ISSN: 2067-3809

Universitatea Politehnica Timișoara

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering

Tome XIII [2020]
Fascicule 4
[October–December]

Editura POLITEHNICA

ACTA TECHNICA CORVINIENSIS
Bulletin of Engineering

Edited by:

UNIVERSITY POLITEHNICA TIMISOARA

with kindly supported by:

THE GENERAL ASSOCIATION OF ROMANIAN ENGINEERS (AGIR)
– branch of HUNEDOARA

Editor / Technical preparation / Cover design:

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

Commenced publication year:
2008

ACTA TECHNICA CORVINIENSIS
Bulletin of Engineering

ASSOCIATE EDITORS and REGIONAL COLLABORATORS

MANAGER & CHAIRMAN

ROMANIA 

Imre KISS, University Politehnica TIMISOARA, Faculty of Engineering HUNEDOARA, Department of Engineering & Management, General Association of Romanian Engineers (AGIR) – branch HUNEDOARA

EDITORS from:

ROMANIA 

Dragoş UŢU, University Politehnica TIMIŞOARA – TIMIŞOARA
Vasile ALEXA, University Politehnica TIMIŞOARA – HUNEDOARA
Sorin Aurel RAŢIU, University Politehnica TIMIŞOARA – HUNEDOARA
Vasile George CIOATĂ, University Politehnica TIMIŞOARA – HUNEDOARA
Simona DZIŢAC, University of Oradea – ORADEA
Valentin VLĂDUŢ, Institute of Research-Development for Machines & Installations – BUCUREŞTI
Dan Ludovic LEMLE, University Politehnica TIMIŞOARA – HUNEDOARA
Emanoil LINUL, University Politehnica TIMIŞOARA – TIMIŞOARA
Virgil STOICA, University Politehnica TIMIŞOARA – TIMIŞOARA
Sorin Ştefan BIRIŞ, University Politehnica BUCURESTI – BUCURESTI
Mihai G. MATACHE, Institute of Research-Development for Machines & Installations – BUCUREŞTI

REGIONAL EDITORS from:

SLOVAKIA 

Juraj ŠPALEK, University of ŽILINA – ŽILINA
Peter KOŠTÁL, Slovak University of Technology in BRATISLAVA – TRNAVA
Tibor KRENICKÝ, Technical University of KOŠICE – PREŠOV
Beata HRICOVÁ, Technical University of KOŠICE – KOŠICE
Peter KRIŽAN, Slovak University of Technology in BRATISLAVA – BRATISLAVA

HUNGARY 

Tamás HARTVÁNYI, Széchenyi István University – GYŐR
Arpád FERENCZ, Pallasz Athéné University – KECSKEMÉT
József SÁROSI, University of SZEGED – SZEGED
Attila BARCZI, Szent István University – GÖDÖLLŐ
György KOVÁCS, University of MISKOLC – MISKOLC
Zsolt Csaba JOHANYÁK, John von Neumann University– KECSKEMÉT
Gergely DEZSŐ, College of NYÍREGYHÁZA – NYÍREGYHÁZA
Krisztián LAMÁR, Óbuda University BUDAPEST – BUDAPEST
Loránt KOVÁCS, Pallasz Athéné University – KECSKEMÉT
Valeria NAGY, University of SZEGED – SZEGED
Sándor BESZÉDES, University of SZEGED – SZEGED
Csaba Imre HENCZ, Széchenyi István University – GYŐR
Zoltán András NAGY, Széchenyi István University – GYŐR
László GOGOLÁK, University of SZEGED – SZEGED

SERBIA 

Zoran ANIŠIC, University of NOVI SAD – NOVI SAD
Milan RACKOV, University of NOVI SAD – NOVI SAD
Igor FÜRSTNER, SUBOTICA Tech – SUBOTICA
Eleonora DESNICA, University of NOVI SAD – ZRENJANIN
Blaža STOJANOVIĆ, University of KRAGUJEVAC – KRAGUJEVAC
Aleksander MILTENOVIC, University of NIŠ – NIŠ
Milan BANIC, University of NIŠ – NIŠ
Slobodan STEFANOVIĆ, Graduate School of Applied Professional Studies – VRANJE
Sinisa BIKIĆ, University of NOVI SAD – NOVI SAD
Masa BUKUROV, University of NOVI SAD – NOVI SAD
Ana LANGOVIC MILICEVIC, University of KRAGUJEVAC – VRNJAČKA BANJA
Imre NEMEDI, SUBOTICA Tech – SUBOTICA
Živko PAVLOVIĆ, University of NOVI SAD – NOVI SAD

CROATIA 

Gordana BARIC, University of ZAGREB – ZAGREB
Goran DUKIC, University of ZAGREB – ZAGREB

BULGARIA 

Krasimir Ivanov TUJAROV, "Angel Kanchev" University of ROUSSE – ROUSSE
Ognyan ALIPIEV, "Angel Kanchev" University of ROUSSE – ROUSSE
Ivanka ZHELEVA, "Angel Kanchev" University of ROUSSE – ROUSSE
Atanas ATANASOV, "Angel Kanchev" University of ROUSSE – ROUSSE

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

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

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

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

INTERNATIONAL SCIENTIFIC COMMITTEE MEMBERS and SCIENTIFIC REVIEWERS

MANAGER & CHAIRMAN

ROMANIA 

Imre KISS, University Politehnica TIMISOARA, Faculty of Engineering HUNEDOARA, Department of Engineering & Management, General Association of Romanian Engineers (AGIR) – branch HUNEDOARA

INTERNATIONAL SCIENTIFIC COMMITTEE MEMBERS & SCIENTIFIC REVIEWERS from:

ROMANIA 

Viorel–Aurel ŞERBAN, University Politehnica TIMIŞOARA – TIMIŞOARA
Teodor HEPUŢ, University Politehnica TIMIŞOARA – HUNEDOARA
Mircea BEJAN, Tehnical University of CLUJ-NAPOCA – CLUJ-NAPOCA
Liviu MIHON, University Politehnica TIMIŞOARA – TIMIŞOARA
Ilare BORDEAŞU, University Politehnica TIMIŞOARA – TIMIŞOARA
Liviu MARŞAVIA, University Politehnica TIMIŞOARA – TIMIŞOARA
Ioan VIDA-SIMITI, Technical University of CLUJ-NAPOCA – CLUJ-NAPOCA
Csaba GYENGE, Technical University of CLUJ-NAPOCA – CLUJ-NAPOCA
Sava IANICI, "Eftimie Murgu" University of REŞIŢA – REŞIŢA
Ioan SZÁVA, "Transilvania" University of BRASOV – BRASOV
Sorin VLASE, "Transilvania" University of BRASOV – BRASOV
Horatiu TEODORESCU DRĂGHICESCU, "Transilvania" University of BRASOV – BRASOV
Maria Luminiţa SCUTARU,"Transilvania" University of BRASOV – BRASOV
Iulian RIPOŞAN, University Politehnica BUCUREŞTI – BUCUREŞTI
Ioan DZITAC, Agora University of ORADEA – ORADEA
Carmen ALIC, University Politehnica TIMIŞOARA – HUNEDOARA

SLOVAKIA 

Štefan NIZNIK, Technical University of KOŠICE – KOŠICE
Karol VELIŠEK, Slovak University of Technology BRATISLAVA – TRNAVA
Juraj ŠPALEK, University of ŽILINA – ŽILINA
Ervin LUMNITZER, Technical University of KOŠICE – KOŠICE
Miroslav BADIDA, Technical University of KOŠICE – KOŠICE
Milan DADO, University of ŽILINA – ŽILINA
Ľubomir ŠOOŠ, Slovak University of Technology in BRATISLAVA – BRATISLAVA
Miroslav VEREŠ, Slovak University of Technology in BRATISLAVA – BRATISLAVA
Milan SAGA, University of ŽILINA – ŽILINA
Imrich KISS, Institute of Economic & Environmental Security – KOŠICE
Vladimir MODRAK, Technical University of KOSICE – PRESOV
Michal HAVRILA, Technical University of KOSICE – PRESOV

CROATIA 

Drazan KOZAK, Josip Juraj Strossmayer University of OSIJEK – SLAVONKI BROD
Predrag COSIC, University of ZAGREB – ZAGREB
Milan KLJAJIN, Josip Juraj Strossmayer University of OSIJEK – SLAVONKI BROD
Miroslav CAR, University of ZAGREB – ZAGREB
Antun STOIĆ, Josip Juraj Strossmayer University of OSIJEK – SLAVONKI BROD
Ivo ALFIREVIĆ, University of ZAGREB – ZAGREB

HUNGARY 

Imre DEKÁNY, University of SZEGED – SZEGED
Béla ILLÉS, University of MISKOLC – MISKOLC
Imre RUDAS, Óbuda University of BUDAPEST – BUDAPEST
Tamás KISS, University of SZEGED – SZEGED
Cecilia HODÚR, University of SZEGED – SZEGED
Arpád FERENCZ, Pallasz Athéné University – KECSKEMÉT
Imre TIMÁR, University of Pannonia – VESZPRÉM
Kristóf KOVÁCS, University of Pannonia – VESZPRÉM
Károly JÁRMAI, University of MISKOLC – MISKOLC
Gyula MESTER, University of SZEGED – SZEGED
Ádám DÖBRÖCZÖNI, University of MISKOLC – MISKOLC
György SZEIDL, University of MISKOLC – MISKOLC
Miklós TISZA, University of MISKOLC – MISKOLC
Attila BARCZI, Szent István University – GÖDÖLLŐ
István BIRÓ, University of SZEGED – SZEGED
József GÁL, University of SZEGED – SZEGED
Ferenc FARKAS, University of SZEGED – SZEGED
Géza HUSI, University of DEBRECEN – DEBRECEN
Ferenc SZIGETI, College of NYÍREGYHÁZA – NYÍREGYHÁZA

GREECE

Nicolaos VAXEVANIDIS, University of THESSALY – VOLOS

BULGARIA

Kliment Blagoev HADJOV, University of Chemical Technology and Metallurgy – SOFIA
Nikolay MIHAILOV, "Anghel Kanchev" University of ROUSSE – ROUSSE
Krassimir GEORGIEV, Institute of Mechanics, Bulgarian Academy of Sciences – SOFIA
Stefan STEFANOV, University of Food Technologies – PLOVDIV

SERBIA

Sinisa KUZMANOVIC, University of NOVI SAD – NOVI SAD
Zoran ANIŠIC, University of NOVI SAD – NOVI SAD
Mirjana VOJINOVIĆ MILORADOV, University of NOVI SAD – NOVI SAD
Miroslav PLANČAK, University of NOVI SAD – NOVI SAD
Milosav GEORGIJEVIC, University of NOVI SAD – NOVI SAD
Vojislav MILTENOVIC, University of NIŠ – NIŠ
Miomir JOVANOVIC, University of NIŠ – NIŠ
Vidosav MAJSTOROVIC, University of BELGRADE – BELGRAD
Predrag DAŠIĆ, Production Engineering and Computer Science – TRSTENIK
Lidija MANČIĆ, Institute of Technical Sciences of Serbian Academy of Sciences & Arts – BELGRAD

ITALY

Alessandro GASPARETTO, University of UDINE – UDINE
Alessandro RUGGIERO, University of SALERNO– SALERNO
Adolfo SENATORE, University of SALERNO– SALERNO
Enrico LORENZINI, University of BOLOGNA – BOLOGNA

BOSNIA & HERZEGOVINA

Tihomir LATINOVIC, University of BANJA LUKA – BANJA LUKA
Safet BRDAREVIĆ, University of ZENICA – ZENICA
Ranko ANTUNOVIC, University of EAST SARAJEVO – East SARAJEVO
Isak KARABEGOVIĆ, University of BIHAĆ – BIHAĆ
Zorana TANASIC, University of BANJA LUKA – BANJA LUKA

MACEDONIA

Valentina GECEVSKA, University "St. Cyril and Methodius" SKOPJE – SKOPJE
Zoran PANDILOV, University "St. Cyril and Methodius" SKOPJE – SKOPJE
Robert MINOVSKI, University "St. Cyril and Methodius" SKOPJE – SKOPJE

PORTUGAL

João Paulo DAVIM, University of AVEIRO – AVEIRO
Paulo BÁRTOLO, Polytechnique Institute – LEIRIA
José MENDES MACHADO, University of MINHO – GUIMARÃES

SLOVENIA

Janez GRUM, University of LJUBLJANA – LJUBLJANA
Štefan BOJNEC, University of Primorska – KOPER

POLAND

Leszek DOBRZANSKI, Silesian University of Technology – GLIWICE
Stanisław LEGUTKO, Polytechnic University – POZNAN
Andrzej WYCISLIK, Silesian University of Technology – KATOWICE
Antoni ŚWIĆ, University of Technology – LUBLIN
Marian Marek JANCZAREK, University of Technology – LUBLIN
Michał WIECZOROWSKI, POZNAN University of Technology – POZNAN
Jarosław ZUBRZYCKI, LUBLIN University of Technology – LUBLIN
Aleksander SŁADKOWSKI, Silesian University of Technology – KATOWICE

AUSTRIA

Branko KATALINIC, VIENNA University of Technology – VIENNA

ARGENTINA

Gregorio PERICHINSKY, University of BUENOS AIRES – BUENOS AIRES
Atilio GALLITELLI, Institute of Technology – BUENOS AIRES
Carlos F. MOSQUERA, University of BUENOS AIRES – BUENOS AIRES
Elizabeth Myriam JIMENEZ REY, University of BUENOS AIRES – BUENOS AIRES
Arturo Carlos SERVETTO, University of BUENOS AIRES – BUENOS AIRES

SPAIN

Patricio FRANCO, Universidad Politecnica of CARTAGENA – CARTAGENA
Luis Norberto LOPEZ De LACALLE, University of Basque Country – BILBAO
Aitzol Lamikiz MENTXAKA, University of Basque Country – BILBAO
Carolina Senabre BLANES, Universidad Miguel Hernández – ELCHE

The Scientific Committee members and Reviewers do not receive any remuneration. These positions are voluntary. We are extremely grateful and heartily acknowledge the kind of support and encouragement from all contributors and all collaborators!

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

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

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

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

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

The evaluated paper may be recommended for:

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

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

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

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

TABLE of CONTENTS

The **ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering, Tome XIII [2020], Fascicule 4 [October – December]** includes original papers submitted to the Editorial Board, directly by authors or by the regional collaborators of the Journal.

Also, the **ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering, Tome XIII [2020], Fascicule 4 [October – December]**, includes scientific papers presented in the sections of:

— **DEMI 2019 – The 14th International Conference on Accomplishments in Mechanical and Industrial Engineering**, organized by Faculty of Mechanical Engineering, University of Banja Luka, BOSNIA & HERZEGOVINA, co–organized by Faculty of Mechanical Engineering, University of Niš, SERBIA, Faculty of Mechanical Engeneering Podgorica, University of Montenegro, MONTENEGRO and Faculty of Engineering Hunedoara, Unversity Politehnica Timisoara, ROMANIA, in Banja Luka, BOSNIA & HERZEGOVINA, 24–25 May 2019. The current identification numbers of the selected papers are the #3, #7, #8, #11, #14 and #16, according to the present contents list.

— **ISB–INMA TEH' 2019 – International Symposium (Agricultural and Mechanical Engineering)**, organized by Politehnica University of Bucharest – Faculty of Biotechnical Systems Engineering (ISB), National Institute of Research–Development for Machines and Installations Designed to Agriculture and Food Industry (INMA Bucharest), Romanian Agricultural Mechanical Engineers Society (SIMAR), National Research & Development Institute for Food Bioresources (IBA Bucharest), National Institute for Research and Development in Environmental Protection (INCDPM), Research-Development Institute for Plant Protection (ICDPP), Research and Development Institute for Processing and Marketing of the Horticultural Products (HORTING), Hydraulics and Pneumatics Research Institute (INOE 2000 IHP) and "Food for Life Technological Platform", in Bucharest, ROMANIA, between 31 October – 1 November, 2019. The current identification numbers of the selected papers are the #12, #17, #20 and #24, according to the present contents list.

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067–3809

Fascicule 4

[October – December]

tome [2020] XIII

ACTA Technica CORVINIENSIS
BULLETIN OF ENGINEERING

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

http://acta.fih.upt.ro

[1.]Anna YEHOROVA, [2.]Ervin LUMNITZER, [3.]Laura DŽUŇOVÁ, [4.]Veronika GUMANOVÁ

METHODOLOGY FOR INCREASING THE QUALITY OF TECHNICAL EQUIPMENT

[1–4.]Technical University of Kosice, Faculty of Mechanical Engineering, Department of Process and Environmental Engineering, Kosice, SLOVAKIA

Abstract: The paper deals with the optimization of the acoustic properties of selected noise sources of household appliances, specifically washing machines. The introductory parts are focused on the analysis of parameters affecting the quality of the product, the so–called "general features of product quality" and a proposal of a new methodology for their evaluation. Attention is paid mainly to a new type of properties, the so–called customer–oriented acoustic properties of the product. Methodologies have been developed for laboratory measurements of psychoacoustic properties and noise visualization, which are then tested in an anechoic chamber by measurement with an acoustic camera and a psychoacoustic head. Methodologies after their evaluation are used in measurements in real conditions. A listening test is created, the results of which can be used to evaluate practical measurements and determine customer–required acoustic, customer–oriented properties.
Keywords: General features of product quality, sound, psychoacoustics, sound quality, listening test

INTRODUCTION

In nowadays, product development is advancing at a very rapid pace. Manufacturers strive to keep current products in a high technical level, for example, a long–term warranty becomes common. However, an increasing problem is not to produce the product, but to sell it. For this reason, manufacturers are focusing on those features that have not been interesting for them so far, but are currently able to increase customer interest in the product. Research into customer behavior shows that it is these features that come to the fore when the customer decides to buy a product.

This process began with the advent of the so–called industrial product design, especially in the automotive industry. Currently, these are areas such as recyclability, energy optimization, adaptive and intelligent properties, acoustics, lighting properties, energy field optimization and much more. One of the attractive areas in which the topic of the paper is focused is the customer–oriented properties of products, which are related to a number of areas, such as noise visualization, psychoacoustics, simulation of sound propagation, the influence of sound on perception and emotional state of a person. An example is the sound that is generated when the car door is closed. In terms of functionality, this is an insignificant phenomenon. However, it is one of the first things that attracts the customer immediately after getting into the car, which is the subject of his interest.

METHODOLOGY

The general objective is to propose a methodology for optimizing the acoustic parameters of products and verify a methodology on a specific product. It is a development in the field of acoustic design and its implementation in the production process of a everyday consumer good – an automatic washing machine. Ultimately, the proposed methodology:

— defines the required acoustic properties of the product,
— evaluates which parameters, quantities and sound properties need to be optimized,
— propose a criterion against which these properties can be assessed.

The methodology is verified on a practical example, used to evaluate the properties of current products on the market. Subsequently, based on this methology, a recommendation was proposed, in which is defined what is necessary to make for specific products, what changes need to be implemented in the development process. It is goal–oriented for practical use in the process of optimizing the acoustic design of machine products, which, however, does not limit the wide range of its use in other areas, practically everywhere where there is a human interaction with sound–generating equipment.

The methodology consists of the following basic stages:

— analysis of the current state in the field of acoustic product design,
— analysis of sound parameters, mostly psychoacoustic, which can be used in the processes of optimizing the acoustic design of products,
— synthesis of acquired knowledge,
— proposal of the method according to the acquired knowledge and on the basis of the study of current knowledge in the researched area,
— creation and evaluation of an listening test,
— recommendations for practice.

Before the process of developing the methodology, a thorough analysis of the current state of the matter in the world was performed. Several authors deal with

this issue in order to improve the acoustic properties of products in their research. T. Novakovic in his publication „Validating impeller geometry optimization for sound quality based on psychoacoustics metrics“, [5], deals with the assessment of vacuum cleaner noise. The author propose a new design of the centrifugal impeller and optimized the sound quality.

The interior of the car, and specifically the control buttons, is dealt with by J. Gaspar in his publication «Psychoacoustics of in–car switch buttons: From feelings to engineering parameters» [6]. The author uses research and questionnaires to design buttons that produce a pleasant sound and thus allows the development of preferred car models.

A. Treiber in the publication "Psychoacoustic evaluation of rotary switches" [7] deals with the evaluation of psychoacoustic parameters of rotary switches.

Various types of sounds from refrigerators in Korea are solved by J. Jeon in the publication "Sound radiation and sound quality characteristics of refrigerator noise in real living environments" [8]. From the results of correlation and multiple regression analyzes of psychoacoustic parameters and subjective evaluations, the author proposed a sound quality index.

The analysis shows that this is an issue that is at a rapidly growing importance in the world. Manufacturers are aware of the need to optimize the acoustic parameters of their products. However, there is still no comprehensive methodology that has brought these tendencies to a standard level.

ANALYSIS OF PARAMETERS AFFECTING PRODUCT QUALITY

Product quality is the main goal of every manufacturer. The basis of all efforts to achieve high product quality are the requirements of customers and all interested parties.

According to the standard STN EN ISO 9000: 2016, "quality is defined as the degree to which a set of inherent characteristics of an object fulfils requirements ". Quality can be defined as the ability to ensure that customer needs are satisfied. Product requirements can be specified by customers or organizations that respond to customer requirements or regulations. Compliance with all requirements must be managed and controlled in such a way that all interested parties are satisfied.

It is clear that all these product quality requirements apply throughout the product life cycle. Significant in the light of efficiency and effectiveness of the implemented quality characteristics (quality features) appears to be the initial stage, i.e. design, development and construction of the product. The quality, safety and reliability of the product requires from all engineers involved in the project a set of activities, starting from the definition of the product characteristics to the implementation phase of the project, which take place simultaneously to achieve a quality and marketable product.

These activities include planning, analysis of results and tests, qualification of components and materials, and control of production processes. Recently, specific product features have come to the forefront. These features do not affect the safety and reliability of the product, have no limits, but are strongly customer–oriented, improve customer–required "quality" features, which increase the attractiveness of the product and eventually its marketability.

The relationship between quality, reliability, safety and specific parameters is described using the so–called general product quality features, Figure 1.

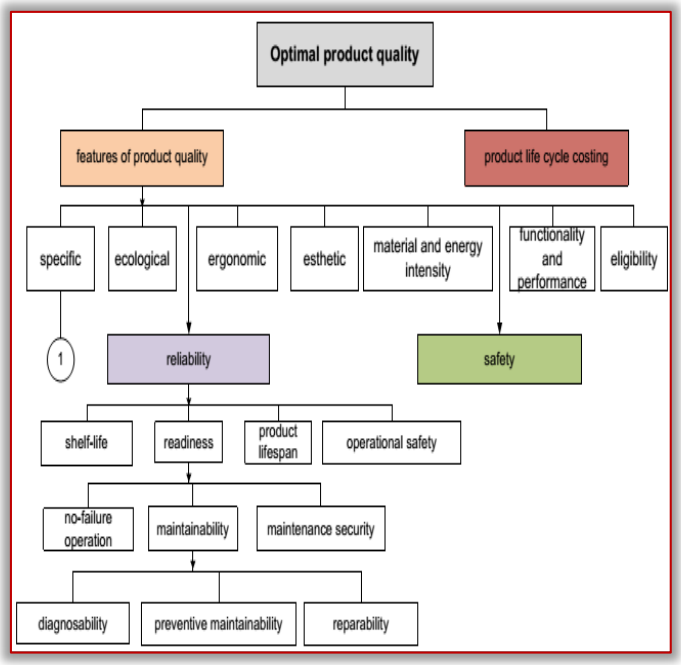


Figure 1. General product quality features

Understanding the needs and expectations of interested parties affects an organization's ability to provide products and services on a permanent basis. It is especially important to identify relevant interested parties in relation to a particular product, evaluate their impact on optimal product quality and identify which features have a critical impact. For these purposes, we have created our own methodology for evaluating general product quality features, specifically washing machines, where we have assigned an interested party to each quality feature and evaluated the customer's impact on quality, see Table 1.

Customer rating is rated on a scale from 1–10 where 10 is the highest rating and 1 is the lowest. We obtained the final evaluation by multiplying the scale of a feature of product quality and the customer rating.

All evaluations are the results of customer surveys in department stores as well as similar studies.

Subsequently, with the help of the matrix of the significance of product quality features (washing machines), we evaluated all properties and assigned them to 3 areas of significance, see Table 2.

Table 1. Evaluation of general product quality features

Features of product quality	Interested parties	Scale	Customer rating	Final evaluation
Specific – customer oriented	Customer	1	10	10
Ecological	Society EU	2	5	10
Recyclability	Ministry of Environment	3	3	9
Ergonomic	EÚ Ministry of Labour, Social Affairs and Family	3	6	18
Esthetic	Customer	1	9	9
Energy intensity	EÚ Manufacturer	2	9	18
Functionality and performance	Customer	1	10	10
Safety	EÚ Ministry of Internal Affairs	3	5	15

The legend: Scale – the importance of the relevant quality feature, evaluated according to a scale from 1–3, where: 3 – defined by legislation (law, government regulation, decree), 2 – recommendations, 1 – not defined by legislation, no recommendations.

Table 2. Matrix of the significance of product quality features

	Scale		
Customer rating	1	2	3
1	1	2	3
2	2	4	6
3	3	6	9
4	4	8	12
5	5	10	15
6	6	12	18
7	7	14	21
8	8	16	24
9	9	18	27
10	10	20	30

The legend: 1–6 – green color – insignificant features of product quality, 7–15 – yellow color – significant features of product quality, 15–30 – red color – very important features of product quality.

Customer evaluation may or may not be legally or normatively substantiated, for example, the energy properties of a product that a customer requires are also enshrined in legislation, but esthetic and specific properties are not specified anywhere.

Recently, the customer has been increasingly preferring specific quality features, which has caused these features to shift to a significant area, even though they have a low scale. That is why it is necessary to deal with the solution of this group of properties.

The definition of sound quality follows from this analysis. In any case we do not want to interfere with quality management systems that have their own area of application. We have focused mainly on a closer definition of the term acoustic quality of the product, or related terms, such as sound quality, product quality in terms of acoustic properties. Here, too, we identify several areas on which this research should be focused:

The area of effects of sound on a person, it is a classic approach, practically the most used so far. In practice, it is often the case about simple reduction of product noise, in rare cases – about the adjustment of the basic properties of sound – tonality or impulsivity.

The area of effects of sound on a person, defined in the scope of his psychological perceptions. It is a modification of psychoacoustic descriptors that affect the overall impression of the product. The point is that the sound of the product does not disturb the person, so that it is not perceived as much as possible. Examples are the modification of the sounds of individual sources in the car – the sound of the engine, aerodynamic sound, the sound generated by tires when rolling, the sound of closing the door, the sound of mechanical controls, the sound of the electric window mechanism, etc.

The area of the effects of sound on the person – the customer who decides to buy the product. Here, the area of sound influences often moves into the subconscious area. The customer does not focus on acoustic properties, but they must not irritate him, on the contrary, they must have a positive effect on his subconscious. Sometimes these are acoustic manifestations of the product, which will be almost never used in practice. Examples include various tapping of the product, switching on the product without load, testing the product in a mode in which it will never be operated, e.g. starting the car in the indoor environment of the show room.

