Cylinder Noise STFT using Spectrogram –(BASE)*

*Figures 11-14 show plots of spectrogram of noise signals radiated from diesel engine. As evident from these plots a reduction in energy level is observed in case of motored condition in range where mechanical noise is dominant. Figure no 15 shows the zoomed contour plots of noise emissions in case of condition BASE in which various mechanical events can be identified.Most of these events are in frequency ranges 10KHz-20KHz.*

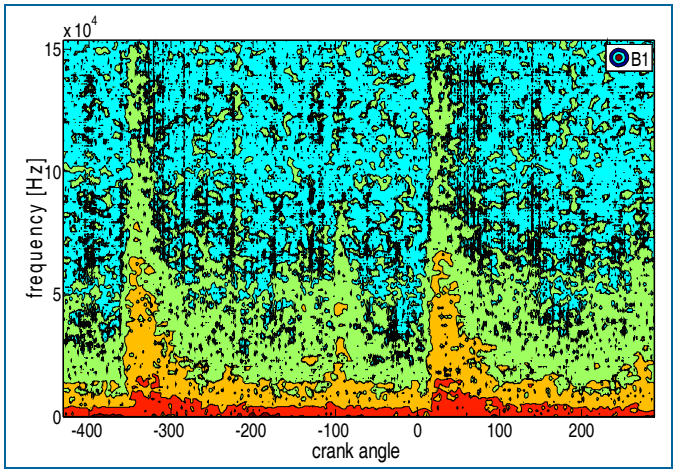


*Figure 12- Cylinder Noise STFT using Spectrogram – (B1)*

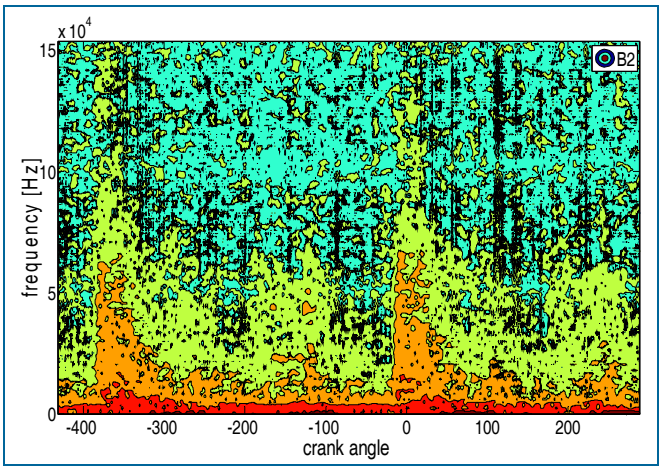


*Figure 13 - Cylinder Noise STFT using Spectrogram – (B2)*

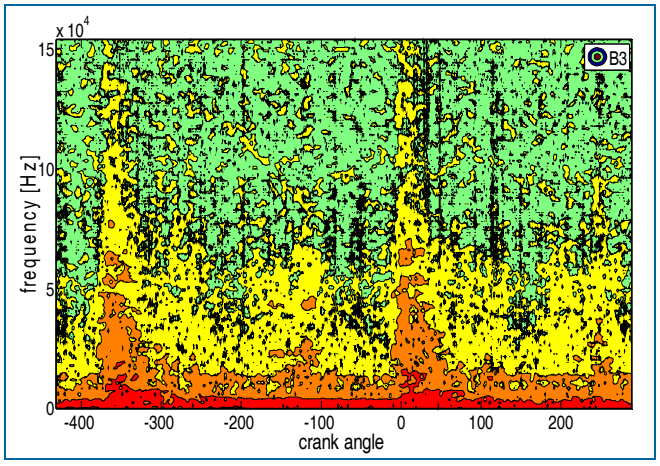


*Figure 14 - Cylinder Noise STFT using Spectrogram –(B3)*

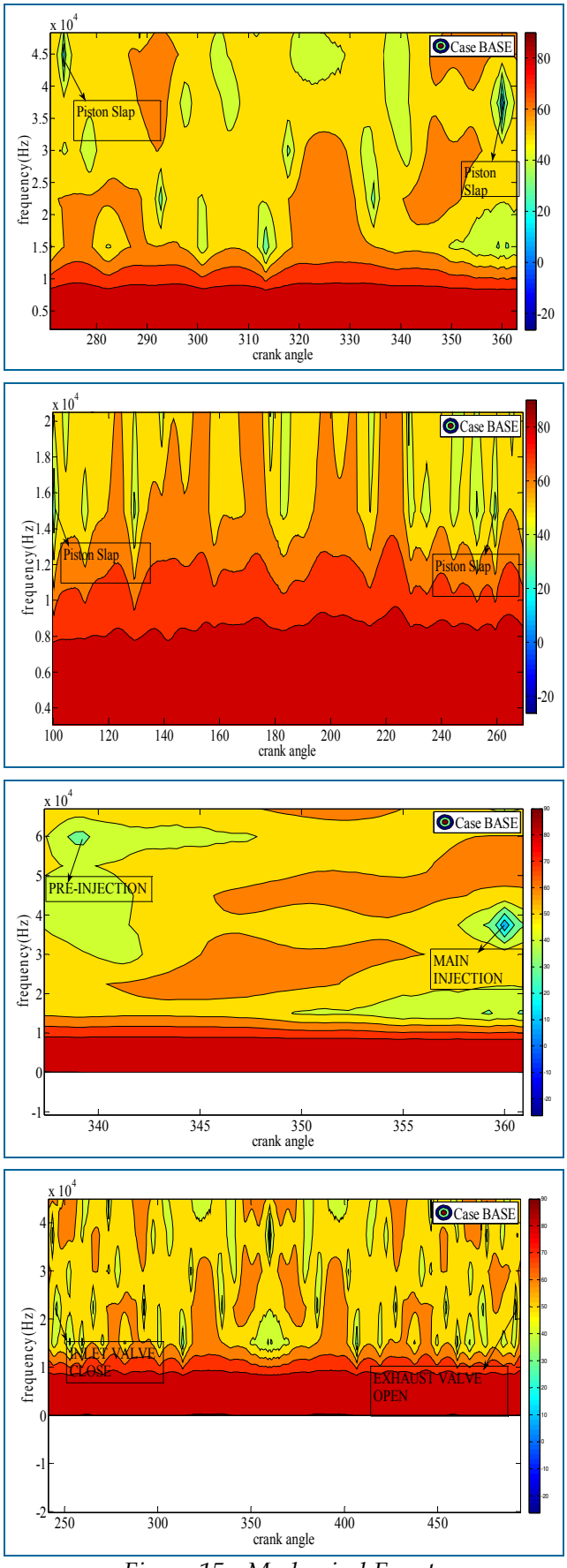


*Figure 15 - Mechanical Events from contour plots*

## CONCLUSION

*Engine noise signals needs time, frequency or time-frequency parameters for complete disciption. With help of time-frequency plots contribution of various sources can be studied. An important application of such plots is in condition monitoring of engines where problems in parts of engines can be detected. This method also provides a more reliable method to correlate various events occurring in the engine operation process.*

## NOMENCLATURE

*$Q_{pre}$ - Amount of fuel injected during pre-injection Period ($mm^3$per stoke)*
*$Q_{main}$ - Amount of fuel injected during main-injection Period ($mm^3$per stoke)*
*$SOI_{pre}$ - Angle of start of pre-injection period (degrees before Top Dead Centre)*
*$SOI_{main}$ - Angle of start of main-injection period (degrees before Top Dead Centre)*
*P rail - Injection Pressure of fuel inside cylinder*
*BTDC - Before Top Dead Centre*
*FFT - Fast Fourier Transformations*
*dB - Decibel Level*
*STFT - Short Time-Frequency Fourier Tranformation*

## REFERENCES

[1.] *Zheng, Leung, ''Internal Combustion Engine Noise Analysis With Time-Frequency Distribution'', Transactions of ASME, Vol 124,July 2002.*
[2.] *Chui, C. K., 1992, An Introduction to Wavelets, Volume 1: Wavelet Analysis and Its Applications, Academic Press, San Diego,CA.*
[3.] *Cohen, L. 1989, ''Time-Frequency Distributions—A Review,'' Proc. IEEE, 77, No. 7, pp. 941–981.*
[4.] *Zheng, G. T. and McFadden, P. D., 1996, ''A Time-Frequency Distribution for Analysis of Signals With Transient Components and Its Application to Early Gear Failure Detection,'' Report OUEL 2088/96, Department of Engineering Science, University of Oxford, Oxford, UK.*
[5.] *Anderton D, ''Relation between Combustion System and Engine Noise'', SAE paper 790270-1979.*
[6.] *Desantes, Torregrosa, ''Wavelet Transform applied to Combustion Noise Analysis in High*

*Speed DI Diesel Engine'', SAE paper no 2001-01-1545.*

*[7.] Stankovic, Bohme, ''Time Frequency analysis of multiple resonances in combustion engine signals'', signal processing 79, pp 15-28, 1999.*

*[8.] Graps, "An introduction to Wavelets'', IEEE computational science and engineering 2(2), 1995.*

*[9.] Tichy J, Gautschi, Piezo-electrische Mebtechnik Spinger, Berlin, 1980.*

*[10.] Usame, Wada, Sonada, ''Piston slap noise of indirect combustion diesel engine'', SAE paper 750801-1975.*

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# STUDY OF DIFFERENTIAL EQUATIONS WITH THEIR POLYNOMIAL AND NONPOLYNOMIAL SPLINE BASED APPROXIMATION

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**Abstract:** The purpose of this paper is to discuss numerical solutions of differential equations including the evolution, progress and types of differential equations. Special attention is given to the solution of differential equations by application of spline functions. Here we are interested in differential equation based problems and their solutions using polynomial and nonpolynomial splines of different orders. It contains crux of various recent research papers based on application of splines of different orders.

**Keywords:** Differential Equations, Boundary value problems, Spline functions, Polynomial & Nonpolynomial Splines
**AMS Mathematics Subject Classification (2000):** 41A15 · 65L10

## INTRODUCTION

Differential equations are mathematically studied from several different perspectives, mostly concerned with their solutions – the set of functions that satisfy the equation. Only the simplest differential equations admit solutions given by explicit formulas; however, some properties of solutions of a given differential equation may be determined without finding their exact form. If a self-contained formula for the solution is not available, the solution may be numerically approximated using computers. In general, it is not possible to obtain the analytical solution of a system of differential equations, obtained from obstacle, unilateral, moving and free boundary-value problems and problems of the defection of plates and in a number of other scientific applications, while many numerical methods have been developed to determine solutions with a given degree of accuracy. In the present paper we discuss the history, classification and numerical solution of differential equations. Here we are merely concerned about the solution of these boundary-value problems by application of spline functions.

We include here one paper based on application of various spline functions to solve different systems of differential equations. The paper is organized as follows: in section 2, we will discuss a brief history of differential equations. In section 3, we consider the general introduction of differential equations. In section 4, we discuss about types of differential equations. In section 5, subdivision of differential equations, in section 6, initial & boundary value problems, in section 7 types of boundary value problems, in section 8 differential equations associated with physical problems arising in engineering is discussed. In section 9, numerical solution of differential equations, in section 10, general introduction to spline, in section 11 spline solution of differential equations and finally in section 12 the conclusion and further development is given.

## HISTORY OF DIFFERENTIAL EQUATIONS

The study of differential equations is a wide field. Many of the laws in physics, chemistry, engineering, biology and economics are based on empirical observations that describe changes in the states of systems. Mathematical models that describe the state of such systems are often expressed in terms of not only certain system parameters but also their derivatives. Such mathematical models, which use differential calculus to express relationship between variables, are known as differential equations.

The history of differential equations traces the development of differential equations from calculus, which was independently invented by

*English physicist Isaac Newton (1665) and German mathematician Gottfried Leibnitz (1674). The term differential equation was coined by Leibnitz in 1676 for a relationship between the two differentials dx and dy for the two variables x and y. Newton solved his first differential equation in 1676 by the use of infinite series, eleven years after his discovery of calculus in 1665. Leibnitz solved his first differential equation in 1693, the year in which Newton first published his results. Hence, 1693 marks the inception for the differential equations as a distinct field in mathematics [1].*

*The different phases of 17th, 18th and 19th Centuries played some crucial role in the history of differential equations. In the year 1695 the problem of finding the general solution of what is now called Bernoulli's equation was proposed by Bernoulli and it was solved by Leibnitz and Johann Bernoulli by different methods. In further development 1724 was important to the early history of ordinary differential equations. Ordinary differential equation acquired its significance when it was introduced in 1724 by Jacopo Francesco, Count Ricatti of Venice in his work in acoustics. Further in the year of 1739 Leonhard Euler solves the general homogeneous linear ordinary differential equation with constant coefficients. L'Hospital came up with separation of variables in 1750, and it is now the physicist's handiest tool for solving partial differential equations. Since its introduction in 1828, Green's functions have become a fundamental mathematical technique for solving boundary-value problems. In 1890 Poincare [2] gave the first complete proof of the existence and uniqueness of a solution of the Laplace Equation for any continuous Dirichlet boundary condition.*

*In 20th Century a lot of quality work has been done in the field of differential equations, but the major concern was the analytic and computational solution of differential equations. In last few decades numerical analysis of differential equations has become a major topic of study. In view of this, this thesis gives a small step towards the development of computational analysis of ordinary differential equations, which have lot of utilities in the field of science and engineering.*

## *GENERAL INTRODUCTION OF DIFFERENTIAL EQUATIONS*

*There is difference between differential equations and ordinary equations of mathematics. The differential equations, in addition to variables and constants, also contain derivatives of one or more of the variables involved. In general, a differential equation is an equation which involves the derivatives of an unknown function represented by a dependent variable. It expresses the relationship involving the rates of change of continuously changing quantities modeled by functions and are used whenever a rate of change (derivative) is known. A solution to a differential equation is a function whose derivatives satisfy the equation.*

*The order and degree are two major terms if we discuss about a differential equation. The order of a differential equation is that of the highest derivative that it contains. For instance, a second-order differential equation contains only second and first derivatives. If a differential equation can be rationalized and cleared of fraction with regard to all derivatives present, the exponent of the highest order derivative is called the degree of the differential equation.*

## *TYPES OF DIFFERENTIAL EQUATIONS*

*The Differential equations can be categorized in ordinary differential equations (ODE), partial differential equation (PDE), delay differential equation (DDE), stochastic differential equation (SDE) and differential algebraic equation (DAE) which are defined as follows:*

*(a) An ordinary differential equation (ODE) is a differential equation in which the unknown function is a function of a single independent variable.*

*(b) A partial differential equation (PDE) is a differential equation in which the unknown function is a function of multiple independent variables and their partial derivatives.*

*(c) A delay differential equation (DDE) is a differential equation in which the derivative of the unknown function at a certain time is given in terms of the values of the function at previous times.*

*(d) A stochastic differential equation (SDE) is a differential equation in which one or more of the terms are a stochastic process, thus*

resulting in a solution which is itself a stochastic process.

(e) A differential algebraic equation (DAE) is a differential equation comprising differential and algebraic terms, given in implicit form.

An ordinary differential equation (ODE) implicitly describes a function depending on a single variable and the ODE expresses a relation between the solution and one or more of its derivatives. Beside the ODE, usually one or more additional (initial) conditions are needed to determine the unknown function uniquely.

A Partial differential equation (PDE) is a relation involving an unknown function of at least two independent variables and its partial derivatives with respect to those variables. Partial differential equations are used to formulate and solve problems that involve unknown functions of several variables, such as the propagation of sound or heat, electrostatics, electrodynamics, fluid flow, elasticity or more generally any process that is distributed in space or distributed in space and time. In general, A partial differential equation (PDE) is an equation involving functions and their partial derivatives.

**SUBDIVISION OF DIFFERENTIAL EQUATIONS**

Each of types of differential equations mentioned above is divided into two subcategories - linear and nonlinear. A differential equation is linear if it involves the unknown function and its derivatives only to the first power; otherwise the differential equation is nonlinear. Thus if $y'$ denotes the first derivative of $y$, then the equation $y'=y$ is linear, while the equation $y'=y^2$ is nonlinear. Solutions of a linear equation in which the unknown function or its derivative or derivatives appear in each term (linear homogeneous equations) may be added together or multiplied by an arbitrary constant in order to obtain additional solutions of that equation, but there is no general way to obtain families of solutions of nonlinear equations, except when they exhibit symmetries. Linear equations frequently appear as approximations to nonlinear equations, and these approximations are only valid under restricted conditions.

**INITIAL & BOUNDARY VALUE PROBLEMS**

Ordinary differential equations (ODEs) describe phenomena that change continuously. They arise in models throughout mathematics, science, and engineering. By itself, a system of ODEs has many solutions. Commonly a solution of interest is determined by specifying the values of all its components at a single point $x=a$. This is an initial value problem (IVP). However, in many applications a solution is determined in a more complicated way. A boundary value problem (BVP) specifies values or equations for solution components at more than one $x$. Unlike IVPs, a boundary value problem may not have a solution, or may have a finite number, or may have infinitely many solutions.

Initial value problem has all of the conditions specified at the same value of the independent variable in the equation (and that value is at the lower boundary of the domain, thus the term "initial" value). On the other hand, a boundary value problem has conditions specified at the extremes of the independent variable. For example, if the independent variable is time over the domain [0,1], an initial value problem would specify a value of $y(t)$ at time 0, while a boundary value problem would specify values for $y(t)$ at both $t = 0$ and $t = 1$.

If the problem is dependent on both space and time, then instead of specifying the value of the problem at a given point for all time the data could be given at a given time for all space. For example, the temperature of an iron bar with one end kept at absolute zero and the other end at the freezing point of water would be a boundary value problem. Whereas in the middle of a still pond if somebody taps the water with a known force that would create a ripple and give us an initial condition.

**TYPES OF BOUNDARY VALUE PROBLEMS**

**(i) Dirichlet Boundary Condition:**

If the boundary gives a value to the problem then it is a Dirichlet boundary condition. For example if one end of an iron rod held at absolute zero then the value of the problem would be known at that point in space. A Dirichlet boundary condition imposed on an ordinary differential equation or a partial differential equation specifies the values a solution is to take on the boundary of the domain. The question of finding solutions to such equations is known as the Dirichlet problem.