PROPOSAL OF PRODUCT QUALITY IMPROVEMENT METHODOLOGY

The essence and goal of this paper is this proposal. Two types of measurements were performed – laboratory measurements and practical measurements.

The laboratory measurements that were performed can be divided into 2 groups:

— measurements of psychoacoustic properties, and

— measurements for the purpose of analysis and visualization of sound by an acoustic camera.

In the initial stages, we focused on the following sounds of the washing machine:

— washing,
— centrifugation,
— opening and closing the doors,
— opening and closing the detergent dispenser,
— tapping on the side wall of the washing machine.

Washing and spinning are sounds that occur during normal washing machine operation. They cannot be heard before installing the washing machine in the home. They are important for the consumer who bought the washing machine. The opening and closing of the door and the detergent dispenser are sounds that can be heard during any manipulation of the respective elements. Tapping on the side wall of the washing machine is a typical customer–oriented feature – it is tracked by customer behavior when choosing a washing machine.

— Measurement with the Acoustic Camera

The primary goal of any localization technique is to accurately analyze and visualize the source of noise, most often directly on a photograph or video of the tested object. The sound source is usually represented as a color map, corresponding to the distribution of the sound pressure or also the place with the highest measured amplitude.

The basic configuration of the device consists of a microphone array (antenna), data recorder, special laptop and appropriate software. The number of microphones is about 30 to 120 and they are variously arranged in space. In the center of this microphone array is lokated a high–definition video camera that optically records a scene, thanks to which the result of the acoustic calculation, i.e. the acoustic map, can be projected into the recording. The acoustic camera includes a converter that "integrates" the signals from the individual microphones and converts them into a suitable format for further processing. Figure 2 illustrates a view of laboratory measurements with an acoustic camera.

Based on the study of the issue, the following methodology was proposed – the sequence of measurements:

(1) source selection,
(2) of assessment method,
(3) visualization of sound with acoustic camera,
(4) analysis of measured data, processing and evaluation,
(5) acoustic images, acoustic films, time course, spectrum, spectrogram,
(6) location of sources, determination of dominant frequencies, their localization, analysis of technical possibilities of sound modification.

Figure 2. A view of the measurement with an acoustic camera in an anechoic chamber

This methodology was tested in an anechoic chamber. In the initial stages of the methodology, decisions are made on the basic measurement methods. Subsequently, the detail measurement with acoustic camera with appropriate decision–making procedures is elaborated in the methodology. Figure 3 shows an acoustic image of door closing at dominant frequencies of 2300–2500 Hz.

Figure 3. Visualization of sound from door closing, dominant frequencies 2300 – 2500 Hz

— Measurements with psychoacoustic head

The following experiments are focused on measuring the psychoacoustic properties of the assessed sound

sources. The following sequence of activities was used for measurements with psychoacoustic head:

(1) selection of source and assessment method,
(2) determination of customer–oriented quality features – properties that do not affect the technical parameters of the product but affect customer decisions. They are dedicated from the analysis of customer behavior in decision–making, surveys, monitoring behavior in shopping centers, etc.
(3) selection of psychoacoustic parameters – roughness, volume, sharpness, fluctuation, tonality,
(4) measurements of psychoacoustic properties,
(5) time record, identification of required acoustic events,
(6) analysis, data processing, measurement evaluation, analysis of technical possibilities of sound modification.

Measurement of psychoacoustic parameters by means of a psychoacoustic head was also performed in an anechoic chamber. Behind the washing machine was a reflective surface that mimics conditions as close as possible to real household conditions. In Figure 4 is shown a view of the measuring point and the location of the sound source and the measuring device.

Figure 4. View of the measuring point in the anechoic chamber

We focused our measurements on 3 customer–oriented quality features – opening and closing the doors, opening and closing the detergent dispenser and knocking on the side wall of the washing machine.

Figure 5 shows a time record of all assessed acoustic events, on the basis of which detailed evaluations of individual acoustic events were performed.

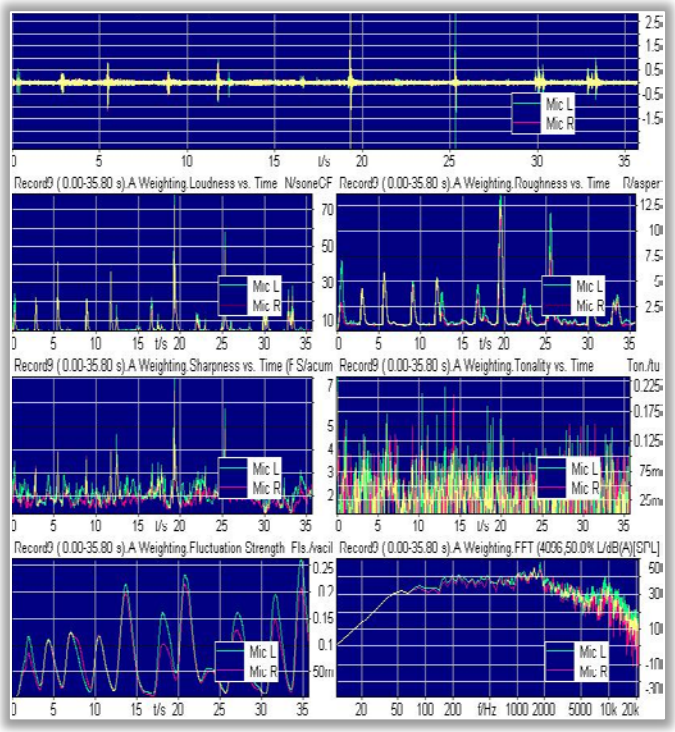


Figure 6. Graphic representation of acoustic and psychoacoustic quantities

CONCLUSIONS

At present, manufacturers strive for their products to reach a high technical level on the one hand and to meet customer requirements on the other hand, which are often different from the ideas of designers and constructors, who attach importance to other requirements, properties, capabilities and other technical parameters. For this reason, manufacturers are now beginning to focus on those features that have not been interesting so far, specifically customer–oriented quality features.

From the performed measurements and their evaluation as well as from the performed psychoacoustic experiment of selected customer–oriented properties of a specific product – washing machine it follows that these properties, although they have no effect on product functionality or technical parameters, are very important to the customer. They often affect the customer's subconscious, influence him and modify his decision–making. The performed experiment serves to determine the recommendations for a washing machine manufacturer who wants to improve these customer–oriented properties and thus increase the marketability of its product.

Acknowledgments

This paper was created within the project KEGA 032 TUKE–4/2018.

References

[1] LUMNITZER, E. et al.: Metodológia komplexného hodnotenia zdravotných rizík v priemysle I . Zręcin: MUSKA sp. z o.o. – 2015 – p. 240

[2] LUMNITZER, E. et al.: Základy psychoakustiky, 2012, Košice pp. 51–73.
[3] LUMNITZER, E. et al.: Hodnotenie vplyvov fyzikálnych faktorov na zdravie človeka. TU, 2014, p. 159
[4] LUMNITZER, E. et al.: Psychoacoustic aspects of the noise perception in engineering. Environmental Protection, Safety, Education and Managment 4 (2014), pp 33–36
[5] NOVAKOVIC, T. et al.: Validating impeller geometry optimization for sound quality based on psychoacoustics metrics. Applied acoustics, volume: 157, article number: UNSP 107013, 2020
[6] GASPAR, J. et al.: Psychoacoustics of in–car switch buttons: From feelings to engineering parameters. Applied Acoustics 110 (2016), pp. 280–296.
[7] TREIBER, A. et al.: Psychoacoustic evaluation of rotary switches. Proceedings of IWSSIP 2008: 15th international conference on systems, signals and image processing, pp. 17–19, 2008
[8] JEON, J. et al.: Sound radiation and sound quality characteristicsof refrigerator noise in real living environments. Applied Acoustics Volume 68, 2007, pp. 1118–1134

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

[1.]Dávid GÖNCZI

FINITE ELEMENT INVESTIGATION IN THE FORMING PROCESS OF ALUMINIUM AEROSOL CANS

[1.]Institute of Applied Mechanics, University of Miskolc, Miskolc, HUNGARY

Abstract: This paper deals with the numerical analysis of the forming process of thin-walled aluminium cans. Our aim is to investigate different finite element modelling techniques to tackle this highly nonlinear problem and to determine the reaction forces during the necking process of aerosol cans. The commercial finite element software Abaqus is used to carry out the calculations. The effect of several parameters on the reaction forces is investigated.
Keywords: FEM, aerosol cans, reaction forces, shell

INTRODUCTION

In recent years the demand of aluminum aerosol cans with complex shapes was continuously growing. Due to the importance of these package products it is recommended to use numerical simulations to analyse the forming process of the cans during the design phase. This way the manufacturers can be competitive on the market and produce more complex shapes.

We can find several books, such as [1], [2] or [3] on the mechanics and finite element modelling of thin shell structures. Papers [4] and [5] investigates the extrusion and forming processes, Belblidia et. al. [6], [7] presented finite element techniques to predict the stress state and burst pressure of aerosol cans. Paper [8] investigated various parameters of the shaping process using experimental data. Takeutshi [9] presented a few basic problems in the forming process of aluminum cans. Paper [10] dealt with the hydroforming of cans. Several works [11-14] tackle the buckling problems of thin shells, which is important to determine the limitations of shapes (geometry) of aerosol cans (that can be manufactured within certain waste product ratio).

AIMS AND DATA

One of the main problems of this process is that it is a highly non-linear mechanical problem, in which the emphasis is on thin-walled shells made from strain-hardened aluminum. A linearly elastic, linearly hardening constitutive law will be used for our models. This problem involves geometric and material non-linearities combined with contact.

During the shaping process of cans, the desired final geometry is always reached within several steps because if too much plastic deformation occurs in one step, buckling (crush/pan) happens resulting in waste product. If the number of forming steps could be minimized, it would mean more efficient manufacturing. Furthermore, there is a continuous demand to use the reserves in the material more and more efficiently, thus the reaction forces (and its ratio to the force that causes loss of stability) within a step is an important data. We can derive safety factors which reflect the reserve of the certain shaping phases.

In this paper, our aim is to calculate the reaction forces during the forming steps with different finite element modelling techniques. The advantages and disadvantages of the different models will be outlined via two forming steps. Furthermore, the effects of various parameters (such as the thickness of the shell, friction coefficient, shape of the forming tool) on the reaction forces will be investigated. The numerical calculations will be carried out by Abaqus 6.13.

The material of the investigated cans is aluminum Al99.5 (EN AW 1050), the Young modulus is E=73 GPa, the Poisson's ratio is 0.4, the yield stress is 120 MPa. The average friction coefficient during the forming process is 0.05 between the aluminum can and steel tool.

In our first numerical example a simple cylindrical can is investigated. The initial geometry can be seen in Figure 1. The thickness of the shell is 0.38 mm, the diameter is 45 mm, the diameter reduction is 2.6 mm in the forming step, and the length of the can is 200 mm. The piece is placed in a sleeve, it is constrained at its bottom flat surface against vertical displacement, at its side of 50 mm height, against radial motion.

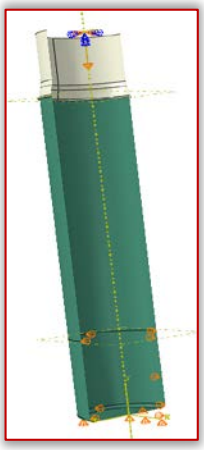


Figure 1. The sketch of the first example

In our second example, a necking step is investigated, where the change in diameter is 2.1 mm (from the

initial 28.6 mm to 26.5 mm). The initial thickness of the shell is 0.48 mm, the initial geometry is more complex, and the boundary conditions are identical to the first example (Figure 2).

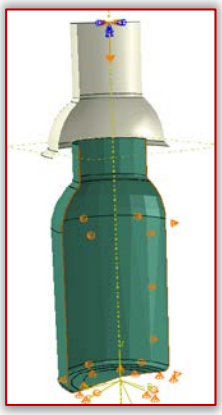


Figure 2. The sketch of the second example

There is a prescribed vertical displacement at the upmost edge of the tool.

MODELLING TECHNIQUES

Three models will be considered with displacement control. Alternatively we can use Risk method, especially if our aim is to include buckling. Due to the complexity of the contact between the can and the tool, it is necessary to pay attention to the contact. This means, that we need to initialize, control and stabilize the contact calculations and avoid errors, furthermore linear elements will be used.

The first technique uses three-dimensional geometry with shell elements. The tool is modelled as a discrete rigid part, the general contact algorithm of Abaqus is used. The advantage of this method over the other two models is that it can be used to investigate the loss of stability for the can.

In our second model, two-dimensional axisymmetric formulation is used, the can is modelled with shell element, the tools are represented by analytical rigid surfaces. We can use either the surface-to-surface or the general contact algorithms of Abaqus. In this case, the number of elements is minimal, the calculation is the fastest (compared to the other two methods).

The third method uses two-dimensional axisymmetric formulation, but the can is modelled with solid continuum elements. The advantage of this technique is the more accurate representation of the geometry, but the number of elements is much greater than in the second model due to locking considerations.

NUMERICAL EXAMPLES

In the first numerical example the diameter of a cylindrical can is reduced by 2.6 mm. According to experiments, the maximum reaction force during the shaping process is 650 N.

The model of the first method can be seen in Figure 3. After the convergence tests, the results are converged to 643N. The force-displacement diagram can be seen in Figure 6.

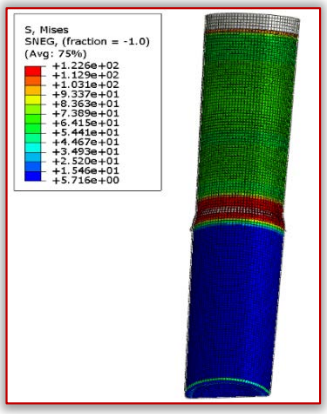


Figure 3. The deformed finite element mesh of the first example (with the von Mises stress distribution)

In our second method axisymmetric formulation is used, the can is modeled using shell elements. Figure 4 shows the model and the contact pressure (approximately 6 MPa) between the analytical rigid tool and the deformable can. In this case the maximum reaction force calculated at the reference point of the tool is approximately equal to the result coming from the previous model (Figure 6).

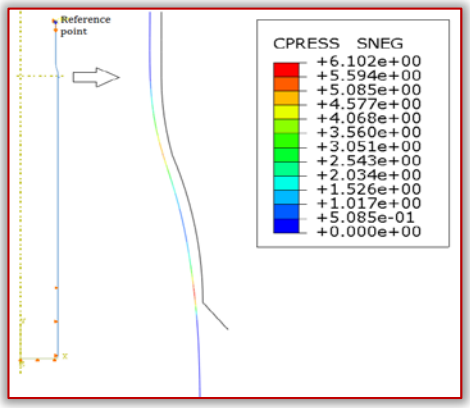


Figure 4. The assembly of the second method and the contact pressure during the forming process

The third modelling technique uses two-dimensional axisymmetric formulation with solid elements. Due to locking, small element size is used (Figure 5), the maximum reaction force is 668 N.

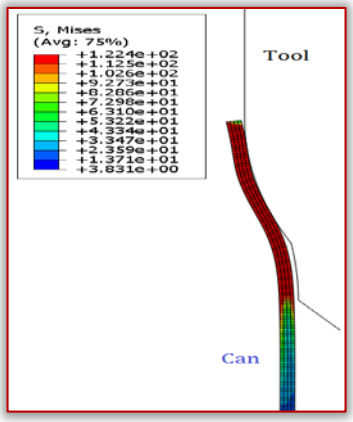


Figure 5. The deformed mesh of the first example using rigid tool and deformable can

Figure 6. The reaction forces during the forming process (green dots: 3D shell, blue line: axisymmetric solid, purple dots: axisymmetric shell)

Next let's considered deformable tool (instead of rigid surfaces), which results in slightly higher contact pressure (Figure 7), although the reaction forces are approximately the same. Furthermore, we modified the boundary conditions of the can, fixed the lower part of the cylindrical shell, the reaction forces did not change significantly.

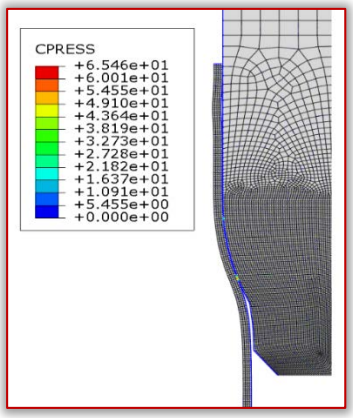


Figure 7. The contact pressure with deformable tool

In the second numerical example a necking process is investigated using three modelling approaches. The initial diameter of the can is 28.6 mm, the diameter reduction is 2.1 mm, the radius combination of the neck is R3.2 mm and R26 mm. According to the experiments, the maximum reaction force is 1.21 kN. Figure 8 presents the stresses coming from the three-dimensional shell formulation. The maximum reaction force is 1201N.

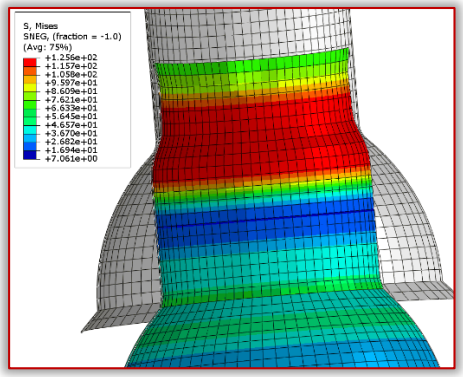


Figure 8. The von Mises stresses calculated from the second problem using the first method

The axisymmetric models can be seen in Figures 9 and 10. The reaction forces coming from the shell elements and continuum elements are equal (1195N). During the calculations of solid finite elements, the contact formulations of Abaqus failed when the sharp corner of the aluminum can touched the internal surface of the tool (even with contact stabilizations), that is why we had to modify the can geometry using a small fillet.

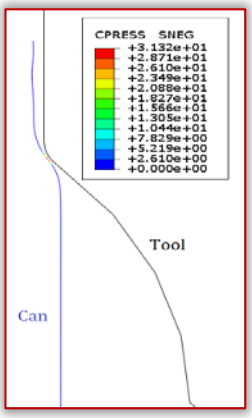


Figure 9. The deformed mesh of the second problem with axisymmetric shell element

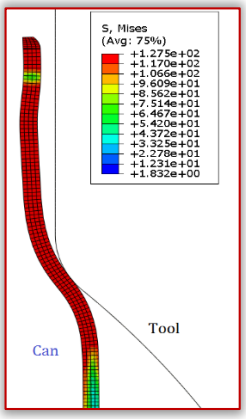


Figure 10. The deformed mesh of the second problem modelled with axisymmetric solid element and rigid tool

In the next step the friction coefficient, the shell thickness and the radius combination of the tool geometry are modified. Table 1 shows the results of the parametric investigation on the maximum reaction forces. When the friction coefficient or the shell thickness of the can increase, the forming forces increase too. With the increase of the initial radius of the tool, the maximum reaction force decreases, although the "spring back" effect is more significant.

Table 1. The effect of the friction coefficient, shell thickness and tool geometry on the maximum reaction forces

Friction coeffic.	Force (N)	Shell thickness	Force (N)	Radius (mm)	Force (N)
0.05	1200	0.48	1200	2.5	1200
0.15	1591	0.3	650	5	1040
0.3	2188	0.7	2230	15	890

Next, the crushing forces must be determined, where the loss of stability occurs. We can use either Riks-method or displacement controlled static analysis to determine the reaction force-displacement curve (and the crushing force form it). Obviously, we cannot use two-dimensional, axisymmetric formulation to tackle buckling problems, thus we have to use the first method (3D shell elements). Then we have to compare the crushing force and the maximum reaction force of the shaping process to evaluate the safety of the forming step. For example in our current case, a factor of safety can be defined as

$$n_c = \frac{F_{\max}}{F_{crush}}, \qquad (1)$$

which must be less than 1 and it reflect the „reserve" of the forming step. In our current example, the crushing force is 2.6 kN, which means that the factor of safety is 0.46. When the friction coefficient is greater, than 0.3 (dry friction between the can and tool) the factor of safety is more than 0.85, thus the number of waste increases (e.g. due to material or geometric imperfections).

CONCLUSIONS

The finite element analysis of the forming process for aluminum aerosol cans was investigated. Different methods were presented to calculate the maximum reaction forces, the force-displacement curves and to determine the feasibility of the forming step. The thin-walled cans were modeled with 3D shell elements, with 2D axisymmetric shell elements and finally with 2D axisymmetric solid elements. The results were compared to each other and to experimental results.

Acknowledgements

The described article was carried out as part of the EFOP-3.6.1-16-2016-00011 „Younger and Renewing University – Innovative Knowledge City – institutional development of the University of Miskolc aiming at intelligent specialisation" project implemented in the framework of the Szechenyi 2020 program. The realization of this project is supported by the European Union, co-financed by the European Social Fund.

References

[1] Reddy J.N.: Theory and Analysis of Elastic Plates and Shells. CRC Press, 2006.
[2] Chapelle D., Bathe C.J.: The Finite Element Analysis of Shells - Fundamentals. 2nd edition, Springer, 2011.
[3] Radwanska M., Stankiewicz A., Wosatko A., Pamin J..: Plate and Shell Structures: Selected Analytical and Finite Element Solutions. John Wiley and Sons Ltd., 2016.
[4] Patten S.: Design and optimisation of aluminium aerosol cans produced by the back extrusion process. MPhil thesis, University of Wales, Swansea, 2001.
[5] Hardy S.J., Abdusslam R.M.: Finite element modelling of the extrusion process for aluminium aerosol cans. Proc. IMechE, Part L, J. Materials: Design and Applications, 221, pp. 265-274, 2007.
[6] Belblidia, F., Corft, N., Hardy, S. J., Shakespeare, V., Chambers, R.: Simulation based aerosol can design under pressure and buckling loads and comparison with experimental trials, Materials and Design, 52, pp. 214-224, 2013.
[7] Belblidia, F., Corft, N., Hardy, S.J. , Bould, D.C. , Sienz, J.: Aerosol cans under pressure and buckling loads, Sustainable Design and Manufacturing, 1, pp. 13-17, 2014.
[8] Folle, L.F., Netto, S.E.S., Schaeffer, L.: Analysis of the manufacturing process of beverage cans using aluminum alloy, Journal of Material Processing Technology, 205, pp. 347-352, 2008.
[9] Takeutshi, H.: Numerical simulation technology for lightweight aluminium can. Journal of Material Processing Technology, 38, pp. 675-687, 1993.
[10] Ceretti, E., Attanasio, A., Fiorentino, A., Giorleo, L., Giardini, C.: Aluminium can shaping by hydroforming: simulative feasibility study and prototype production, The International Journal of Advanced Manufacturing Technology, 68, pp. 1797-1807, 2013.
[11] Hegadekatte, V., Shi, Y.: Buckling of beverage cans under axial loading, Simulia India Regional Users Meeting, pp. 1-16, 2011.
[12] Sawant, D.A., Venkatesh, M. A.: Buckling and crushing analysis of cylindrical aluminium cans & optimizing the parameters effecting crush strength using FEM, International Research Journal of Engineering and Technology, 3(6), pp. 32081-3085, 2016.
[13] Gönczi, D., Baksa, A., Kiss, L.P.: Alumínium palackok nyakazási lépésinek és stabilitásvesztésének modellezési sajátosságai. Multidiszciplináris tudományok, 9(2),pp. 56-63, 2019. [in Hungarian, Modelling considerations for the numerical simulation of buckling during the necking process of aluminum cans]
[14] Kiss L.P.: The effect of various imperfections ont he buckling of aluminium shells. Acta Technica Corviniensis – Bulletin of Engineering. 13(1), pp. 49-52, 2020.

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

[1.]Stevan MAKSIMOVIĆ, [2.]Katarina MAKSIMOVIĆ, [3.]Ivana VASOVIĆ,
[4.]Mirko MAKSIMOVIĆ, [5.]Dragi STAMENKOVIĆ

STRENGTH ANALYSIS OF HELICOPTER MAIN ROTOR BLADE MADE FROM COMPOSITE MATERIALS

[1.]Military Technical Institute, Belgrade, SERBIA
[2.]Secretariat for Utilities and Housing Services Water Management, Belgrade, SERBIA
[3.]Lola Institute, Belgrade, SERBIA
[4.]Belgrade Waterworks and Sewerage, Belgrade, SERBIA
[5.]Visoka Brodarska Škola Akademskih Studija, Belgrade, SERBIA

Abstract: In this investigation some aspects of design, production and experimental verification of composite structural elements are considered. Attention is focused on strength analysis of composite structures with application to helicopter main rotor blades HT-40. Special attention in this consideration is focused on strength analyses of composite structures with application on helicopter main rotor blades. For that purpose strength analysis of helicopter main rotor blade segment made from composite materials is considered using finite element method (FEM) and experimental verifications. In this study honeycomb sandwich structure is considered. Just honeycomb sandwich structural element is modeled using shell finite elements. For structural analysis of this type construction Msc/NASTRAN software code is used. For precise determination of aerodynamic loads of main rotor blades in this consideration the complete helicopter is modeled using CFD numerical simulation including main rotor, tail rotor and fuselage. To validate computation procedure in this consideration the honeycomb structural element is experimental tested. The results of numerical simulations are compared with own experiments.
Keywords: helicopter main rotor blade, sandwich construction, strength analyses, Finite Element Method (FEM), experimental verification

INTRODUCTION

Due to its good mechanical properties with respects to strength and stiffness of composite materials have found application in the aerospace industry. Here is considering the use of composite materials in helicopter main rotor blades HT-40 or precise segments of these blades. In the basic version of the blade segments of the honeycomb structure have been wherein the dural skins. After the end of their useful lives, these segments are redesigned and made of composite materials. Reserved the sandwich construction but skins made of composite materials and proper honeycomb filling. Strength calculations and experimental verification were realized in a Military Technical Institute (MTI) and production of composite blades in Moma Stanojlović - Batajnica. Defining loads the main rotor blades of helicopters was carried out using CFD numerical simulation [1,2]. Structural analysis of the blade segments is mainly realizen by means of FEM [3-8] including strength analysis of segments with one side and the analysis of the strength of an adhesive bond with the main segments of the spar of the blade with other side. In addition to the strength of the analysis calculation is carried out and experimental verification of complete segments of the composite strength of the blade and their connection to the main spar. In this consideration are shown the essential aspects of the results of structural analysis and experimental verification of the strength of the blade segment.

STRUCTURAL ANALYSIS OF SEGMENT OF MAIN ROTOR BLADE

In the process of designing complex constructions of composite materials such as the considered segment of the blade of the main helicopter rotor, a precise analysis of the stress states and reserve strength factors is essential. By using FEM applications have determined the stresses as well as the critical zones from the aspect of strength and potentially critical sites that can occur during exploitation [3,4]. Figure 1 shows the global structural drawings of the entire blade, while only the composite segment is considered.