*For example, in the case of an ordinary differential equation such as*

$$\frac{d^2y}{dx^2} + 5y = 1 \qquad (1)$$

*on the interval [0,1] the Dirichlet boundary conditions take the form*

$$y(0) = \alpha_1 \text{ and } y(1) = \alpha_2 \qquad (2)$$

*where $\alpha_1$ and $\alpha_2$ are given numbers.*

***(ii) Neumann Boundary Condition:***

*If the boundary gives a value to the normal derivative of the problem then it is a Neumann boundary condition. For example if one end of an iron rod had a heater at one end then energy would be added at a constant rate but the actual temperature would not be known. A Neumann boundary condition imposed on an ordinary differential equation or a partial differential equation specifies the values the derivative of a solution is to take on the boundary of the domain. In the case of ordinary differential equation such as*

$$\frac{d^2y}{dx^2} + 5y = 1$$

*on the interval [0, 1] the Neumann boundary conditions take the form*

$$y'(0) = \alpha_1 \text{ and } y'(1) = \alpha_2 \qquad (3)$$

*where $\alpha_1$ and $\alpha_2$ are given numbers.*

***(iii) Cauchy Boundary Condition:***

*If the boundary has the form of a curve or surface that gives a value to the normal derivative and the problem itself then it is a Cauchy boundary condition. A Cauchy boundary condition imposed on an ordinary differential equation or a partial differential equation specifies both the values a solution of a differential equation is to take on the boundary of the domain and the normal derivative at the boundary. It corresponds to imposing both a Dirichlet and a Neumann boundary condition.*

$$\frac{d^2y}{dx^2} + 5y = 1$$

*Cauchy boundary conditions can be understood from the theory of second order, ordinary differential equations, where to have a particular solution one has to specify the value of the function and the value of the derivative at a given initial or boundary point, i.e.,*

$$y(a) = \alpha_1 \text{ and } y'(a) = \alpha_2 \qquad (4)$$

*where $\alpha_1$ and $\alpha_2$ are given numbers and a is a boundary or initial point.*

***DIFFERENTIAL EQUATIONS ASSOCIATED WITH PHYSICAL PROBLEMS ARISING IN ENGINEERING***

*As the world turns, things change, mountains erode, river beds change, machines break down, the environment becomes more polluted, populations shift, economics fluctuate, technology advances. Hence any quantity expressible mathematically over a long time must change as a function of time. As a function of time, relatively speaking, there are many quantities which change rapidly, such as natural pulsation of a quartz crystal, heart beats, the swing of a pendulum, chemical explosions, etc. When we get down to the business of quantitative analysis of any system, our experience shows that the rate of change of a physical or biological quantity relative to time has vital information about the system. It is this rate of change which plays a central role in the mathematical formulation of most of the physical and biological models amenable to analysis.*

*Engineering problems that are time-dependent are often described in terms of differential equations with conditions imposed at single point (initial/final value problems); while engineering problems that are position dependent are often described in terms of differential equations with conditions imposed at more than one point (boundary value problems). Some of the motivational examples encountering in many engineering fields are as follows:*

*(i) Coupled L-R electric circuits*
*(ii) Coupled systems of springs*
*(iii) Motion of a particle under a variable force field*
*(iv) Newton's second law in dynamics (mechanics)*
*(v) Radioactive decay in nuclear physics*
*(vi) Newton's law of cooling in thermodynamics.*
*(vii) The wave equation*
*(viii) Maxwell's equations in electromagnetism*
*(ix) The heat equation in thermodynamics*
*(x) Laplace's equation, which defines harmonic functions*
*(xi) The beam deflections equation*
*(xii) The draining and coating flows equation*

***NUMERICAL SOLUTION OF DIFFERENTIAL EQUATIONS***

*The study of differential equations is a wide field in both pure and applied mathematics. Pure mathematicians study the types and properties of*

*differential equations, such as whether or not solutions exist, and should they exist, whether they are unique.*

*Applied mathematicians emphasize differential equations from applications, and in addition to existence/uniqueness questions, are also concerned with rigorously justifying methods for approximating solutions. Physicists and engineers are usually more interested in computing approximate solutions to differential equations. These solutions are then used to simulate celestial motions, simulate neurons, design bridges, automobiles, aircraft, sewers, etc. Often, these equations do not have closed form solutions and are solved using numerical methods.*

*Mathematicians also study weak solutions (relying on weak derivatives), which are types of solutions that do not have to be differentiable everywhere. This extension is often necessary for solutions to exist, and it also results in more physically reasonable properties of solutions, such as shocks in hyperbolic (or wave) equations.*

*Numerical techniques to solve the boundary value problems include some of the following methods:*

***- Shooting Methods:*** *These are initial value problem methods. In this method, we convert the given boundary value problem to an initial value problem by adding sufficient number of conditions at one end and adjust these conditions until the given conditions are satisfied at the other end.*

***- Finite Difference Methods:****In finite difference method (FDM), functions are represented by their values at certain grid points and derivatives are approximated through differences in these values. For the finite difference method, the domain under consideration is represented by a finite subset of points. These points are called "nodal points" of the grid. This grid is almost always arranged in (uniform or non-uniform) rectangular manner. The differential equation is replaced by a set of difference equations which are solved by direct or iterative methods.*

***- Finite Element Methods:*** *In finite element method (FEM), functions are represented in terms of basis functions and the ODE is solved in its integral (weak) form. In this method the domain under consideration is partitioned in a finite set of elements. In this the differential equation is discretized by using approximate methods with the piecewise polynomial solution [3].*

***- Spline Based Methods:*** *In spline based methods, the differential equation is discretized by using approximate methods based on spline. The end conditions are derived for the definition of spline. The algorithm developed not only approximates the solutions, but their higher order derivatives as well.*

## *GENERAL INTRODUCTION TO SPLINE*

*Usually a spline is a piecewise polynomial function defined in a region D, such that there exists a decomposition of D into sub-regions in each of which the function is a polynomial of some degree m. Also the function, as a rule, is continuous in D, together with its derivatives of order up to (m-1).*

*Thus, a spline function of order m, $S_\Delta(x)$, interpolating to a function u(x) defined on [a,b] is such that:*

*(i) In each subinterval $[x_{j-1}, x_j]$=1,2,….,N, $S_\Delta(x)$ is a polynomial of degree at most m.*

*(ii) The first, second, third... (m-1)th derivatives of $S_\Delta(x)$ are continuous on [a,b].*

*In its most general form a polynomial spline $S_\Delta(x)$ consists of polynomial pieces in $[x_i, x_{i+1}]$, i=0,1,2,….N-1 where the given N points are called knots. The vector $(x_0,….x_{N-1})$ is called a knot vector for the spline. If the knots are equidistantly distributed in the interval [a,b] we say the spline is uniform, otherwise we say it is non-uniform.*

*If the polynomial pieces on the subintervals $[x_i, x_{i+1}]$, i=0,1,2,….N-1, all have degree at most n, then the spline is said to be of degree ≤ n (or of order n+1).*

***Examples:*** *Suppose the interval [a,b] is [0,3] and the subintervals are [0,1), [1,2), and [2,3]. Suppose the polynomial pieces are to be of degree 2, and the pieces on [0,1) and [1,2) must join in value and first derivative (at x=1) while the pieces on [1,2) and [2,3] join simply in value (at x=2). This would define a type of spline $S_\Delta(x)$ for which*

$$S_\Delta(x) = -1 + 4x - x^2, 0 \le x < 1$$

$$S_\Delta(x) = 2x, 1 \le x < 1$$

$$S_\Delta(x) = 2 - x + x^2, 2 \le x \le 3$$

*would be a member of that type, and*

$$S_\Delta(x) = -2 - 2x^2, 0 \le x < 1$$

$$S_\Delta(x) = 1 - 6x + x^2, 1 \le x < 2$$

$$S_{\Delta}(x) = -1 + x - 2x^2, 2 \le x \le 3$$

would also be a member of that type.

The simplest spline has degree 0. It is also called a step function. The next simplest spline has degree 1. It is called a linear spline. The spline of degree 2 is called quadratic spline.

The literature of splines is replete with names for special types of splines. These names have been associated with the choices made for representing the spline or the choices made in forming the extended knot vector or any special conditions imposed on the spline or the choice of introducing a parameter such as:

(i) B – splines is obtained using basis B-splines as basis functions for the entire spline .

(ii) Bezier splines is obtained using Bernstein polynomials as employed by Pierre Bézier to represent each polynomial piece.

(iii) Uniform splines is obtained using single knots for $C^{n-1}$ continuity and spacing these knots evenly on [a,b].

(iv) Non-uniform splines is obtained using knots with no restriction on spacing.

(v) Natural splines is obtained enforcing zero second derivatives at end values a and b.

(vi) Interpolating splines are requiring that given data values be on the spline.

(vii) Polynomial spline is a piecewise polynomial function defined in a region D, such that there exists a decomposition of D into sub-regions in each of which the function is a polynomial of some degree m.

The connecting polynomials could be of any degree and therefore we have different types of spline functions such as linear, quadratic, cubic, quartic, quintic, sextic, septic, octic, nonic etc. They are also known as 'polynomial spline' function.

(viii) Nonpolynomial spline

To deal effectively with problems we introduce 'spline functions' containing a parameter τ. These are 'non-polynomial splines'. These 'splines' belong to the class $C^2$ and reduce into polynomial splines as parameter $\tau \to 0$ [4, 5].

## SPLINE SOLUTION OF DIFFERENTIAL EQUATIONS

In the study of problems arising in astrophysics, problem of heating of infinite horizontal layer of fluid, eigenvalue problems arising in thermal instability, obstacle, unilateral, moving and free boundary-value problems, problems of the defection of plates and in a number of other scientific applications, we find a system of differential equations of different order with different boundary conditions. In general, it is not possible to obtain the analytical solution of them; we usually resort to some numerical methods for obtaining an approximate solution of these problems.

In the present paper various spline techniques for solving boundary value problems in ordinary differential equations are briefly discussed. It contains crux of various recent research papers based on application of quadratic, cubic, quartic, quintic, sextic, septic, octic, nonic and other higher order spline functions to solve different systems of ordinary differential equations. The recent spline techniques, which are used frequently in various fields like; biology, physics and engineering, are considered in this paper.

## Quadratic Spline Techniques to Solve Boundary Value Problems:

A quadratic spline function $S_{\Delta}(x)$, interpolating to a function u(x) defined on [a,b] is such that

(i) In each subinterval $[x_{j-1}, x_j]=1,2,\ldots,N$, $S_{\Delta}(x)$ is a polynomial of degree at most two.

(ii) The first derivative of $S_{\Delta}(x)$ is continuous on [a,b].

Considering the paper [6] by Siraj-ul-Islam et al. having the system of second-order boundary value problem of the type

$$y'' = \begin{cases} f(x), & a \le x \le c \\ g(x)y(x) + f(x) + r, & c \le x \le d \\ f(x), & d \le x \le b \end{cases} \qquad (5)$$

with the boundary conditions

$$y(a) = \alpha_1 \text{ and } y(b) = \alpha_2 \qquad (6)$$

and assuming the continuity conditions of y and y' at c and d. Here, f and g are continuous functions on [a,b] and [c,d] respectively. The parameters r, $\alpha_1$, $\alpha_2$ are real finite constants.

In this research article, quadratic non-polynomial spline functions are used to develop a numerical method for obtaining smooth approximations to the solution of a system of second-order boundary-value problems of the type (5). The new method is of order two for arbitrary α and β if $2\alpha + 2\beta - 1 = 0$ and method of order 4 if $\alpha = 1/12$ along with $2\alpha + 2\beta - 1 = 0$.

***Cubic Spline Techniques to Solve Boundary Value Problems:***

*A cubic spline function $S_\Delta(x)$ of class $C^2[a,b]$ interpolating to a function u(x) defined on [a,b] is such that*

*(a) In each interval $[x_{j-1}, x_j]$=1,2,….,N, $S_\Delta(x)$ is a polynomial of degree at most three,*

*(b) The first and second derivatives of $S_\Delta(x)$ are continuous on [a,b].*

*Considering the article [7] by E. A. Al-Said having the system of second-order boundary value problem of the type*

$$u'' = \begin{cases} f(x), & a \le x \le c \\ g(x)u(x) + f(x) + r, & c \le x \le d \\ f(x), & d \le x \le b \end{cases} \qquad (7)$$

*with the boundary conditions*

$$u(a) = \alpha_1 \text{ and } u(b) = \alpha_2 \qquad (8)$$

*and assuming the continuity conditions of u and u' at c and d. Here, f and g are continuous functions on [a,b] and [c,d], respectively. The parameters r, $\alpha_1$, $\alpha_2$ are real finite constants.*

*The main purpose of this article is to use uniform cubic spline functions to develop some consistency relations which are then used to develop a numerical method for computing smooth approximations to the solution and its derivatives for a system of second-order boundary-value problems of the type (7). In this paper the author has shown that the present method gives approximations which are better than those produced by other collocation, finite-difference, and spline methods.*

***Quartic Spline Techniques to Solve Boundary Value Problems:***

*A quartic spline function $S_\Delta(x)$, interpolating to a function u(x) defined on [a,b] is such that*

*(i) In each subinterval $[x_{j-1}, x_j]$=1,2,….,N,, $S_\Delta(x)$ is a polynomial of degree at most four.*

*(ii) The first, second and third derivatives of $S_\Delta(x)$ are continuous on [a,b].*

*Considering the paper by E. A. Al-Said [8] having the system of fourth order boundary value problem of the type*

$$u^{(iv)} = \begin{cases} f(x), & a \le x \le c \\ g(x)u(x) + f(x) + r, & c \le x \le d \\ f(x), & d \le x \le b \end{cases} \qquad (9)$$

*with the boundary conditions*

$$\begin{aligned} u(a) = u(b) = \alpha_1 \text{ and } u''(a) = u''(b) = \alpha_2, \\ u(c) = u(d) = \beta_1 \text{ and } u''(c) = u''(d) = \beta_2, \end{aligned} \qquad (10)$$

*where f and g are continuous functions on [a,b] and [c,d] respectively. The parameters r, $\alpha i$ and $\beta_i$, i=1,2 are real constants.*

*In the this paper, the authors have used the quartic spline functions to develop a new numerical technique for obtaining smooth approximations of the solution of (9) and its first, second and third derivatives. They derived the consistency relations and developed the new quartic spline method. The convergence analysis of the method, the numerical experiments and comparison with other methods are discussed.*

***Quintic Spline Techniques to Solve Boundary Value Problems:***

*A quintic spline function $S_\Delta(x)$, interpolating to a function u(x) on [a,b] is defined as:*

*(i) In each subinterval $[x_{j-1}, x_j]$=1,2,….,N, $S_\Delta(x)$ is a polynomial of degree at most five.*

*(ii) The first, second, third and fourth derivatives of $S_\Delta(x)$ are continuous on [a,b].*

*To be able to deal effectively with such problems we introduce 'spline functions' containing a parameter ω. These are 'non-polynomial splines' defined through the solution of a differential equation in each subinterval. The arbitrary constants are being chosen to satisfy certain smoothness conditions at the joints. These 'splines' belong to the class $C^4[a,b]$ and reduce into polynomial splines as parameter ω→0. A paper based on quintic spline is as follows -*

*Considering the paper by Arshad Khan and Tariq Aziz [9] having a third-order linear and non-linear boundary value problem of the type*

$$y'''(x) = f(x, y), \ a \le x \le b, \qquad (11)$$

*Subject to*

$$y(a) = k_1, y'(a) = k_2, y(b) = k_3. \qquad (12)$$

*In this paper, the authors have derived a fourth order method to solve third-order linear and non-linear BVPs using quintic splines. They presented the formulation of their method for third-order linear and non-linear BVPs. To retain the pentadiagonal structure of the coefficient matrix, they derived fourth order boundary equations.*

*In this paper, the methods discussed are tested on two problems from the literature [10], and absolute errors in the analytical solutions are calculated.*

*The results confirm the theoretical analysis of the methods. For the sake of comparisons, the authors also tabulated the results by the method of Caglar et al. [11]. We have also applied nonpolynomial quintic spline [12-15] to solve second order linear differential equations.*

***Sextic Spline Techniques to Solve Boundary Value Problems:***

*A sextic spline function $S_\Delta(x)$, interpolating to a function u(x) on [a,b] is defined as:*

*(i) In each interval $[x_{j-1}, x_j]$=1,2,….,N, $S_\Delta(x)$ is a polynomial of degree at most six.*

*(ii) The first fifth derivatives of $S_\Delta(x)$ are continuous on [a,b].*

*(iii) $S_\Delta(x_i)=u(x_i)$, i=0(1)N+1.*

*Consider the paper [16] having a system of second-order boundary-value problem of the type (7) and (8). The authors J. Rashidinia et al. have developed a new numerical method for solving a system of second-order boundary-value problems based on sextic spline. They have shown that the results obtained are very encouraging and their method has better numerical results than those produced by collocation, finite difference and splines methods when solving (7).*

*Here the authors have considered the obstacle boundary-value problem of finding y such that, on* $\Omega = [0, \pi]$,

$$\begin{aligned} &-y'' \geq f(x), \\ &y(x) \geq \psi(x), \\ &[y''- f(x)][y(x) - \psi(x)] = 0, \\ &y(0) = y(\pi) = 0, \end{aligned} \qquad (13)$$

*Where f(x) is a given force acting on the string and Ψ(x) is the elastic obstacle. The authors have studied problem (13) in the framework of a variational inequality approach. It can be shown (see for example [17-21]) that the problem (13) is equivalent to the variational inequality problem:*

$$a(y, v - y) \geq (f, v - y), \quad \text{for all } v \in K,$$

*where K is the closed convex set* $K = \{v : v \in H_0^1(\Omega), v \geq \psi \text{ on } \Omega\}$. *This equivalence has been used to study the existence of a unique solution of (13).*

***Septic Spline Technique to Solve Boundary Value Problems:***

*A septic spline function $S_\Delta(x)$, interpolating to a function u(x) on [a,b] is defined as:*

*(i) In each interval $[x_{j-1}, x_j]$, $S_\Delta(x)$ is a polynomial of degree at most seven.*

*(ii) The first six derivatives of $S_\Delta(x)$ are continuous on [a,b].*

*(iii) $S_\Delta(x_i)=u(x_i)$, i=0(1)N+1.*

*In a nonpolynomial septic spline we introduce a parameter k. The arbitrary constants are being chosen to satisfy certain smoothness conditions at the joints. This 'spline' belongs to the class $C^6[a,b]$ and reduces into polynomial splines as parameter $k \to 0$.*

*Considering the paper by Ghazala Akram et al. [22] having the system of sixth-order boundary value problem of the type*

$$\left.\begin{aligned} &y^{(6)}(x) + f(x)y(x) = g(x), && x \in [a,b], \\ &y(a) = \alpha_0, y(b) = \alpha_1, \\ &y^{(1)}(a) = \gamma_0, y^{(1)}(b) = \gamma_1, \\ &y^{(2)}(a) = \delta_0, y^{(2)}(b) = \delta_1, \end{aligned}\right\} \qquad (14)$$

*where* $\alpha_i, \gamma_i$ *and* $\delta_i, i = 0,1$ *are finite real constants and the functions f(x) and g(x) are continuous on [a,b].*

*In the present paper, the authors have applied non-polynomial spline functions that have a polynomial and trigonometric parts to develop a new numerical method for obtaining smooth approximations to the solution of such system of sixth-order differential equations.*

*The nonpolynomial spline function, under consideration has the form*

$$T_n = span\{1, x, x^2, x^3, x^4, x^5, \cos(kx), \sin(kx)\},$$

*where kis taken to be the frequency of the trigonometric part of the spline function. It is to be noted that k can be real or pure imaginary which is used to raise the accuracy of the method. In this paper using derivative continuities at knots, the consistency relation between the values of spline and its sixth order derivatives at knots is determined. The nonpolynomial spline solution approximating the analytic solution of the BVP (14) is determined, using the consistency relation involving the sixth order derivatives and the values of the spline along with the end conditions. The error bound of the solution is also determined.*

*The method presented in this paper has also been proved to be second order convergent. Two examples are considered for the numerical illustrations of the method developed. The method*

*is also compared with those developed by El-Gamel et al. [23] and Siddiqi and Twizell [24] as well and is observed to be better.*

***Octic Spline Technique to Solve Boundary Value Problems:***

*An octic spline function $S_\Delta(x)$, interpolating to a function u(x) on [a,b] defined as:*

*(i) In each interval $[x_{j-1}, x_j]$=1,2,….,N, $S_\Delta(x)$ is a polynomial of degree at most eight.*

*(ii) The first seventh derivatives of $S_\Delta(x)$ are continuous on [a,b].*

*(iii) $S_\Delta(x_i)=u(x_i)$, i=0(1)N+1.*

*Considering the paper by S. S. Siddiqi et al. [25] having the system of eighth-order boundary value problem of the type*

$$\begin{aligned} &y^{(\text{viii})}+\phi(x)y+\psi(x) \qquad -\infty<a\le x\le b<\infty,\\ &y(a)=A_0,\ y^{(\text{ii})}(a)=A_2,\ y^{(\text{iv})}(a)=A_4,\ y^{(\text{vi})}(a)=A_6,\\ &y(b)=B_0,\ y^{(\text{ii})}(b)=B_2,\ y^{(\text{iv})}(b)=B_4,\ y^{(\text{vi})}(b)=B_6, \end{aligned} \tag{15}$$

*where y=y(x) and Φ(x) and φ(x) are continuous function defined in the interval x∈ [a,b]. $A_i$ and Bi, i=0,2,4,6 are finite real constants.*

*In this paper, the authors have used octic spline to solve the problem of the type (15). The spline function values at the midknots of the interpolation interval and the corresponding values of the even-order derivatives are related through consistency relations. The algorithm developed approximates the solutions, and their higher-order derivatives, of differential equations. Four numerical illustrations are given to show the practical usefulness of the algorithm developed. It is observed that this algorithm is second-order convergent.*

***Nonic Spline Technique to Solve Boundary Value Problems:***

*A nonic spline function $S_\Delta(x)$, interpolating to a function u(x) on [a,b] defined as:*

*(i) In each interval $[x_{j-1}, x_j]$=1,2,….,N, $S_\Delta(x)$ is a polynomial of degree at most nine.*

*(ii) The first eighth derivatives of $S_\Delta(x)$ are continuous on [a,b].*

*(iii) $S_\Delta(x_i)=u(x_i)$, i=0(1)N+1.*

*Considering the paper [26] having the system of eighth-order boundary value problem of the type*

$$\left.\begin{aligned} &y^{(8)}(x)+f(x)y(x)=g(x), \qquad x\in[a,b],\\ &y(a)=\alpha_0, y(b)=\alpha_1,\\ &y^{(1)}(a)=\gamma_0, y^{(1)}(b)=\gamma_1,\\ &y^{(2)}(a)=\delta_0, y^{(2)}(b)=\delta_1,\\ &y^{(3)}(a)=\upsilon_0, y^{(2)}(b)=\upsilon_1, \end{aligned}\right\} \tag{16}$$

*where $\alpha_i,\gamma_i,\delta_i$ and $\upsilon_i, i=0,1$ are finite real constants and the functions f(x) and g(x) are continuous on [a,b].*

*In the present paper, Ghazala Akram et al. have used Nonic spline for the numerical solutions of the eighth order linear special case boundary value problem given by equation (16). The end conditions are derived for the definition of spline. The algorithm developed not only approximates the solutions, but their higher order derivatives as well. The method presented in this paper has also been proved to be second order convergent. Two examples compared with those considered by Siddiqi et al. [25] and Inc et al. [27], show that the method developed in this paper is more efficient. Collocation method is developed for the approximate solution of eighth order linear special case BVP, using nonic spline. The method is also proved to be second order convergent.*

***Tenth Degree Spline Technique to Solve Boundary Value Problems:***

*A Tenth degree spline function $S_\Delta(x)$, interpolating to a function u(x) on [a,b] defined as:*

*(i) In each interval $[x_{j-1}, x_j]$=1,2,….,N, $S_\Delta(x)$ is a polynomial of degree at most ten.*

*(ii) The first ninth derivatives of $S_\Delta(x)$ are continuous on [a,b].*

*(iii) $S_\Delta(x_i)=u(x_i)$, i=0(1)N+1.*

*Considering the paper by S. S. Siddiqi et al. [28] having the system of tenth-order boundary value problem of the type*

$$\left.\begin{aligned} &y^{(x)}(x)+\phi(x)y=\psi(x), \qquad -\infty<a\le x\le b<\infty,\\ &y(a)=A_0, y^{(ii)}(a)=A_2,\\ &y^{(iv)}(a)=A_4, y^{(vi)}(a)=A_6,\\ &y^{(viii)}(a)=A_8, y(b)=B_0, y^{(ii)}(b)=B_2,\\ &y^{(iv)}(b)=B_4, y^{(vi)}(b)=B_6,\\ &y^{(viii)}(b)=B_8, \end{aligned}\right\} \tag{17}$$

*where y=y(x), Φ(x) and Ψ(x) are continuous function defined in the interval x∈ [a,b] and $A_i$ and Bi, i=0,2,4,6,8 are finite real constants.*

*In the present paper, linear, tenth-order boundary-value problems (special case) are solved, using polynomial splines of degree ten. The spline function values at midknots of the interpolation interval and the corresponding values of the even-order derivatives are related through consistency relations. The algorithm developed approximates the solutions and their higher-order derivatives, of*

*differential equations. Four numerical illustrations are given to show the practical usefulness of the algorithm developed. It is observed that this algorithm is second-order convergent.*

***Eleventh Degree Spline Technique to Solve Boundary Value Problems:***

*An Eleventh degree spline function $S_\Delta(x)$, interpolating to a function u(x) on [a,b] defined as:*

*(i) In each interval $[x_{j-1}, x_j]$=1,2,….,N, $S_\Delta(x)$ is a polynomial of degree at most eleven.*

*(ii) The first tenth derivatives of $S_\Delta(x)$ are continuous on [a,b].*

*(iii) $S_\Delta(x_i)=u(x_i)$, i=0(1)N+1.*

*In a nonpolynomial Eleventh degree spline we introduce a parameter k. The arbitrary constants are being chosen to satisfy certain smoothness conditions at the joints. This 'spline' belongs to the class $C^{10}[a,b]$ and reduces into polynomial splines as $k\to 0$.*

*Considering the paper [29] having the system of tenth-order boundary value problem of the type*

$$\left.\begin{aligned} &y^{(10)}(x)+f(x)y(x)=g(x), \qquad x\in[a,b],\\ &y(a)=\alpha_0, y(b)=\alpha_1,\\ &y^{(1)}(a)=\gamma_0, y^{(1)}(b)=\gamma_1,\\ &y^{(2)}(a)=\delta_0, y^{(2)}(b)=\delta_1,\\ &y^{(3)}(a)=\upsilon_0, y^{(2)}(b)=\upsilon_1,\\ &y^{(4)}(a)=\zeta_0, y^{(4)}(b)=\zeta_1, \end{aligned}\right\} \quad (18)$$

*where $\alpha_i,\gamma_i,\delta_i,\upsilon_i$ and $\zeta_i, i=0,1$ are finite real constants and the functions f(x) and g(x) are continuous on [a,b].*

*In this paper, S. S. Siddiqi et al. have obtained numerical solutions of the tenth-order linear special case boundary value problems using eleventh degree spline. The end conditions consistent with the BVP are also derived. Siddiqi and Twizell [28] presented the solutions of tenth-order boundary value problems using tenth degree spline, where some unexpected results for the solution and higher order derivatives were obtained near the boundaries of the interval. No such unexpected situation is observed in this method, near the boundaries of the interval and the results are better in the whole interval. The algorithm developed approximates the solutions, and their higher order derivatives. Numerical illustrations are tabulated to compare the errors with those considered by Siddiqi and Twizell [27] and the method is observed to be better.*

***Twelfth Degree Spline Technique to Solve Boundary Value Problems:***

*A twelfth degree spline function $S_\Delta(x)$, interpolating to a function u(x) on [a,b] defined as:*

*(i) In each interval $[x_{j-1}, x_j]$=1,2,….,N, $S_\Delta(x)$ is a polynomial of degree at most twelve.*

*(ii) The first eleven derivatives of $S_\Delta(x)$ are continuous on [a,b].*

*(iii) $S_\Delta(x_i)=u(x_i)$, i=0(1)N+1.*

*Considering the paper [30] having the system of twelfth-order boundary value problem of the type*

$$y^{(xii)}+\phi(x)y=\psi(x), \qquad -\infty<a\le x\le b<\infty$$
$$y^{(2k)}(a)=A_{2k}, y^{(2k)}(b)=B_{2k}, \qquad k=0,1,2,....,5 \quad (19)$$

*where y=y(x), Φ(x) and Ψ(x) are continuous function defined in the interval x∈ [a,b] and $A_i$ and Bi, i=0,2,4,6,8,10 are finite real constants.*

*In the present paper, S. S. Siddiqi et al. have solved linear twelfth-order boundary-value problems (special case), using polynomial splines of degree twelve. The spline function values at midknots of the interpolation interval and the corresponding values of the even-order derivatives are related through consistency relations. The algorithm developed approximates the solutions and their higher-order derivatives, of differential equations. Two numerical illustrations are given to show the practical usefulness of the algorithm developed. It is observed that this algorithm is second-order convergent.*

***Thirteenth Degree Spline Technique to Solve Boundary Value Problems:***

*A thirteen degree spline function $S_\Delta(x)$, interpolating to a function u(x) on [a,b] defined as:*

*(i) In each interval $[x_{j-1}, x_j]$=1,2,….,N, $S_\Delta(x)$ is a polynomial of degree at most thirteen.*

*(ii) The first twelve derivatives of $S_\Delta(x)$ are continuous on [a,b].*

*(iii) $S_\Delta(x)=u(x)$, i=0(1)N+1.*

*In a nonpolynomial thirteenth degree spline we introduce a parameter k. The arbitrary constants are being chosen to satisfy certain smoothness conditions at the joints. This 'spline' belongs to the class $C^{12}[a,b]$ and reduces into polynomial splines as $k\to 0$.*

*Considering the paper by S. S. Siddiqi et al. [31] having the system of twelfth-order boundary value problem of the type*

$$\left.\begin{aligned} &y^{(12)}(x)+f(x)y(x)=g(x), \qquad x\in[a,b],\\ &y(a)=\alpha_0, y(b)=\alpha_1,\\ &y^{(1)}(a)=\gamma_0, y^{(1)}(b)=\gamma_1,\\ &y^{(2)}(a)=\delta_0, y^{(2)}(b)=\delta_1,\\ &y^{(3)}(a)=\upsilon_0, y^{(2)}(b)=\upsilon_1,\\ &y^{(4)}(a)=\zeta_0, y^{(4)}(b)=\zeta_1,\\ &y^{(5)}(a)=\omega_0, y^{(5)}(b)=\omega_1, \end{aligned}\right\} \quad (20)$$

*where* $\alpha_i,\gamma_i,\delta_i,\upsilon_i,\zeta_i$ *and* $\omega_i, i=0,1$ *are finite real constants and the functions f(x) and g(x) are continuous on [a,b].*

*In this paper numerical solutions of the twelfth order linear special case boundary value problems are obtained using thirteen degree spline. The end conditions are derived for the definition of spline. Siddiqi and Twizell [30] presented the solutions of twelfth order boundary value problems using 12th degree spline, where some unexpected results for the solution and its derivatives were obtained, near the boundaries of the interval. No such situation is observed in this method. The algorithm developed, approximates not only the solution but its higher order derivatives as well. Numerical illustrations are tabulated to demonstrate the practical usefulness of the method.*

*This paper is organized in three sections. Using derivative continuities at knots, the consistency relations between the values of spline and its higher order derivatives at knots are determined in first section. In second section the end conditions are derived to complete the definition of spline which completes the required spline solution approximating the solution of the BVP (20). In third section, two examples are considered for the implementation of the method developed. In this paper the method developed not only approximates the solution of BVP, but its higher order derivatives as well. The method developed, provides encouraging results. The possibility of finding the solutions of further higher order BVPs can also be explored in future.*

## CONCLUSION

*This paper is devoted to the evolution, progress, types and spline solutions of differential equations. There is now considerable evidence that in many circumstances a spline function is a more adaptable approximating function than a polynomial involving a comparable number of parameters. Recent trends in computational mathematics, mathematical physics and mechanics are toward the wide use of spline functions to solve such problems. The main advantages of application of spline function are its stability (the local behaviour of a spline at a point does not affect its overall behaviour) and calculation simplicity In solving problems arising in astrophysics, problem of heating of infinite horizontal layer of fluid, eigenvalue problems arising in thermal instability, obstacle, unilateral, moving and free boundary-value problems, problems of the deflection of plates and in a number of other problems of scientific applications, spline functions are not only more accurate but also we have a variety of choices to use quadratic, cubic, quartic, quintic, sextic, septic, octic, nonic or higher splines to solve them.*

## REFERENCES


[1.] *Korzybski, Alfred. (1994). Science and Sanity: an Introduction to non-Aristotelian Systems and General Semantics (Section: Differential equations, pg. 595). Institute of General Semantics.*

[2.] *Poincare, H., Sur les equations aux derives partielles de la physique mathematique, American Journal of Mathematics 12 (1890) 211-294.*

[3.] *S. Surana K., A. Rajwani; J. N. Reddy, The k-Version Finite Element Method for Singular Boundary-Value Problems with Application to Linear Fracture Mechanics, 7(3), 2006, 217 – 239.*

[4.] *Manoj Kumar and Pankaj Kumar Srivastava, Computational techniques for solving differential equations by cubic, quintic and sextic spline, International Journal for Computational Methods in Engineering Science & Mechanics , 10( 1) (2009) 108 – 115.*

[5.] *Manoj Kumar and Pankaj Kumar Srivastava, Computational techniques for solving differential equations by quadratic, quartic and octic Spline, Advances in Engineering Software 39 (2008) 646-653.*

[6.] *Siraj-ul-Islam, Muhammad Aslam Noor, Ikram A. Tirmizi, Muhammad Azam Khan, Quadratic non-polynomial spline approach to the solution of a system of second-order boundary-value problems, Applied Mathematics and Computation 179 (2006) 153-160.*

[7.] *E. A. Al-Said, The use of cubic splines in the numerical solution of a system of second-order boundary value problem, Computer and Mathematics with Applications 42 (2001) 861-869.*

[8.] *E. A. Al-Said and Muhammad Aslam Noor, Quartic spline method for solving fourth order obstacle boundary value problems, Journal of Computational and Applied Mathematics 143(2002) 107-116.*

[9.] *Arshad Khan, Tariq Aziz, The numerical solution of third-order boundary-value problems using*

quintic splines, Applied Mathematics and Computation 137 (2003) 253-260.
[10.] S. I .A. Tirmizi, On numerical solution of third-order boundary-value problems, Communication in Applied and Numerical Mathematics 7 (1991) 309-313.
[11.] H. N. Caglar, S.H. Caglar, E.H. Twizell, The numerical solution of third-order boundary-value problems with fourth-degree B-spline functions, International Journal of Computer Mathematics 71 (1999) 373-381.
[12.] Pankaj Kumar Srivastava, Manoj Kumar & R N Mohapatra, Quintic Nonpolynomial Spline Method for the Solution of a Special Second-Order Boundary-value Problem with engineering application, Computers & Mathematics with Applications, 62 (4) (2011) 1707-1714.
[13.] Pankaj Kumar Srivastava and Manoj Kumar: Numerical Treatment of Nonlinear Third Order Boundary Value Problem, Applied Mathematics, 2 (2011) 959-964.
[14.] Pankaj Kumar Srivastava, Manoj Kumar & R N Mohapatra, Solution of Fourth Order Boundary Value Problems by Numerical Algorithms Based on Nonpolynomial Quintic Splines, Journal of Numerical Mathematics and Stochastics, 4 (1) : 13-25, 2012
[15.] Pankaj Kumar Srivastava and Manoj Kumar: Numerical Algorithm Based on Quintic Nonpolynomial Spline for Solving Third-Order Boundary value Problems Associated with Draining and Coating Flow, Chinese Annals of Mathematics, Series B, 33B(6), 2012, 831–840.
[16.] J. Rashidinia, R. Jalilian , R. Mohammadi, M. Ghasemi, Sextic spline method for the solution of a system of obstacle problems, Applied Mathematics and Computation, 190 (2007) 1669-1674.
[17.] Baiocchi C., Capelo A., Variational and Quasi-variational Inequality, John Wiley and Sons, New York, 1984.
[18.] E. A. Al-Said, Spline solutions for system of second-order boundary-value problems, International Journal of Computer Mathematics 62 (1996) 143-154.
[19.] F. Villagio, The Ritz method in solving unilateral problems in elasticity, Meccanica (1981) 123 -127.
[20.] Kikuchi N., Oden J. T., Contact Problems in Elasticity, SIAM, Publishing Co., Philadelphia, 1988.
[21.] M. A. Noor, K.L. Noor, Th. Rassias, Some aspects of variational inequalities, Journal of Computational and Applied Mathematics 47 (1993) 285-312.
[22.] Ghazala Akram, Shahid S. Siddiqi, Solution of sixth order boundary value problems using non-polynomial spline technique, Applied Mathematics and Computation 181 (2006) 708–720.
[23.] M. El-Gamel, J.R. Cannon, J. Latour, A.I. Zayed, Sinc-Galerkin method for solving linear sixth-order boundary-value problems, Mathematics of Computation 73 (247) (2003) 1325–1343.
[24.] S. S. Siddiqi, E.H. Twizell, Spline solutions of linear sixth-order boundary value problems, International Journal of Computer Mathematics 60 (1996) 295–304.
[25.] S. S. Siddiqui, E.H.Twizell, Spline solutions of linear eighth-order boundary-value problems, Computer Methods in Applied Mechanics and Engineering 131 (1996) 309-325.
[26.] Ghazala Akram, Shahid S. Siddiqi, Nonic spline solutions of eighth order boundary value problems, Applied Mathematics and Computation 182 (2006) 829–845.
[27.] M. Inc, D.J. Evans, An efficient approach to approximate solution of eighth-order boundary-value problems, International Journal of Computer Mathematics 81 (6) (2004) 685–692.
[28.] S. S. Siddiqi and E.H. Twizell, Spline solutions of linear tenth-order boundary-value problems, International Journal of Computer Mathematics 68 (1998) 345-362.
[29.] S. S. Siddiqi, Ghazala Akram, Solutions of tenth-order boundary value problems using eleventh degree spline, Applied Mathematics and Computation 185 (2007) 115–127.
[30.] S. S. Siddiqi and E.H. Twizell, Spline solutions of linear twelfth-order boundary-value problems, Journal of Computational and Applied Mathematics 78 (1997) 371-390.
[31.] S. S. Siddiqi, Ghazala Akram, Solutions of twelfth order boundary value problems using thirteen degree spline, Applied Mathematics and Computation 182 (2006) 1443–1453.


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# ANALYSIS MULTI-OUTPUT TRANSMISSION MECHANISMS

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***Abstract:*** *This article describes output transmission mechanisms. Transmission (transmission mechanism) transmits or distributes power from the prime mover to the driven machine. He changes the frequency of speed, torque and driving forces. Transfer changes rotary motion into rotary motion of other parameters or on straight sliding movement and vice versa.*
***Keywords:*** *multistage transmission mechanism, outputs*

## INTRODUCTION

*Currently it is possible in technical and technological experience to watch a permanent increase in demand for both quality and accuracy of production equipment and technology, but also of industrial and non-industrial areas. This requirement is particularly associated with the search for more effective design solutions different parts of machine technology. This is also the search for suitable alternatives to transmission mechanisms resulting in the possibility of their application.*

*In terms of output, the transmission system can be divided into:*

- *One outputs – group of one-output transmission is characterized by a single output shaft.*
- *Multiple outputs – a group of multi-output transmission is specific in terms of the output shaft. Multi–output transmission may have two or more output shafts. Number of outputs, respectively output shafts $n_{vj}$ is based on the number of jointly engaging sprocket $n_{zi}$ mounted on the inner wheel is defined by: $n_{vj} = n_{zi} - 1$.*

## MULTIPLE OUTPUTS TRANSMISSION SYSTEM

*Multi–output transmission mechanisms can be divided into:*

*1) Transfers to the output of the drive shaft against the drive shaft,*
*2) Transfers retro driven output shaft,*
*3) Transfers with double–sided output.*

*Example multi-output transfer is in the figure 1st and 2nd. This three-output transmission mechanism was designed on KNTZ FVT TU in Košice. The main objective was to contribute to the expansion of assortment of gear mechanisms, resulting in the possibility of their application in machinery manufacturing technology.*

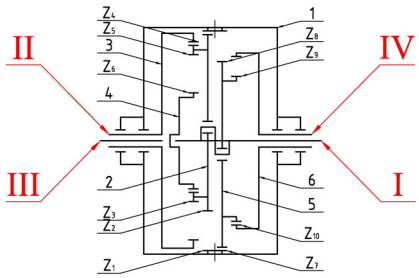


*Figure 1. The principal scheme of a two sided three-output gear mechanism*

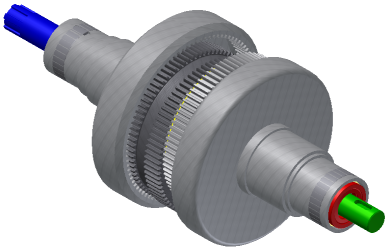

*Figure 2. Model of three-output gear mechanism*

*Multiple outputs gear transmission mechanisms are mechanisms that can be implemented with tooth system:*

- *involute – to conventional modules $m \geq 1$ mm*
- *with small modules with $m < 1$ mm*
- *not-involute (cycloidal) – the size of the module according to the specific design of the transmission mechanism*
- *not-teeth ($m = 0$) – like friction gears*

## PROPOSAL FOR MEASURING MULTI-OUTPUT TRANSMISSION MECHANISMS OF THE STAND

*Based on the known solutions-stage multi-output transmission mechanisms are suitable for two basic solutions:*

1. *Proposed new test equipment (of the stand) for testing the gear mechanism at the output shaft of each load separately and for the two output shafts respectively load of all output shafts. This proposal is the realization of a new measuring device designed so that each output shaft is loaded (braked) separately. Measurement of the transfer will be carried out while individually on each output shaft respectively along with other output shaft or all shafts together. An example of this principle over the circular solution is shown in figure 3rd.*

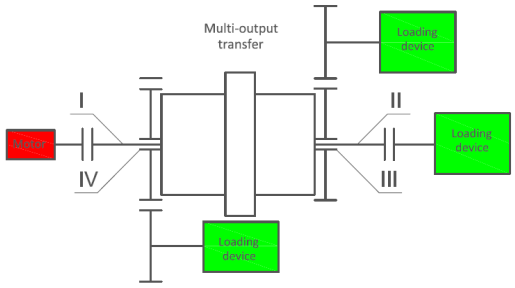


*Figure 3. Schematic measurement of the stand with a separate shaft driven load*

2. *The principle of measuring more stand-circuit transmission mechanisms is based on the principle Nieman at the load of gear (tooth system), the bias caused by cross-shaft driven two mutually related transfers. Such a solution is a measurement of the stand can be considered very useful especially because it gearing at full load power is only needed to cover losses in the respective transfer mechanism. Example Schematic of the stand-circuit over the Nieman principle is shown in figure 4th.*