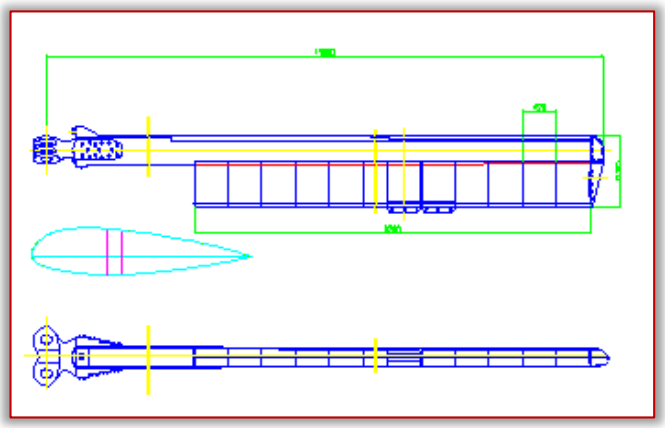


Figure 1. Helicopter main rotor blade

In this consideration the structural analysis of critical part of the segment of composite blade, shown in Figure 4, is considered. This part is subjected axial

force Fx = 50.8 N originating from aerodynamic drag forces on the blade segment. Structural analysis of the complex specimen carried out by using Finite Element Method (FEM). Here FEM [5-7] is used for strength analysis of skins made from composite materials and all other components including glued compound for binding to a metal segment of the composite spar on one side and a comparison with the experimental results on the other hand.

Resuts of structural analysis by FEM using software code MSC/NASTRAN [8] are shown in Figures 2, 3. We note that the maximal loaded parts are joints of honeycomb with composite skin on upper side assembly, as well as the places of bonding the composite spar for dural or dural tail part. The primary objective of this analysis was the modeling of composite structures with honeycomb filling and then comparisons with experimental results. The maximum value of the stresses in junction zones honeycomb with composite skins, which are also critical points with respects to the initial failure and the fracture.

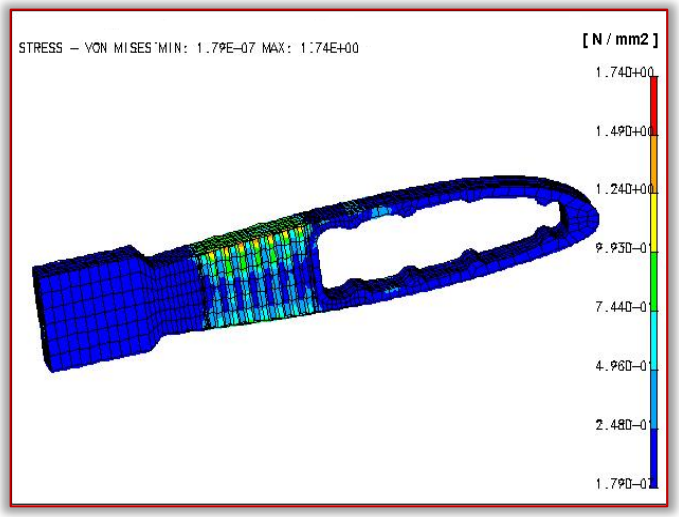


Figure 2. Specimen of helicopter rotor blade – Von Misses stress distribution

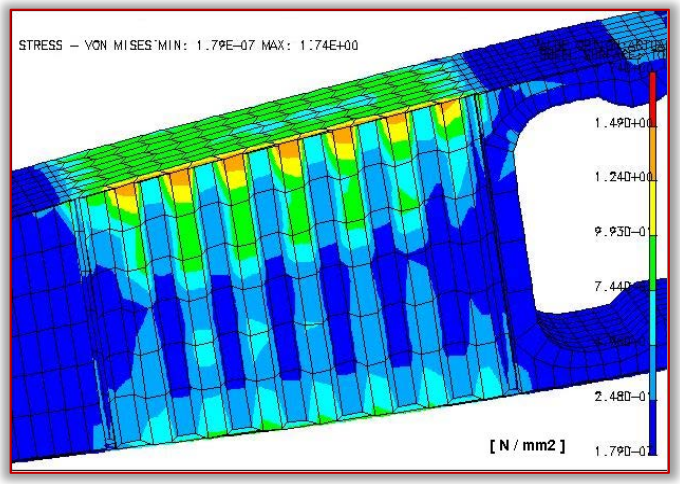


Figure 3. Von Misses stress distribution in honeycomb part of segment of blade

In the previous figures are presented graphically the results of the stress state in all parts of the complex composite specimen the main rotor blades of helicopters.

EXPERIMENTAL STRENGTH ANALYSIS OF THE SEGMENT OF MAIN ROTOR BLADE

In order to determine the static strength tests were carried out complete static strength. Static tests are realized in the segment blades for loads that occur on the last segment - at the end of the range of blades. Figure 4 shows the composite segment of the main rotor blade together with the work spar with that within perform static tensile tests.

During the tests were measured strain / stresses by means of strain gauges and displacements. Figure 8 shows a complete consruction of the blade segments and the method of introducing the load. It introduces all three components of the load acting on himself composite blade segment.

The tests were performed:

(1) to limit load (j = 1.0),

(2) to computation ultimate load (j = 1.5) and the effective failure.

Test results blade segment are shown loading case for j = 1 is defined as follows:

- N = 2539 N - force component normal to the chord,
- T = 279 N - component force in the direction of chord and
- F_C = 2202 N - centrifugal force (normal to the plane of airfoil, towards the end of the rotor).

Point of attack of the aerodynamic force is half of the expansion segment and in the first third of the chord segment, while striking point of centrifugal force in the tendon segment.

Figure 6 shows the arrangement of strain gauges on bottom side of segment of composite material. Measured strains / stresses in the rosette for a cycle to limit loads, indicated with 3,4, and 5 in Figure 6, as shown in Figure 7.

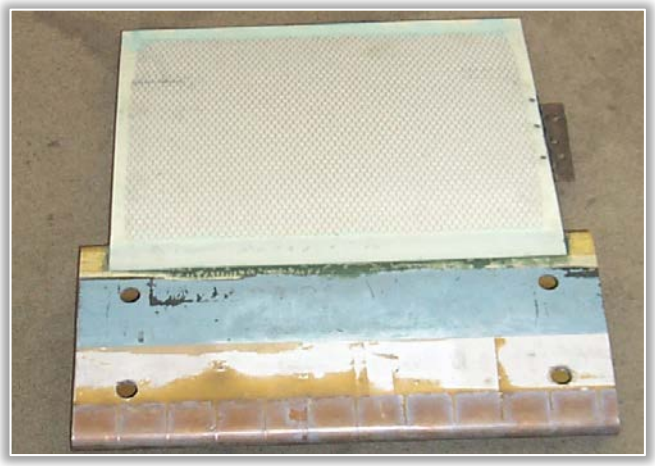


Figure 4. The composite segment with part spar

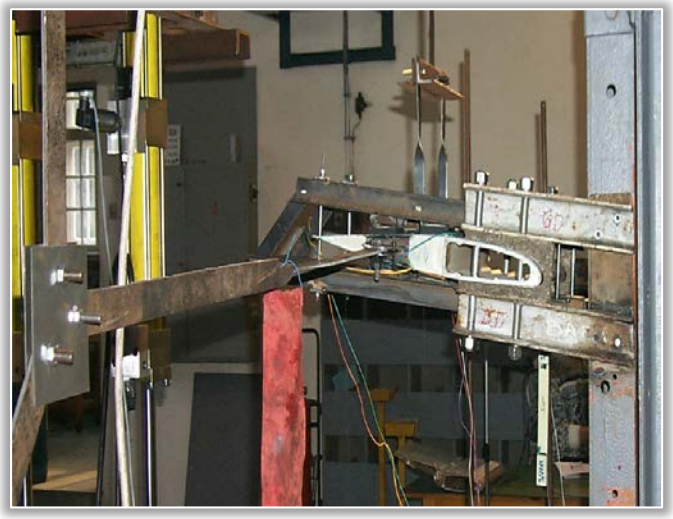


Figure 5. The manner of incorporation and the introduction of load testing for static strength of the composite blade segment

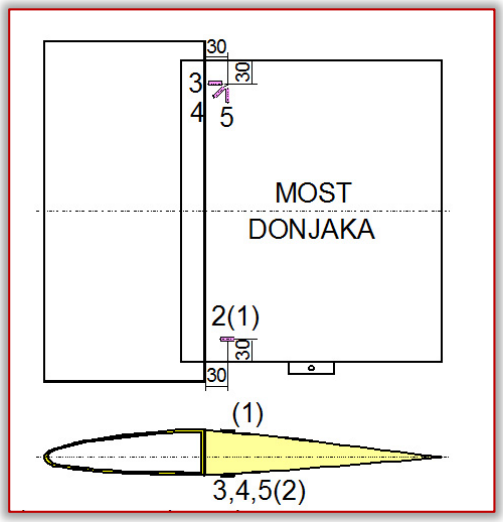


Figure 6. Schedule of strain gauges for measuring the stresses

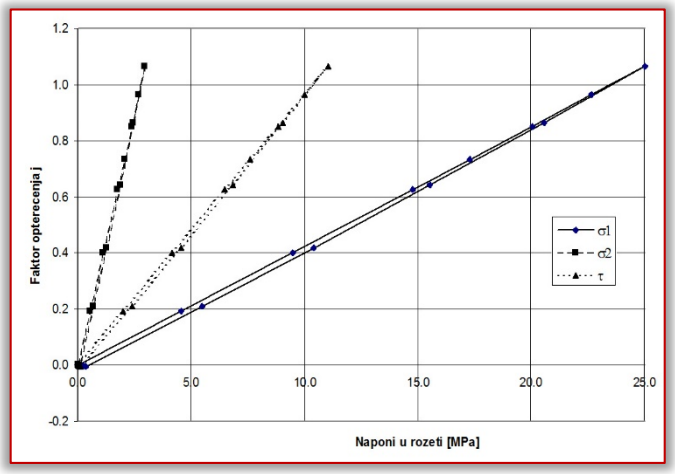


Figure 7. Experimental determined stresses in strain gages up to coefficient of load j=1.08

Measured strains/stresses in the strain gages/rosette for a cycle to limit loads, indicated with 3, 4, and 5 in Figure 6, are shown in Figure 7.

CONCLUSIONS

The paper presents a computation analysis of the determination of the stress states in the composite segment of the blade of the main rotor of the helicopter HT-40 with one and its experimental strength test on the other side. Structural analysis of stress conditions using FEM encompassed the precise modeling of the complete segment of the blade, including the honeycomb filling and the self-bonding connections between the composite segment and the metal part spar.

In order to verify the real strength of the composite segment was carried out experimental analysis of the strength of the composite blade segment. Tests were carried out with the measurements of stresses and displacements up to the effective fracture. For this tests was selected the most loaded blade segment located at the end of the blade span. Effective fracture of the segment during the test is determined by the high workload which is in turn verified the validity of the composite segment in terms of strength. In parallel tests were performed static strength metal segments with honeycomb and composite segment with honeycomb filling.

The investigation up to the effective failure metal and composite helicopter main rotor blade segment was found that the composite segment with a coefficient of mountainous workload (j_1 = 4,48) has significantly higher static strength relative to the metal segment (j_1 = 2,97).

Acknowledgments

This work was partially supported by the Ministry of Science and Technological Developments of Serbia under Projects ON 174001 and TR-35011.

Note:

This paper is based on the paper presented at DEMI 2019 – The 14th International Conference on Accomplishments in Mechanical and Industrial Engineering, organized by Faculty of Mechanical Engineering, University of Banja Luka, BOSNIA & HERZEGOVINA, co–organized by Faculty of Mechanical Engineering, University of Niš, SERBIA, Faculty of Mechanical Engineering Podgorica, University of Montenegro, MONTENEGRO and Faculty of Engineering Hunedoara, Unversity Politehnica Timisoara, ROMANIA, in Banja Luka, BOSNIA & HERZEGOVINA, 24–25 May 2019.

References

[1] Maksimović S., Kozić M., Maksimović K., Georgijević D., Ognjanović O., Definition of load spectra using CFD method and fatigue life estimation of helicopter rotor blades, OTEH 2011, pp. 122-127

[2] Jankovic D, Maksimovic S., M Kozic, Stupar S., Maksimovic K., Vasovic I., Maksimovic M., CFD Calculation of Helicopter Tail Rotor Airloads for Fatigue Strength Experiments, Journal of Aerospace Engineering, (2017), vol. 30 No. 5.

[3] Maksimović, S., Improved geometrically nonlinear finite element analysis and failure of fibre reinforced composite laminates, Proc. Int. Symp. Brittle Matrix

Composites 4, Warsaw, September 13-15, Edited by Brandt, A. M, Li, V.C and Marshall, I. H., Woodhead Publishing limited, Cambridge, 1994

[4] Maksimović, S., Failure analysis of layered composite structures: Computation and Experimental Investigation, ECF 16, 16th European Conference of Fracture, ECF 16, Alexandroupolis, Greece, 2006.

[5] Vasović, I., Strength Analysis of Filament Wound Composite Tubes, Hemijska industrija, Vol. 64, No.3, 2010.

[6] Maksimović S., Vasović I., Maksimović M., Đurić M., Residual life estimation of damaged structural components using low-cycle fatigue properties, The Third International Congress of Serbian Society of Mechanics, Vlasina lake, 5-8 July 2011

[7] Maksimović S., Vasović I., Maksimović M., Some aspects to design of aircraft structures with respects to fatigue and fracture mechanics, DEMI 2011, 10th Anniversary International conference on Accomplishments in Electrical and Mechanical Engineering and Information Technology, University of Banja Luka, Faculty of Mechanical Engineering, 26th-28th May 2011.

[8] MSC/NASTRAN Theoretical Manuals

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

[1.]Mihai Gabriel MATACHE, [2.]Gheorghe VOICU, [1.]Mariana EPURE,
[1.]Iulian Florin VOICEA, [1.]Iuliana GĂGEANU, [2.]Mădălina GHILVACS

MEASURING VIBRATIONS LEVEL DURING TRANSPORTATION WORK FOR AN ELECTRICAL TRACTOR

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

Abstract: Vibrations usually aren't wanted in any technical system. This rule applies also to agricultural tractors, since their apparition could affect the normal functioning of the machine. One new type of agricultural tractors are the electrical ones, which have appeared in nowadays agriculture because of the need to protect the environment and to mitigate the technology's negative impact on the environment. Because of the electrical engine construction, this will generate less vibration during normal functioning, fact which will attenuate also the tractor's total vibration level. Because transportation is one very important work for which the electrical tractor could be used, its vibration comportment during this type of work is of particular interest for engineers. This paper presents researches done in order to assess the vibration level of an experimental model electric tractor during transportation work. The experiments were performed on the experimental plots from INMA Bucharest on a total distance of 3 km. The raw data for longitudinal, transversal and vertical directions were recorded and processed in order to obtain the RMS values for vibration.
Keywords: vibration level, electric tractor, transportation

INTRODUCTION

A system vibration is always caused by an excitation force. This force could be applied from outside the system, or could be coming from inside. Effect of this force, the vibration, is completely determined by the excitation force, its direction and frequency. This is the reason why, through vibration analysis could be determined the excitation forces which acts on a functioning machine. The effect depends on the machine's state and the knowledge of vibration characteristics will allow for a flaw diagnose in case of need.

It's considered that an agricultural tractor vibration is characterizing its functioning state. Vibrations are caused mainly by dynamic effects of the execution tolerances of subassemblies, by gaps and direct contact between moving parts of the gears as also by effect of forces which are unbalanced in rotating or alternating moving parts. Many times, the reduced amplitude vibrations could excite the resonance frequencies of some parts, being eventually amplified until unacceptable levels.

In most cases, vibrations are unwanted, because are causing dramatic shortening of the life span of tractors changeable parts and accidental stops which are affecting the work quality they are performing. This is the reason why is considered that if an equipment doesn't vibrate, it will continue to work for a long time, while if the one which vibrates it's left without taking measures it will have a short life span. Each tractor part will produce a vibration with one or several specific frequencies. Knowing the spectral component of the global vibration, it could be determined in which of the moving parts has appeared an issue. The main source of vibration of a classic tractor it's its diesel engine. For this reason are sought solutions for vibration reduction, like mounting the engine on rubber supports which will cushion and absorb the vibrations [3].

Advantages of electric engines driven tractors are multiple: zero emissions, batteries recharging from charging stations using renewable energy, reduced noise and vibrations in exploitation, high torque from almost zero rotating speeds. Disadvantages arise from reduced autonomy due to batteries limitations, relatively long recharging time and need for battery replacement at several years of usage.

At international level there are researches done in order to assess the vibration effect on the operator both for different agricultural equipment handled by hand [7,9] and for agricultural vehicles [1,2,5,6]. The measuring method is the same in both cases, with several differences due to particular equipment's using conditions. Ideally the weighted vibration level should be under 2.5 m/s^2, so that the human worker to be shielded by any danger [11]. One of the electric tractors advantage is represented by the low level of vibrations during work, fact which will assure a nice working environment, without any negative effects for the worker. Vibration measurement represents a serious tool to assess the design of agricultural transportation equipment and it's used to measure the dynamic response during simulations and real-life tests [4, 8].Within this paper is presented the assessment of vibration level during transportation work for an electric tractor prototype produced by INMA Bucharest and partners, in order to verify the

degree of comfort of the driver as also to limit the unwanted vibration effects on its reliability.

MATERIAL AND METHOD

The transportation experiments were conducted on a 28.8 kW prototype of agricultural electric tractor. The electric motor used for propelling the tractor gives maximum output torque, even at very low revolutions per minute. The tractor was fitted with a mechanical transmission which allowed for a minimum travel speed of 1.71 km/h and maximum of 26 km/h for a nominal rotational speed of the electric motor of 2350 s^{-1}.

Vibration measurements were performed on vertical, transversal and longitudinal direction, using a triaxial accelerometer, mounted on the tractor's floor, according to figure 1, using mounting methods provided in [10].

Figure 1. Accelerometers mounting

The data acquisition software for raw vibration data was DEWESOFT, software dedicated for the used Sirius data acquisition system. The accelerometer was calibrated on each channel using a Type 4294 Calibration Exciter with 10 m/s^2 r.m.s. acceleration at 159.2 Hz. The accelerometers were mounted on the metallic parts of the tractor through magnetic supports, fact which assured a stable position during measurements. The data acquisition was performed with a 10 kHz sample rate, continuously and the recorded data was saved in ASCII files.

The root mean square (r.m.s) was calculated using formula 1 for each string of recorded values.

$$a_{rms} = \sqrt{\frac{\sum_{i=1}^{n} a_i^2}{n}} \quad (1)$$

where a_i is the instantaneous value of the i-th sample acceleration and n represents the total amount of samples.

Vibration determination was done on a combined test route of tarmac road and dirt road. The track characteristics were as follows:

- Total distance 6,4 km
- Maximum speed 26 km/h
- Mean speed 6 km/h

The tractor was pulling a loaded trailer with a total mass of 1400 kg.

RESULTS

In figure 2 are presented the vibration evolution in time measured by the floor mounted accelerometer, inside the cabin (x axis longitudinal direction – red, y axis vertical direction – blue, z axis transversal direction - green) on tarmac road and in figure 3 the vibration measured on dirt road. In order to quantify energetically the vibration level and to report the measured values to the limits imposed in regulations and directives, the raw values were processed and reported as r.m.s. values.

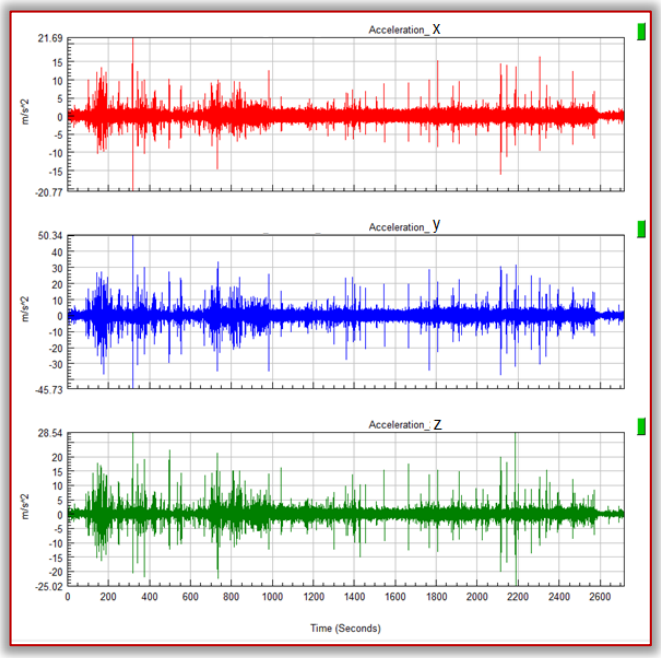


Figure 2. Vibrations evolution during transportation experiment for tractor's floor on tarmac road

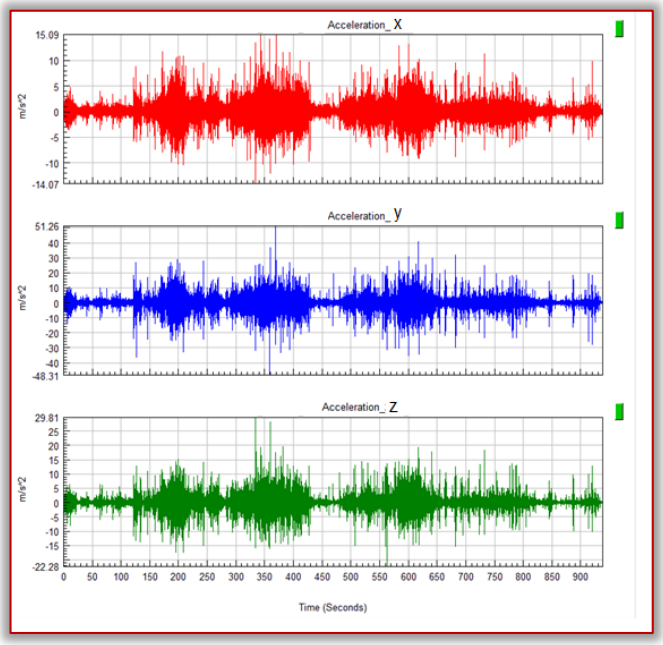


Figure 3. Vibrations evolution during transportation experiment for tractor's floor on dirt road

In figures 2 and 3 can be observed the random character of the recorded vibrations, due to the road conditions. However, the amplitudes are relatively low, and cannot affect the tractor's reliability. In table 1 are presented the vibration statistical parameters computed based on the recorded waves for vibrations, for all the transportation route. The values are reported for longitudinal and vertical direction, for both measuring points (electric tractor chassis and floor).

Table 1: Electric tractor statistic vibration data

Vibration data	X axis	Y axis	Z axis
	Tarmac road		
Maxim (m/s²)	21.69	50.34	28.54
Minim (m/s²)	-20.77	-45.73	-25.02
R.M.S (m/s²)	0.629	1.198	0.6165
	Dirt road		
Maxim (m/s²)	15.05	51.26	29.81
Minim (m/s²)	-14.07	-48.31	-22.28
R.M.S (m/s²)	1.035	1.932	1.138

In figure 4 and 5 are presented the power spectrums peak versus frequency, of the recorded vibrations in both conditions, tarmac and dirt road, with the identified frequencies and peaks. The amplitudes identified are really low, under 0.6 m/s² for both conditions, which means that the identified frequencies don't have an important impact on the total impact vibration data.

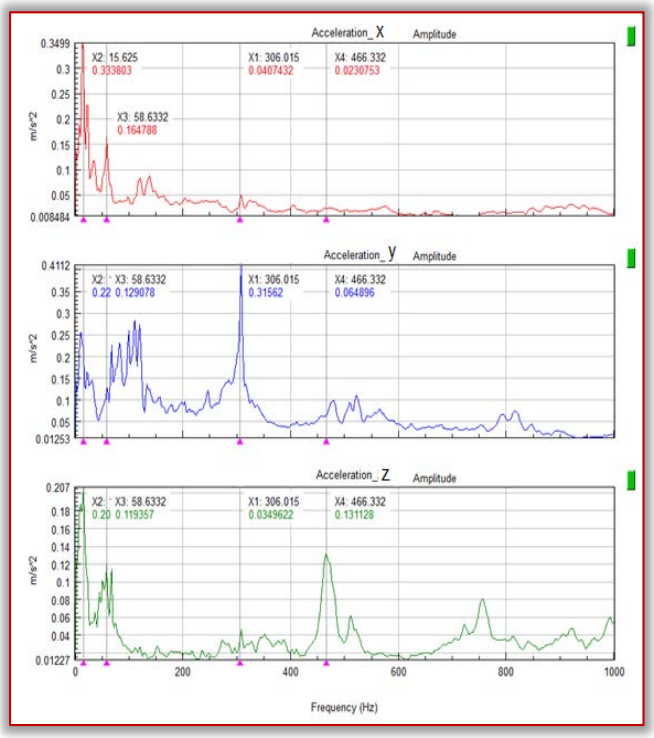


Figure 4. Power spectrum of vibrations during transportation experiment for tractor's floor on tarmac road

In figure 4 we can observe a high amount of small amplitude peaks, due to the higher test speed and to the leveled aspect of the road. In figure 5 we observe a smaller number of peaks but with higher amplitudes. This is due to the lower transportation speed and to a less leveled road. Biggest amplitudes are observed on the y axis, which corresponds to the vertical direction and which are accounted for the dynamic movement of the tractor's mass due to the bumps and holes which were present on the dirt road.

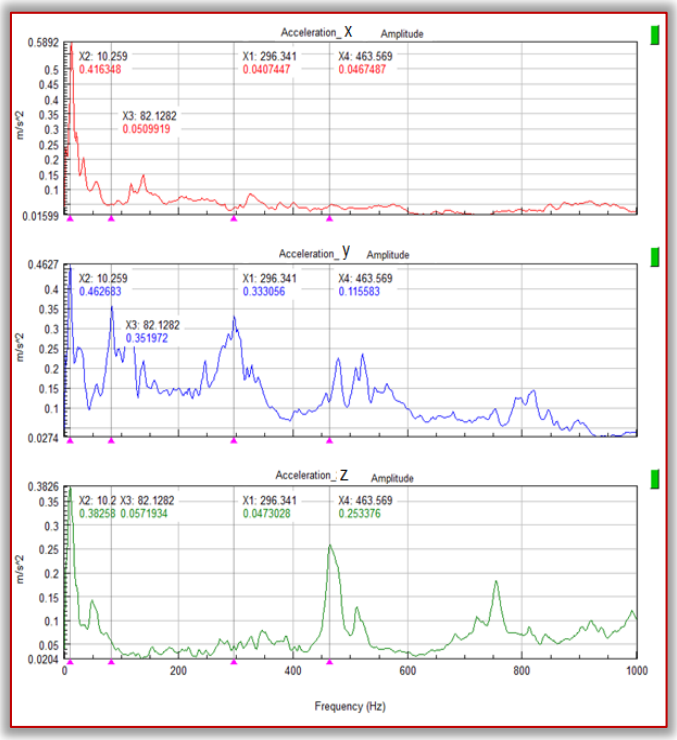


Figure 5. Power spectrum of vibrations during transportation experiment for tractor's floor on dirt road

CONCLUSIONS

The paper presented measurements performed for assessment of vibrations level for electric tractor during transportation work which allow for improving of safety conditions that has to be assured in order to mitigate vibration effects. The recorded vibrations had a random character, which was mainly provoked by the road characteristics, the electrical engine having no negative effect on the tractor's behavior.