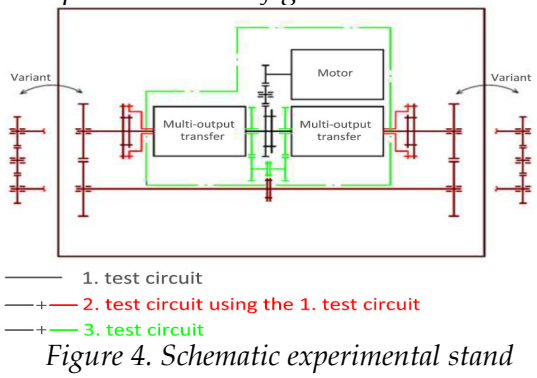


*Figure 4. Schematic experimental stand*

## CONCLUSIONS

*To be considered advantageous alternative no.2, thus measuring stend transmission mechanisms based on the Nieman principle. Functional models are verified under static load under DC rotation shaft. As the most important asset we can say that at full load tooth system is only needed for power losses in the respective transfer mechanism. Additional amenities may be noted that the experimental stand is thus possible to test all three sets of gears connected to each other via the output shaft (I-II, II-III, III-III), either individually or all at once. The principles of testing saves energy needed to carry out tests and also eliminates the need for special arrangements necessary to draw the load.*

## REFERENCES

[1.] *Litecká, J. - Pavlenko, S.: The new constructional solutions of gear hobs for spur gear production. In: EWTECH 2011 : international conference on advanced manufacturing engineering : 14th-15th September 2011, Brno, Czech Republic. - Brno : University of Technology, 2011 P. 75-78. - ISBN 978-80-214-4267-2*

[2.] *Haľko, J.: Both side more-output transmission with harmonic gear. In: Technological Developments in Networking, Education and Automation. - Dordrecht : Springer, 2010 P. 1-4. - ISBN 978-90-481-9151-2*

[3.] *Haľko, J - Maščenik, J.: Principle multiple output both side gear with harmonic transmission: In: SBW 2009 : Robotization and automation in welding and other techniques : 5. international scientific-professional conference : conference proceedings : Slavonski Brod, 11.-13.11.2009. - Slavonski Brod : Mechanical Engineering Faculty, 2009 P. 145-152. - ISBN 978-953-6048-51-9*

[4.] *Maščenik, J. - Gašpár, Š.: CA technológie ako efektívny nástroj v procese výroby. 2011. In: Ai Magazine. Roč. 4, č. 2 (2011), s. 86-87. - ISSN 1337-7612*

[5.] *Dvojstupňový Viacvýstupový Harmonický Prevod - Úžitkový vzor (tzv. malý patent) zaregistrovaný Úradom priemyselného vlastníctva SR pod č. 3937 dňa 11.08.2004. Autori: Ing. Jozef Haľko a prof. Ing. Vladimír Klimo, CSc*

[6.] *Pilc, J. - Demeč, P. - Čilliková, M.: Stavba obrábacích strojov : súčasné trendy: In: Strojárstvo. Roč. 12, č. 11 (2008), s. 8-9. - ISSN 1335-2938*

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# INVESTIGATION OF MULTI-STAGE THERMO-ELECTRIC SYSTEM BY PSO METHOD AND ICA OPTIMIZATION ALGORITHM

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**Abstract:** *The aim of this research is to investigate the optimized some properties of thermoelectric system such as efficiency and power production in generator systems. First, the maximum efficiency and power production in multi-stage thermoelectric systems, which are connected electrically in both parallel and series, are computed. Then, the performance of these systems is compared and the priorities of their usage at their operating temperatures are determined. In this study, despite other studies which use thermoelectric characteristics of materials at the average temperature of the system, the characteristic average operating temperatures of each stage is used. The procedures for optimizing the system are the particle swarm optimization method (PSO) and Imperialist competitive algorithm (ICA) and finally these two methods is compared with each other in order to calculate the efficiency of thermoelectric systems and the results of this investigation represent that: ICA method is 5 percent closer to experimental results.*

**Keywords:** *Thermoelectric systems, Optimization, Efficiency, Generated Power. Swarm optimization method (PSO), Imperialist competitive algorithm (ICA)*

## INTRODUCTION

*According to recent estimations, fossil fuels will run out in sixty four years, therefore, people will have to turn to new sources of energy.*

*Using renewable energy such as hydro, wind and solar are among the most accepted, and improving their efficiency and performance has attracted scientists' interest [1]. One method is using energy producing devices with solid state [2]. These devices have low maintenance cost and they operate without polluting the environment.*

*Thermoelectric devices are divided into two major groups: coolers [3-6] and generators [7-10]. Coolers operate on the basis of Peltier effect and generators operate on the basis of Seebeck effect. Thermoelectric generators produce electricity when there is a temperature difference, and thermoelectric coolers produce a temperature difference in the presence of electricity.*

*In the present time, the only limitation of using these devices is their low efficiencies; generators at 5-6 percent [11], and the coefficient of performance of coolers is around 1, closer to 4 for a typical system [12].*

*Thermoelectric materials' characteristics such as thermal conductivity, electrical resistance, seebeck and Peltier coefficients are all functions of temperature [13], which themselves can be topics for researches to investigate.*

*Yilbas and Sahin suggested a slenderness ratio for maximizing performance [14]. Beside of researches trying to improve thermodynamic material characteristics, a lot of research has done on thermodynamic systems configuration to improve the overall system performance [15-17].*

*Even with limited performance, some of research effort has led to using these systems in combination of other systems. For example in automotive industry a lot of works have been done in transforming exhaust heat energy to electricity [18-23].*

*Recently Lee and his colleagues have developed a solar-thermoelectric system which has attracted much attention [24]. They have found $Bi_2Te_3$, considering its operating temperature, is the best material for a solar-thermoelectric system. In solar energy, Wei He analyzed a design of a heat pipe solar-electric generator unit [25].*

## THERMOELECTRIC MATERIALS' WORK PROCEDURE

When an electrical conductor is positioned between two different temperatures, the conductor has the ability to transfer the thermal energy from the hot spot to the cold one. In addition, the physical procedure of heat transfer tends to transfer the electrical charge carriers in the direction of the heat transfer.

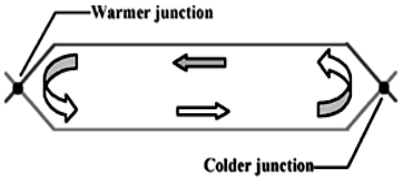


Figure 1. Schema of a simple circuit with 2 wire

This movement of charge carriers can be used to produce electrical current, if we are able to complete the circuit in an effective way.

If the conductor completing the circuit is like the first conductor, the flow of the thermal energy produces an electrical potential for charge carriers' movements in both conductors. Moreover, the electrical potential in one of the conductor is exactly the opposite of that of the other conductor. As a result, there will be no current in the circuit.

If we use two different conductors, we will have a completely different result.

With different abilities of transferring carriers, the produced current resulted from thermal potential in one conductor will dominate the produced current resulted from thermal potential of the other conductor (and in some cases it will completely dominate the other current). The pure effect is a continuous current which is the difference between the produced current of the two conductors.

The presence of this pure current shows that there is an electrical potential along the path of the heat flow which could be easily measure by opening the circuit and using a potentiometer.

Notice that the ability of different materials in producing voltage by presence of a temperature difference is called seebeck effect. The produced voltage, also, is called seebeck voltage. In fact, the produced voltage by the thermocouple is a function of two parameters: the temperature difference between the two points and the characteristics of the used conductors (like dependence on temperature). Of course, thermocouples are used to measure temperatures not to produce power.

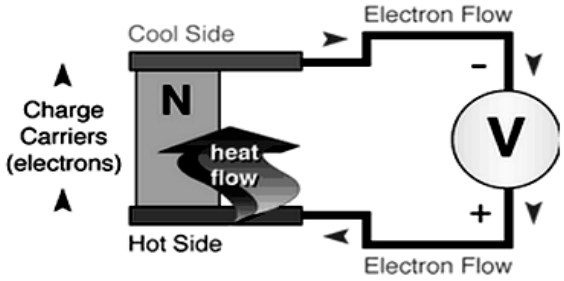


Figure 2. Schema of N-type circle include the voltmeter

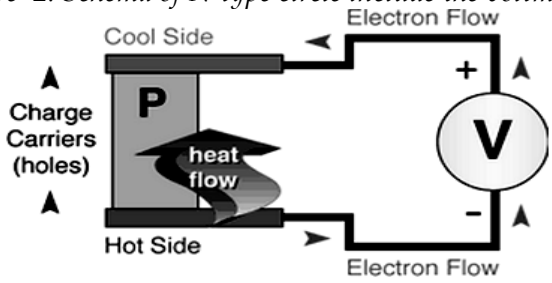


Figure 3. Schema of P-type circle include the voltmeter

Thermo-electric power producing facilities use semi-conductor materials for which the seebeck effect is optimized.

The circuit in Figure (2) shows a simple sample. An N-type semi-conductor circle connected to a voltmeter is shown in this figure.

When heat is transferred from the hot spot to the cold spot, charge carriers are transferred with heat. Heat, also, causes the movement of charge carriers in the return path. For producing power in thermo-electrics, P circle are used too. Figure (3) shows a primary schematic.

Notice the reverse movement of electrons. These are all of the cases of using type-N and P materials in a power producing generator which we can correctly optimize the seebeck effect.

As it is shown in Figure (4), N and P circle are in a parallel position, but are circle from an electrical point of view. Because the electrical current (electrons' movements) is in the opposite direction of the cavity current, the current producing potentials in circle are not each others' opposite.

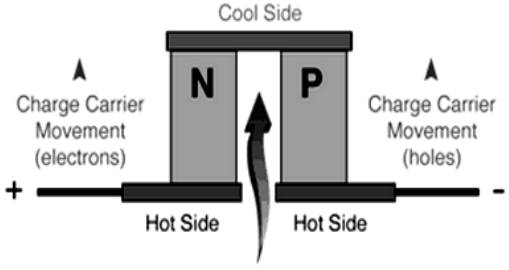


Figure 4. Schema of parallel type

In fact, in practical PEGs, a lot of N and P couples are used to gain applicable voltage.

## IMPERIALIST COMPETITIVE ALGORITHM

The optimization problem can be absolutely delineated to find an argument x that related cost $f(x)$ is optimum, it has been widely used in many different position such as industrial planning, resource allocation scheduling, pattern identification. Different methods have been suggested to solve the problem. developmental algorithms such as: particle swarm optimization [26,27], genetic algorithm [28,29], taboo search [30-32], bees algorithm [33-35], and colony optimization [36-38], and simulated annealing [39,40] are collection of algorithms that are suggested and established for solving optimization problem in many different engineering and science fields in last decades. Imperialist competitive algorithm (ICA) is offered for first time by Ateshpaz-Gargari and Lucas in 2007 [41] and established for optimization inspired by the imperialistic competition and has a important relationship to many engineering applications [41]. Like other developmental methods, the proposed algorithm begins with an initial population. Population individual called country that they are in two types: colonies and imperialists who all together form some empires. Imperialistic competition among these empires forms the base of the proposed developmental algorithm. During this contest, feeble empires collapse and powerful empires take possession of their colonies. Imperialistic contest optimistically converge to a position in which there exist just one empire and its colonies are in the same state and have the same cost as the imperialist [41]. Using this algorithm, one may discover the optimum condition of the several functions. In this connecting the suggested model based on retrogression analysis is then embedded into the ICA to optimize the objective function. The aim of optimization algorithms is to discover optimal solution in terms of the variables of the problem (optimization variables). Hence an arrangement of variable values to be optimized is formed. In Genetic Algorithm terminology, this arrange is called "chromosome" but in this Algorithm the term "country" is used for this arrange. In an $N_{var}$-dimensional optimization problem, a countries an $(1\times N_{var})$ arrange. This arrangement is defined by:

$$Country = [\, p_1, p_2, p_3, \ldots\ldots p_{Nvar}] \qquad (1)$$

The variable values in the country are shown as floating point numbers. The cost of a country is discovered by evaluating the cost function $f$ at the variables $(p_1, p_2, p_3, \ldots\ldots p_{Nvar})$ [41].

$$Then\ cost = f(p_1, p_2, p_3, \ldots\ldots p_{Nvar}) \qquad (2)$$

The flowchart of the ICA algorithm is demonstrated in Figure 5.

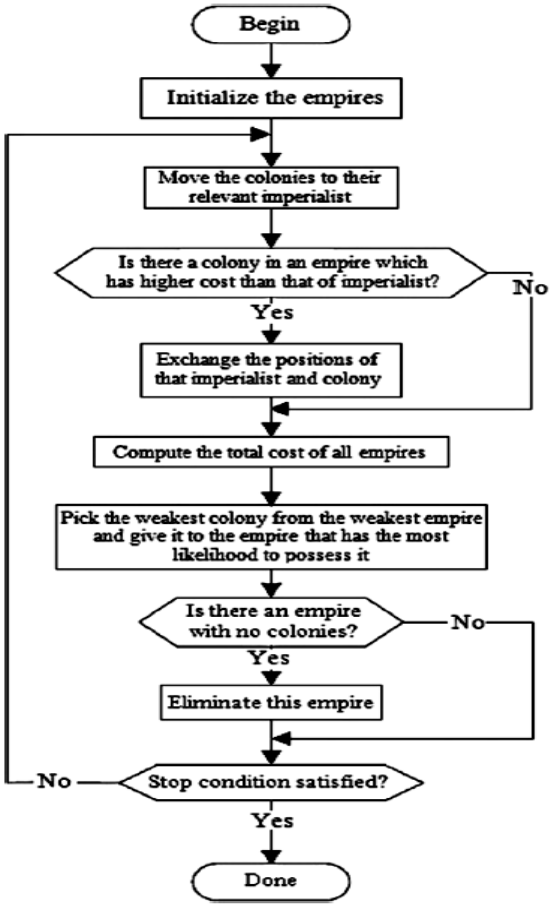


Figure 5. The flowchart of ICA algorithm

To begin the optimization algorithm the initial population of size $N_{pop}$ is produced. The $N_{imp}$ of nearly most powerful countries to form the empires is chosen. The remaining $N_{col}$ of the population is going to be the colonies each of which possessed by an empire. Now, there two kinds of countries: imperialist and colony. To form the initial empires, the colonies are then divided among imperialists, according to their powers. It is the initial number of colonies of an empire must be proportionate to its power in a direct manner. To divide the colonies among imperialists relatively the normalized cost of an imperialist are explained by $C_n = c_n - Max\{c_i\}$, where $c_n$ is the cost of nth imperialists, and $C_n$ is its normalized cost. Having the normalized power of each imperialist is explained by [41].

$$Pn=\frac{C_n}{\sum_{i=1}^{Nimp} c_i} \quad (3)$$

*From the other point of view, the normalized power of an imperialist is the portion of colonies that must be belonged to that imperialist.*

*Therefore the initial number of colonies of an empire is going to be:*

$$N.C._n = round\{p_n.N_{col}\} \quad (4)$$

*That $N.C._n$ is the initial number of colonies of nth empire and $N_{col}$ is the number of all colonies. To divide the colonies for per imperialist $N.C._n$ of the colonies is selected in random manner and is given them to it. These colonies together with the imperialist are going to form nth empire. A schematic demonstration of the initial population of per empire can be seen in Figure 6.*

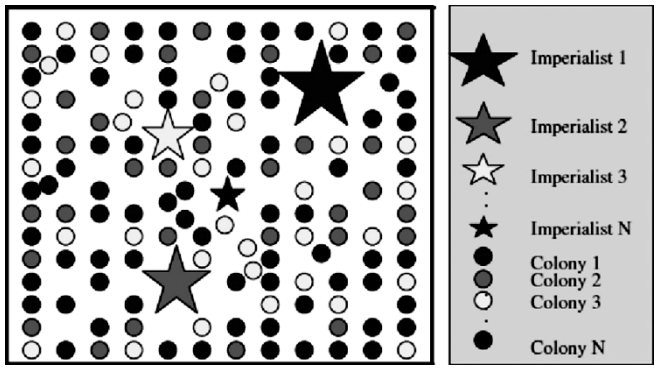


*Figure 6. Moving colonies toward their relevant imperialists [41]*

*As shown in figure, more powerful (bigger) empires have more number of colonies while weaker (smaller) empires have less number [41]. As mentioned above imperialist countries began to enhance their colonies. This reality has been modeled by moving up all the colonies in the direction of imperialist. This movement is demonstrated in Figure 7, where the colony moves in the direction of the imperialist by x units.*

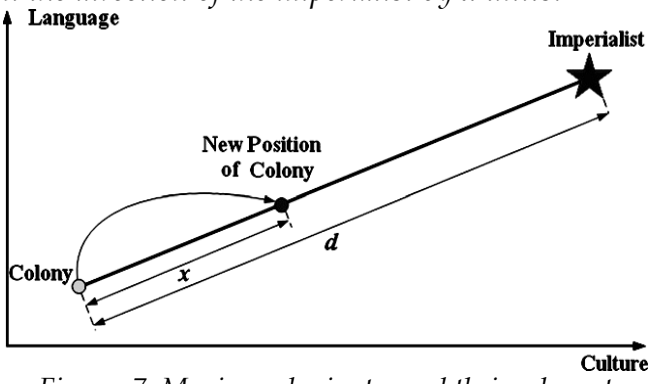


*Figure 7. Moving colonies toward their relevant imperialist*

*The new situation of colony is demonstrated in a darker color. The direction of the movement is the vector from colony in the direction in the direction of imperialist. In Figure 7 x is an accidental (random) variable with uniform or any proper profile [41]. Then for x*

$$p \sim U(0, \beta \times d) \quad (5)$$

*where $\beta$ is a number bigger than 1 and d is the distance between imperialist and colony. A $\beta>1$, brings out the colonies to get closer to the imperialist position from both sides. To investigate different points around the imperialist an accidental amount of deviation was added to the direction of movement. Figure 8 demonstrates the new direction.*

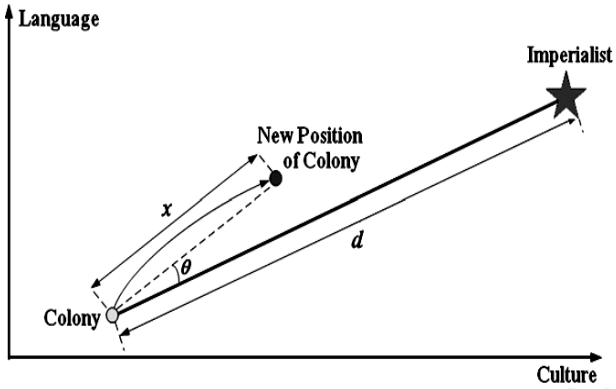


*Figure 8. Procedure of the proposed algorithm [41]*

*In Figure 8, $\theta$ is a accidental number with uniform or any proper profile. Then*

$$\theta \sim U(-\gamma, \gamma) \quad (6)$$

*That $\gamma$ is a parameter that modifies the deviation from the original direction. However the values of $\beta$ and $\gamma$ are arbitrary, in most of our performing a value of about 2 for $\beta$ and about $\pi/4$ (Rad) for $\gamma$, have resulted in nice convergence of countries to the global minimum.*

## *PARTICLE SWARM OPTIMIZATION*

*Particle swarm optimization is a new procedure in solving optimization problems [26]. In this algorithm, there are some things which are called particles and are distributed in the searching space of the function which has to be optimized each particle calculates the amount of the cost function in its own location within the space.*

*Then, by combining two sets of information of the present location and the best previous location where it used to be, and also, the information of one or some of the best particles of the group, it chooses a direction to move.*

*This method uses low order relation, which helps the result to converge faster. In this paper, we used violation technique to satisfy the boundary conditions of the problem.*

*In the PSO method, the motions of the particles are a direct result of adding three components such as global -search, local search, and the previous traveled distance which is multiplied by a set of certain weighting coefficients. In this case, the method to search for the particle could be modified by manipulating the weighting coefficients, but it is better to conduct a wide global search first, and then a local search around the most likely location.*

*In PSO method, finding optimal weights for faster convergence, accurate space search and better performance is a challenging problem for scientists [27].*

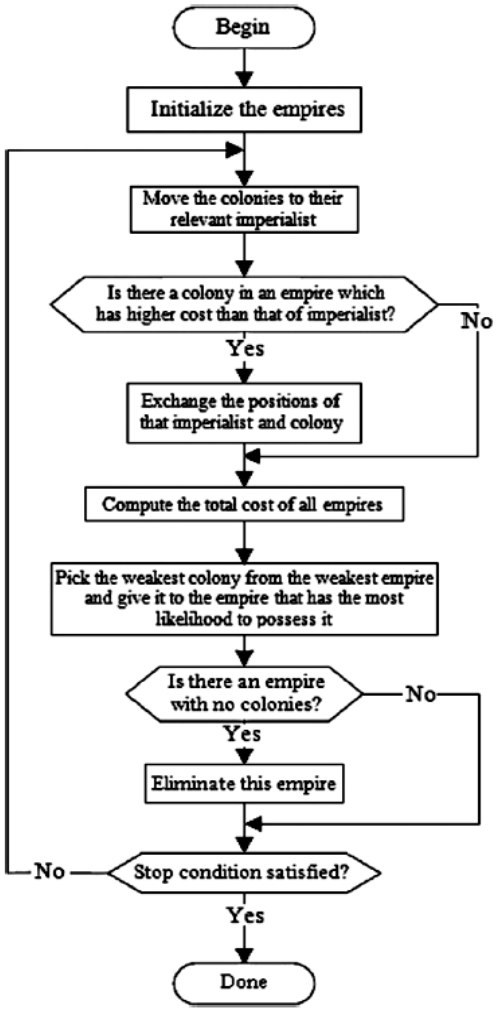


*Figure 9. Flowchart of PSO algorithm*

*This research looks for an optimal arrangement of Single-stage through four-stage thermo-electric generators, taking their operating temperatures into consideration. Different stages of the system are connected to each other in parallel and in series, and the results of these systems are compared to each other. $Bi_2Te_3$ is used as the thermoelectric material which is a very useful and practical substance for this application.*

## DEFINING THE MODEL

### Schematic and structural definitions of the model

*Structural model of thermoelectric systems is presented in Figure (10):*

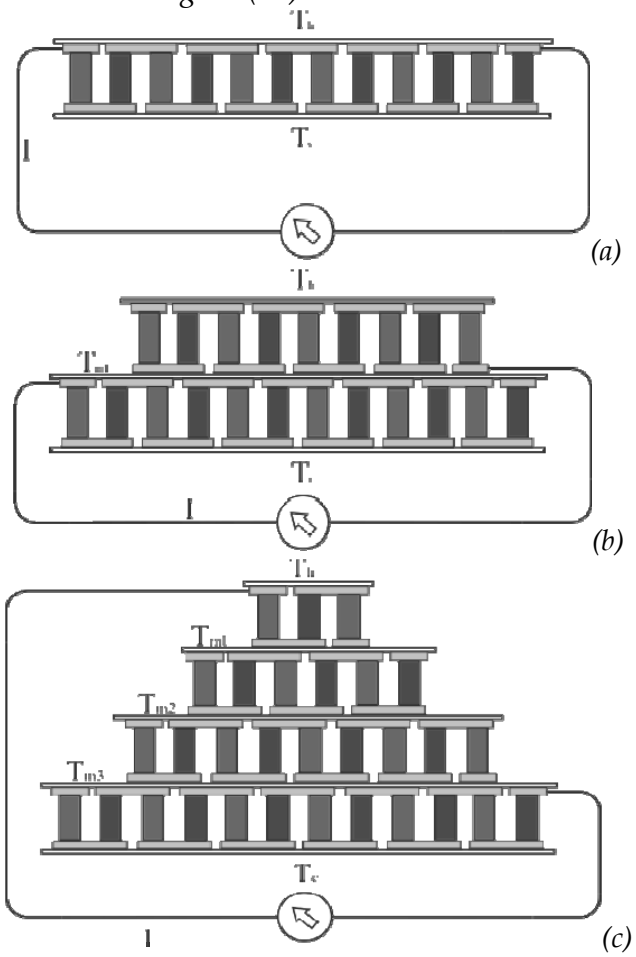


*Figure 10. The thermoelectric system,(a) the single-stage system,(b) the two-stage series system, and (c) the four-stage series system*

*The two-stage series system is composed of two single-stage systems which are on top of one another, connected by a wire in series. This concept of two-stage thermoelectric systems can be extended to four-stage thermoelectric systems, as shown in Figure 10 (c) and.*

*Structural model of parallel thermoelectric systems is shown in Figure (11).*

*Multi-stage parallel thermoelectric systems are similar to the series thermoelectric systems with only one difference, which is, the produced power enters the circuit in each stage.*

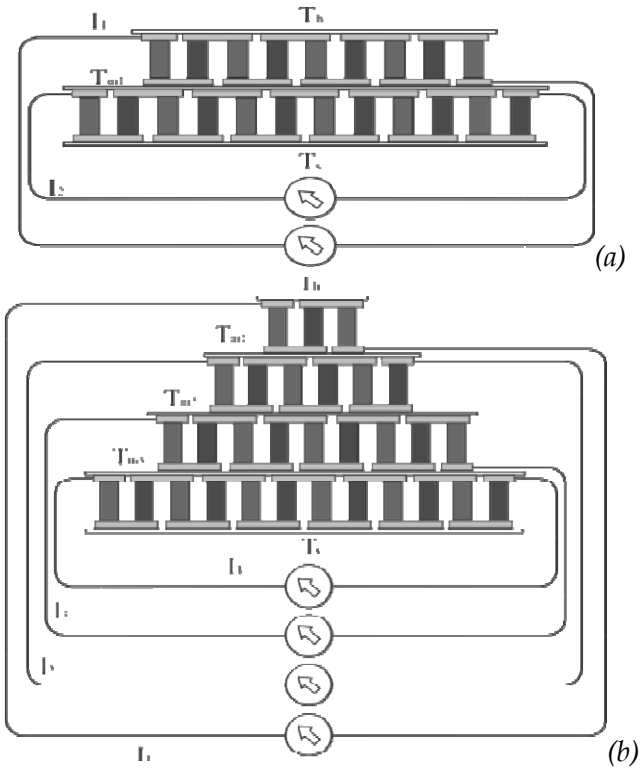

Figure 11. The parallel thermoelectric system, (a) the two-stage system, (b) the four-stage system

***Mathematical definition of the model***

*The system's inlet heat, outlet heat, and work in a single-stage thermoelectric system are calculated using the second law of thermodynamics as follows [28]:*

$$Q_{in} = N\ x\ [ST_hI - \frac{1}{2}R_{in}I^2 + K(T_h - T_c)] \quad (7)$$

$$Q_{out} = N\ x\ [ST_CI + \frac{1}{2}R_{in}I^2 + K(T_h - T_c)] \quad (8)$$

*The cost functions in this study are the system's efficiency and produced power, which are based on thermodynamic laws. The produced power of the system is calculated as follows:*

$$P = Q_{in} - Q_{out} = N\ x\ [SI(T_h - T_c) - RinI^2] \quad (9)$$

*Also, the systems efficiency is given by:*

$$\eta = \frac{P}{Q_{in}} \quad (10)$$

*In order to extend the above equations to multi-stage systems, these equations must be applied to each stage. Considering the thermodynamic condition emphasizing the equivalence of the inlet and outlet heat transfer during each stage, at the end, equations (9) and (10) are applied to the whole system. In this case, the lender coefficient of the thermoelectric couple, are considered to be: G=5 x $10^{-3}$ [m].*

- ✓ *In a parallel two-stage thermoelectric generator, there are five optimization variables as follow: $T_m$, $I_1$, $I_2$, $N_1$, $N_2$. In a series two-stage thermoelectric generator, I1 equals I2; as a result, the number of optimization variables reduces to four. Thermodynamic condition in two-stage systems is $Q_{outlet\ from\ stage\ 1} = Q_{inlet\ to\ stage\ 2}$ which should be satisfied during the optimization process.*
- ✓ *In a parallel three-stage thermoelectric system, there are eight optimization variables as follow: $T_{m1}$, $T_{m2}$, $I_1$, $I_2$, $I_3$, $N_1$, $N_2$, $N_3$ In a series three-stage thermoelectric system $I_1$, $I_2$, and $I_3$ are equal; as a result, the number of optimization variables reduces to six. Thermodynamic conditions in three-stage systems are $Q_{outlet\ from\ stage\ 1} = Q_{inlet\ to\ stage\ 2}$ and $Q_{outlet\ from\ stage\ 2} = Q_{inlet\ to\ stage3}$ which should be satisfied during the optimization process.*
- ✓ *In a parallel four-stage thermoelectric system, there are eleven optimization variables as follow: $T_{m1}$, $T_{m2}$, $T_{m3}$, $I_1$, $I_2$, $I_3$, $N_1$, $N_2$, $N_3$. In a series four-stage thermoelectric system $I_1$, $I_2$, $I_3$, and $I_4$ are equal; as a result, the number of optimization variables reduces to eight. Thermodynamic conditions in four-stage systems are $Q_{outlet\ from\ stage\ 1} = Q_{inlet\ to\ stage\ 2}$, $Q_{outlet\ from\ stage\ 2} = Q_{inlet\ to\ stage\ 3}$ and $Q_{outlet\ from\ stage\ 3} = Q_{inlet\ to\ stage\ 4}$ which should be satisfied during the optimization process.*

*For example, the equations of entering and exiting heats in a parallel three-stage thermo-electric system are:*

$$Q_{1,in} = N_1x[S_1T_hI_1 - \frac{1}{2}R_1I_1^2 + K_1(T_h - T_{m1})] \quad (11)$$

$$Q_{1,out} = N_1x[S_1T_{m1}I_1 - \frac{1}{2}R_1I_1^2 + K_1(T_h - T_{m1})] \quad (12)$$

$$Q_{2,in} = N_2x[S_2T_{m1}I_2 - \frac{1}{2}R_2I_2^2 + K_2(T_{m1} - T_{m2})] \quad (13)$$

$$Q_{2,out} = N_2x[S_2T_{m2}I_2 - \frac{1}{2}R_2I_2^2 + K_2(T_{m1} - T_{m2})] \quad (14)$$

$$Q_{3,in} = N_3x[S_3T_{m2}I_3 - \frac{1}{2}R_3I_3^2 + K_3(T_{m2} - T_c)] \quad (15)$$

$$Q_{3,out} = N_3x[S_3T_cI_3 - \frac{1}{2}R_3I_3^2 + K_3(T_{m2} - T_c)] \quad (16)$$

$$P = Q_{1,\ in} - Q_{\ 3,\ out} \quad (17)$$

$$\eta = \frac{P}{Q_{1,3in}} \quad (18)$$

*If we substitute I for $I_1$, $I_2$, and $I_3$ in equations (11) to (16), the equations of a series thermoelectric system could be obtained.*

*Characteristics of the thermoelectric material $Bi_2Te_3$ (K, R, S) are available in [29].*

*In this case, the following equation is used for the number of thermoelectric couples:*

$$\sum_{i=1}^{j\ \text{numberofch anges}} N_i = 100 \qquad (19)$$

## RESULTS AND DISCUSSION

*The obtained mathematical equations presented in mathematical model section were optimized under the specified conditions, and the values of the desired cost function were calculated, and the independent parameters associated with the values were found. Now, the results of series and parallel thermoelectric systems are going to be compared.*

### Reasons of efficiency and power decrease by increasing temperature

*As it was observed from the obtained results, the efficiency (at the temperatures higher than 700K) and the produced power (at temperatures higher than 1000K) decline. The reasons for this behavior will be discussed further.*

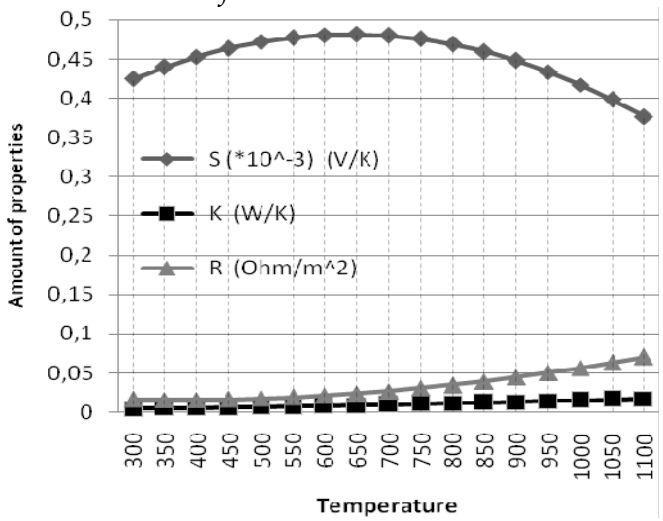


*Figure 12. Changes of the characteristics of the thermoelectric material ($Bi_2Te_3$) with mean temperature of hot surface and cold surface*

*Thermoelectric properties obtained by using the average temperatures of hot and cold surfaces. From Figure (12), it can be seen that R and K variables ascend as the temperature increases, but the S variable (seebeck coefficient) starts to decrease once the mean temperature exceeds 650K. In solving the governing equations of the inlet and outlet heat and the produced power in a single-stage thermoelectric system (eq (7),(8) and (9)), the K variable is eliminated in the equation, which calculates the produced power.*

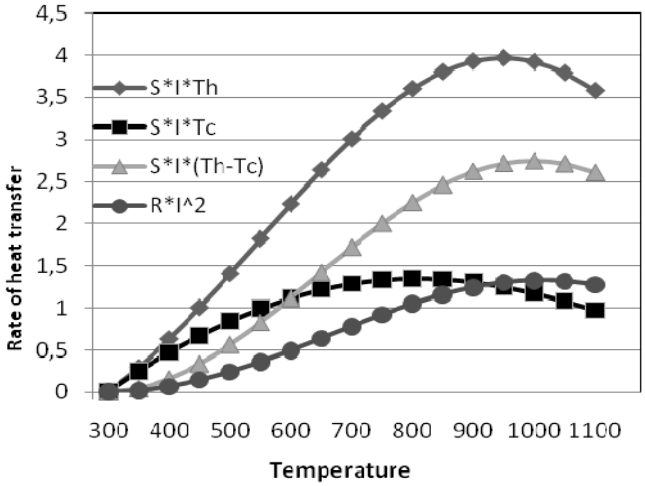


*Figure 13. Effect of differences of constituted elements of system on rate of heat transfer*

*The reason why the produced power decreases at temperatures higher than 1000K is because the seebeck coefficient decreases, resulting in the decrease of the term SI ($T_h$-$T_c$).*

*The ascending behavior of R and the descending behavior of S at mean temperatures above 650K, also have an impact on the rate at which power is produced. As it was mentioned earlier, the efficiency of a thermoelectric system equals eq(10) The numerator of this equation behaves exactly the same as the procedure mentioned in the previous section, but in the denominator, the rate of conductive heat transfer is added to the other effective elements of the system's power.*

*As it can be seen in figure 12 the K coefficient has ascending behavior with respect to temperature. In addition, the term ($T_h$-$T_c$) has ascending behavior as the surface temperature increases; as a result, the amount of the conductive heat transfer dramatically increases which makes the denominator grow faster than the numerator which leads to the decreasing behavior of the efficiency at temperatures above 700K. The same behavior can be observed in multi-stage thermoelectric systems.*

*However, in multi-stage systems the common part temperature of the stages can be determined in order to decrease the undesired effect of decreasing seebeck coefficient on the ascending heat conduction which leads to lower efficiency.*

*Not to mention that the descending slope of the efficiency could be decreased as well. It is also worth mentioning that in order to improve the*

*thermoelectric characteristics of materials, the produced power, the efficiency of the system and the seebeck coefficient should be increased, and the electrical resistance coefficient along with the thermal conductivity should be decreased.*

***Optimizing the efficiency of the system***

*As it can be seen in figure 13, in series thermo-electric systems, the efficiency of the system has approximately the same value in single-, two-, and four-stage thermo-electric systems until the hot surface temperature reach 600K (assuming the cold surface has a temperature of 300K).*

*However, as the temperature of the hot surface increases beyond 600K, the efficiency of the single-stage system decreases dramatically, and around 1600K, the efficiency and produced power approach zero. On the other hand, in two-, and four-stage thermo-electric systems, although the efficiency decreases at higher temperatures, its slope is far less than that of the single-stage system.*

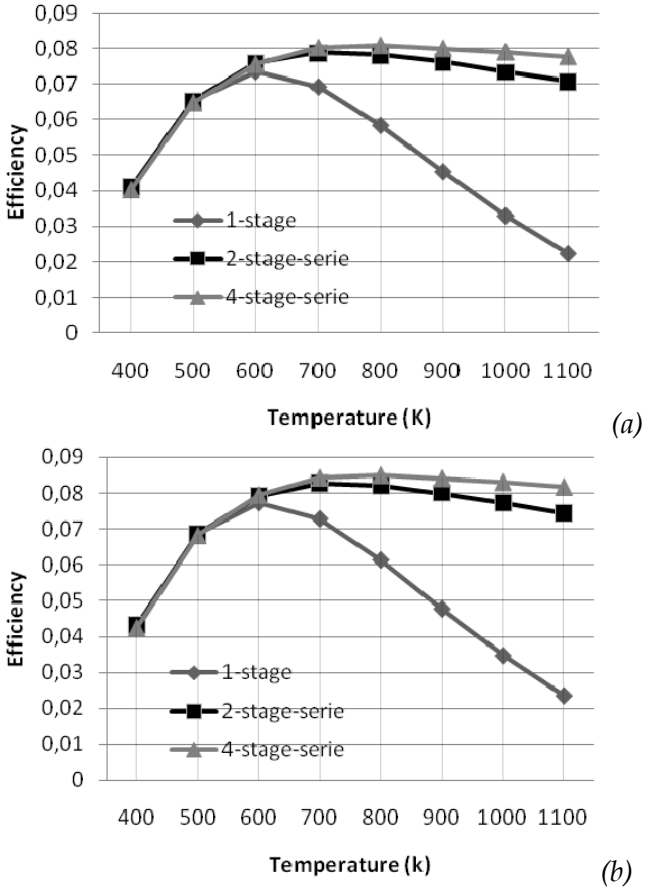


*Figure 14. The effect of hot surface's temperature and number of stages in a series thermo-electric system (a) is based on PSO method and (b) is based on ICA method*

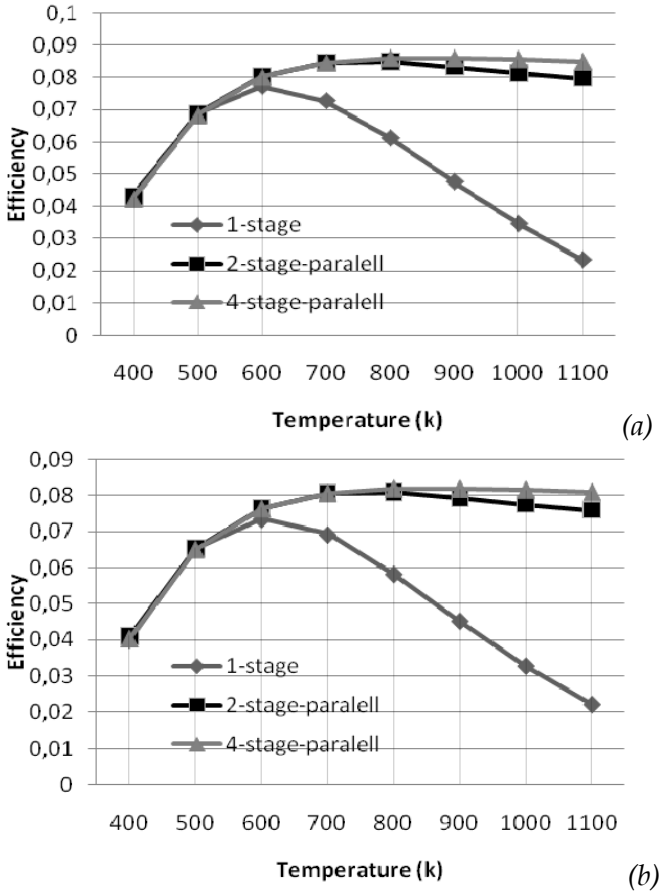


*Figure 15. The effect of hot surface's temperature and number of stages in a parallel thermo-electric system (a) is based on PSO method and (b) is based on ICA method*

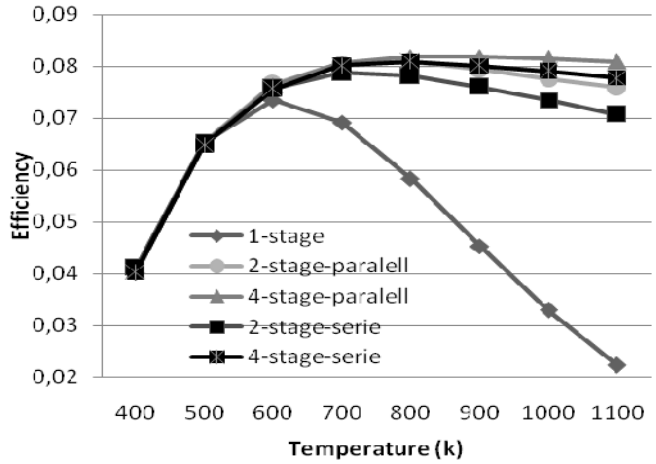


*Figure 16. The effect of hot surface's temperature and number of stages in a parallel and series thermo-electric system base on PSO method*