The obtained results for the vibration level on the tractor's floor were under 2.5 m/s² r.m.s values. These results are under the attention limit, specified in European directive 2002/44/EC, meaning that the operator's integrity isn't endangered. Also, the obtained results assure the fact that the tractor's reliability isn't affected by vibrations during transportation work.

Acknowledgement

This work was supported by a grant of the Romanian Research and Innovation Ministry, through Sectoral Plan, contract no. 1PS/2019 and through Programme 1 – Development of the national research-development system, subprogramme 1.2 – Institutional performance – Projects for financing excellence in RDI, contract no. 16PFE.

References

[1] Scarlett A. J., Price J. S., Semple D. A., Stayner R. M. - Whole-body vibration on agricultural vehicles: evaluation of emission and estimated exposure levels, Silsoe Research Institute and RMS Vibration Test Laboratory for the Health and Safety Executive 2005
[2] Cutini M., Costa C., Bisaglia C., "Development of a simplified method for evaluating agricultural tractor's operator whole body vibration," Journal of Terramechanics, vol. 63, pp. 23–32, 2016
[3] Ene Gh., Pavel C., - Introducere in tehnica izolarii vibratiilor si zgomotului, Editura Matrix ROM, Bucuresti, 2012
[4] Enlai Zheng, Song Cui, Yuanzhao Yang, Jinlin Xue, Yue Zhu, Xiangze Lin, "Simulation of the Vibration Characteristics for Agricultural Wheeled Tractor with Implement and Front Axle Hydropneumatic Suspension", Shock and Vibration, vol. 2019, Article ID 9135412, 19 pages, 2019
[5] Griffin M.J., A comparison of standardized methods for predicting the hazards of whole-body vibration and repeated shocks, Journal of Sound and Vibration, Volume 215, Issue 4, 1998, Pages 883-914
[6] Lines J., Stiles M., Whyte R., "Whole body vibration during tractor driving," Journal of Low Frequency Noise, Vibration and Active Control, vol. 14, no. 2, pp. 87–104, 1995
[7] Monarca D., Biondi P., Cecchini M., Santi M., Guerrieri M., Colantoni A., Colopardi F., Transmission of vibrations from portable agricultural machinery to the Hand-Arm System (HAV): risk assessment and definition of exposure time for daily action and exposure limits, International Conference: September 15-17, 2008 Ragusa – Italy, "Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-food Systems".
[8] Sfîru R., Vlădut V., Cârdei P., Ciupercă R., Matache M., Stefan V., Ungureanu N., - Technical aspects regarding axles calculation of road transport means, Publishing house Lambert Academic Publishing, 2014
[9] Sorica, E., Vladut, V., Cardei, P., Sorica, C., Bracacescu, C., 2017. Comparative analysis of the noise and vibration transmitted to the operator by a brush cutter, Acoustics and Vibration of Mechanical Structures—AVMS-2017: Proceedings of the 14th AVMS Conference, pp. 165-172.
[10] EN ISO 5341 Mechanical vibration- Measurement and evaluation of human exposure to hand-transmitted vibration.
[11] Directive 2002/44/EC of the European Parliament and of the Council of 25 June 2002 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration) (sixteenth individual Directive within the meaning of Article 16 (1) of Directive 89/391/EEC)

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

[1.]Anjanaa DHRITLAHRE, [2.]Anu G. PILLAI

REDUCTION OF VOLTAGE SAG USING SRF THEORY CONTROL BASED DVR FOR POWER QUALITY ENHANCEMENT

[1,2.]Department of Electrical Engineering, College of Shri Sankaracharya Group of Institution Bhilai, University of CSVTU Bhilai, INDIA

Abstract: To make developed country, recent year India shift towards the research area for the development to lead the research. The main task of power system is to supply their customer a continuity power supply at ever, but in action it's not take place; because of the whole power system is the big network which includes different types of loads, at the instant of common compiling sensitive loads connected in which voltage distortion in supply side or load side is highly repellent. Voltage dip is the most frequent arising power quality issues mainly occurs in distribution system since it main causes disturbance for domestic and industrial equipment. In this paper the simulink model of DVR for reduction of voltage sag and its control by reference frame theory algorithm has carried in MATLAB simulink to enhance the power quality issues

Keywords: Power Quality, Voltage Sag, THD, DVR, Park Transformation, SRF Theory

INTRODUCTION

Electrical power system, power quality is extensive term to describe the effectiveness and its performances. Modern society goes to progress area and they interest not only the supply of power, but also the consistent and good quality of power supply hence reliability of system and quality of power this two is the most essential phrase of any power system, we know that assortment of the entire electric network modules in power system is related to generate the energy and this valuable energy transmit, distribute and utilize by different consumers according to their obligation. This complex network hundreds of generating location and loads center are unified, the power are primarily generated at power station and this power transmitted over long distance to a load center usually cities or towns and there are lots of way in which the lack of power quality difficulty affect consumers [1].

There can be absolutely different definitions for power quality "Any power difficulty manifested in voltage, current, or frequency deviations that outcome in collapse or misoperation of consumer equipment." Or power quality is a set of electrical restrictions that allow a part of apparatus to function in its proposed manner without the hammering of existences. [2-3].

Power quality problems include variety of trouble in the vein of voltage sag, swell, outage, voltage unbalances, flickers, harmonics, etc. out of this due to some faults voltage sag/swell frequently occurring power problems, harmonics distortion can harmful collision in a capable electric distribution system and can generate excessive amounts of heat causes collapse and failure. This entire power problem can affect the precision of utility gauge analysis, malfunctioning of equipments, and downtime and damage consequential loss of production [4]. In this paper synchronous reference frame (SRF) theory control algorithm based DVR is used to enhance the power quality problem, DVR is costume power device connected in series for the compensation of voltage related power quality issues hence reduction of voltage sag and harmonics present load side due to nonlinear load this device is used.

OPERATION AND WORKING OF DVR

The power quality problem begin within the site of common coupling due to the voltage fall in feeders and transformers, different kind of trouble, faults, use of nonlinear loads, etc affects the consumer. "Voltage sag is the incessantly arise conflict i.e. 10 to 90% for the short duration or 0.5 cycle, and to compensate voltage quality issues dynamic voltage restorer (DVR) is used."

Figure1 shows the DVR connected in feeder-2 in this parallel distribution feeder, when fault occurred in distribution feerder-1, voltage at feeder-2 will sag, without connection of DVR loss of production in power, failure and malfunctioning of equipment and consumer face the problems. DVR is the series allied apparatus; connect between distribution transformer and perceptive loads by revenue of security. Series compensator are used for both inject the voltage of essential magnitude and frequency or restorer the voltage across the load to save from harm the sensitive loads.

DVR used metal oxide semiconductor field effect transistor based pulse width modulation to inject the same and conflicting voltages of disorder to protect and uncontaminated synchronized voltage waveform crossways the sensitive loads. The waveform of injected voltage is variable, for production of varying voltage, PWM converters would require, DVR also consist low cost rectifier to support the dc bus can emulate the series line voltage to avoid the voltage dip[5-6].

Figure 2 shows the phasor diagram of voltage injection scheme of DVR, 'VL' (Pre-sag) is the voltage across the sensitive load at sag condition, for the duration of sag situation voltage reduce to 'Vs' at angle of Ø. According to the phase angle of the load voltage, the injection of voltages can be realized; in phase with the supply voltage VC1 represents the voltage injection. With the injection of VC2, the magnitude of load voltage remains same, but it leads supply voltage Vs by a small angle. In VC3, the load voltage retains the same phase as that of the pre-sag condition [7].

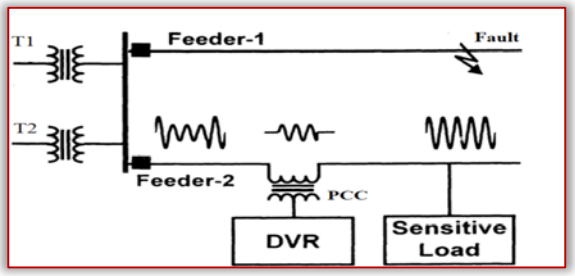


Figure 1. Connection of DVR to reduce voltage sag.

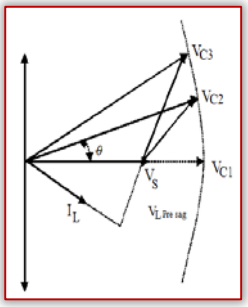


Figure 2. Phasor diagram of voltage injection scheme for DVR.

CONTROL ALGORITHM OF DVR

The control algorithm of DVR is the based on evaluation of reference load voltage for power quality enhancement in distribution system.

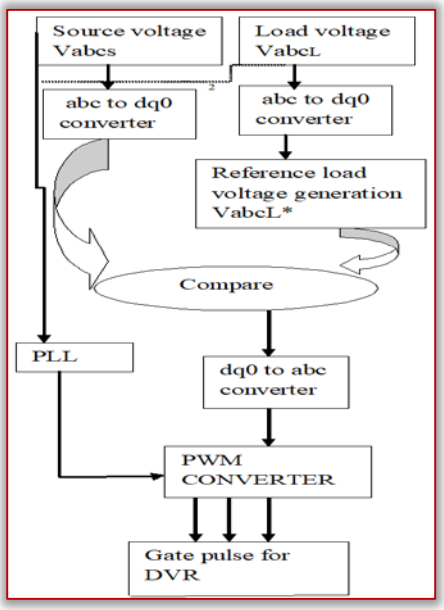


Figure 3. Flowchart of Control Algorithm of DVR

Figure 3 shows the flowchart of control algorithm of DVR in which estimation of voltage sag; synchronous reference frame theory is used. 'In synchronous reference frame theory the voltage (Vs) at the position of common coupling, and the terminal load voltage (VL) sensed to derive the MOSFET gate signal. The reference load voltage (V^*_{abcL}) are extracted using the consequent unit vector.

The amplitude of load voltage at the spot of common coupling is deliberate as

$$V_L = \sqrt{2/3(V_{La}^2 + V_{Lb}^2 + V_{Lc}^2)} \quad (1)$$

Unit vector is calculated as

$$\begin{bmatrix} U_a \\ U_b \\ U_c \end{bmatrix} = 1/V_L \begin{bmatrix} V_{La} \\ V_{Lb} \\ V_{Lc} \end{bmatrix} \quad (2)$$

Where V_{La}, V_{Lb}, V_{Lc} is the load voltage.

Now reference load voltage are calculated as

$$\begin{bmatrix} V^*_{aL} \\ V^*_{bL} \\ V^*_{cL} \end{bmatrix} = V^*_L \begin{bmatrix} U_a \\ U_b \\ U_c \end{bmatrix} \quad (3)$$

Where V^*_L is the reference value of magnitude of the load Voltage?

The load voltage is converted into the reference voltage by using of abc-dq0 adaptation using park transformation with unit vector derivative with the help of phase locked loop [8].

Park transformation is derived as:

$$\begin{bmatrix} V_{Ld} \\ V_{Lq} \\ V_{Lz} \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \sin\omega t & \sin(\omega t - 2\pi/3) & \sin(\omega t + 2\pi/3) \\ \cos\omega t & \cos(\omega t - 2\pi/3) & \cos(\omega t + 2\pi/3) \\ 1/2 & 1/2 & 1/2 \end{bmatrix} \begin{bmatrix} V_{La} \\ V_{Lb} \\ V_{Lc} \end{bmatrix} \quad (4)$$

Similarly the reference voltage and source voltage at PCC is also renewed into the abc-dq0. Now the DVR voltage is achieve as

$$V_{Cd} = V_{ds} - V_{dL}$$
$$V_{Cq} = V_{qs} - V_{qL}$$

Reference DVR voltage are obtain as

$$V^*_{Cd} = V_{dr} - V_{dL}$$
$$V^*_{Cq} = V_{qr} - V_{qL}$$

The DVR voltage as the fame of 'abc' is obtain by using reverse park transformation

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} \sin\omega t & \cos\omega t & 1 \\ \sin(\omega t - 2\pi/3) & \cos(\omega t - 2\pi/3) & 1 \\ \sin(\omega t + 2\pi/3) & \cos(\omega t + 2\pi/3) & 1 \end{bmatrix} \begin{bmatrix} V_d \\ V_q \\ V_z \end{bmatrix} \quad (5)$$

This DVR voltage is use in the PWM controller to generate the gate signal, PWM controller works with the constant switching frequency. Phase lock loop is an electronics path consisting of a phase detector that evaluates the phase of signal with the phase of input signal to maintain the phase coordinated.

SIMULINK MODEL

Simulink model for test system considers in which two parallel feeder are cleared show in Figure4a In this model the three-phase to ground fault and double line to ground fault is created in feeder-1 at the duration

of 0.15 sec (0.4sec to 0.55 sec) and Figure4b shows the simulink model of test circuit with a dynamic voltage restorer connected in feeder-2.

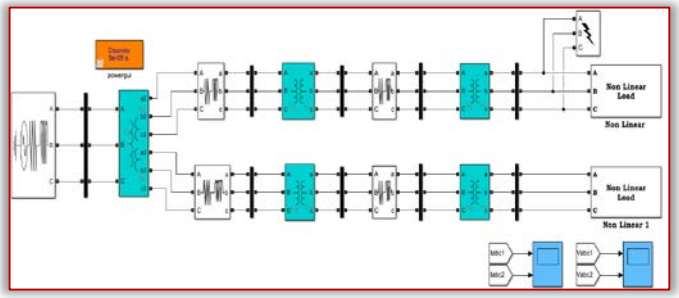


Figure 4a. Simulink model of test system without custom power device

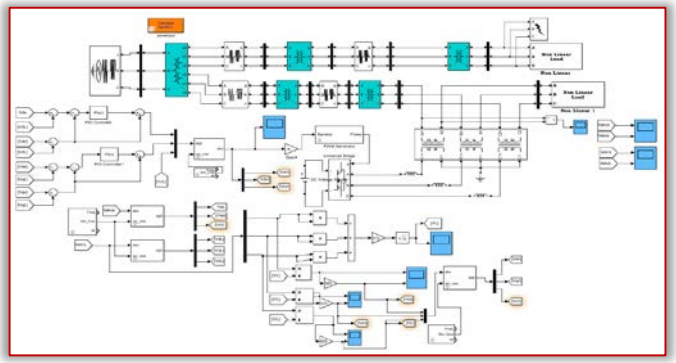


Figure 4b. Simulink model of SRF control based DVR for reduction of voltage sag.

RESULT AND DISCUSSION

Dynamic voltage restorer is the piece of equipment used for the reduction of a different power quality issues, reference theory control algorithm is used to control of DVR in manner to inject the required control voltage for voltage sag alleviation. In Simulink model the three phase to ground fault is created in f-1 sag is automatically occurred in adjacent feeder-2 shows Figure 5a.

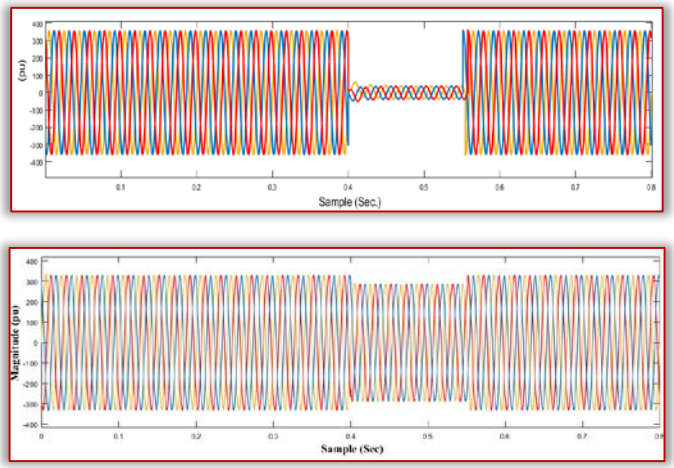


Figure 5a. 1)Load voltage where three phase to ground Fault occurred, 2)Load voltage of adjacent feeder.

To overcome this power quality problem (voltage sag) SRF control algorithm based control of DVR is used. The performance of the DVR is demonstrated under the supply voltage Figure4b shows the performance of DVR under voltage sag condition, when fault created in parallel feeder-1 for the duration of 0.15sec, at the same duration the voltage sag involuntarily occurred in adjacent feeder-2. The source voltage, load voltage, voltage injected by DVR, The reference voltage (VL*), dc bus voltage are depicted in Figure5b.

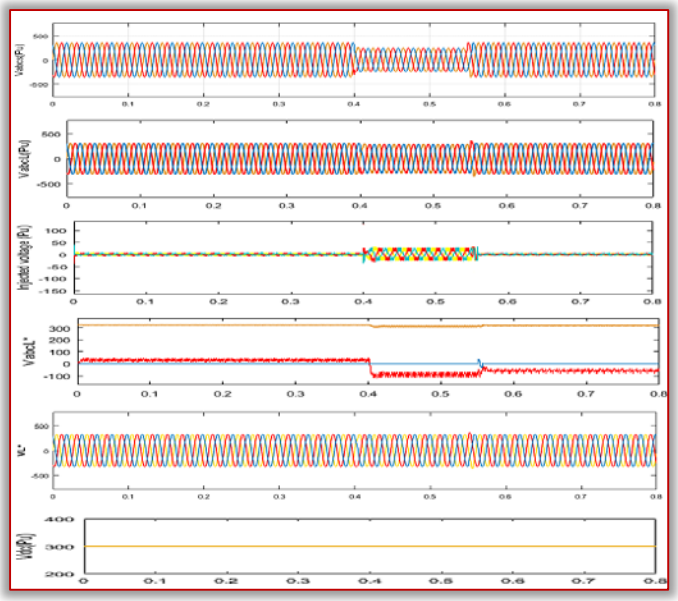


Figure 5b. Performance characteristics of SRF control based DVR for voltage sag when three phase to ground fault occurred.

DVR with its control algorithm is connected in feeder-2 between the distribution transformer and the load. All the parameter for the three phase parallel distribution system data specified in appendix A. The load voltage is maintained sinusoidal by injected the recompense voltage of DVR. DC bus voltage is persistent constant at the value of 300 volt and terminal voltage is at is practical at the reference value according to the peak value of source voltage. The performance of total harmonics distortion at the fundamental frequency of (50Hz) also carried in Figure 5c the THD for the 20 cycle out of 40 cycles is observed 2.69%.

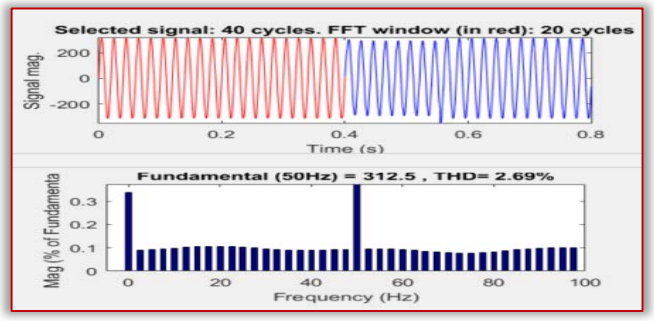


Figure 5c. The performance of harmonic by FFT analysis.

Figure 5d shows the load voltage where double line to ground fault occurred in feeder 1, the voltage sag automatically occurred in adjacent feeder at the same duration, source voltage , load voltage, injected voltage are depicted in Figure 5e.

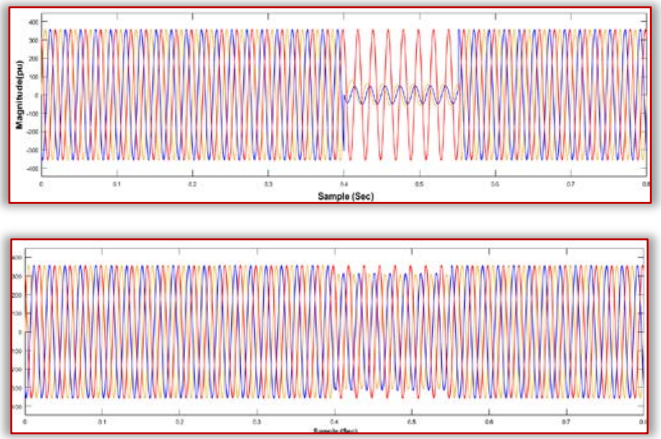


Figure 5d. 1)load voltage where double line to ground fault occurred; 2) load voltage at ajacent feeder.

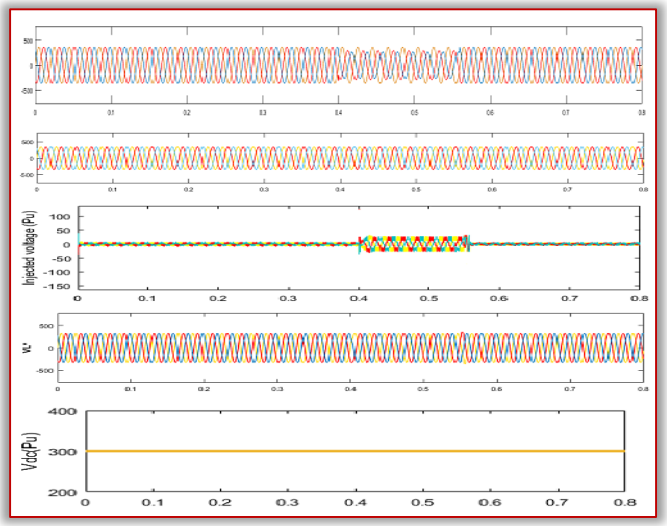


Figure 5e. Performance characteristics of SRF control based DVR for voltage sag when double line to ground fault occurred.

The performance of for voltage sag mitigation is shown where the source voltage for DVR is consider 440 volt whose peak value is obtain as: $V_{peak} = 440 \times 0.8 = 352$ volt. Hence the reference load voltage (V_L^*) is obtain according to this peak value of the source voltage, all this performance the voltage sag reduced and power quality can be enhanced.

CONCLUSION

The increasing use of sensitive loads power quality problem and its mitigation to enhance power problem today its most important research area. Voltage sag is the frequently stirring power problem manifested in consumer load side. DVR is the series connected custom power device use for the reduction of voltage related disturbances and effective device for sensitive load. The simulation result shows that voltage sag is compensated with the permissible THD with the help of DVR. SRF control technique is used to control the DVR to obtain an injected voltage, with the help of park transformation the reference voltage is calculated and to generate a gate pulse the PWM controller is used and to maintain a phase coordination between input and output the phase lock loop is required. All this performance condition is demonstrated in MATLAB simulink.

Appendix

The parameter consider for test system: Ac source feeder: 33kv, line frequency: 50Hz, Power transformer: 33/66kv, Distribution transformer: 33e3/440 volt, consumer load: single phase bridge rectifier with R= 6 Ω, L = 0.15e-3H.

The parameter for the DVR Source voltage: 440 volt frequency 50 Hz, PCC Transformer Ratio: 1:3 ,DC bus: 300 volt, inductance L = 0.008H.

List of Abbreviation

SRF - Synchronous reference frame
PWM - Pulse width modulation
DVR - Dynamic voltage restorer
PCC - Point of common coupling
MOSFET - Metal oxide semiconductor field effect transistor

References

[1] Arindam Gosh and Gerard Ledwich, "Power Quality Enhancement using Custome Power Devices", Kluwer Academic Publishers group Dordrecht, 2002.
[2] Roger C. Dugen and Surya Santoso, "Electrical Power System Quality" MC Grow Hill componie, 2004.
[3] C. Sankaran, " Power Quality" CRC Press Boca Raton London New York Washington, 2002, ch.-1.
[4] Kusko, Marc T.Thompson, "Power Quality In Electric System", Mc Grow Hill Componie New York, 2007. DOI: 10.1036/0071470751. Ch. 3,8,10.
[5] Mohammad Imran, S.M.Kulkarni, "Dynamic Voltage Restorer for Mitigation of Voltage Sag and Swell", International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS-2017), Pp. 3333-3335.
[6] Amir Hameed Abed, Javad Rahebi, Ali Farzamnia, "Improvement for Power Quality by using Dynamic Voltage Restorer in Electrical Distribution Networks", IEEE-2017, 2nd International Conference on Automatic Control and Intelligent Systems (I2CACIS 2017), 21 October 2017, Kota Kinabalu, Sabah, Malaysia, Pp. 122-127.
[7] Prasad A. Raut, Manohar N. Kalgunde, "An Overview And Design Of Dynamic Voltage Restorer To Improve Power Quality In Microgrid", IEEE-2015 International Conference on Energy Systems and Applications (ICESA 2015) Dr. D. Y. Patil Institute of Engineering and Technology, Pune, India 30 Oct - 01 Nov, 2015, PP. 632-635.
[8] J. Bangarraju, K Amritha, " Unit Vector Of SRF Control Algorithm Based DVR For PQ Improvement", IEEE-2017 international conference on smart technology for smart nation. Pp. 1160-1165.
[9] Bhim singh, ambrish chanda, " Power Quality Problem And Mitigation Techniques", john wiley and son ltd 2015, first addition.

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

[1.]Mariana Mirela STĂNESCU

EXPLORING CWT BASED ALGORITHM AS ADDITIONAL AND ACCURATE TOOL FOR DETECTING ECG ABNORMALITIES

[1.]Faculty of Applied Sciences, Polytechnic University of Bucharest, ROMANIA

Abstract: The wavelet transform has emerged in recent years as a key tool for time–frequency analysis and coding for ECG. The main advantage of this type of detection is that less time is allocated for processing the ECG signal with the continuous wavelet transform Db 5 (CWT). This paper aims to investigate a Db 5 continuous wavelet transform (CWT) analysis for selected ECG signals from the St.Petersburg Arrythmia Database. The results revealed that the flattened QRS complex and P and T waves containing low frequencies can be easily observed. The research findings emphasized the potential of Db5 technique as a powerful supplementary tool to investigate ECG features. This option can moderate rapid and precise diagnosis of cardiac diseases.
Keywords: ECG features, coronary disease, ischemia, Db wavelet, MATLAB

INTRODUCTION

The electrocardiogram (ECG) is a graphical recording of the direction and magnitude of heart electrical activity, which is generated by depolarization and repolarization of atria and ventricles. ECG recording analysis is a subjective and difficult process due to its small graphical dimensions. Most of the time it is done in a very short time, imposed by the severity of the anomaly and the speed with which decisions must be made. Fine changes, even the very little obvious ones of the electrical potential for repolarization and depolarization are valuable indicators of the many diseases. Most useful information for ECG diagnostics is found in amplitudes of the P–QRS–T waves. The normal ECG waveform and anomalous waveforms are represented in Figures 1–3.