*By comparing figures (17) and (18), it could be determined that the behavior of the parallel thermo-electric system is highly similar to that of the series system.*

*Like series thermo-electric systems, in parallel thermo-electric systems, the maximum efficiency is independent of the number of stages till it reaches*

*the temperature of 600K, but at temperatures higher than 600K, the maximum efficiency in the single-stage thermo-electric decreases dramatically and loses its advantages over the systems with more than one stage.*

*It is clear that in multi-stage parallel thermo-electric systems, the efficiency is slightly higher than that of the series systems. By increasing the number of stages, not only the efficiency increase, but also less power is obtained for 100 thermo-electric couples, which is an important advantage of these systems, where we have constraints on space.*

***Optimizing the generated power of the system***

*As it is shown in figure 17, the maximum power among the series thermo-electric systems is produced in the single-stage thermo-electric system. Where, as the temperature of the hot surface increases up to 1000K, the produced power has an ascending manner. Beyond 1000K the trend begins to decent. As the number of the stages increases to 2 and higher, the overall amount of produced power decrease, but there is no descending trend until the temperature reaches 1100K.*

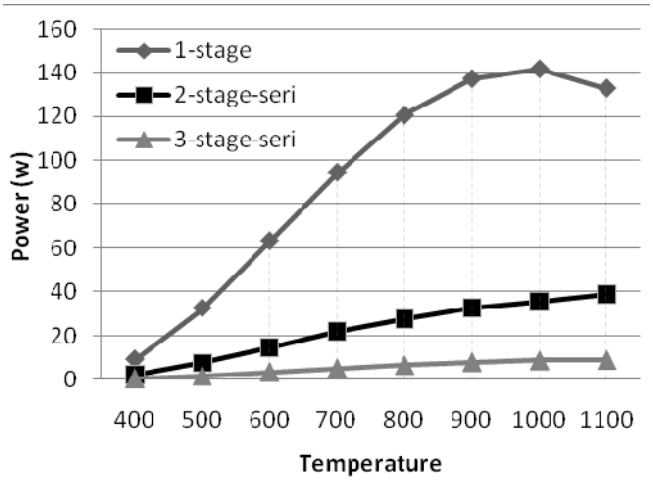


*Figure 17. The effect of the hot surface's temperature and the number of stages on the produced power in Watt in series design*

*During efficiency optimization, the parallel thermo-electric system had a better efficiency respect to the series one. The same result was obtained during produced power optimization. The parallel systems with more stages have a higher produced power slope, than that of the series ones. Therefore, the power produced in a parallel system is significantly higher than that of a series system.*

*It is worth mentioning that the results are obtained when there are 100 couples of thermo-electric series which are divided between the stages when there are several stages in the system. This distribution of thermo-electric couples among different stages results smaller systems, where this is considered as one of important advantages of these systems.*

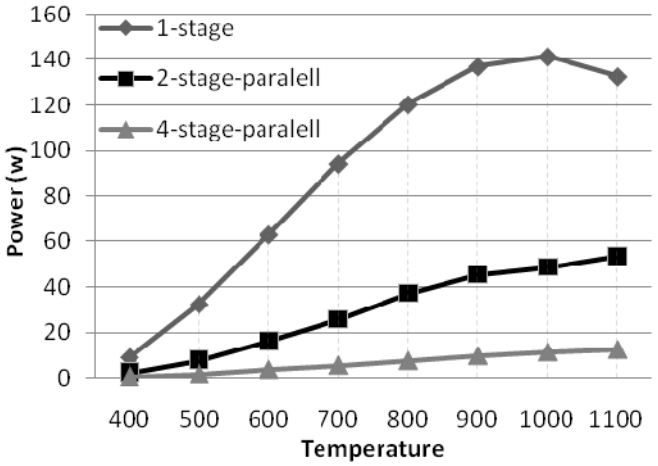


*Figure 18. The effect of the hot surface's temperature and the number of stages on the produced power in Watt in parallel design*

***CONCLUSION***

*The objective of this study is to find a model of physical and electrical design for thermo-electric systems in order to have the highest efficiency and produced power. Based on the results, the following conclusions are made.*

*In single-stage systems the hot and cold surface temperatures highly affect the output values of the system; as an example, the efficiency and produced power increase up to 600K and 1000K, respectively.*

*If the temperature of the hot surface is less than 600K, using single-stage systems is preferred because there is no noticeable difference between the efficiency of a single-stage system and that of a multi-stage system. However, the amount of power produced is higher for a single-stage system. On the other hand, if the temperature exceeds 600K, multi-stage systems have a better efficiency. However, the produced power of a single-stage system will still be higher.*

*Nevertheless, in multi-stage systems with equal number of couples, sometimes the space occupied is half and in some cases one third of the single-stage system which is important when there is a limitation on the available space.*

*As it is clear from the results, parallel systems have higher efficiency and produced more power than series systems, and at temperatures higher than 600K, the associate graph has a lower slope in efficiency decrease, so parallel systems have a more stable performance at higher or variable temperatures although this stability does not guarantee the stable output numbers.*

*The fact that design and control of multi-stage systems, especially parallel ones, is highly complicated and expensive, should be considered when choosing a system. It could be concluded that even under the best conditions, the output efficiency of a parallel multi-stage system is slightly higher than 8 percent which is not a substantial improvement. So using multi-stage thermo-electric systems over single-stage ones is not advantageous, unless there are some limitations on space, or the purpose is to produce little amount of electricity and the typical systems are not affordable. If the usage of a thermo-electric system is desired, the multi-stage parallel systems are the better choice, given the results of this study. However, These systems are far from ideal. Thanks to the improvements in the realm of nanotechnology, there is hope to improve the thermo-electric characteristics of materials such as the Seebeck effect, the Peltier effect, heat conductivity, and electric resistance; as a result, it is possible in the near future that power production systems, solid state cooling and heating systems such as thermo-electric systems will leave the conventional systems behind in both efficiency and power production.*

*The procedures for optimizing the thermoelectric system are the particle swarm optimization method (PSO) and Imperialist competitive algorithm (ICA) and these two methods is compared with each other in order to calculate the efficiency of thermoelectric system as shown in Figure 14 and Figure 15 the results of these methods for both series and parallel systems are close to each other, but the results of this investigation represent that: ICA method is 5 percent closer to experimental results.*

## NOMENCLATURE

$T_h$ : *Temperature of hot surface*
$T_c$ : *Temperature of cold surface*
$T_{m1}$ : *Temperature of surface between stage1 and stage2 at multi-stage systems*
$T_{m2}$ : *Temperature of surface between stage2 and stage3 at multi-stage systems*
$T_{m3}$ : *Temperature of surface between stage3 and stage4 at multi-stage systems*
$S$ : *seebeck coefficient of a thermoelectric circle*
$R$ : *electric resistance of a thermoelectric circle*
$k$ : *heat conductivity of a thermoelectric circle*
$G$ : *slenderness ratio*
$I$ : *electric current at series systems*
$I_o$ : *electric current at parallel system at stage(1-4)*
$N_o$: *number of thermoelectric circle at stage (1-4)*
$Q_{in}$ : *inlet heat to system*
$Q_{out}$ : *outlet heat from system*
$P$ : *generation power by system*
$\eta$ : *efficiency of thermoelectric system*

## REFERENCES


[1.] *Rahman S. Going green; "The growth of renewable energy", IEEE Power and Energy Magazine; pp.16-18, 2003.*

[2.] *Riffat SB, Ma X. "Thermoelectrics: a review of present and potential applications." Applied Thermal Engineering. pp. 13-35, 2003.*

[3.] *Simons RE, Ellsworth MJ, Chu RC. "An assessment of module cooling enhancement with thermoelectric coolers." J Heat Transfer-Trans ASME. pp. 76-84, 2005.*

[4.] *Wu KH, Hung CI. "Thickness scaling characterization of thermoelectric module for small-scale electronic cooling." J Chin Soc Mech Eng. pp. 75-81, 2009.*

[5.] *Cheng TC, Cheng CH, Huang ZZ, Liao GC. "Development of an energy-saving module via combination of solar cells and thermoelectric coolers for green building applications." Energy. pp. 33-40, 2011.*

[6.] *Chen WH, Liao CY, Hung CI. "A numerical study on the performance of miniature thermoelectric cooler affected by Thomson effect." Appllied Energy. pp. 64-73, 2012.*

[7.] *Champier D, Bedecarrats JP, Rivaletto M, Strub F. "Thermoelectric power generation from biomass cook stoves." Energy. pp. 35-42, 2010.*

[8.] *Champier D, Bedecarrats JP, Kousksou T, Rivaletto M, Strub F, Pignolet P. "Study of a TE (thermoelectric) generator incorporated in a multifunction wood stove." Energy. pp. 18-26, 2011.*

[9.] *Martinez A, Astrain D, Rodriguez A. "Experimental and analytical study on thermoelectric self cooling of devices." Energy. pp. 50-60, 2011.*

[10.] Chen M, Rosendahl LA, Condra T. "A three-dimensional numerical model of thermoelectric generators in fluid power systems." Int J Heat Mass Transfe. pp. 45-55, 2011.
[11.] Amatya R, Ram RJ. "Solar thermoelectric generator for micropower applications." Journal of Electronic Materials. pp. 35-40, 2010.
[12.] Esarte J, Min G, Rowe DM. "Modelling heat exchangers for thermoelectric generators." J Power Sources. pp. 2-6, 2001.
[13.] Yamashita O. "Effect of linear temperature dependence of thermoelectric properties on energy conversion efficiency." Energy Conversion and Management . pp. 3-9, 2008.
[14.] Yilbas BS, Sahin AZ. "Thermoelectric device and optimum external load parameter and slenderness ratio". Energy. pp. 80-84, 2010.
[15.] Gaowei Liang, Jiemin Zhou, Xuezhang Huang. Analytical model of parallel thermoelectric generator."; Applied Energy 88. pp. 5193-5199, 2011
[16.] Liang GW, Zhou JM, Huang XZ, et al. "Analytical model of series semiconductor thermoelectric generators."; J Jiangsu Univ Sci Technol, pp. 4-9, 2011.
[17.] Zhang HJ, Chen H, et al. "Research on the generating performance of seriesparallel connection and reappearance of a semiconductor thermoelectric module."; Acta Energiae Solaris Sinica. pp. 4-7, 2001.
[18.] Hsiao YY, Chang WC, Chen SL. "A mathematic model of thermoelectric module with applications on waste heat recovery from automobile engine." Energy. pp. 47-54, 2010..
[19.] Hsu CT, Huang GY, Chu HS, et al. "Experiments and simulations on lowtemperature waste heat harvesting system by thermoelectric power generators." Appllied Energy. pp. 1-7, 2011.
[20.] Masahide M, Michio M, Masaru O. "Thermoelectric generator utilizingautomobile engine exhaust gas." Therm Sci Eng. pp. 7-8, 2001.
[21.] Yodovard P. "The potential of waste heat thermoelectric power generation from diesel cycle and gas turbine cogeneration plants." Energy Source. pp. 3-4, 2001.
[22.] Yu C, Chau KT. "Thermoelectric automotive waste heat energy recovery using maximum power point tracking." Energy Convers Manage. pp. 6-12, 2009.
[23.] Xu LZ, Li Y, Yang Z, et al. "Experimental study of thermoelectric generation from automobile exhaust." J Tsinghua Univ (Sci Technol). pp. 7-9, 2010.
[24.] Li P, Cai L, Zhai P, Tang X, Zhang Q, Niino M. "Design of concentration solarthermoelectric generator." Journal of Electronic Materials . pp. 22-30, 2010.
[25.] Wei He, Yuehong Su, S.B. Riffat, JinXin Hou, Jie Ji. "Parametrical analysis of the design and performance of a solar heat pipe thermoelectric generator unit." Applied Energy 88. pp. 5083-5089, 2011.
[26.] J. Kennedy, R.C. Eberhart, "particle swarm optimization", in: Proceedings of IEEE International Conference on neural Networks, Piscataway: IEEE, 1995, PP. 1942-1948.
[27.] K. Lei, Y. Qiu, Y. He, "A new adaptive well-chosen inertia Weight strategy to automatically harmonize global and local search ability in particle swarm optimization", in: Proc. 1st International symposium on systems and control in aerospace and astronautics, (ISSCAA 2006), pp.977-980.
[28.] C.L Wu K.W Chau, "A flood forecasting neural network model with genetic algorithm", Int. J. Environ. Pollut. 28 (2006) 223-238.
[29.] N. Muttil, K.W.Chu, "Neural network and genetic programming for modelling coastal algal blooms", Int. J. Environ. Pollut. 28 (2006) 223-238.
[30.] D. de Werra, A. Hertz, Tabu search techniques: "A tutorial and an application to neural networks", OR Spekter. (1989) 131-141.
[31.] A. Hertz, Finding a feasible course schedule using tabu search, J. Discrete Appl. Math. 35 (1992) 255-270.
[32.] R. Battiti, G. Tecchiolli, "The Reactive Tabu Search", Department of Mathematics, University of Trento, Trento, Italy, 1992.
[33.] D.T.Pham, A. Ghanbarzadeh, E.Koc, S. Otri, "Application of the bees algorithm to the training of radial basis function network for control chart pattern recognition", in: Proc. 5th CIRP International Seminar on Intelligent Computation in Manufacturing Engineering (CIRP ICME 06), Ischia, Italy, 2006.
[34.] T.Pham, E. Koc, A. Ghanbarzadeh, S. Otri, "Optimization of the Weights of multi-layered perceptions using the Bees algorithm, in: proc. 5th International Symposium on Intelligent Manufacturing systems, Turkey, 2006
[35.] D.T. Pham, A.J. Soroka, A. Ghanbarzadeh, E. Koc, S. Otri, M. Packianather, "optimizing neural networks for identification wood defects using the bees algorithm, in: Proc, 2006 IEEE International

*Conference on Industrial Informatics, Singapore, 2006.*

[36.] *R.S. Parpinelli, H.S. Lopes, A.A. Freitas, "Data mining with ant colony optimization algorithm", IEEE Trans. Evol. Comput. 6 (2002) 321-332.*

[37.] *C. Blum, M. Sampels, "Ant colony optimization for FOP shop scheduling: A case study on different pheromone representation", in: proceeding of the 2002 congress on Evolutionary computation, Honolulu, USA.*

[38.] *W. Ying, X. Jianying, "Ant colony optimization for multicast routing" in: The 2000 IEEE Asia-pacific Conference on Circuits and Systems, Tianjin, China.*

[39.] *BE. Rosen, J.M. Goodwin, "optimization neural networks using very fast simulated annealing" Neural Parallel Sci. Comput. (1997) 383-392.*

[40.] *M.F. Cardoso, R.L. Salcedo, S.F. Azevedo, D. Barbosa, "A simulated annealing approach to the solution of minlp problems, Comput. Chem. Eng. 21 (1997) 1349-1364.*

[41.] *E. Astashpaz-Gargari, C. Lucas, "Imperialist competitive algorithm: an algorithm for optimization inspired by imperialistic competition", in: IEEE Congress on Evolutionary computation, Singapore, 2007.*

[42.] *Eberhart, R. C., Kennedy, J. "A new optimizer using particle swarm theory" [A]. In: Proceedings of the Sixth International Symposium on Micromachine and Human Science [C]. Nagoya, Japan, pp. 39-43, 1995.*

[43.] *Clerc, M. (1999). "The Swarm and the queen: towards a deterministic and adaptive particle swarm optimization." Proc. 1999 Congress on Evolutionary Computation, Washington, DC, pp 1951-1957. Piscataway, NJ: IEEE Service Center.*

[44.] *Christophe Goupil, Wolfgang Seifert, Knud Zabrocki, Eckhard Muller and G. Jeffrey Snyder; "Thermodynamics of Thermoelectric Phenomena and Applications"; Entropy. pp. 1481-1517, 2011.*

[45.] *Melcor Materials Electronic Products Corporation Product Specifications. NJ: Treton; 1992.*


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# THE NEW UNIFIED THEORY OF ENERGY (UNITHE) SUPPORTING CERN MEASUREMENTS AND ITS UTILIZATION IN ENERGY TRANSFORMATIONS

[1.] Contact Energy System Ltd., HUNGARY

**Abstract:** The science can be treated on novel scientific bases by recognizing the elementary block together with the working mechanism– and the system technique of our Universe. With the help of new scientific bases, which are supported by the CERN measurements, its axioms can be derived and all the experimental results can be well explained. Understanding the controlling property of the field energy gives the opportunity to make it use of work as a new energy source.
**Keywords:** Energy quantum with dipole property, pondusian and non–pondusian energy system, new source of energy, CERN

## INTRODUCTION

Nowadays an intense interest is taken in novel, clean and environmental–friendly energy sources due to several urgently important reasons. These kind of reasons e.g. the world running out of the traditional energy supplies, which sources also heavily encumber the nature, or the problem of global warming–up, but also the nuclear power not an alternative because its dangerousness. By this time the technology has reached a highly advanced level, which enables us to study physical effects that can't be described using the well–known scientific theories (e.g. effects of hadrons collisions, nanotechnological, astrophysical). The purpose of the new field theory which is a novel energy theory, would be to compensate the scientific gaps. The space of our existence, the Universe can be divided into two parts in terms of energetically, so we can distinguish the pondusian energy system, which system show mass property, and the non–pondusian energy system, which doesn't show mass property. So a pondusian energy system with a m body mass volume is always encompassed inside and out within the non–pondusian energy system, which is also known as field energy. The elementary block of the non–pondusian energy system is the energy quantum with dipole properties, which can be named as the „God particle" after Leon Lederman. The further thinking of the above described leads to a new field model, which creates the bases of a new scientific theory, that can point out a novel way of energy transforming thus a new energy source. As far as I know there are several field theories were born so far, but as my factual knowledge none of them provide a fully nature–like, realistic model. The field model of the new field theory has been proven nature–like when describing physical phenomena.

## THE NEW FIELD MODEL, THE PONDUSIAN AND NON–PONDUSIAN ("FIELD ENERGY") ENERGY SYSTEMS IN THEOREM STYLE

1. Our space of existence, the Universe is filled up with field energy.
2. The elementary block of the field energy is the energy quantum with dipole properties.
3. The non–pondusian energy systems (field energy) are created by the zero spin field of the space arisen from the infinite freedom building blocks.
4. The pondusian energy systems are originated by the energies that have spin. These energy systems show mass property, and they are

created from the basically zero spin field and found in that too.

5. The pondusian or more known as matter like energy with mass property systems are constituted by periodic functioning formations, which are creating a pulsing oriented field – the source of gravitation. The pulsing oriented field is transmitted by the zero spin energy field.
6. The excited pondusian energy system shows dipole property at macro scale (e.g. magnets, electric charge separation), which external oriented field or also referenced as external aura can be used to produce physical work. This physical work is done normally by the non–pondusian energy system, which always regularize statically and dynamically to the minimum energy. (keep in mind the 3rd definition!)
7. The energy source of the aura is the field energy, and the catalyst is the excited material. So the field energy can be utilized as a new drainless energy source, which works nature–like, following the rule of non–pondusian energy system.

The science can be treated on a novel basis with the help of introducing the non–pondusian energy systems as field energy. This can help to redefine certain fields of science in order to make it more complete. For this reason two new concepts are introduced, one is the contact energy field vector $\bar{E}_K$, which helps the mathematization of the interaction of pondusian systems, the other is a new interaction type, – the 5th – called inertial interaction, which is required to describe the interaction function between pondusian and non–pondusian systems. For example we can utilize the principle of minimum energy in the interaction of the magnetic fields of today's excellent performing, high quality and strong industrial magnets. With regard to the conventional naming and notation used by the description of electrical machines, we describe the one excited magnetic field with a $\bar{\phi}$ – flux field vector, and the other magnetic field with a $\bar{I}$ – current field vector. Their interactions with each other can be described with the $\bar{E}$ – contact energy field vector, which is handled as a potential energy, so the equation arise as the following:

$$\bar{E} = \left(\bar{\phi} \cdot \bar{I}^*\right)^* \cdot (-j) = T - j \cdot E_0 \ \text{(VAs)},$$

where $T$ – is the mechanical energy, $E_0$ – is the energy of the contact field. These energy components are regulated by the field energy always to the minimum energy.

With the help of introducing the inertial interaction, the ether–, relativity– and quantum theory can be unified in the UNIFIED THEORY OF ENERGY (UNITHE), so the strong, weak, EM and the gravitational interactions can be handled and re–construed on the same bases. Thereupon the axioms of today's physical science, like inertia, gravity, magnetic or electric field, aren't axioms anymore, because they can be described using the UNITHE. With this nature–like model there is no part of the space without energy or matter, in another way said vacuum doesn't exist! The newest results in science, like particles with the speed above the speed of light [4] and information propagations can be explained nature–like. Consider a classical experiment, a moving electric charge in an electric field. If an electric charge is accelerated by a constant electric field then the acceleration of the charge will be decreasing over time. Explanation according to Theory of relativity (Einsteinian theory): since the volume of the electric charge and the volume of the electric field strength are constants, therefore the accelerating force is constant also, so after Newton $\vec{F} = m_e \cdot \vec{a} = \text{constant}$ which is only true if the volume of $m_e$ is increasing when the volume of $\vec{a}$ is decreasing. The result of the experiment supports the theory of relativity. Explanation according to the UNITHE: the change of the momentum can be written after Newton axiom in the following form $\vec{F} = d(m_e \cdot \vec{v})/dt = \text{constant}$, furthermore $\vec{F}_I = \vec{v} \cdot (dm_e/dt)$ and $\vec{F}_E = m_e \cdot (d\vec{v}/dt)$. The $\vec{F}_I$ denotes the change of the internal aura force system of the electric charge with volume $m_e$ and velocity $\vec{v}$. In order to the volume of the mass and charge of the particle be constant, the $m_e$ shouldn't change, therefore $\vec{F}_I = 0$. But the force required to change the external aura of the $m_e$ mass by $d\vec{v}$ (otherwise said the contact energy band switch) is increasing as the speed $\vec{v}$ is higher but still the $d\vec{v}/dt = \text{constant}$. So consequently if $\vec{F}$ and $m_e$ are unchanged and $\vec{v}$ is

*increasing, then* $d\vec{v}/dt = \vec{a}$ *should decrease. In this manner we have got the same result as in the Einsteinian physics, but in this theory system the volume of the particle* $m_e$ *doesn't changed. If a mass moves with a mass* $m_e$ *and with* $\vec{v} = constant$ *speed, then it is converting the space in front of it to its aura shape by a* $\vec{F}_E^*$ *restraining force, but the same time the field energy reconverts with* $-\vec{F}_E^*$ *propulsive thrust the space behind the mass. Therefore the energy is unchanged of the mass with volume* $m_e$ *and with* $\vec{v} = constant$ *speed. Furthermore due to the invariableness of the mass energy* $m_e(v) = m_{0e}$*, which arises relatively with zero speed. Concisely the momentums of the bodies are caused by the band switch (the difference of propulsive thrusts and restraining forces) of the contact energy band, which band is a function of velocity.*

## THE FIELD ENERGY, THE ORIENTED FIELD, FIELD INTERACTIONS AND THEIR MODELING

*The elementary block of the field energy is: the energy quantum with dipole property. Its main feature is that it fills up our space of existence with equivalent probability and with equivalent energy density probability, so creating the zero spin energy field, the Universe. Furthermore the field energy can be modeled in an elementary volume with an extremely small and infinitely large by the piece of dipole energy quanta, which summarized energies is equal to unit in the elementary volume. But a unit volume contains infinite elementary volumes so the non–pondusian energy of a unit volume is infinitely large. (The matter originates also from the field energy by rearrangement of the energy! {see definition* $4^{th}$*, further explanation later}).*

*The oriented field is: a dipole like arranged, non–pondusian energy system, which shows energy difference in the space! For example the magnetic or electric fields are oriented fields, their systems technologies only differ at the excitation mode of the material.*

*The model of field energy: the field energy – which is dipole like, has infinite d.o.f. energy with zero spin, fills up the space with equivalent probability and with equivalent energy density, and also allows for the energy spectrum of the oriented field – can be modeled in a unit volume as energy quanta with discrete frequency values, ranging zero to infinite with an unit energy value (Figure 1).*

*Thus:*

$$P_i[W] = 1 \cdot f_i[Ws/s] = 1/T_i[Ws/s] \Rightarrow P(T) = 1/T\,.$$

*The energy of a unit volume:*

$$\int_0^\infty P(T) \cdot dT = \int_0^\infty \frac{1}{T} \cdot dT = \left[\ln \frac{\infty}{0}\right] = \ln \infty = \infty\,[Ws],$$

*which gives the result of the original definition!*

*Where* $f[Hz]$ *– frequency,* $T[s]$ *– time of period, a* $P[W]$ *– power.*

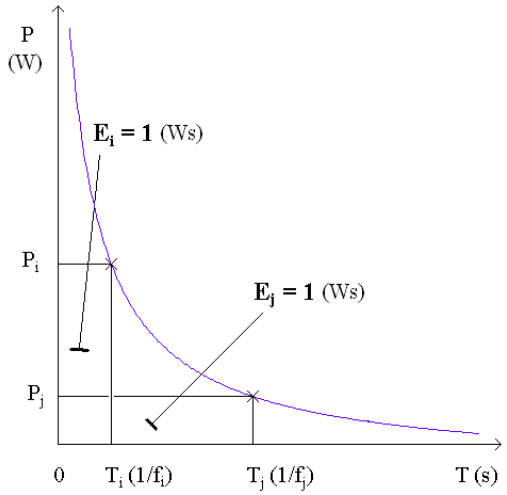


*Figure 1. The power–time–frequency spectrum of the field energy containing unit energy*

*The gravitational field: is the simultaneous oriented field (the periodic pulsating oriented field and the oriented field) of the material (pondusian energy system) and the excited material. The feature of the oriented field of the material, that it is a periodic pulsing oriented field, which is created by the periodically moving elementary particles in the same structure. As model like, in the half period of the pulsing the north spectrum is the determinant, but in the other half the south spectrum is determinant in the same inertial system. Therefore when one mass has north spectrum then the other has south spectrum. (It attracts always! Always the larger mass synchronizes on self the lesser mass! In respect of two masses e.g. the Sun – Earth relation the attracting force presents itself relating to the Earth in the direction of the line between mass centres, perpendicular to this the force in the going direction namely the tangential force – from the*

*spectral's phase angles –, and the rotation providing moment! This all arises from the force system of the pulsating synchronized field's contact energy.) For this reason the gravitational field between the bodies is a periodic pulsing oriented field which is created by the bodies! An analogue electric model of the excited material's oriented field is shown on the Figure 2, where $I$ is the intensity of the oriented field, $t^-$ is the time of the resultant negative effect, $t^+$ is the time of the resultant positive effect.*

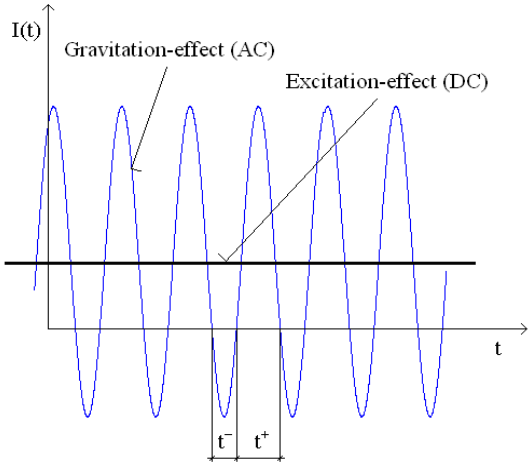


*Figure 2. The analogue electric model of the oriented field of excited material*

*Explanation of mass and its measurement: The ether existed in Maxwell's time (1831 – 1879) which was filling up the space but was basically totally unknown. Today it is called as black energy, vacuum energy, zero–point energy, Higgs–field, field energy, non–pondusian energy system, etc. But Einstein was also a master mind in his time (1879 – 1955) and he would like to prove the existence of ether with experiments. The results of his efforts were unsuccessful in this matter.*

*Afterwards came the ingenuity of Einstein with the statement of non–existing ether (this is still not proved today yet!). The outcome of the declaration is the theory of relativity. The mass–energy equivalence in equation form by Einstein:*

$$E = m \cdot c^2 \quad (\mathrm{Ws} = \mathrm{Nm} = \mathrm{J} = \mathrm{VAs}),$$

*in case of a photon:* $E_f = m_f \cdot c^2$.

*Bring back and fill–in the space with the unknown ether on the foundation of the new energy theory, considering it as a non–pondusian energy system. Place a photon into the space which is now filled–in with field energy and write down the mass–energy equivalence equation for the photon* $E_f$ *after Einstein:*

$$E_f = m_f \cdot c^2 = E_{Kf} = (m_f \cdot c) \cdot (c) = E_{0f}.$$

*It can be easily seen from the equation, that the energy of the photon equals with the contact energy* $E_K$*, which was introduced before. Now the contact energy can be written as a scalar, because of the same direction of velocity, furthermore the index "f" refers to the photon. As opposed to the relation* $E_f$ *the relation of* $E_{Kf}$ *implies the energy of the two energy systems that are in contact. More precisely the contact between the photon's energy spectrum or aura that has "c" speed and "*$m_f$*" mass and the energy spectrum or aura of the field that has "c" speed and "*$f_c$*" frequency. This contact between energy systems are always controlled by the field energy to the minimum energy level. (Referring back to the inertial interaction.) So as the newly introduced field theory the activation energy required to emerge a photon from a source and the conservation of its energy is done by the field energy by providing its moving with "c" speed. In this manner the movement of the photon with the speed of light is the steady state of it. The* $E_{0f}$ *refers to the constancy of* $m_f = m_{0f}$*. The controlled energy, which is provided by the field energy, can be expressed in equilibrium as* $E^c_{field} = E_{kinetic,\,foton}$*. Therefore the energy arisen from the contact of oriented fields:*

$$E_{Kf} = E^c_{field} + (1/2) \cdot (m_{0f} \cdot c) \cdot (c) = E^c_{field} + (1/2) \cdot (I'_f) \cdot (c).$$

*The featuring energies (energy values change, with respect to the notation in literature) written up with oriented field contacts:*

$$E_{kinetic} = (1/2) \cdot m \cdot v^2 = (1/2) \cdot (I') \cdot (v)\,[Nm],$$
$$E_{rotational} = (1/2) \cdot \Theta \cdot \omega^2 = (1/2) \cdot (L') \cdot (\omega)\,[Nm],$$
$$E_{coil} = (1/2) \cdot L \cdot I^2 = (1/2) \cdot (\phi) \cdot (I)\,[VAs],$$
$$E_{capacitive} = (1/2) \cdot C \cdot U^2 = (1/2) \cdot (Q) \cdot (U)\,[VAs],$$
$$E_{potential} = m \cdot g \cdot h\,[Nm],$$

*where the (1/2) multiplier is left because there is no change in the aura!*

*Without showing the proof [1], the mass, denoted with "*$m$*" in the mass–energy equivalence formula by Einstein, has an aura in the new UNITHE. Furthermore it has only one kind of a value, which is independent from its speed, it can be called as the*

*stationary mass $m_0$, that value changes only when the inner aura changes. Ergo the value of $m_0$, that is measurable, is arisen by the interaction of the pondusian and non–pondusian energy systems. If we re–think the working mechanism of the mass–spectrometer, then the following can be said. The required volume of inertial energy is measured during the accelerating process of the pondusian mass $m$ in the non–pondusian energy field. So the inertia of the mass $m$ is measured, which value is the same as the Einsteinian stationary mass. Due to the formerly mentioned the following can be stated that not the speed is limited of a material moving in space, but its acceleration!*

*The explanation of mass defect at nuclear fusion: let the $M(A,Z)$ be the mass of the atom nucleus with $A$ nucleon number and $Z$ atomic number, $m_p$ the mass of the proton, $m_n$ the mass of the neutron. Due to the principle of the conservation of matter:*

$$M(A,Z)+\Delta m = Z\cdot m_p + (A-Z)\cdot m_n .$$

*The $\Delta m = mass\ defect$, which is explained as the followings, energy is liberated and left the nucleus as a certain mass during the fusion, which results of a new atom. Because of mass–energy equivalence of the theory of relativity:*

$$\Delta m\cdot c^2 = E_{binding} .$$

*As the new field theory: there is only energy transformation during the fusion of protons and neutrons, there isn't any reduction in mass nor energy liberation! As the new field theory the basic properties of a particle like its mass, charge and spin, need to be extended with its periodic pulsing oriented field and also with its oriented field, another said with its inner and external aura! The $m_p$ takes part in the combination process with its periodic pulsing oriented field together with its oriented field, which exists due to the excitation of the particle. In the same way takes part in the process the other particle $m_n$ with its periodic pulsing oriented field. When they are close enough, then their periodic pulsing oriented field get synchronised to each other which results in a strong gravitational interaction so forming a nucleus with $M$ mass. From the point of energy the resulting new periodic pulsing oriented field of the nucleus (external aura) is as less as the inner gravitational interaction absorbs in contact energy $E_K$ form. The oriented field of the proton remains unchanged, because it didn't get in interaction with anything! Relating the theories:*

$$\Delta m\cdot c^2 = E_{binding} = E_K\,[VAs]\,!$$

*The second equality not only statutory, but shows its nature–like consentaneity.*

*The process of neutron decay and its explanation: the process is discussed by the Feynman diagram. The starting and resulting masses of the decay process:*

$$m_{neutron} \rangle m_{proton} + m_{electron} + m_{antineutrino} .$$

*During the decay a $W^-$ boson emerges, which mass $m_{W^-} \cong 80\cdot m_{neutron}$. The laws of the classical physics don't permit this! As the theory of quantum mechanics, it is a resonance mass where the particle isn't on the mass shell, that is described by a Breit–Wigner distribution. The dispersion, deviation of the mass distribution and the lifetime of the particle can be calculated using the principle of uncertainty.*

*The physical phenomenon is well described by these mathematical methods, but the questions why it is happening so, and what the cause of the event is, are remaining still unanswered! Higgs tried to explain the experimental results. He claimed it is because the tricky Higgs mechanism. Introducing a new field, the Higgs field, it appears that the properties of vacuum are changing! If the "$W^-$(and also $Z^-$)" bosons meet with a neutral Higgs field during their travel in vacuum, then they "feel resistance". Thus becoming mass. This is the only explanation until for the question why have the two types of bosons mass. The final evidence would be if the Higgs particle without spin has been found. This is being researched in all of the recently built particle accelerators (e.g. CERN). Analysing the neutron decay on the novel field theory basis, we can see a neutron state which has a low value energy difference in energetically stabile and labile state of motion. Placing a neutron $m_{neutron}$ into a natural varying (disturbing) external oriented energy field the neutron will suffer aura change in its labile energy state and will be converted into a stabilized state of motion with mass of $m_{proton}$. The consequence of the aura change is the change of state of the field energy of contact*

*field, which means a transition into a dynamic turbulent state, that has spin. Thus this is making the non–pondusian energy system – the dipole energy quanta – to operate on periodical way, which periodic pulsing oriented field (aura) shows inertia that can be measured as $m_{W^-}$ mass. While the turbulent energy combination with $m_{W^-}$ mass can't get into stabile state because $\Delta E \langle E_{critical}$, therefore it reverts into its zero spin state. The energy combinations with oriented field (electron, antineutrino), that are within the unstable $m_{W^-}$ mass energy combination, are remaining still unchanged, because of the energy conservation principle and energy equilibrium provided by the non–pondusian energy field. At last the antineutrino will be with his pair the energy of the zero spin field. Remarks: The zero spin field researched by Higgs, could be defined the non–pondusian energy system or field energy! If energy difference change occurs from the interaction of pulsing oriented fields and that energy difference is above the critical volume "$\Delta E \rangle E_{critical}$" in the near surroundings of a point in the space, then periodic pulsing oriented field could be created at that location. In this way matter could be created from the field energy (e.g. born of black holes etc.)! If a random energy difference occurs that difference is more above the critical value $\Delta E >> E_{kritikus}$, and the self–energizing process turns into steady state, then continuous energy transformation maintained so the non–pondusian energy system (field energy) as an energy source will be radiated mostly in matter form (like photons) by the source field. This is the way as stars and our Sun could be born and work! During the process while the self–excitation gets into a steady state form could pour out system of substances which could be remain in interaction through gravitation. Returning back to the Higgs–boson, likely it doesn't exist in its imagined form, but masses like $W^-$ and $Z^-$ bosons and so their differing series could be arisen. The most recent news (2012. July) about Higgs boson discovery and its measurement data prove my statement. Since there are more Higgs–bosons than the physicist thought. It comes up that not only one type of Higgs–boson exists, which refers to the "shadow world" of particles namely the super symmetrical particles [10]. These thoughts are allowable in the point of view of today's scientific knowledge. The mathematical formulations also can be established, but the natural processes, my 33 years experimental experience and the experimental data of particle colliders all support the new field theory UNITHE. On this new basis it can be clearly seen, that during the collision of $a+b$ particles not only $a+b$ components emerge, but their contact field, precisely their non–pondusian energy transformed into periodical form can appear also. These forms can be detected which are determined by the state of motion of $a+b$ particles with a collision probability (that is to say the probability result of the reactions $a+b \rightarrow c+d+\cdots$ etc.), this is done so the conservation of energy principle and the energy equilibrium are continuously secured statically and dynamically by the rearrangement of the non–pondusian energy system.*

*As in the recent literature [8] (2009) about theory of relativity is stated generally:*

$$m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}},$$

*where: $m_0 =$ stationary mass, $c =$ speed of light.*

*But the author of the book also states that the $m = m_0$, with referencing on the experiments of the CERN. So after the book, the phenomenon which was described in the previous expression is caused by the time dilation. The before says are well harmonizing in the official axiom system of the relativity theory. Furthermore the author states that the ether doesn't exist with referencing to the Michelson–Morley experiment. The result of the before mentioned experiment is that the relative speed of the ether to the Earth is zero. Developing the train of thought, then the ether doesn't exist. The result of this kind of thinking is that the experiment supports Einstein's theory. I am delighted to learn that the result also should be a zero relative speed ether, field energy, non–pondusian energy system when reconsidering the experiment on the basis of the new field theory. The new unified theory of energy is also able to construe nature–like the recent scientific experiments [9]. The experiences of experiments are shortly: if there are electron pairs created with*

*more kilometres distance among them, change of the state of one electron results in a change in the other electron's state in a way that the change in the second electron occurs more faster than the speed of light. Other experiment, if we study electron(s) that are able to interfere, and using an electron detector than the interfering phenomenon stops. These couldn't be explained on today's scientific bases. The phenomena which were mentioned before or the paper [9], couldn't be explained in a nature–like way using today's scientific axioms, we can get only deductive but unknown results in a point of view of nature. Analysing the phenomena and their process that take place in the nature, it seems that there isn't any physical event that couldn't be explained nature–like with the new theory of energy.*

*The UNITHE could be the basis of the future's science, which premonitory sign is stated for my pleasure by the erudite and experienced academician Péter Lévai [11]: "The new physics is coming. Either the new particle fits into the Standard model or not, the story is far from its end. Since the Standard model only describes the visible matter and its interaction. The 96% of the Universe is constituted by a matter, which is only sensible through gravitational interaction, so it falls beyond the Standard model's range. The job of LHC will be the exploration of this new physics. "The story just begins. Our self–confidence is at right place after these results, we can start off to the next 15 years." – said Lévai." Peter Higgs and Francois Englert shared the 2013 Nobel Prize in physics for the Higgs mechanism and theory of the Higgs boson, but it remains a problem that the expected one type of Higgs boson was not found! On the basis of my 33 years research background it can be stated: the theory of relativity is irrefutably true on the bases of today's science!*

*The new unified theory of energy also proves irrefutably true on the new bases! But! The theory of relativity is unable to explain the most fundamental physical phenomena, but the new unified theory of energy is able! So! The theory of relativity should be adjusted to the nature! The unified theory of energy is nature like!*

## *PRACTICAL RESULTS OF THE NOVEL FIELD THEORY*

### *A*/ The energy controlled drive of an asynchronous motor with frequency inverter:*

*In the followings the contact energy field vector is denoted with $\bar{E}$ („K" index is left).*

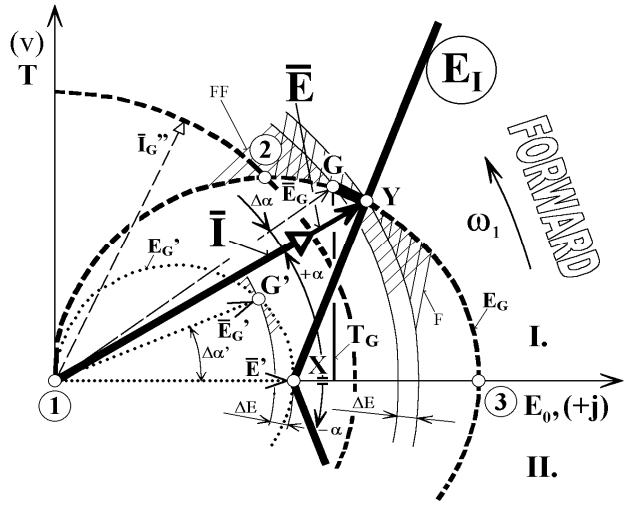


*Figure 3. The combined contact energy and its control diagram of the induction machine*