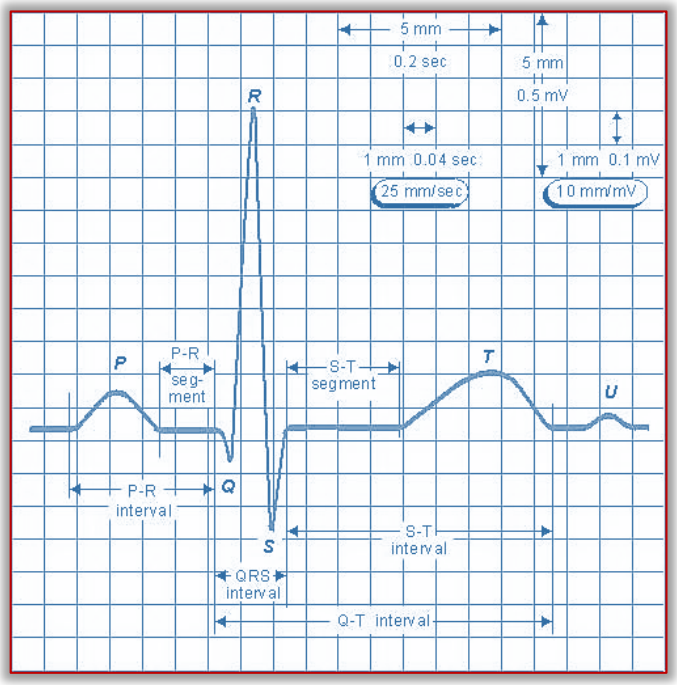


Figure 1. Normal ECG wave values. [1]

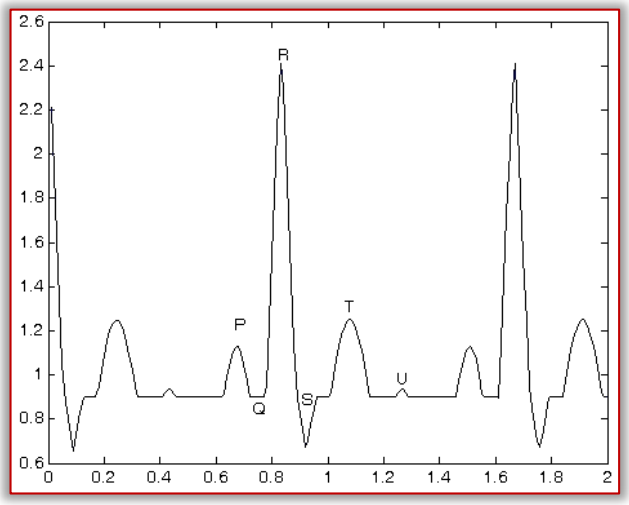


Figure 2. Normal sinus Rhytm.[2]

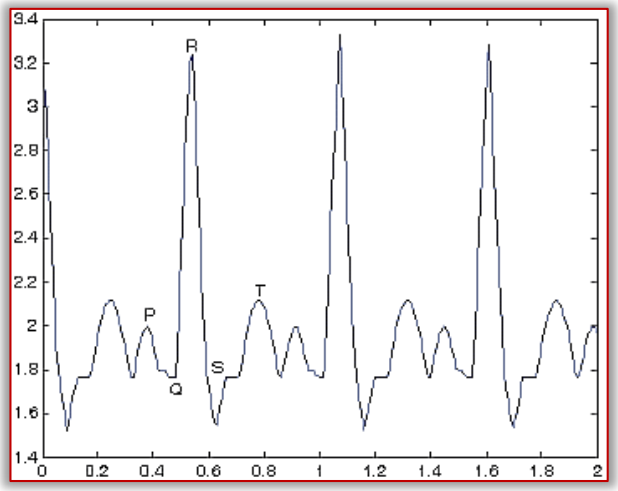


Figure 3. Sinus tachycardia. [2]

The P wave is the electrical fingerprint of the current that causes the atrial contraction. The QRS complex corresponds to the current that produces the ventricular contraction. Their repolarization generates the T wave, and the U wave, not always visible, is considered to be the representation of the activity of Purkinje fibers. The presence or absence of

these, as well as QRS and PR intervals, are significant parameters in the screening and diagnosis of cardiovascular disease.
The various cardiac abnormalities can be recognized according to ECG parameters (table 1).

Tabel 1. ECG parameter values related to cardiac diseases. [3]

1. Dextrocardia	P–wave inverted
2. Tachycardia	interval R–R < 0.6 s, QRS between 0.1 şi 0.12 s
3. Bradycardia	interval R–R > 1 s
4. Hyperkalemia	high T–wave P–wave absent
5. Myocardic Ischaemia	T–wave inverted
6. Hypercalcaemia	QRS interval < 0.1 s
7. Sinoatrial blockade	A complete absence of the cardiac cycle
8. Supraventricular tachycardia (SVT)	QRS greater than 0.12 s, long duration of P wave (over 80 ms)
9. Right or left branch block (BBB)	QRS greater than 0.12 s
10. Paroxysmal atrial fibrillation	P–wave length (over 80 ms)
11. Left ventricular hypertrophy	R peak over 2.6 mV in V5

Martis et al. [4] analyzes various computer–assisted cardiac diagnosis systems (CACD), methods of analysis, challenges for the future of cardiovascular disease screening.
These methods, (including wavelet transforms), cannot alone accurately represent the inherent characteristics, but can serve as combined tools and help clinicians diagnose cardiovascular disease more precisely.
In recent years, the wavelet transform has become one of the topics in signal theory, which has enjoyed a big interest from numerous research groups. The multi–resolution analysis techniques, especially those based on the wavelet transform, have successfully become useful practical approaches.
The analysis of biomedical signals (ECG, EEG, EMG), solving differential equations or noise filtering are some of the areas of applicability of the functions called "wavelet".
In the 19th century, the French mathematician J. Fourier, showed that any periodic function can be expressed as an infinite amount of complex periodic exponentials. This property of functions was first applied to non–periodic functions, then to discrete periodic and non–periodic signals, becoming an appropriate tool for calculations. In 1965, a new algorithm called Fourier Transform (FFT) was developed. [5].
The wavelet transform WT is defined as a convolution of the wavelet function $\psi_{a,b}(t)$, with signal x (t) [3]. The dyadic discrete orthogonal wavelet functions are associated with the scaling functions φ (t). The scaling function can produce the approximation coefficients a by convolution with the signal. The continuous wavelet transform (CWT) is given by the relationship:

$$C_{a,b} = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} x(t) \psi^*_{a,b} \left(\frac{t-b}{a} \right) dt \qquad (1)$$

By choosing an orthonormal wavelet function basic $\psi_{a,b}(t)$, the original signal can be reconstructed [6]. Wavelet $\psi_{a,b}(t)$ is translated by b and dilated by the factor scale a (a > 0).
The CWT map x(t) is a two variables function C (a, b) that can be utilized to compare the original signal and a wavelet scaled by a at a given time b.
The commonly chosen set of scales is the dyadic scale, where $a = 2^b$ for b=1, .. N.
An important aspect is the choice of a wavelet function that closely matches the signal to be processed [7]. A continuous function can be decomposing more efficiently via basic wavelet functions; thus edge artifacts are avoided. The wavelet function "mother" keeps the signal details, and the evolution information is stored in the coefficients obtained by decomposing the function "father".
Daubechies wavelet functions are the best option for analyzing biosignals characterized by a sharp peak because they have much less energy stored in the high band. Daubechies wavelets implemented numerically via square filters provide adequate processing results. The large filters give a better energy concentration than those given by small filters.
ECG is a graphical recording of the direction and magnitude of electrical activity, which is generated by depolarization and repolarization of atria and ventricles (Figure 1). Most useful information for ECG diagnostics is found in the ranges and amplitudes of the P–QRS–T waves.
The development of the methods of automatic extraction of accurate and rapid information characteristic of ECG is of major importance for the long term analysis of ECG signals [7]. ECG features can be extracted and used in the subsequent automatic analysis.
One of the practical benefits of the ECG wavelet–based approach is related to the diagnosis of transient ischemia, namely the fact that the T–wave anomaly it can be evaluated without the need to identify the final point [7].
Another major advantage of the wavelet transform is its ability to highlight the details of the optimal frequency–time ECG signal. The peaks of the flattened QRS complexes and the P–T waves containing lower frequencies become more visible [3].
Daubechies 6 (Db6) functions have similar shape to the QRS complex and their energy spectrum is concentrated around low frequencies [8]. Figure 4 shows the details of an ECG signal with a short series of noise added at its end, decomposed with D6

wavelets. The original signal X is displayed on the top. Most of the signal details are kept at scale 2^5, the high–frequency noise is captured at the smallest scales, namely 2^2 and 2^1. The signal details at scale 2^5 reflect the similarity of the Db6 with the QRS complex.

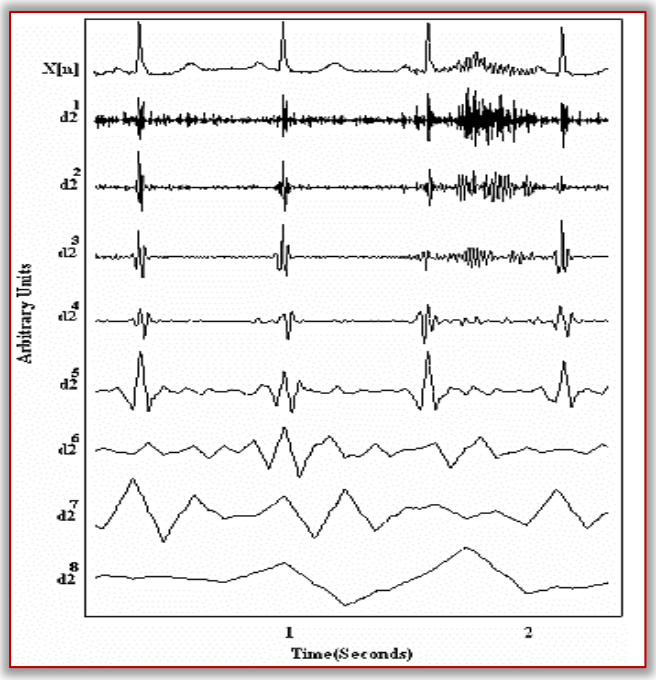


Figure 4. The original ECG signal (X) and decomposed with Daubechies D6 wavelet/different scaling orders $d2^m$ [3].

Another ECG–shape suitable wavelet is Db5 (Figure 5).

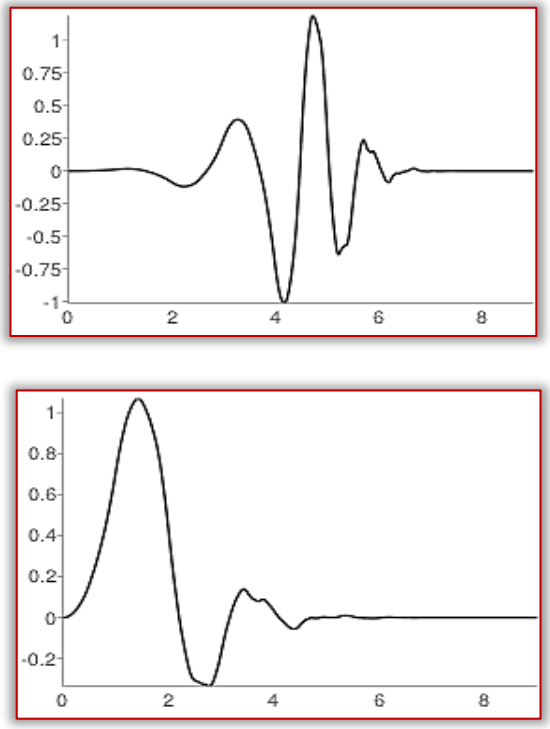


Figure 5. Wavelet and scalar function forms for Daubechies 5. [9]
(a) Wavelet function ψ DB5, (b) Scaling function φ

The detection of P wave, QRS complex and T wave in an ECG signal is a difficult problem due to the variation in time of signal, physiological conditions and the presence of noise. Senhadji et al [8] compared the potential of different types of wavelets (Daubechies, splines and Morlet) to recognize and describe isolated heartbeats. Sahambi et al [6,10], used dyadic wavelet maxima analysis to detect and measure different features of the signal, especially QRS localization, P and T waves. The algorithm was validated as a method of determining ECG signal synchronization intervals, including QRS. Romero Legarreta et al [11] used the continuous wavelet transform (CWT), which offers high time–frequency resolution, better definition of the maximum values of QRS parameters.

In a study with D4 transform, Pichot et al [12] analyzed the night heart rhythm of subjects who performed tiring exercises for three weeks, with a resting week. This rhythm had a significant progressive decline during the study. Gamero et al [13] reported that Daubechies D12 wavelet used in myocardial ischemia analysis is an important tool for dynamic assessment of ECG parameter changes.

Chen [14], using Daubechies D8 DWT, found that sympathovagal balance, estimated by the low and high (LF / HF) frequencies, increases before the onset of unsupported ventricular tachycardia.

In recent studies, potential of NN classifiers is exploit for the automatic detection and classification of ECG parameters [15,16]. Al–Fahoum and Howitt [15] proposed a network for the automatic detection and classification of arrhythmias that employ ECG preprocessing using Daubechies D4 wavelet. They obtained the correct classification of 97, 5% arrhythmias from a data set of 159 arrhythmia files from three different sources, with the correct classification of 100% for both ventricular fibrillation and ventricular tachycardia.

METHODOLOGY

Based on literature documentation, an investigation was designed centered on the idea that Db5 of the Daubechies family, are suitable for studying the characteristic ECG parameters for different cardiac diseases and normal signal.

The importance of this research lies in shedding light on the status quo of the complementary techniques of ECG processing among the signal and image in real–time evaluation. The research findings may hold benefits to fast investigation of ECG features and rapid and precise interpretation diagnosis of cardiac diseases.

The samples used were original records collected from patients with coronary heart disease (17 men and 15 women, ages 18–80; average age: 58 years, included in St. Petersburg Arrythmia Database [17]. These signals were chosen for the pathological features,

which could be studied with this type of wavelet. Like all signals from the Physionet database, these sample recordings are noted for normal heart rate, RR intervals, presence of premature atrial (APC) and ventricular (PVC) contractions), tachycardia and bradycardia episodes, branch blockages (BBB; RBBB; LBBB), etc.

The experimental group comprises sequences of ECG signals, coming from:

- patients with normal heart (P4 and 6) – further noted with N;
- patients with coronary heart disease and hypertension (noted with CAD);
- patients with a transient ischemic attack (noted with TIA).

For this purpose were selected various sequences of ECG, recorded at the V5 level (precordial). This channel was chosen for several reasons: here begins the S wave; in V5 it can be measured the duration of the QT interval; V5 is often used as a reference for different values of the ECG parameters (for example, the R wave with a value greater than 2.7 mV is a sign of left ventricular hypertrophy (LVH).

The sampling frequency of these signals is 257 Hz. The sample signals were processed with the continuous wavelet transform Db 5 (CWT), Matlab for Windows Professional. The frequency and energy spectra of the reconstructed signals are highlighted and compared with those of the normal signal.

EXPERIMENTAL RESULTS AND DISCUSSIONS

The ECG signals with coronary heart disease and hypertension (CAD) and transient ischemic attack (TIA) analyzed with CWT were compared with those of normal signals. The various abnormalities are highlighted by the changes in the value of the coefficients. [18]

The main categories of data obtained are revealed in Figures 6–9. Local maxima (or minima) have been detected after wavelet transformation, at different levels, occurring at different times during the cardiac cycle.

The decomposition of the input signal highlights the different frequency content of characteristic ECG waves so that they are distinguished by decomposition at different scales.

The wavelet transform is suitable for approaching ECG signals, characterized by high–frequency components with short durations and low–frequency components with long durations. [19]

We observe the ordered and symmetrical form of the local maxima lines in the case of the normal rhythm, versus the variable interval and the distribution of maxima lines in the case of the signal 1 (CAD, HTA). The dashed lines highlight the disturbances in ECG form.

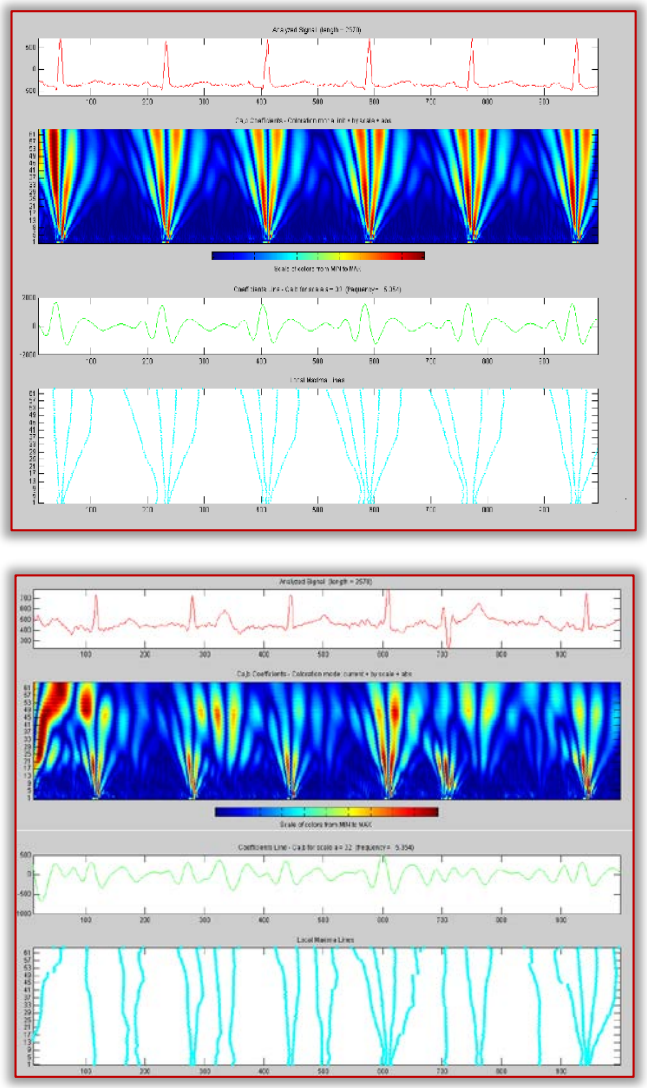


Figure 6 – Spectrogram for signal 12, normal sinus rhythm (top) and signal 1, patient with CAD and HTA (bottom)

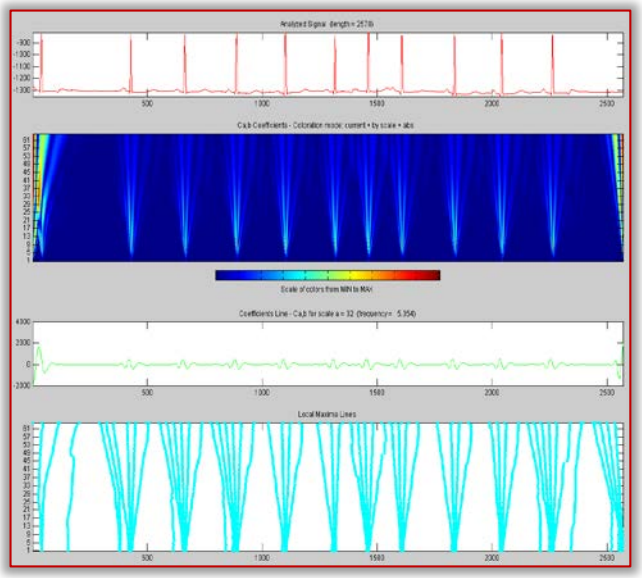


Figure 7 – Energy spectrogram of the QRS complex for ECG signal 20, with ventricular couplings, premature atrial contractions (APCs), atrial couplings, paroxysmal tachycardia

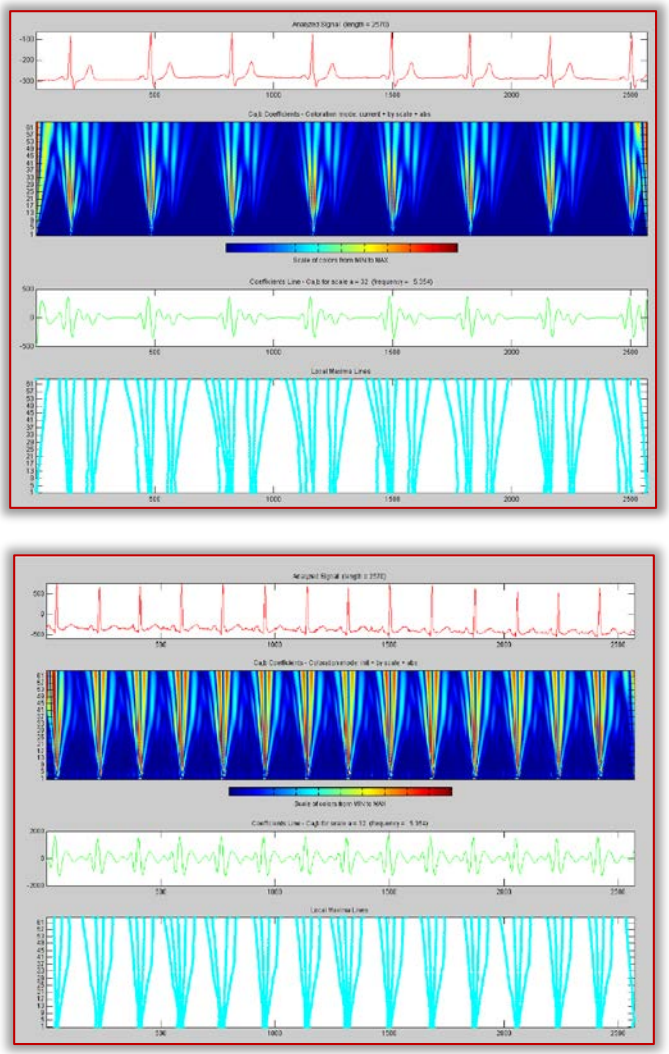


Figure 8 – Spectrogram ptr. Signal 16, TIA, with RBBB, polymorphic PVC (top). Normal sinus rhythm bottom

It easy to notice the different sizes of the R–R intervals and the large value of the T–wave amplitude (which appears in the spectrogram as a "shadow" of the QRS complex) (Figure 8)

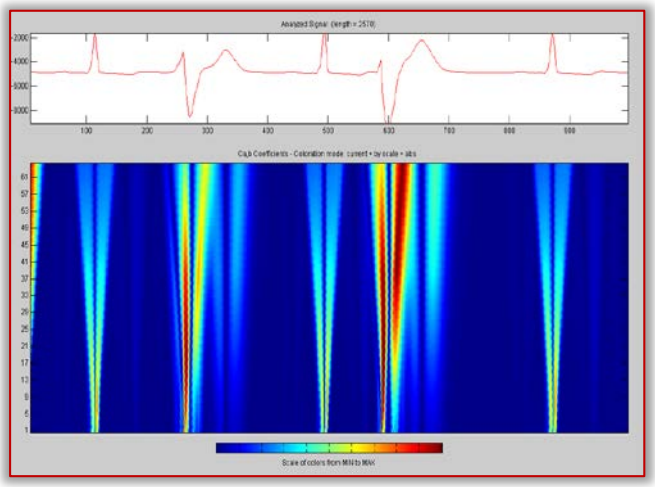


Figure 9 – Spectrogram ptr. Signal 72, CAD, with PVC and tachycardia couplings

The characteristic of this signal (Figure 9) is the sharp form of the P wave, the high R–R rhythm and the long duration of QRS (bradycardia). It should be noted that the shape of the QRS complex is atypical, with the Q wave almost absent, relatively small value of the R wave, deformation of the ST segment, high value of the T wave.

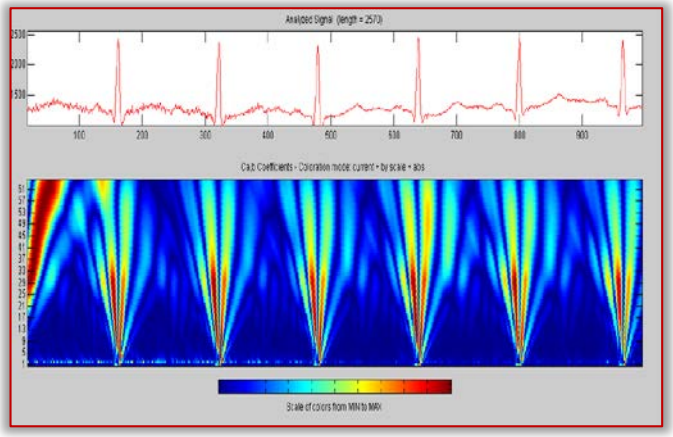


Figure 10 – Spectrogram for ptr. Signal 57, CAD, ventricular coupling (VC) of tachycardia

In this case (Figure10) it is evident the deformation of both pre and post QRS waves, ie P and T.

In all cases, the flattened QRS complex and the P and T waves containing low frequencies can be easily observed. At the same time details appear on small scales about the high frequency spectrum of the signal.

CONCLUSIONS

The wavelet transform has emerged in recent years as a key tool for ECG time–frequency analysis and coding. The main advantage of this type of detection is that less time is allocated for processing the ECG signal.

The choice of the Db5 transform was made after rigorous research of the recent results in ECG processing with different families of Wavelet. Although the Daubechies wavelet algorithm is conceptually more complex and requires a larger volume of calculation, its advantage is that it takes over the detail, which is lost by other Wavelet transforms. Db5 continuous wavelet transform (CWT) of selected signals from the St.Petersburg Arrythmia Database revealed that the flattened QRS complex and P and T waves containing low frequencies can be easily observed and analyzed. At the same time, details about the high–frequency spectrum of the signal appear on small scales.

The practical benefit of wavelet–based experimental approaches is that T–wave anomalies can be detected without the necessity to identify the initial and final T–wave moments. Also, it can be emphasized the choice of the Db families is also conditioned by the spectrum of frequencies, values and orientations of the ECG characteristic parameters we want to study. This is at the same time a major disadvantage of this technique.

The findings of this paper show the ability to separate the relevant signal components and emphasized the wavelet–based techniques potential in case of particular medical field–interpreting the pathology of CAD and TIA diseases. This present Db5 approach can complements other minimally invasive investigation and diagnostic techniques, like neural network algorithms.

In order to improve and point out the clinical utility of this processing technique as a diagnostic and prognostic tool in different fields of cardiology, laborious future studies must be incorporated.

Acknowledgment

The author declared no potential conflicts of interest for the research, authorship, and/or publication of this article. This research did not receive any specific grant from funding agencies in the public, commercial, or not–for–profit sectors.