*On the Figures 3–7 a four quarter drive are shown that was developed by me at Retronic prozess–systemtechnik GmbH, (West)Germany [7]. During the work three patents were born. The rotational speed is controlled by the system without neither any feedback nor computation. But the control of the rotation is more dynamic and more accurate as in the conventional solutions. The optimal way of using the energy is controlled as in the living systems, by the fault signal of contact energy $E_F$ (Figure 4). The control function $E_I$ which can be adapted to the system:*

$$E_I = \sqrt{2} \cdot I \cdot \sqrt{\left(\frac{B-A}{B-2A+I}\right)^Z}$$

*where the A, B, Z parameters should be set after the Figure 4 in order to adapt to a specific system.*

*The main parts of the system (Figure 4): IFIMD induction motor drive frequency inverter, EM energy model, ERU energy reference unit, EC energy controller, CC current controller, SFSCU frequency of the axis seeking and follow–up unit, RFI frequency of the rotor adjuster. In 1995 a research engineer from the Siemens stated that this system is twenty – twenty–five years before the industrial demands. This statement is still true today.*

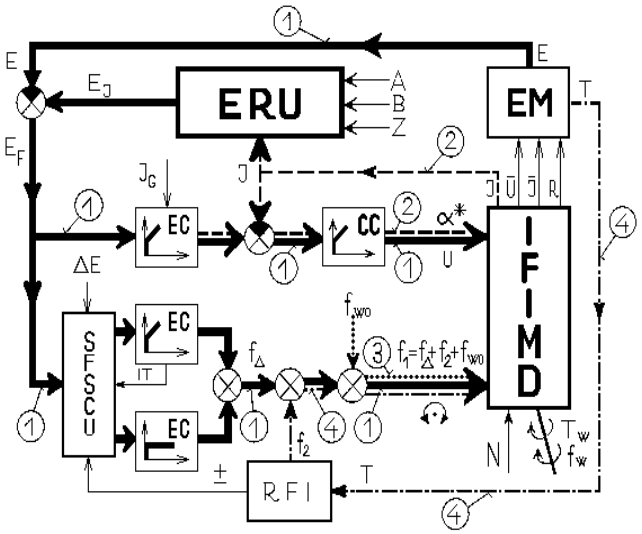


Figure 4. The current based energy control (CBEC)

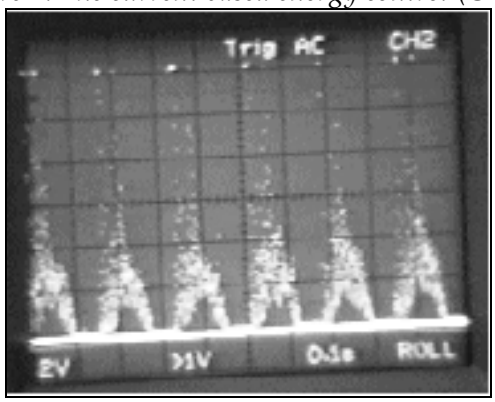


Figure 5. The combined contact energy and its control diagram of the induction machine

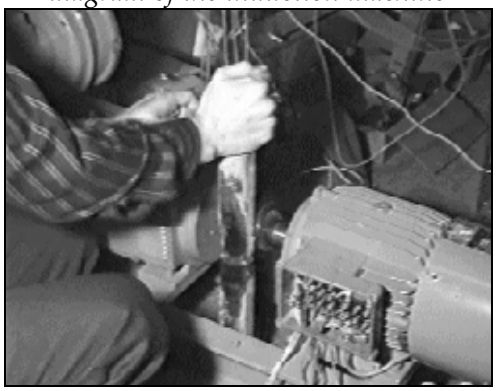

Figure 6. The dynamic breaking of the induction motor

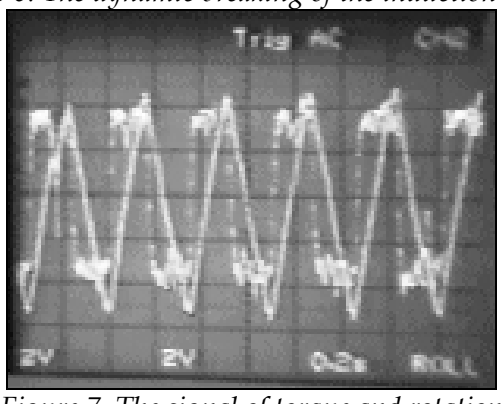


Figure 7. The signal of torque and rotation

***B*/ The mechanically constrained new type of energy transforming:***

*An example is shown on the Figures 8–10, which shows a method for transforming the* $\overline{E} = \overline{E}_{xy}$ *contact energy of magnetic fields in a mechanical way. The* I *is a planetary moving magnet, and* II *is a ring magnet. Additional details of the device can be found in the literature [5]. This device has become a patent in 2009 [3].*

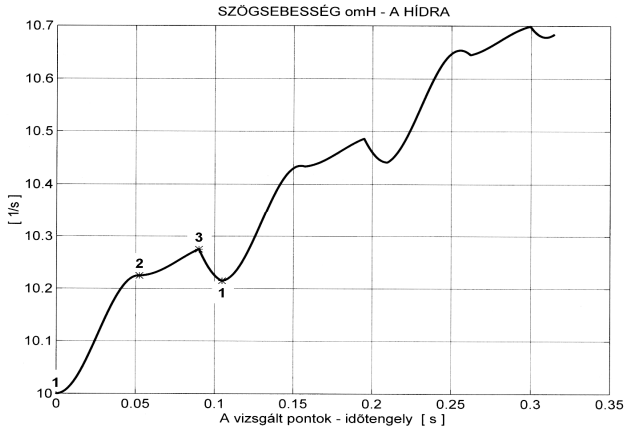


Figure 8. The angular velocity of bridge

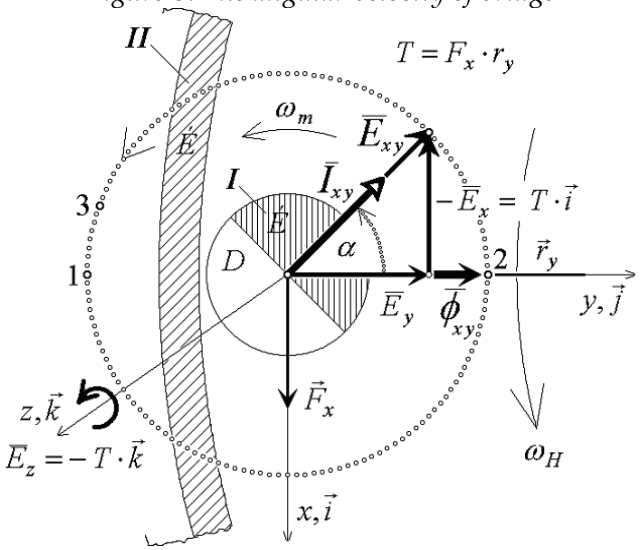


Figure 9. The contact energy

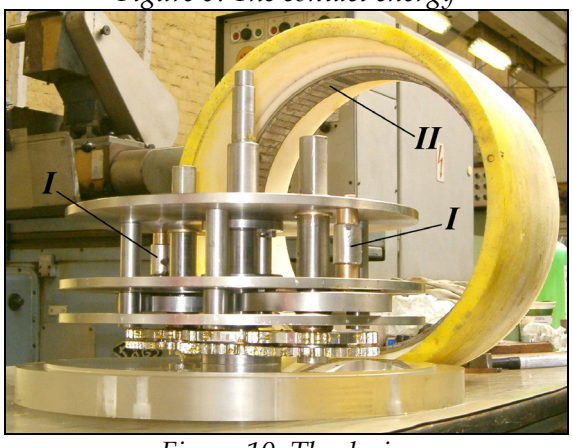


Figure 10. The device

***C*/ The new way of energy transforming, that is mimicking the nature and free in move:***

*The simplest electric device, the transformer is also an energy controlled system. The control – the correction of the fault of the field due to the load – is made by the oriented field, which is described with* $\bar{\phi}[Vs]$*. This non–pondusian energy field controls always as the following function:*

$$\bar{\phi}(t) = \int_0^t \bar{U}_k(t) \cdot dt = L \cdot \bar{I}_g(t).$$

*The* $\bar{U}_k[V]$ *is the constraint voltage of the generator,* $\bar{I}_g[A]$ *is the response current of the exciting constraint,* $L[H]$ *is the inductivity of the system. In this energy transforming device (and in all of our devices) only the energy transportation can be accomplished by the field energy. In the energy transforming devices of the future, the field energy would also produce work, so appearing a new source of energy that is undrainable, which could control with infinite power. The announcement for an European patent has been made of a high power energy transforming device on April 2011 [1] and the international announcement with priority reference has been made in 2012 [2], which was published in October 2012.*

*The previously mentioned A*, B*, C* type of energy transformations and their set of efficiency: the energy transformation is shown on the Figure 11. and the efficiency set is shown on Figure 12. The methods that are valid for A*, B* processes, and are discussed in [6]. The generalized and re–worked version (Figures 11–12.) handles the energy transmission of the A*, B*, C* methods together, and shows how the efficiency will conform as the UNITHE if considering the work capacity of the non–pondusian energy system.*

*Our machinery couldn't be described as closed systems considering the new field theory the UNITHE, because of the material like pondusian systems are located in the non–pondusian systems, which permeates through everything. This is the interferer element of the gravitation also, so the gravitation couldn't be shielded, or remember the Michelson–Morley experiment, which also proves the correctness of the new field theory ⇒ mass couldn't be transferred by the pondusian energy system because of its system technique, it only can guarantee the conservation and equilibrium of energy!*

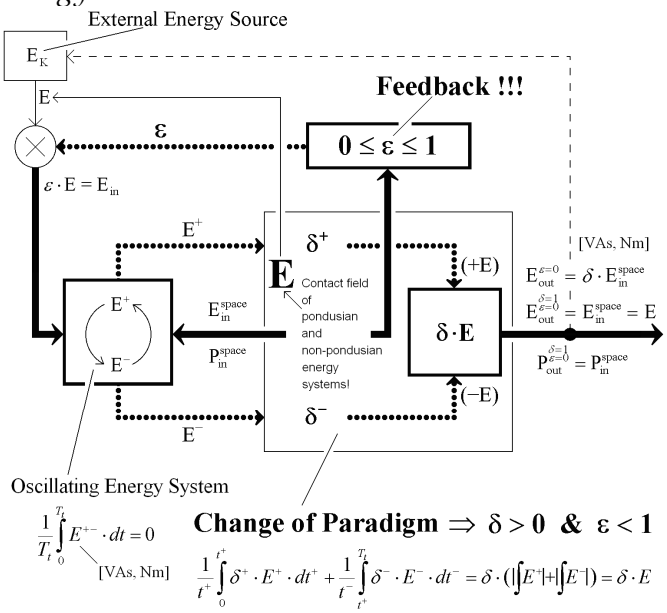


*Figure 11. The model of A*, B*, C* type energy transformation processes without losses*

*Considering the energy transformation processes (Figure 11) the determinant energy is the* $E$*, which energy arises from the contact relation of the fields. The mechanics is attacked by the force system of the before mentioned energy. The mechanical construction determines that in which direction it is going to work and what comes out on the output. It is important to notice, that the Universe' static and dynamic energy equilibrium, the conservation of energy, the transmission of information and the energy source of work all provided by the controlling laws of non–pondusian energy system for the equipments and for the vital and non–vital systems. The contact energy* $E$ *feedback is taken account by a feedback factor* $\varepsilon$ *on the input of model on Figure 11. We can mind our periodically working systems as an alternating energy. The forms of these for different working types (A*, B*, C*) are determinant. In the future we are not going to deal with the conventional losses.*

*The characteristic energy transmission mechanism of the appliances are shown on Figure 11. Where:*

- $E$ *contact energy,*
- $T_t$ *one cycle time of the magnetic contact,*
- $\varepsilon$ *contact energy feedback coefficient,*
- $\delta$ *contact energy rectification coefficient,*
- \+ *magnetic moving support impact emergence,*

– *magnetic moving block impact emergence.*

*Value* $\delta = 1$ *is resulted in the conventional build–up machines (A*) by the energy transmission of alternate energy system. By the optimization of these constructions it is tried, that the feedback to the input to be maximal* $\varepsilon = 1$, *because of the prosperous efficiency of energy transportation.*

*The plus work beyond the input energy transportation of the non–pondusian system appears on the output of the new type of energy rectification machines (B*, C*), as a new energy source in a traditional manner, so for the different machines* $\delta > 0$ *and* $\varepsilon < 1$, *which results a paradigm shift.*

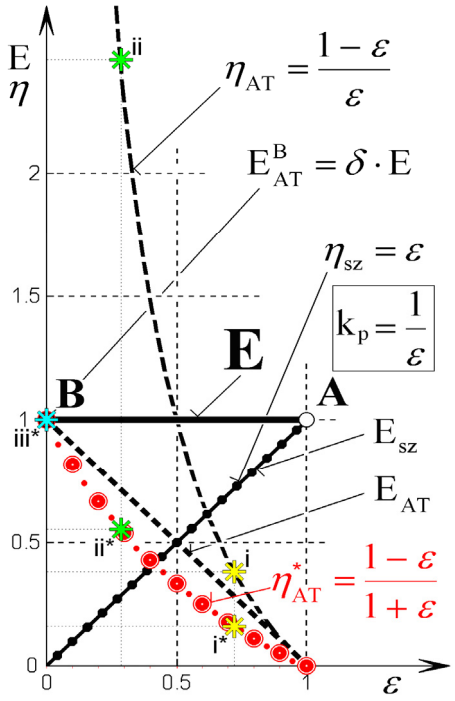


*Figure 12. The energy transportation and transformation, as well as the efficiency of these without losses*

*The characteristic energy transmission and efficiency of the appliances are shown on Figure 12. on traditional and new bases. Where:*

$E$ *contact energy with always unit work,*

$E_{AT}$ *from the contact field transformed non–pondusian energy,*

$E^B_{AT}$ *from the contact field transformed non–pondusian energy in operating point "B",*

$E_{sz}$ *transported energy by the contact field,*

$\varepsilon$ *contact energy feedback coefficient,,*

$\delta$ *contact energy rectification coefficient,*

$k_p$ *power amplification coefficient,*

$\eta_{AT}$ *efficiency on traditional base, with respect to the transformed non–pondusian energy,*

$\eta_{sz}$ *efficiency on traditional base, with respect to the energy transportation non–pondusian energy,*

$\eta^*_{AT}$ *efficiency on new base, with respect to the transformed non–pondusian energy.*

*The energy transportation and their efficiency in machine types A*, B*, C* consider Figure 12:*

□ *In conventional build–up machines that are optimized to operation point "A"* $\varepsilon = 1$, *(A* type):*

$$E_{sz} = E \cdot \varepsilon,$$

$$\eta_{sz} = \frac{E_{sz}}{E} = \frac{E \cdot \varepsilon}{E} = \varepsilon.$$

□ *New type, alternating, mechanical energy rectification machines with operation point "B"* $\varepsilon = 0$ *(B* type):*

$$E^B_{AT} = \delta \cdot E,$$

$$0 \le \delta \le 1,\ \eta^B_{AT} = \infty.$$

□ *New type, alternating, full energy rectification, synchronous moving, copying the nature working behavior machines (C* type):*

$$k_p = \frac{1}{\varepsilon},$$

$$E_{Be} = E \cdot \varepsilon,$$

$$E^*_{Be} = E + E \cdot \varepsilon,$$

$$E_{AT} = E - E \cdot \varepsilon,$$

$$\eta_{AT} = \frac{E_{AT}}{E_{Be}} = \frac{1-\varepsilon}{\varepsilon} = k_p - 1,$$

$$\eta^*_{AT} = \frac{E_{AT}}{E^*_{Be}} = \frac{1-\varepsilon}{1+\varepsilon} = \frac{k_p - 1}{k_p + 1}.$$

*Taking into consideration the work of the non–pondusian energy system as a new energy source the efficiency of the energy transformation is the following:*

$$0 \le \eta^*_{AT} \le 1.$$

*The energy conservation verifies back! The conventional input power can be neglected by from the output back fed systems, the operation points by these will be on point "B". The energy demand of the power amplification ($k_p$) by the electrical amplifiers is provided by the power supply unit (PSU); in the new systems instead of the PSU the non–pondusian energy system do the job, realizing*

*with this a new energy source, which actually always existed!*

**SUMMARY**

*Analyzing the information recently has come to light, it seems like there is no such physical phenomenon which could not be defined nature–like by the Unified Theory of Energy (UNITHE). In the reflectance of the results, the new energy source could definitely be the basis of future energy management. The new field theory is entirely supported by the CERN measurements and by the results of engineering science. The Higgs–boson as a new particle proves Higgs theory. The non–pondusian energy systems have the same and more functions as the Higgs–boson plus it can translate all today's axioms like gravitation, planetary motions, etc. which research has just begun in the particle accelerators. The new field model and the new field theory open the door for reinterpretation of the interactions on common bases.*

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**REFERENCES**

[1.] *Fekete, G., Pintér, Cs.: Method and apparatus for exploiting interaction energy of magnetic fields, European patent application, Number: E11462006, 2011. (published in October 2012).*

[2.] *Fekete, G., Pintér, Cs.: Method and apparatus for exploiting interaction energy of magnetic fields, International patent application, Number: PCT/HU2012/000029, 2012. (published in October 2012).*

[3.] *Fekete, G.: Process for moving "inducted voltage"–less rolling part placed in magnetic field and equipment for realisation of process, University of Miskolc, Hungarian patent: HU 226 570 B1, 2009.*

[4.] *Fekete, G.: The New Unified Theory of Energy (UNITHE) and Practically Useful Results. 12th International Conference on Energetics – Electrical Engineering, ENELKO 2011, Cluj, 6–9 October 2011, Proceedings, pp: 28–37.*

[5.] *Fekete, G.: Rectifying of Contact Energy in New Systems. 16th International Conference on Electrical Drives and Power Electronics (EDPE 2007), High Tatras, Slovakia, 2007, Proceedings: Power Generation and Transmission, Full paper on CD–ROM.*

[6.] *Fekete, G.: Study of Transfer of Contact Energy of Industrial Magnets in a New Magnetic Power Machine. 16th International Conference on Electrical Machines, ICEM 2004, Cracow – Poland, 2004. Proceedings, pp: 503–504, Full paper, CD–ROM.*

[7.] *Fekete, G.: A New Energy Controlled Current Source Inverter Fed Induction Motor Drive, 9th International Conference and Exhibition on Power Electronics and Motion Control, EPE–PEMC 2000, Kosice, Slovak Republic, 2000. Proceedings, Vol. 7. , pp: 130–134.*

[8.] *Hraskó, P.: A relativitáselmélet alapjai. Tankönyv, Typotex Kiadó, 2009, ISBN 978 963 279 027 5*

[9.] *internet: http://www.idokep.hu/hirek/quantum–radar–delayed–choice–eraser (site checked: 2014. 03. 03.).*

[10.] *internet: http://www.origo.hu/tudomany/20120712–higgs–bozon–standard–modell–szuperszimmetria.html (site checked: 2014. 03. 03.).*

[11.] *internet: http://www.origo.hu/tudomany/20120704–az–ev–vegere–derulhet–ki–hogy–valoban–a–higgsbozont–fedezteke.html?beuszo (site checked: 2014. 03. 03.).*

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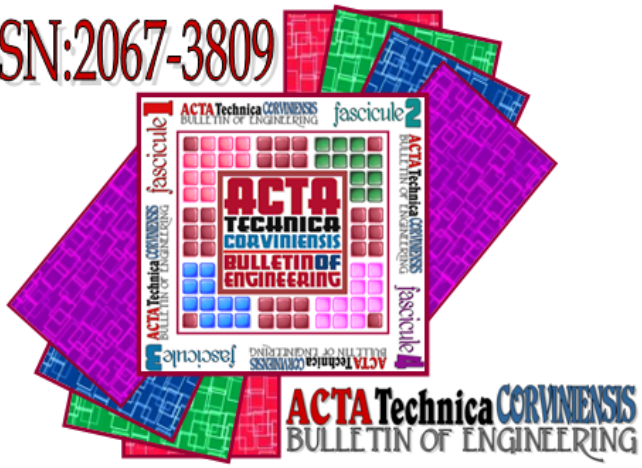


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