References:

[1] Malmivuo, J., Plonsey, R., Bioelectromagnetism–Principles and aplications of bioelectric and biomagnetic fields, Oxford University Press,1995
[2] Saritha, C., Sukanya, V., Narasimha Murthy, Y., ECG signal analysis using wavelet transforms, Bulgarian Journal of Physics, 35, 2008, pp. 68–77
[3] Mahmoodabadi, S. Z. , Ahmadian, A., Abolhasani, M.D., Eslami, M., ECG Feature Extraction Based on Multiresolution Wavelet Transform, Proceedings of the 2005 IEEE Engineering in Medicine and Biology 27th Annual Conference Shanghai, China, 2005
[4] R. J. Martis, U. R. Acharya and H. Adeli, Current method in electrocardiograph characterization, Computers in Biology and Medicine, 48, 2014, pp.133–149
[5] http://users.rowan.edu/~polikar/WAVELETS/WTpart1.html
[6] Sahambi J., S., Tandon, S.M., Bhatt R.K.P., Using wavelet transforms for ECG characterization: an on–line digital signal processing system, 1997a, IEEE Engineering in Medicine and Biology,16, pp. 77–83
[7] Mahmoodabadi, S.Z., Ahmadian, A., Abolhasani, M.D., ECG feature extraction using Daubechies wavelets, Proceeding of the fifth IASTED International Conference, Benidorm, Spain, 2005
[8] Addison, P. S., Wavelet transforms and the ECG: a review, Physiological Measurement, 26, 2005, pp. R155–R199
[9] http://wavelets.pybytes.com/wavelet/db5/
[10] Sahambi J.S., Tandon, S.M. and Bhatt R.K.P., Quantitative analysis of errors due to power–line interference and base–line drift in detection of onsets and offsets in ECG using wavelets, Medical & Biological Engineering & Computing, 1997b, 35, pp. 747–751
[11] Legarreta, I., Addison P.S., Reed, M.J., Grubb, N.R., Clegg, G.R., Robertson C.E., Watson, J.N., Continuous wavelet transform modulus maxima analysis of the electrocardiogram: beat–to–beat characterization and beat–to–beat measurement, 2005, International Journal of Wavelets, Multiresolution and Information Processing, 3, pp. 19–42
[12] Pichot V., Bourin E., Roche F., Garet M., Gaspoz J.–M., Duverney D., Antoniadis A., Lacour J.–R., Barthelemy J.–C., Quantification of cumulated physical fatigue at the workplace Pflugers Arch.– European Journal of Physiology, 2002, 445, pp. 267–72
[13] Gamero, L.G., Vila, J., Palacios, F., Wavelet transform analysis of heart rate variability during myocardial ischemia, Medical & Biological Engineering & Computing, 2002, 40, pp. 72–8
[14] Chen, S.W., A wavelet–based heart–rate variability analysis for the study of nonsustained ventricular tachycardia, IEEE Transactions On Biomedical Engineering, 2002, 49, pp. 736–42
[15] Al–Fahoum A. S., Howitt, I., Combined wavelet transformation and radial basis ne ural networks for classifying life–threatening cardiac arrhythmias, Medical & Biological Engineering & Computing. 1999, 37, pp. 566–73
[16] Ritu Singh, Rajesh Mehta, Navin Rajpal, Efficient wavelet families for ECG classification using neural classifiers, Procedia Computer Science, 132, 2018, p. 11–21
[17] www.physionet.org/physiobank/database/incartdb/
[18] H.M. Arunkumar, A. Padmanabha Reddy, Wavelet scalogram for detection of R–peaks in noisy ECG, Signal International Journal of Innovative Technology and Exploring Engineering, 8 (10), 2019, pp. 132–36
[19] Moga, M., Moga, V.D., Luca,C., Mihalas,Gh., Wavelets as methods for ECG signal processing, Romanian journal of internal medicine, 42(1), 2004, pp. 217–24

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

[1.]Andjelko ALEKSIC, [2.]Milenko SEKULIC, [3.]Borislav SAVKOVIC,
[4.]Marin GOSTIMIROVIC, [5.]Ilija KAMENKO, [6.]Pavel KOVAC

OPTIMIZATION OF CUTTING PARAMETERS BY NATURE-INSPIRED ALGORITHMS

[1-6.]University of Novi Sad, Faculty of Technical Sciences, Novi Sad, SERBIA

Abstract: The surface roughness is very important factor for product quality. This paper presents an approach for determining the optimum machining parameters leading to minimum surface roughness during face milling process by nature-inspired algorithms. Face milling experiments were conducted on a vertical-spindle milling machine and experimental data were collected based on a three-factor-five-level design of experiment. The developed regression model for surface roughness was used to obtain optimal cutting parameters by nature-inspired algorithms (GA, PSO, and ACO). The analysis of this paper shows that these algorithms are capable of predicting the optimum cutting parameters.
Keywords: optimization, cutting parameters, nature-inspired algorithms

INTRODUCTION

Optimization is the process of defining the most favorable solutions for given initial conditions, from a set of possible solutions. It can be said, there is no area of human activity, system or process which cannot be optimized

A wide range of optimization methods and algorithms are used to solve the optimization parameters of cutting. Different subdivisions of these methods and algorithms can be found in the literature. Optimization algorithms can be classified into two different types by the opinion of some authors [1]: Traditional optimization algorithms (Mathematical programming; Analytical methods; Statistical methods, Adaptive methods) , and Non-traditional optimization algorithms (Genetic algorithm, Particle Swarm Optimization, Artificial Bee Colony, Ant Colony Optimization, Bat Algorithm, Firefly Algorithm, Gray Wolf Optimizer, Cuckoo Search …)

The aim of this paper is to optimize the input parameters of the face milling process by nature-inspired algorithms.

MATERIALS AND METHODS

— EXPERIMENTAL SETUP AND RESULTS

Experimental work was carried out at the Faculty of Technical Sciences, in the Laboratory for Conventional Machining. The conditions for experimental testing are given in this chapter. Conditions apply to: the workpiece material, machine tool, cutting tool and cutting conditions.

» The workpiece material

Experimental tests were carried out on aluminum alloy 7075 (Al-Zn-Mg-Cu), which was made using the conventional casting method. The workpiece has been 100 mm in width and length, and thickness 15 mm.

» Machine tool

The experimental work was carried out at the Department of Production Engineering, the Faculty of Technical Sciences in Novi Sad. The machining was conducted on a Vertical-spindle Milling Machine („Prvomajska“ FSS-GVK-3) in dry condition.

» Cutting tool

A face milling cutter with ø100 mm diameter („Jugoalat“ G.037), with cemented carbide inserts („Corun“ type SPKN 1203ED R) with tool cutting edge angle $\kappa=75°$ and rake angle $\gamma=0$.

Cutting conditions:

- Cutting speed v, or the corresponding spindle speed n,
- Feed per tooth s_1, or the corresponding feed rate s, so it is: $s= s_1 \cdot z \cdot n$, number of teeth has been $z=1$ and
- Depth of cut a.

In regard to the workpiece material and tool producer recommendations for cutting conditions, Table 1 have been presented, for a 3-factor design of experiments. All of the experiments were conducted with one insert without coolant. The mean surface roughness Ra was measured with a "Marsurf PS1" device.

Table 1 Machining parameters and their levels

Levels	Cutting speed v [m/min]	Cutting speed v [m/s]	Feed per tooth s1 [mm/ tooth]	Depth of cut a [mm]	Spindle speed n
Maximum +1,41	351,86	5,864	0,223	2,6	1120
High +1	282,74	4,712	0,177	1,72	900
Midium 0	223,05	3,717	0,141	1,14	710
Low -1	175,93	2,932	0,112	0,75	560
Minimum -1,41	141,37	2,356	0,089	0,5	450

Based on the three-factor experiment plan on five levels, with each input parameter varied to five levels, a mathematical model for the mean arithmetic roughness of the machined surface was obtained, equation 2.1 [2].

24 experiments were performed, according to the Design of Experiments. The experimental results were later used to obtain a mathematical model for calculating the mean arithmetic roughness of Ra. The mathematical model is a necessary condition for the optimization of the face milling process, respectively finding optimal values of the input parameters of the processing process.

$$R_a = Cv^{p_1} s_1^{p_2} a^{p_3} \exp\begin{bmatrix} p_{11}(\ln v)^2 + p_{22}(\ln s_1)^2 \\ +p_{33}(\ln a)^2 + \\ p_{12}\ln v \ln s_1 + p_{13}\ln v \ln a \\ +p_{23}\ln s_1 \ln a \end{bmatrix} \quad (2.1)$$

Table 2. The value of the constants and exponents

C	p_1	p_2	p_3	p_{11}
201568,89	0,23366	11,20405	0,54344	-0,28380
p_{22}	p_{33}	p_{12}	p_{13}	p_{23}
2,44943	0,02290	-0,27871	-0,09218	0,27384

GENETIC ALGORITHM (GA) BACKGROUND

The GA is a search algorithm for optimization, based on a Darwinian theory of evolution and on the concept of "survival of the fittest". The basic object of the genetic algorithm is a chromosome, and the function of aim is the fitness.

The basic operators applied to chromosomes are the crossover, the mutation, and the selection. A generation is made the crossover, the mutation, and the selection, which is equivalent to one iteration in traditional optimization techniques.All genetic algorihtms function by the same principle which can be shown the most easily in further steps (Figure 1).

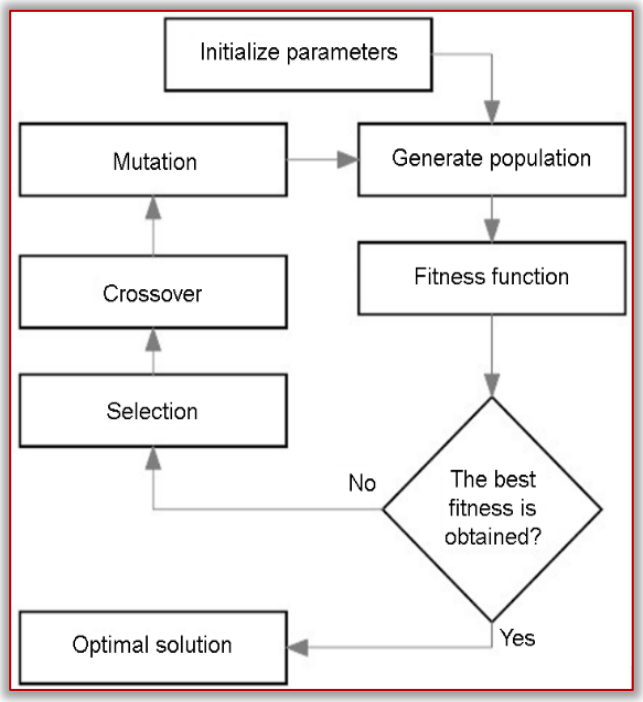


Figure 1. Methodology of GA optimization [3]

PARTICLE SWARM OPTIMIZATION (PSO) BACKGROUND

Particle Swarm Optimization (PSO) is a stochastic algorithm with population-based solution. The particle swarm optimization algorithm was detected by accident, while observing the computer simulates movements of bird flock. Reynolds C.W. in his work 1986, examined the flock of birds as a set of particles, where each particle (i.e. bird) adapts its flight to the following rules: Avoiding a collision between birds; adjusting flight speeds to closest birds and trying to stay close to other birds.

Particle swarm optimization have been successfully applied to complicated optimization of process parameters in turning (one and multiple pass), face milling (one and multiple pass), and milling, grinding. Optimal cutting speeds, feed rate, feed per tooth, depth of cut, the number of revolutions of the main spindle and the number of passes in the function of: minimum processing time, minimum processing costs, maximum process efficiency, minimum roughness of the treated surface, minimum cutting forces.

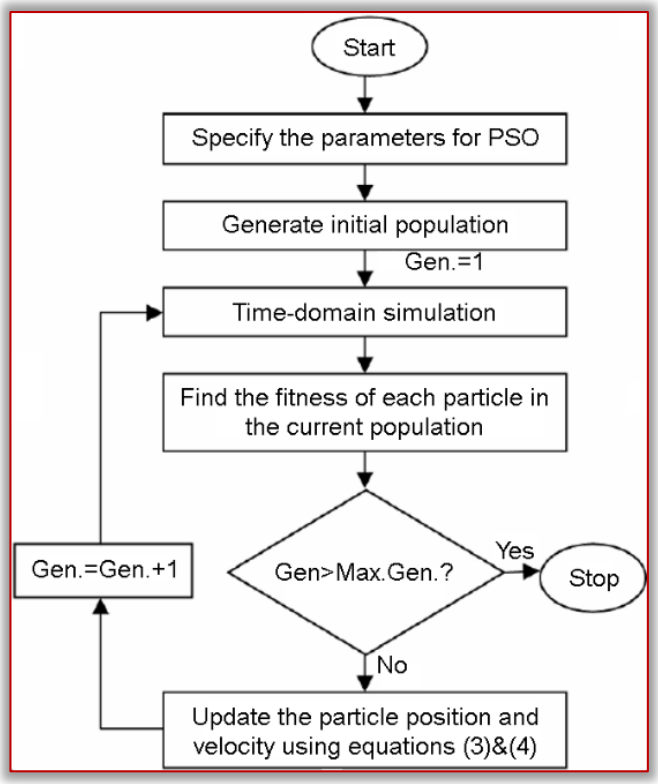


Figure 2. Methodology of PSO optimization [4]

ANT COLONY OPTIMIZATION (ACO) BACKGROUND

Ant Colony Optimization (ACO) is a population-based metaheuristic, that can be used to solve difficult optimization problems. In ACO, a set of software agents called artificial ants search for good solutions to a given optimization problem. In order to apply ACO, the optimization problem is transformed into the problem of finding the best path in the weighted

graph. Artificial ants gradually build solutions by the movement along the graph. Construction process of the solution is stochastic and is based on a pheromone model, i.e. on a set of parameters associated with graph components, either nodes or edges, whose values are modified by artificial ants during the search process.

The ants, although they are blind, can find the shortest path to the food source. This feature of ants has been made available to solve real problems by using certain features and some additions.

Characteristics of ants created by artificial ant are: communication between the ants by using the chemical pheromone, preferring the roads with a higher amount of pheromones, fast increasing the amount of pheromones on short roads, than on longer ones.

Characteristics that are added to real ants: live in an environment where time is calculated discreetly, they are not completely blind and they can access to details of the problem, they can retain information for solving a specific problems with a certain amount of memory. In Fig. 3 shows the computer diagram of ACO.

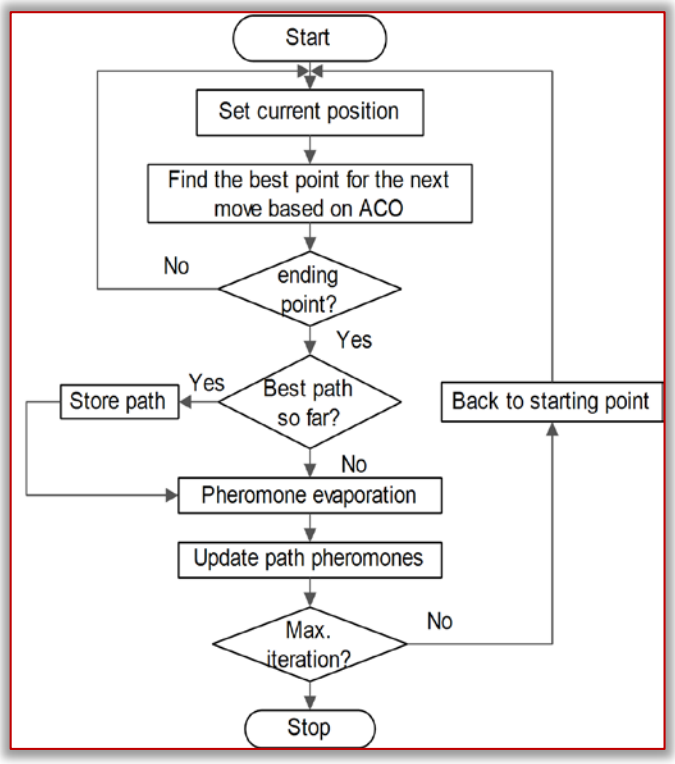


Figure 3. Methodology of ACO optimization [5]

RESULTS AND DISCUSSION

The optimization of the face milling process, or the determination of the optimum values of the cutting conditions, was carried out using various nature-inspired algorithms. Three single-criteria methods were used for this work: Genetic Algorithm – GA, Particle Swarm Optimization – PSO, and Ant Colony Optimization - ACO. The aim function in all three cases was the minimum value of mean surface roughness $\mathbf{R_a}$, respectively $(\mathbf{R_a})_{\mathbf{min}}$. The optimization process was carried out in the MATLAB software package. This software has a number of modules that allow to execute the script code for each of the optimization methods. In Table 3 is shown the limit values of the input parameters (cutting conditions).

Table 3. Limit values of input parameters

Parameters name	Minimum value	Maximum value
v [m/s]	2,356	5,864
s_1 [mm /tooth]	0,089	0,223
a [mm]	0,5	2,6

In Table 3 are presented results obtained using various optimization techniques. Optimal values of input parameters are fully matched by using different nature-inspired algorithms (ACO, PSO, and GA). Results have confirmed that nature-inspired algorithms, as useful for optimization machining processes.

Table 4. Optimal values of input parameters during the face milling process

Method	Output parameter		Optimal parameters of cutting		
			v [m/s]	s_1 [mm/z]	a [mm]
GA	R_a [μm]	0,8236	2,36	0,1011	2,6
PSO	R_a [μm]	0,8236	2,36	0,1011	2,6
ACO	R_a [μm]	0,8236	2,36	0,1011	2,6

CONCLUSION

This paper has discussed determining the optimum machining parameters leading to minimum surface roughness during face milling process by nature-inspired algorithms. Results have confirmed that nature-inspired algorithms as useful for optimization of machining processes. Some general conclusions are next:

- Preliminary experimental research is needed to form a mathematical model;
- High-quality optimization solutions cannot be expected, without a high-quality and reliable mathematical model;
- In order to perform optimization using an ant algorithm, it is necessary to introduce penal factors that allow the search space to be limited, which is not the case for the PSO;
- There is need for a script code when used some methods (PSO and ACO);
- The time of finding optimal solutions is less with the PSO method than ACO.

Acknowledgement:
The paper is the result of the research within the project TR 35015 financed by the Ministry of Education, Science and Technological Development of Republic of Serbia.

Note:
This paper is based on the paper presented at DEMI 2019 – The 14th International Conference on Accomplishments in Mechanical and Industrial Engineering, organized by Faculty of Mechanical Engineering, University of Banja Luka, BOSNIA & HERZEGOVINA, co–organized by Faculty of Mechanical Engineering, University of Niš, SERBIA, Faculty of Mechanical Engeneering Podgorica, University of Montenegro, MONTENEGRO and Faculty of Engineering Hunedoara, Unversity Politehnica Timisoara, ROMANIA, in Banja Luka, BOSNIA & HERZEGOVINA, 24–25 May 2019.

References

[1] Sekulic, M., Pejic, V., Brezocnik, M., Gostimirovic, M., Hadzistevic, M. (2018): "Prediction of surface roughness in the ball-end milling process using response surface methodology, genetic algorithms, and grey wolf optimizer algorithm", Advances in Production Engineering & Management, vol. 13, no. 1, p. 18-30.

[2] Savković, B. (2015): "Modeling of machinability functions in the milling process", Doctoral Thesis, Faculty of Technical Sciences, Novi Sad.

[3] Dhokia, V. G., Kumar, S., Vichare, P., Newman, S.T. (2008). "An intelligent approach for the prediction of surface roughness in ball-end machining of polypropylene", Robotics and Computer-Integrated Manufacturing, vol. 24, p. 835– 842.

[4] Peyvandi, M., Zafarani, M., Ibrahim Nasr, E. (2011): "Comparison of Particle Swarm Optimization and the Genetic Algorithm in the Improvement of Power System Stability by SSSC-based Controller", Journal of Electrical Engineering and Technology, vol 6, no. 2, p. 182-191.

[5] Brand, M., Masuda, M., Wehner, N., Yu, X. H. (2010): "Ant colony optimization algorithm for robot path planning", International Conference on Compute Design and Applications (ICCDA 2010), vol. 3, p. 436–440.

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

[1.]Tihomir MAČKIĆ, [2.]Goran JOTIĆ, [3.]Milan TICA, [4.]Jovica ILIĆ

MECHANICAL PROPERTIES OF MODIFIED FLIPWING HYDROKINETIC TURBINES

[1.]Mechanical Faculty of Banja Luka, Banja Luka, BOSNIA & HERZEGOVINA

Abstract: Energy demand from renewable sources imposes the need for the development of new types of water turbines in the field of hydrokinetic turbines. In this paper experimentally examined the mechanical properties of hydrokinetic turbine type Flipwing. Two shapes and sizes of blades were used, with some turbine design variations. Compared to the basic version of the Flipwing turbine, using modified design has yielded significant increases in turbine power.
Keywords: hydrokinetic turbine, Flipwing, design optimization, power measurement

INTRODUCTION

Hydrokinetic power is defined as the power derived from the kinetic energy of the water flow. Unlike a water-head turbine which convert potential energy of water to mechanical energy, hydrokinetic water turbines or water stream turbines uses kinetic energy from fast flowing water. The presence of water turbines that can use the kinetic energy of water is insignificant, because of the low efficiency and cost-effectiveness.

Flipwing turbine is horizontal axis hydrokinetic turbine, which was patented by the company Hydrovolts [1]. The rotor consists of 4 freely rotating blades (Figure 1), which stops at the central shaft. The efficiency of this turbine is 10% [2].

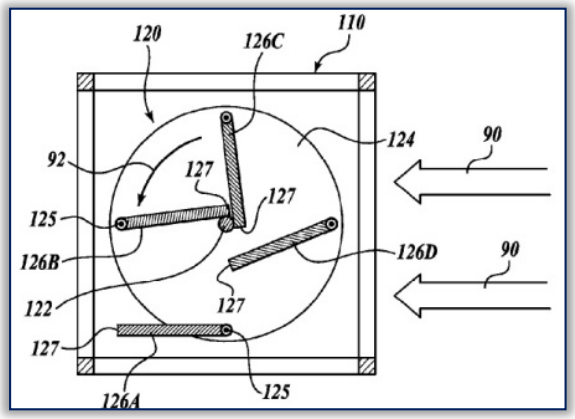
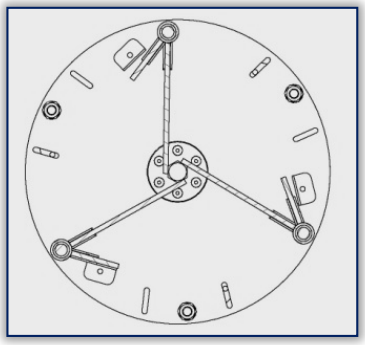


Figure 1. Flipwing turbine from Hydrovolts [1]

Company R+T Fliesenhandels GmbH has improved and simplified the design of the rotor of Flipwing turbines, reducing the number of blades on 3 and adding smaller blades (Figure 2a), which allowed a larger grip. This led to an increasing of efficiency to14%. This result is given in a report submitted by the Vienna Model Basin Ltd [3] (Figure 2b).

Some types of hydrokinetic turbines, which have a more complicated rotor design, achieve significantly higher efficiency than the Flipwing turbine [4, 5]. The aim of this work is to perform optimization, through modifying the design of housing and rotor blades of Flipwing turbines, to maximize efficiency.



(a)

ANALYSE

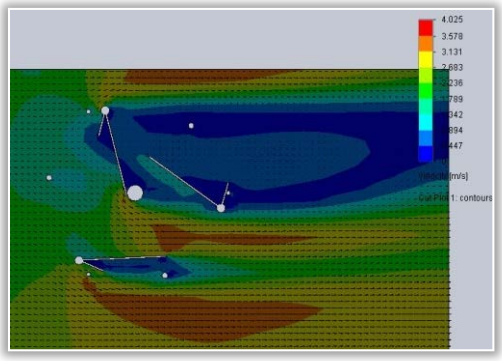
V_w [m/s]	Q_s [Nm]	n_s [rpm]	P_D [W]	η [-]	c_w [-]
2.0	126.7	32.2	426.7	0.147	1.481
2.5	198.7	38.5	800.3	0.141	1.318
3.0	268.8	45.3	1274.4	0.130	1.180
3.5	288.0	58.8	1772.3	0.114	1.254
4.0	283.1	75.8	2247.0	0.097	1.495

(b)

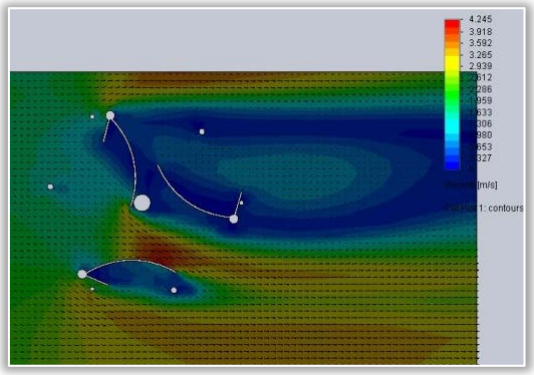
Figure 2. Modified Flipwing turbine with 3 blades and the efficiency results

DESCRIPTION AND TECHNICAL CHARACTERISTICS

At the beginning, a simple CFD analysis was performed (Figure 3) to determine the optimum shape and radius of the blades. It has also been found that increasing the number of blades effects in increasing the efficiency.



a)



b)

Figure 3. Simple CFD analysis with flat and curved blades

Accordingly, the rotor of the modified Flipwing turbine was made in two different construction solutions, in terms of rotating blades:

- Solution 1 - double wooden flat blades (Figure 4a),
- Solution 2 - single metal curved blades (Figure 4b).

a)

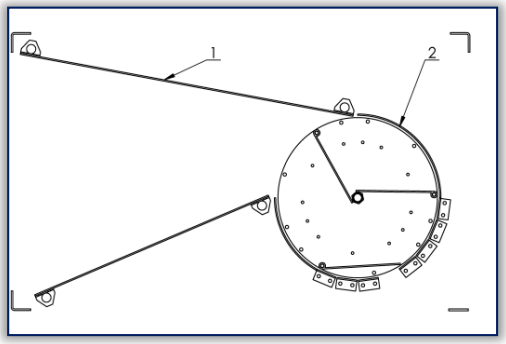
b)

Figure 4. Two different construction solutions of blades

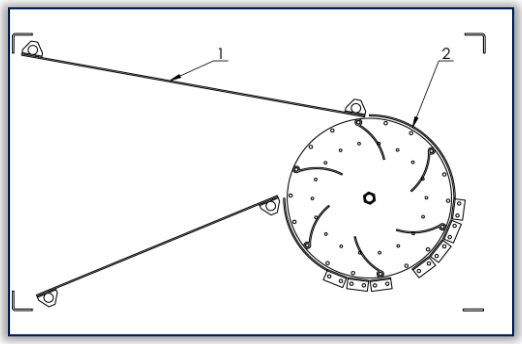
The rotor parameters for the proposed two construction solutions are as follows:

Parameters	Solution 1	Solution 1
number of sections	4	4
rotor length	2180	2180
rotor diameter	700	700
number of blades	12	24
dimension of blades	500 x 340	500 x 170
blades radius	0	160 mm
working angle of blade (˚)	75	30, 75, -

In addition, turbine rotors are placed in a special housing (Figure 5). On the front side of the housing there is an element for directing the water flow (1) or inlet part, while on the rear side are secured arc segments that can be disassembled. The aim is to examine the impact of individual housing segments on the overall power of the turbine.



(a)



(b)

Figure 5. Special housing of turbine rotors

POWER MEASUREMENT AND RESULTS

In the process of measuring the power of the turbine, the direct (in-line) method of the torque measure was used. The method implies that the sensor is mounted directly in the transmission. The power generated by the turbine rotor is obtained by the indirect measurement method using the following form:

$$P = M \cdot \frac{\pi \cdot n}{30} \ [W] \qquad (1)$$

where is: M – the value of the measured torque on the transducer,

n – angular speed of output shaft.

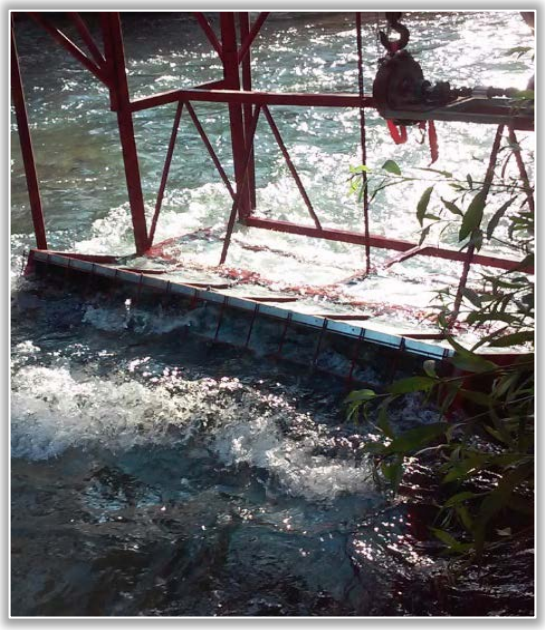
The calculated power is increased by the value of power losses in the transmission elements. The following measuring equipment was used in the

process of measuring torque and angular speed (Figure 6a):

- torque transducer 2 kNm,
- preamplifier MD 18,
- universal measuring amplifier HBM Darmstadt Germany,
- friction brake and
- angular speed encoder L-TACHO.

During measurements, the turbine with inlet part is immersed in the water to the level of complete turbine maintenance (Figure 6b).

(a)



(b)

Figure 6. Measurement of the power of modified Flipwing turbines

Torque and angular speed measurements were performed by multiple sampling with the same and different operating modes of the turbine.

The results of the measurements for the first construction solution are shown in Table 1 and for second construction solution are shown in Table 2.

Table 1. Measurement results – 1st construction solution of rotor

Water speed [m/s]	Torque [Nm]	Angular speed [min^{-1}]	Power [W]	Note
1.4	19	85	169	2.1.
1.4	18.5	76	147	2.2.
1.4	26.4	71	196	2.3.
1.6	17.8	115	214	2.1.
1.6	17.7	117	217	2.1.
1.6	15.3	137	219	2.1.
1.6	26	92	250	2.3.
1.6	19.8	123	255	2.3.
1.6	14.2	113	168	2.4.

Note:
2.1. Measurement without housing and inlet part.
2.2. Measurement with housing and without inlet part, partially immersed.
2.3. Measurement with housing and inlet part, fully immersed.
2.4. Measurement without the rear side.

Table 2. Measurement results – 2nd construction solution of rotor

Water speed [m/s]	Torque [Nm]	Angular speed [min^{-1}]	Power [W]	Note
1.4	15.8	51	84.3	3.1.
1.4	18.3	45	86.2	3.2.
1.4	22	38	87.5	3.3.
1.4	32	71	238	3.4.
1.4	30.6	79	253	3.5.

Note:
3.1. Measurement without housing and inlet part. Short working angle of blades.
3.2. Measurement without housing and with inlet part. Short working angle of blades.
3.3. Measurement with housing and inlet part. Short working angle of blades.
3.4. Measurement without housing and with inlet part. Long working angle of blades.
3.5. Measurement with housing and inlet part. Long working angle of blades.

SUMMARY

Experimental results have shown that the power of the Flipwing turbine increases if the rotor is made with a larger number of curved blades. The best result was design with 6 curved blades. allowing long working stroke of blades (for a working angle of 75°). Compared to the original design with three flat blades. an increase in power was achieved up to 40%.

The turbine housing has a different effect on the increase in power at the proposed structural solutions. In the case of curved blade construction. the increase is only 6%. while in the case of flat blades it is 16%.

However. with the first design solution. removing the rear side of the housing reduces turbine power by 50%. Since housing significantly increase the cost

price of production. it is proposed (for the second constructive solution) making Flipwing turbine without housing.

Note:

This paper is based on the paper presented at DEMI 2019 – The 14th International Conference on Accomplishments in Mechanical and Industrial Engineering. organized by Faculty of Mechanical Engineering. University of Banja Luka. BOSNIA & HERZEGOVINA. co–organized by Faculty of Mechanical Engineering. University of Niš. SERBIA. Faculty of Mechanical Engeneering Podgorica. University of Montenegro. MONTENEGRO and Faculty of Engineering Hunedoara. Unversity Politehnica Timisoara. ROMANIA. in Banja Luka. BOSNIA & HERZEGOVINA. 24–25 May 2019.

References

[1] William B. Hamner. Hinged-blade cross-axis turbine for hydro-electric power generation. Pub. No.: US 2010/0237626 A1. Pub. Date: Sep. 23. 2010.
[2] Evan Mangold (2012). An analysis of its performance and potential in the roza and kittitas canals. Master Thessis. The Evergreen State College. November 2012.
[3] Dr. Clemens Strasser (2015). Hydrodynamische Modellversuche - Tiefschlächtiges Wasserrad. BERICHT Nr. 2666/01. Vienna Model Basin Ltd.
[4] In Seong Hwang. Yun Han Lee and Seung Jo Kim. Optimization of cycloidal water turbine and the performance improvement by individual blade control. Applied Energy 86 (2009) .pp:1532–1540.
[5] A. Kumar. R.P. Saini. Performance parameters of Savonius type hydrokinetic turbine – A Review. Renewable and Sustainable Energy Reviews 2016. 64: 289-310.

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

Faculty of Engineering Hunedoara.
5. Revolutiei. 331128. Hunedoara. ROMANIA
http://acta.fih.upt.ro

[1.]C.S. SANDEEP, [2.]N. VIJAYAKUMAR, [3.]A. Sukesh KUMAR

A NOVEL APPROACH FOR THE EARLY DIAGNOSIS OF ALZHEIMER'S DISEASE

[1-3.]Dept of ECE, College of Engineering, University of Kerala, Trivandrum, INDIA

Abstract: Alzheimer disease (AD) is the most common dementia type disease after the age of 65. This leads to cognitive disability to the person being affected. The existing methods are not able to definitely diagnose the disease at an earlier stage. Also, if we can diagnose the disease earlier, treatments can be given at a proper time. Accordingly, an innovative technique should be developed with good accuracy, specificity, and sensitivity. In this scenario, the Magnetic Resonance Imaging (MRI) can be utilized. In this research work, a method has been proposed using Discrete Wavelet Networks (DWNs). This method gives better results in case of MRI images.
Keywords: Alzheimer's disease; DWNs; Early Diagnosis; Feature Selection; and MRI

INTRODUCTION

Alzheimer's disease is considered as a neuronal disease that upsets neuron cells. Once the nerve cells are damaged due to this disease, it cannot reproduce the cells and causes damaged to the nearby cells. This permanent damage of the cells leads to permanent memory impairment. The disease progression is classified according to the progressive nature of the disease [1, 2]. When the disease progresses to the severe stage, the patient conditions become more critical. In addition to the patient, the family members are also affected. AD normally occurs due to protein accumulation called as plaques, and tangles [3, 4].

Plaques are present outside the nerve cells and tangles are those that present inside the nerve cells. In AD patients, the deposits of plaques and tangles are seen more than normal subjects. The main parts of the brain that is affected by AD in the earlier stage are hippocampus, frontal, temporal, occipital and, parietal lobes. In these areas, there is a loss of neuronal cells and more deposits of proteins. Also, there is cortical atrophy in these areas [5-7]. Therefore, brain imaging techniques can be used for the diagnosis of this disease. At present, there is several brain imaging methods for diagnosing AD. From those Magnetic Resonance Imaging (MRI) gives considerable results than other because it reveals relevant information about the most critical areas that are causing AD. MRI is non-invasive equipment for determining cross-sectional areas of brain as well as records the changes in the tissue region including the hippocampus, frontal lobes, temporal, occipital lobes, and parietal lobes [8, 9]. Due to this, MRI scans are becoming popular. The images obtained from MRI devices show more reliable and consistent in the case of AD. After selecting the most suitable brain imaging technique, next is to make an automated expert system using computers for the diagnosis of the disease. For this purpose, we can use the advanced Biomedical Engineering technology for making an automated system using computers.

REVIEW OF LITERATURE

Feature selection is a substantial process in the automatic computer diagnosis of brain pictures. The different techniques for this process are genetic algorithm, artificial neural networks (ANNs), fuzzy logic; and support vector machines (SVMs). Another method that can be used in conjunction with the above is wavelet Networks (WNs). In this research, we are using WNs for the segmentation process. The WNs can overcome the different limitations caused by other segmentation techniques. By using WNs, we can reduce noise from the images to minimum; avoid complex calculations, efficient image retrieval and separation of background from the image [10].

In this paper, feature selection of MRI images has been developed based on WNs. They can be characterized into adaptive wavelet networks (AWNs) that uses Continuous Wavelet Transforms (CWTs) and the other is discrete wavelet Networks (DWNs) which uses Discrete Wavelet Transform (DWT) [11]. In this research, DWN has been used extensively. The advantages of DWN over AWN are as follows. Unlike AWN, DWN uses simple computations and are not as sensitive to initial values as AWN [12]. The other factors to choose DWN to construct the networks are wavelets, scale and shift parameters. In addition to inner parameters there are outer parameters like the weight of the wavelet neurons, calculated using least squares estimation [13, 14].

Therefore, in this research work we are using DWNs for the segmentation of MRI images for the feature selection process. After the segmentation process is over, necessary features of MRI are extracted and select the appropriate features for the classification of images.

FEATURE SELECTION OF MRI IMAGES

During the feature selection of MRI pictures, segmentation is a prominent task. Figure 1 shows the feature selection method using MRI. The different block represents Image Acquisition, Preprocessing, WN Construction, Segmentation, Image

Postprocessing, Extraction of features, and Feature Selection. The first step in this method is to acquire the MRI scans using MRI scanner as in figure 2. The second step is the removal of noise from the images using filters.. Filters can be classified into linear and non-linear filters. In this research, we are using a non-linear median filter to removes the unneeded noise on the obtained MRI image before proceeding to the segmentation process.

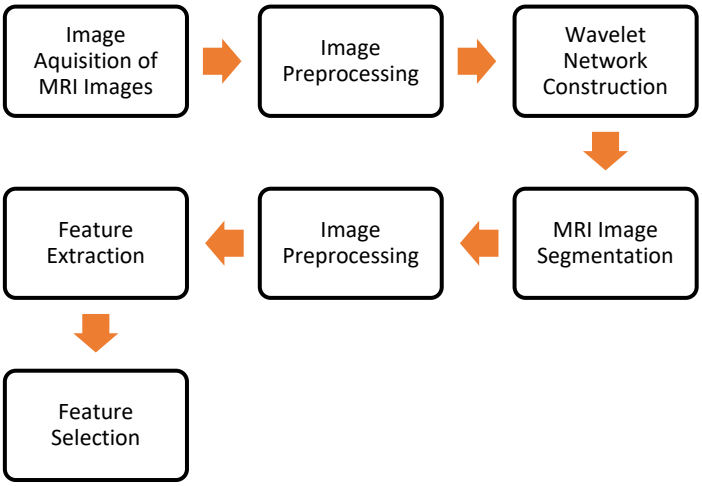


Figure 1.Block diagram of MRI Feature Selection Process

The third step is the WN construction from the MRI scans stored in the computer using DWNs. Once the network construction is completed, segmentation can be done [15]. In the pre-processing stage, the edges and heirs that are no longer needed has been removed. After that various features connected with MRI has been extracted. The final step is the feature selection method in which only the optimum features are selected.

Figure 2. MRI device

THE SEGMENTATION ALGORITHM USING WAVELET NETWORKS FOR THE FEATURE SELECTION PROCESS

Figure 3 shows the block diagram of the segmentation algorithm for the feature selection process. Wavelets are mainly used to reduce the magnitudes of MRI picture information from a bigger value. A Discrete Wavelet Network consisting of one output, d inputs and q Wavelet neurons can be calculated as in equation (1).

$$\sum_{i=1}^{n} w_i \psi_{pi,qi}(X) = \sum_{i=1}^{n} w_i 2^{-p_i d/2} \psi(2^{pi} X - qi) \quad (1)$$

From the above equation, wi is the weight coefficients, ψpi, qi are the parameters of primary wavelet network [16].

While using DWNs, the Red Green Blue (RGB) matrix values of MRI data that is given as DWN input changes from a minimum value to maximum. These variations will cause problems in the segmentation as well as classification process. Therefore, the RGB data is to be normalised in the range [0,1]. This stage is also called as pre-processing stage of the feature selection process [17]. The normalisation of input data is calculated as in equation (2).

$$x_{n,new}^{(k)} = \frac{x_{n,old}^{(k)} - t_k}{T_k - t_k} \quad (2)$$

From the equation (2), $x_{n,new}^{(k)}$ is the value of the matrix, t_k denotes lowest value and T_k denotes highest value of the matrix.

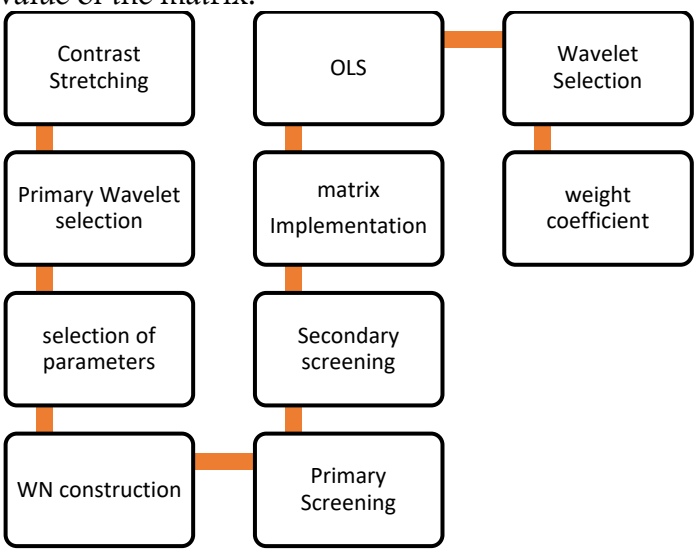


Figure 3.Block diagram for the feature selection process

The next step in this algorithm is to select the principal wavelet for the construction of DWN for the segmentation process. For the purpose of creating a DWN with good efficiency, the wavelets must be chosen with utmost care. In this scenario, we cannot use a single dimensional wavelet. Therefore, multi-dimensional wavelets should be employed. There are different types of wavelets available in biomedical processing. After executing the program for feature extraction with different wavelets, Marr and Morlet Wavelet combination has been chosen as the principal wavelet [18]. The Marr function is represented as in equation (3)

$$\psi_1(x) = [(d - abs(x^2) * e\hat{}(-abs(\frac{x^2}{2})] \quad (3)$$

Likewise, the Morlet wavelet function is given by the equation (4).

$$\psi_2(x) = Ce^{\frac{-x^2}{2}} * \cos(5x) \quad (4)$$

By using dimension d=2 and constant C=1, the equation changed as shown in equation (5).

$$\psi(x) = [((d - abs(x^2) * e\hat{}(-abs(\frac{x^2}{2}))) * (Ce^{\frac{-x^2}{2}} * \cos(5x))] \quad (5)$$

After selecting the principal wavelet, the succeeding step is to select the scaling and shifting parameter functions for crating the wavelet lattice. The lowest scale level with P_{min} and the highest scale level with P_{max} have been selected [19]. After choosing the shift and scale parameters, a wavelet lattice is constructed with d=2 as in equation (6).

$$\psi_{pi.qj}(x) = 2^{-p_i d/2}\psi(2^{p_i}x - q_j) \quad (6)$$

After the construction of Wavelet lattice, there are there exist so many redundant wavelets that cause inaccuracies in the segmentation section. Therefore the most suitable wavelets should be selected with shift and scale parameters. For this purpose, the primary screening is used. In this screening, the matrix I_k is formed from the selected wavelets [20]. In the next stage, the secondary screening is employed in which matrix I is formed from the matrix I_k. In the next stage, the wavelet matrix is calculated from the selected shift and scale parameters after the screening process [21]. Therefore, in the next stage is the employing of Orthogonal Least Square algorithm to select the suitable parameters from the matrix. After employing the OLS estimation, the wavelet network is computed by the equation (7)

$$f = \sum_{i=1}^{s} w_i \psi_i(x) \quad (7)$$

From the equation (7), s denotes neurons and wi is the weight. In the next only the required Wavelet neurons are selected and index of WN is given by equation (8).

$$MSE = \frac{1}{P}\sum_{k=1}^{P}(\hat{f}^{(k)} - f^{(k)})^2 \quad (8)$$

Finally, the weight coefficients have been calculated successfully [22, 23].

IMAGE PRE AND POST PROCESSING

MRI pictures acquired digitally are exposed to different Digital Image Processing Techniques. The standard picture ratio is taken as 360x360 pixels. Normally, the picture comprises of unwanted distortion in the form of hairs, bubbles and so on. These commotions cause errors in the final output. So as to stay away from that, pictures are exposed to different image processing schemes such as Image Pre-processing and Post-processing. Pre-processing is the removal of commotions in the picture such as hair and bubbles. The principal strategy of pre-processing is to carefully evacuate the hairs and bubbles and makes the image smooth for the segmentation process. After the segmentation process, there are some unwanted regions are formed near the boundaries and edges. This can be removed by image post-processing in which unneeded regions are removed and region of interest is calculated.

EXTRACTING MRI FEATURES

The features that can be extracted from MRI images are are described as below.

Ellipticity is a grade of resemblance with the oval contour that is achieved in-between the area of the utmost real fitted area elliptically. It shows larger values during normal and smaller values during abnormal conditions.

Texture feature is an arranged group of metrics in image processing to evaluate the deceptive surface. It provides evidence of spatial arrangement of color or intensities in an MRI image.

Red average value is the mean value of the pixels in the red region.

Regional minima are to seizure the consistency calculated using number of minima and the area of object. Moment is defined as the histogram of the MRI image inside the object. Median is measured by arranging all initial value of the pixel from the adjacent neighborhood into numerical order. Contrast is the difference in the luminance or colour of the MRI image, thereby the objects can be easily found out. Entropy is a statistical degree of uncertainty to characterize input image. Maximally Stable Extreme Regions (MSER) features are used for spot recognition in images. Min-Eigen feature find corners using Eigenvalues and returns a corner point's object in a two-dimensional grayscale image. Curvature variance is the measurement of curvature that is usually present in the objects outline. It shows maximum for AD and minimum for normal by measuring the variance of their assessment dissemination. Salience variance is used as the precise enlargements of an outline forming discrete regions. Some of the features obtained are shown in figure 4.

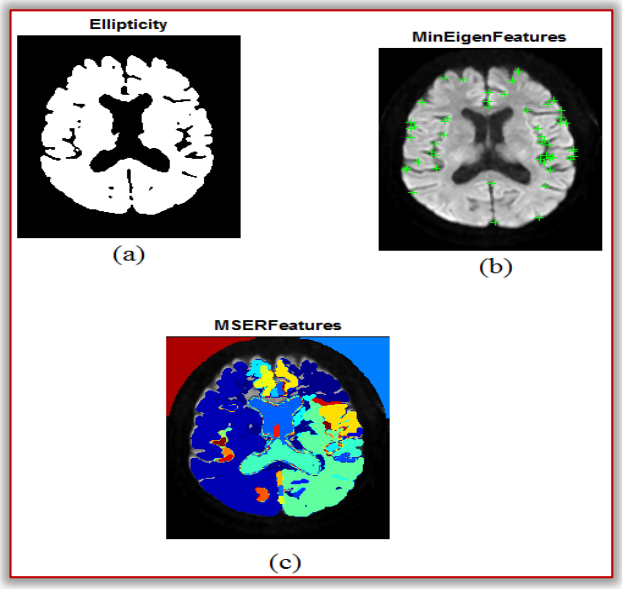


Figure 4. (i) Ellipticity (ii) Min-Eigen (iii) MSER feature

FEATURE SELECTION OF MRI IMAGES

The next process is to find out the best features that are more suitable for the diagnosis of AD. For finding out the optimal feature, we have executed the MRI images with each feature separately for the classification of images. Finally, we have selected six features for the classification stage. The features are Ellipticity, Texture feature, curvature variance, MSER features, Min-Eigen, and saliency variance.

RESULTS AND DISCUSSION

The dataset includes 100 MRI images taken under same environmental conditions. The size of image obtained is 5 megabyte, images have been made noise free using non-linear median filter. Figure 5 shows the different process of segmentation in MRI images.

Table.1. Comparison of MMDWNS, NN, FCM, and ED

Method	Accuracy (%)	Precision (%)	Sensitivity (%)	Specificity (%)	Similarity (%)	Border Error (%)
proposed	99.55	94.57	94.22	99.72	99.57	11.12
GA	99.45	92.15	93.34	99.65	99.12	13.14
NN	99.43	92.05	93.24	99.63	98.43	17.72
SVM	99.11	88.44	86.96	99.05	89.93	22.34
FCM	98.73	82.18	83.84	98.53	82.14	32.97

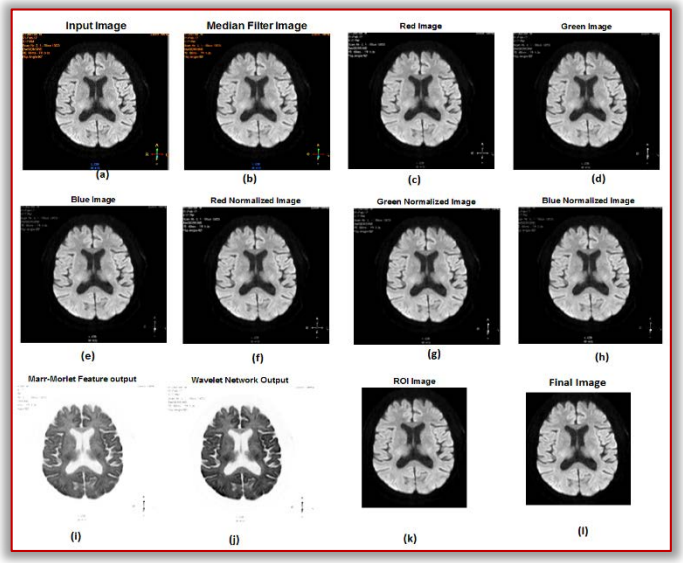


Figure 5. The different process of segmentation in MRI images: (a) input image, (b) Median filter image (c) Red image (d) Green image (e) Blue image (f) Red Normalized image (g) Green Normalized image (h) Blue Normalized image (i) Marr-Morlet feature output (j) Wavelet Network Output (k) ROI image (l) final output.

In this research, feature selection of the MRI images has been done with DWNs for the early diagnosis of AD. We have compared the proposed work with genetic algorithm GA, Neural networks (NNs), Support Vector Machines (SVM), and Fuzzy C- Means (FCM) for accuracy, precision, sensitivity, specificity, similarity and border error rate, our method is better than the other four as in table 1.

CONCLUSIONS

In this paper, feature selection of MRI has been done using Discrete Wavelet Network. For the feature selection process, images are obtained through MRI scanner and stored as a database. After that, normalisation has been done before image segmentation. Image pre-processing has done before segmentation stage and Image post-processing has been done after segmentation and then region of interest is calculated to get the final segmented image. After segmentation, feature extraction of MRI has been done and features have been extracted, in which 6 significant features have been selected. The proposed method has been compared with other relevant methods and shows better results. Therefore, this innovative method can definitely helpful for diagnosing Alzheimer's disease affectively.

Acknowledgment

We would like to express our gratitude to Sree Gokulam Medical College and Research Foundation, Trivandrum, India for providing the necessary MRI images for the preparation of this paper. Also we are thankful to the professors Dr.K.Mahadevan, Ophthalmology department and Dr.Manoj.P, Neurology department for their support in this research work.

References

[1] Escudero, J, Ifeachor, E, Zajicek, JP, Green, C, Shearer, J, Pearson, S & Alzheimer's Disease Neuroimaging Initiative 'Machine learning-based method for personalized and cost-effective detection of Alzheimer's disease' IEEE Transactions on Biomedical Engineering, vol. 60, no. 1, pp. 164-8, 2013.

[2] Sandeep C. S., Sukesh Kumar A., "The Early Diagnosis of Alzheimer's Disease Using Advanced Biomedical Engineering Technology", Neurological Disorders and Imaging Physics, Volume 2: Application to Autism Spectrum Disorders and Alzheimer's, IOP Expanding Physics, 2019.

[3] P. Padilla, M. Lopez, J. M. Gorriz, J. Ramirez, D. Salas-Gonzalez and I. Alvarez, "NMF-SVM Based CAD Tool Applied to Functional Brain Images for the Diagnosis of Alzheimer's Disease," in IEEE Transactions on Medical Imaging, vol. 31, no. 2, pp. 207-216, Feb. 2012.

[4] J. H. Morra, Z. Tu, L. G. Apostolova, A. E. Green, A. W. Toga and P. M. Thompson, "Comparison of AdaBoost and Support Vector Machines for Detecting Alzheimer's Disease Through Automated Hippocampal Segmentation," in IEEE Transactions on Medical Imaging, vol. 29, no. 1, pp. 30-43, Jan. 2010.

[5] M. S. Tahaei, M. Jalili and M. G. Knyazeva, "Synchronizability of EEG-Based Functional Networks in Early Alzheimer's Disease," in IEEE Transactions on Neural Systems and Rehabilitation Engineering, vol. 20, no. 5, pp. 636-641, Sept. 2012.

[6] Convit, A., de Leon, M.J., Tarshish, C., et al., Hippocampal volume losses in minimally impaired elderly. Lancet 345, 266, 1995.

[7] Sandeep C S, Sukesh Kumar A, A Review on the Early Diagnosis of Alzheimer's Disease (AD) through Different Tests, Techniques and Databases AMSE

JOURNALS –2015-Series: Modelling C; Vol. 76; N° 1; pp 1-22
[8] S. Duchesne, A. Caroli, C. Geroldi, C. Barillot, G. B. Frisoni and D. L. Collins, "MRI-Based Automated Computer Classification of Probable AD Versus Normal Controls," in IEEE Transactions on Medical Imaging, vol. 27, no. 4, pp. 509-520, April 2008.
[9] Simpson, Ivor & W. Woolrich, Mark & L. R. Andersson, Jesper & R. Groves, Adrian & Schnabel, Julia. Ensemble Learning Incorporating Uncertain Registration. IEEE transactions on medical imaging. 32. 10.1109/TMI.2012.2236651, 2012.
[10] Faro, Alberto & Giordano, D & Spampinato, Concetto & Ullo, Simona & Di Stefano, Angela. Basal Ganglia Activity Measurement by Automatic 3-D Striatum Segmentation in SPECT Images. Instrumentation and Measurement, IEEE Transactions on. 3269 - 3280. 10.1109/TIM.2011.2159315, 2012.
[11] Bobinski, M., de Leon, M.J., Wegiel, J., et al., The histological validation of post mortem magnetic resonance imaging-determined hippocampal volume in Alzheimer's disease. Neuroscience 95, 721– 725, 2000.
[12] Sandeep C S, Sukesh Kumar A ,"A Psychometric Assessment Method for the Early Diagnosis of Alzheimer's disease", International Journal of Scientific & Engineering Research -IJSER (ISSN 2229-5518), Volume 8 Issue 3 –MARCH 2017
[13] Q. Zhang and A. Benveniste, "Wavelet networks," IEEE Trans. Neural Netw., vol. 3, no. 6, pp. 889–898, Nov. 1992.
[14] H.H. Szu, B. A. Telfer, and S. L. Kadambe, "Neural network adaptive wavelets for signal representation and classification," Opt. Eng., vol. 31, no. 9, pp. 1907–1916, Sep. 1992.
[15] H. Zhang, B. Zhang, W. Huang, and Q. Tian, "Gabor wavelet associative memory for face recognition," IEEE Trans. Neural Netw., vol. 16, no. 1, pp. 275–278, Jan. 2005.
[16] O. Jemai, M. Zaied, C. B. Amar, and M. A. Alimi, "Pyramidal hybrid approach: Wavelet network with OLS algorithm-based image classification," Int. J. Wavel. Multir. Inf. Process., vol. 9, no. 1, pp. 111–130, Mar. 2011.
[17] Sandeep C S, Sukesh Kumar A, Susanth M J," Cognitive Examination for the Early Diagnosis of Alzheimer's Disease", IEEE International Conference on Trends in Electronics and Informatics, SCAD College of Engineering, Tirunelveli, May 2017, ISBN: 978-1-5090-4257-9, DOI: 10.1109/ICOEI.2017.8300876
[18] Hinton DR, Sadun AA, Blanks JC, Miller CA. Optic-nerve degeneration in Alzheimer's disease. N Engl J Med.; 315:485–487, 1986.
[19] Sadun AA, Bassi CJ. Optic nerve damage in Alzheimer's disease. Ophthalmology. ; 97:9–17. 1990
[20] CS Sandeep, A. Sukesh Kumar, K. Mahadevan, P. Manoj, "Analysis of Retinal OCT Images for the Early Diagnosis of Alzheimer's Disease", Springer-Advances in Intelligent Systems and Computing book series (AISC), Vol.749, pp. 509-520, ISSN 2194-5357, 2018
[21] R. Galvao, V. M. Becerra, and M. F. Calado, "Linear–wavelet networks," Int. J. Appl. Math. Comput. Sci., vol. 14, no. 2, pp. 221–232, Aug. 2004.
[22] S. A. Billings and H. L. Wei, "A new class of wavelet networks for nonlinear system identification," IEEE Trans. Neural Netw., vol. 16, no. 4, pp. 862–874, Jul. 2005.
[23] J. Gonzalez-Nuevo, F. Argueso, M. Lopez-Caniego, L. Toffolatti, J. L. Sanz, P. Vielva, and D. Herranz, "The mexican hat wavelet family.application to point source detection in CMB maps," Mon. Not. Roy. Astron. Soc., vol. 369, pp. 1603–1610, 2006

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

Fascicule 4

[October – December]

tome [2020] XIII

ACTA Technica CORVINIENSIS
BULLETIN OF ENGINEERING

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

http://acta.fih.upt.ro

[1.]Tamás SZŐCS, [2.]Zoltán Bálint SUSI

THERMOELASTIC PROBLEM OF MULTILAYERED CURVED BEAMS

[1,2]Institute of Applied Mechanics, University of Miskolc, Miskolc, HUNGARY

Abstract: The main objective of this paper is to determine the thermal stresses and displacements in multilayered curved beams subjected to thermal loading and concentrated moment. An analytical solution is presented to tackle this thermoelastic problem of multilayered circular arc with constant radius. The model can be modified to determine the stresses within radially graded curved beams. The developed plane stress method is compared to result coming from finite element simulations. Our main focus is to determine the analytical solution for the stresses and displacement within the beam which is subjected to constant temperature field and concentrated moment at the end of the beam.
Keywords: curved beam, multilayered, thermal stresses

INTRODUCTION

Curved beams are frequently used components in frame structures. Recent years a lot of studies have been performed on the mechanics of multilayered and functionally graded beams from different aspects. A lot of books deal with the stress analysis of beams, such as [1-7]. Bimetal components are one of the applications for multilayered beams. Several works have dealt with the mechanics of bimetallic strips which consist of two different components [8–12] although curved beams were not considered.

Papers such as [13-16] deal with the stability problem of curved beams subjected to only mechanical loading. These articles present an analytical method to the non-linear stability investigation of curved beams. The model can be used not only for homogeneous materials but also for functionally graded distributions. In [15] the mechanical load is a concentrated radial force at the crown point, while in [16], it is exerted in the small vicinity of the crown. Furthermore, in [13] the application point can be arbitrary along the centroidal axis. There are several papers (e.g. [17-19]) where multilayered structures were analysed and used to approximate simple radially graded components, such as disks or spherical bodies.

In paper [18] an analytical solution was developed for spheres using Boussinesq displacement potentials, in which the functions of the material properties – except the Poisson's ratio - are power law functions, in paper [19] the problem is solved as the superposition of the simpler subproblem. Then these multilayered methods were used to calculate stresses in radially graded spheres.

Pydah and Sabale [20] solved the flexure problem of bi-directional functionally graded circular beams subjected to various tip loads. Eslami et. al [21] used a two-step perturbation technique to present the solution of functionally graded shallow tube subjected to lateral pressure and temperature field, where the properties of the arch were distributed through the radial direction using a specific power law function.

In paper [22] a method is presented to calculate the stresses and displacements in bimetal curved beam subjected to only constant temperature field based on strength of materials and plane stress theories. In the work [23] the solution of a radially graded circular curved beam is presented, where the modulus of elasticity varies according to a power law function. Ecsedi and Baksa [24] presented a method to calculate the stresses in circular polar orthotropic beams subjected to radial loading.

A multilayered curved beam is considered. The number of layers is denoted by n, the homogeneous layers are perfectly bonded. A cylindrical coordinate system will be used, the sketch of the problem - for four layers, as an example - can be seen in Figure 1. Our main focus is to determine the analytical solution for the stresses and displacement within the beam which is subjected to constant temperature field (T) and concentrated moment at the end of the beam. The internal radius of the i-th layer is denoted by R_i, the outer radius is R_{i+1}. The symmetry plane of the problem is the z=0 plane.

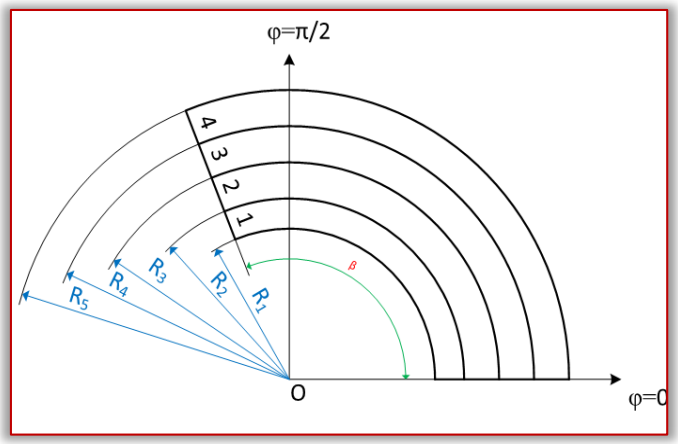


Figure 1. The sketch of the problem in case of 4 layers

GOVERNING EQUATIONS

In the basis of the plane stress model, the boundary conditions of the considered problem can be expressed as

$$\begin{aligned}&\sigma_r(R_1,\varphi)=\sigma_r(R_{n+1},\varphi)=\\&=\tau_{r\varphi}(R_1,\varphi)=\tau_{r\varphi}(R_{n+1},\varphi)=0,\\&0\le\varphi\le\beta,\end{aligned}\tag{1}$$

$$\begin{aligned}&\sigma_\varphi(r,\beta)=\sigma_\varphi(r,0)=\\&=\tau_{r\varphi}(r,\beta)=\tau_{r\varphi}(r,0)=0,\\&\sigma_\varphi(r,\beta)=\sigma_\varphi(r,0)=0,\\&R_1\le r\le R_{n+1},\end{aligned}\tag{2}$$

furthermore the following weak form equations will be satisfied:

$$N=\int_{R_1}^{R_{n+1}}\sigma_\varphi(r,\beta)\mathrm{d}A=\int_{R_1}^{R_{n+1}}\sigma_\varphi(r,0)\mathrm{d}A=0,\tag{3}$$

$$M=\int_{R_1}^{R_{n+1}}r\sigma_\varphi(r,\beta)\mathrm{d}A=\int_{R_1}^{R_{n+1}}r\sigma_\varphi(r,0)\mathrm{d}A.\tag{4}$$

In the previous equations σ_r and σ_φ, are the radial and tangential normal stresses. According to the Euler-Bernoulli beam theory, the displacement field can be given as:

$$\begin{aligned}&u_i(r,\varphi)=U_i(r)+f_1\cos\varphi+f_2\sin\varphi,\\&v_i(r,\varphi)=Dr\varphi+f_1\sin\varphi-f_2\cos\varphi+f_3r,\\&(i=1...n),\end{aligned}\tag{5}$$

where u and v denote the radial and tangential displacement components. From the kinematic boundary conditions the unknown f and D constants can be determined. For example we can use:

$$u_{ri}(R_1,0)=0,\ v_1(R_1,0)=0,\ v_2(R_n,0)=0.\tag{6}$$

The kinematic equations yield

$$\varepsilon_{\varphi i}=\frac{U_i}{r}+D,\varepsilon_{ri}=\frac{\mathrm{d}U_i}{\mathrm{d}r},i=1...n,\tag{7}$$

where ε_{ri} and $\varepsilon_{\varphi i}$ denote the normal strain coordinates of the strain tensor in the i-th layer. The stress-strain relation for the i-th layer can be expressed as

$$\varepsilon_{ri}=E_i^{-1}(\sigma_{ri}-\nu_i\sigma_{\varphi i})+\alpha_iT,\tag{8}$$

$$\varepsilon_{\varphi i}=E_i^{-1}(\sigma_{\varphi i}-\nu_i\sigma_{ri})+\alpha_iT,\ (i=1...n).\tag{9}$$

The combination of Eqs. (8) and (9) with the compatibility condition leads to

$$\begin{aligned}&r\frac{\mathrm{d}\varepsilon_{\varphi i}}{\mathrm{d}r}+\varepsilon_{\varphi i}-\varepsilon_{ri}-D=0,\ (i=1...n),\\&r\frac{\mathrm{d}}{\mathrm{d}r}(-\nu_i\sigma_{ri}+\sigma_{\varphi i}+E_i\alpha_iT)-\\&-(1+\nu)\sigma_{ri}+(1+\nu)\sigma_{\varphi i}-E_iD=0.\end{aligned}\tag{10}$$

From the equilibrium equation we get

$$\begin{aligned}&\frac{\mathrm{d}\sigma_{ri}}{\mathrm{d}r}+\frac{\sigma_{ri}-\sigma_{\varphi i}}{r}=0,\\&\sigma_{\varphi i}=r\frac{\mathrm{d}\sigma_{ri}}{\mathrm{d}r}+\sigma_{ri},\ (i=1...n).\end{aligned}\tag{11}$$

The combination of the previous equations yields the following differential equation for the different layers

$$\begin{aligned}&r\frac{\mathrm{d}}{\mathrm{d}r}((1-\nu_i)\sigma_{ri}+r\frac{\mathrm{d}\sigma_{ri}}{\mathrm{d}r}+E_i\alpha_iT)-\\&-(1+\nu)\sigma_{ri}+(1+\nu)\left(r\frac{\mathrm{d}\sigma_{ri}}{\mathrm{d}r}+\sigma_{ri}\right)-E_iD=0.\end{aligned}\tag{12}$$

The solution of the differential equation can be expressed as

$$\begin{aligned}&\sigma_{ri}(r)=C_{i1}+\frac{C_{i2}}{r^2}+\frac{E_iD}{2}\ln r,\\&\sigma_{\varphi i}(r)=C_{i1}-\frac{C_{i2}}{r^2}+\frac{E_iD}{2}(\ln r+1),\end{aligned}\tag{13}$$

where the number of unknown constants is $2n+1$. The boundary and fitting conditions of the multilayered beam (with thickness b) are:

$$\begin{aligned}&\sigma_{r1}(R_1)=\sigma_{rn}(R_n)=0,\ \sigma_{ri}(R_i)=\sigma_{ri}(R_i),\\&U_1(R_i)=U_2(R_i),\ (i=1...n),\end{aligned}\tag{14}$$

$$\sum_{i=1}^{n}\int_{R_i}^{R_{i+1}}r\sigma_\varphi\mathrm{d}r=\int_{R_i}^{R_{n+1}}r\sigma_\varphi\mathrm{d}r=Mb^{-1}.\tag{15}$$

With system of equations (14), (15) we can calculate the unknown constants for the different layers. The stress distribution does not depend on the angular coordinate.

This method can be modified to calculate stresses within radially graded beams subjected to constant temperature and concentrated moment. In this case we need n homogeneous layers and we have to discretize the values of the material properties for the different layers. One technique is to use the value of the function of the material parameters at the middle of the layer R_{mi} [19]

$$\begin{aligned}&E_i=E(r=R_{mi}),\nu_i=\nu(r=R_{mi}),\\&\alpha_i=\alpha(r=R_{mi}),\ i=1...n.\end{aligned}\tag{16}$$

The more layers we use the more accurate the solution is.

NUMERICAL EXAMPLES

In our first numerical examples the following numerical data will be used:

$$R_1=1\text{m},\ R_2=1.05\text{m},\ R_3=1.09\text{m},\ R_4=1.14\text{m},$$
$$E_1=69\text{ GPa},\ E_2=200\text{ GPa},\ E_3=69\text{ GPa},$$

$$v_1 = 0.33,\ v_2 = 0.3,\ v_3 = 0.33,\ \alpha_1 = 2.2 \cdot 10^{-5}\frac{1}{\mathrm{K}},$$

$$\alpha_2 = 1.1 \cdot 10^{-5}\frac{1}{\mathrm{K}},\ \alpha_3 = 2.2 \cdot 10^{-5}\frac{1}{\mathrm{K}},\ T = 150°\mathrm{C},$$

$$\beta = 290°.$$

The presented method is compared to results coming from finite element simulations. We used Maple and Abaqus CAE to carry out the calculations. The deformed mesh of the first problem can be seen in Figure 2. Quadratic coupled temperature-displacement elements were used to formulate the steady-state plane stress model [33].

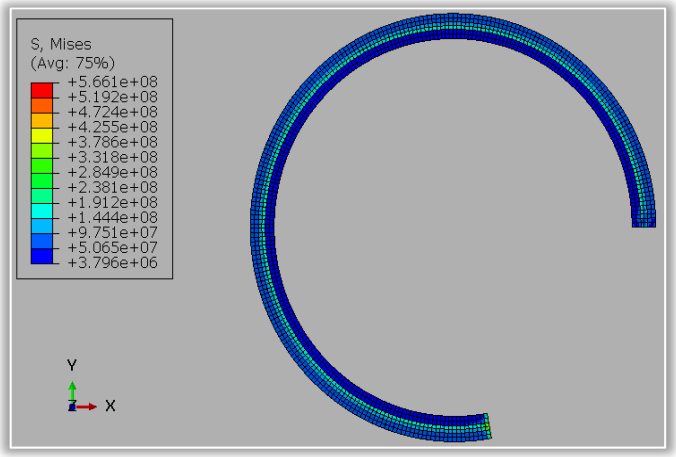


Figure 2. The finite element model of the first problem with the von Mises stress

In Figure 2 we can see that the stress distribution does not depend on the angular coordinate except at the ends of the beam. The stress distributions are plotted in Figure 3 in case of pure constant temperature loading.

In the next case we apply an additional concentrated moment (5 kNm) at the free end of the curved beam. The results can be seen in Figure 4.

In the second numerical example the following numerical data will be considered:

$$R_1 = 0.03\mathrm{m},\ R_2 = 0.035\mathrm{m},\ R_3 = 0.04\mathrm{m},$$

$$R_4 = 0.045\mathrm{m},\ R_5 = 0.05\mathrm{m},\ E_1 = 117\ \mathrm{GPa},$$

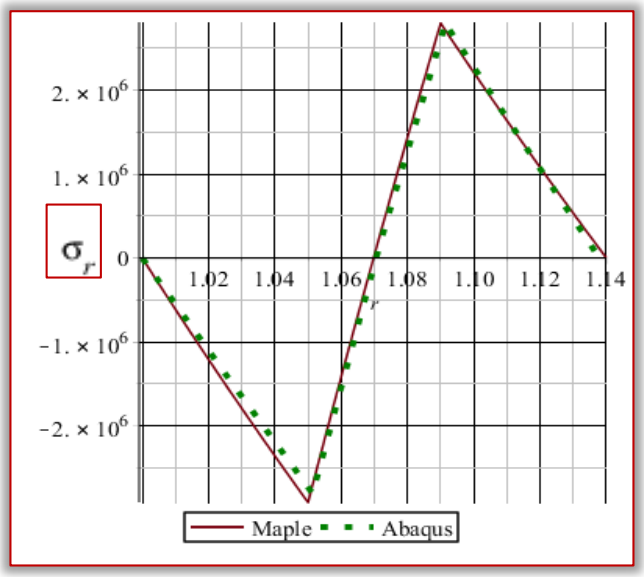
$$E_2 = 200\ \mathrm{GPa},\ E_3 = 69\ \mathrm{GPa},\ E_4 = 117\ \mathrm{GPa},$$

$$v_1 = 0.355,\ v_2 = 0.3,\ v_3 = 0.33,\ v_4 = 0.355,$$

$$\alpha_1 = 1.62 \cdot 10^{-5}\frac{1}{\mathrm{K}},\ \alpha_2 = 1.1 \cdot 10^{-5}\frac{1}{\mathrm{K}},$$

$$\alpha_3 = 2.2 \cdot 10^{-5}\frac{1}{\mathrm{K}},\ \alpha_4 = 1.62 \cdot 10^{-5}\frac{1}{\mathrm{K}},\ T = 150°\mathrm{C},$$

$$\beta = 120°.$$



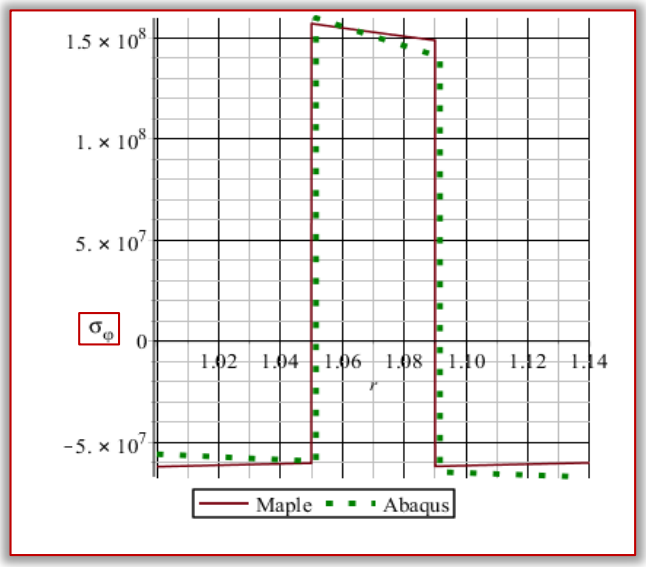
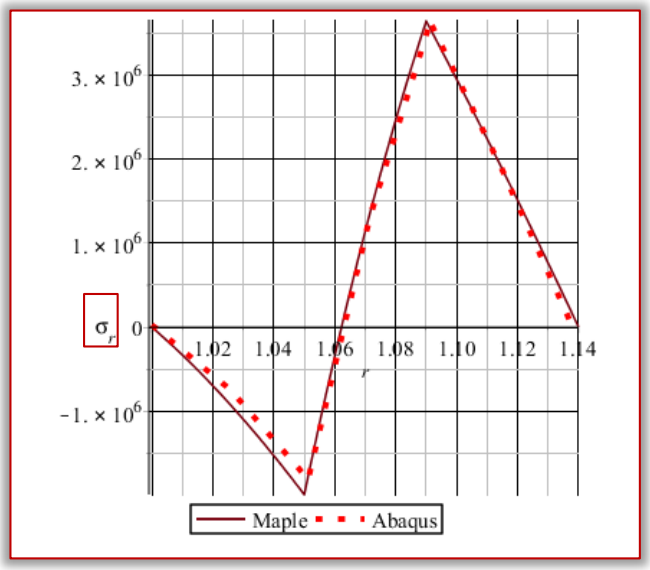


Figure 3. The normal stresses of the first problem subjected to constant temperature field



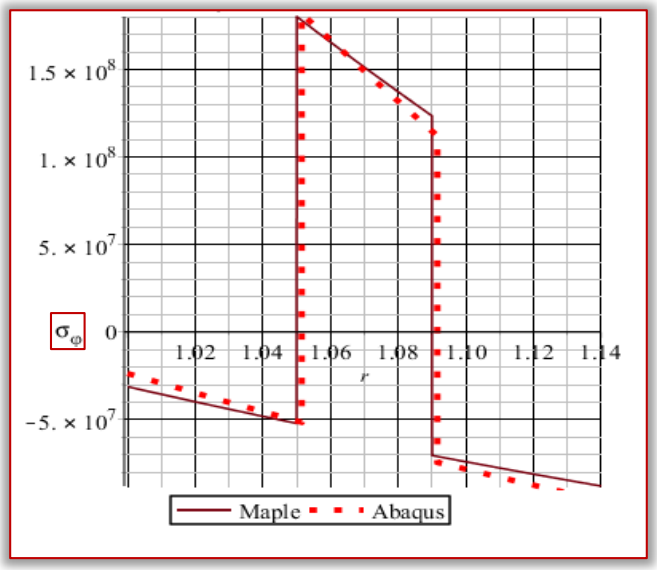


Figure 4. The normal stress distribution of the first problem with constant temperature and concentrated moment

The number of layers is four, the geometry is more strip-like and the mesh of the problem is shown in Figure 5.

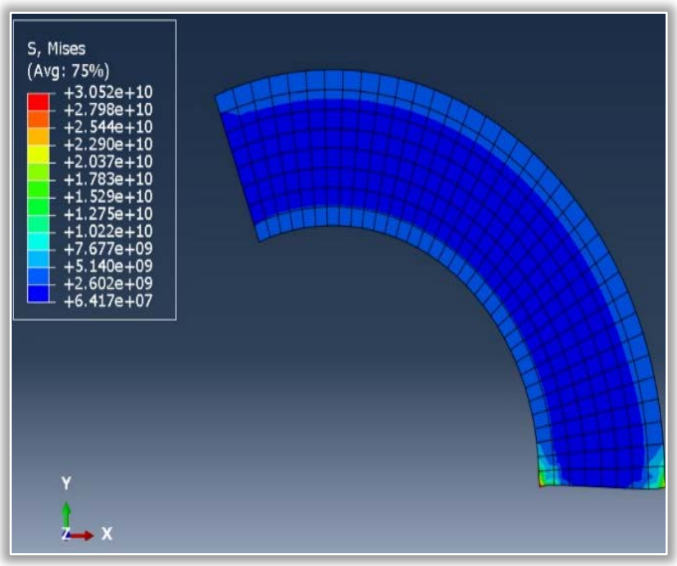
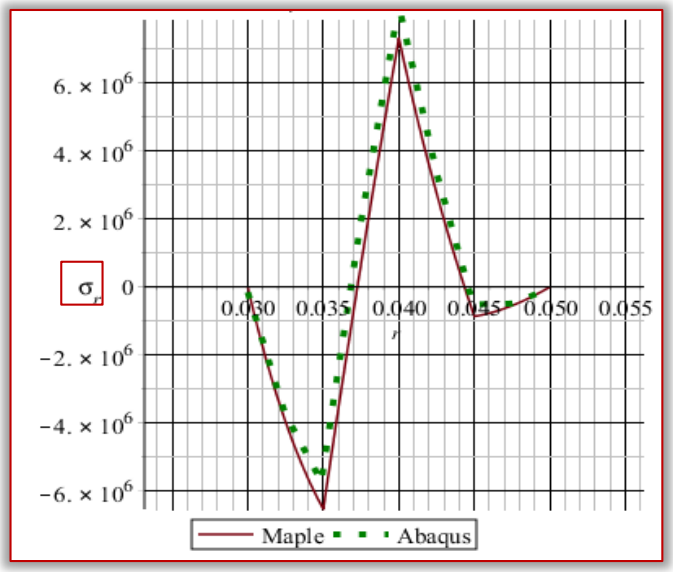


Figure 5. The mesh of the second problem with the von Mises stress distribution

Figure 6 shows the normal stress distribution of the curved beam subjected to constant temperature field while in Figure 7 we can see the effect of an additional moment M=5 kNm on the stress distribution.

The results are in good agreement and we verified that the stress field of these multilayered curved beams with constant curvature depends only on the radial coordinate except in the vicinity of the end cross sections.



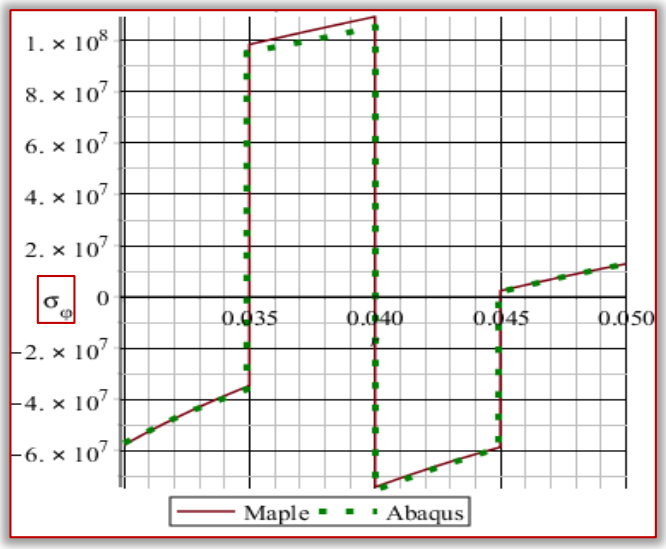
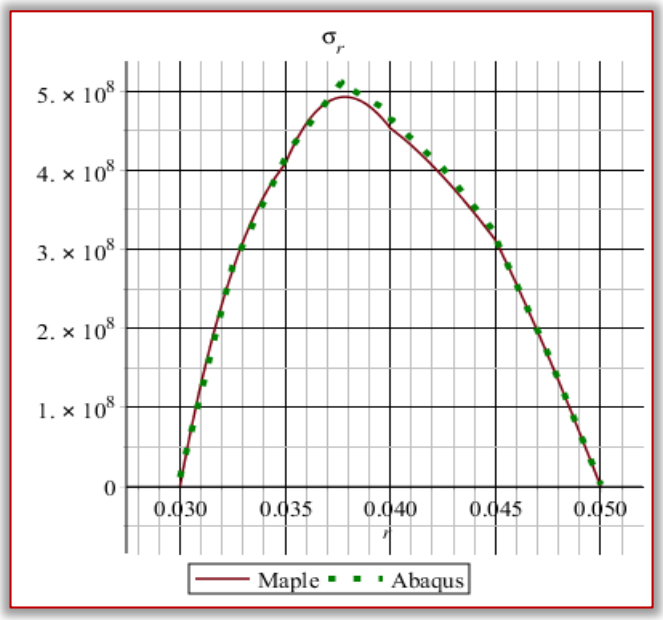


Figure 6. The normal stresses of the first problem with constant temperature field



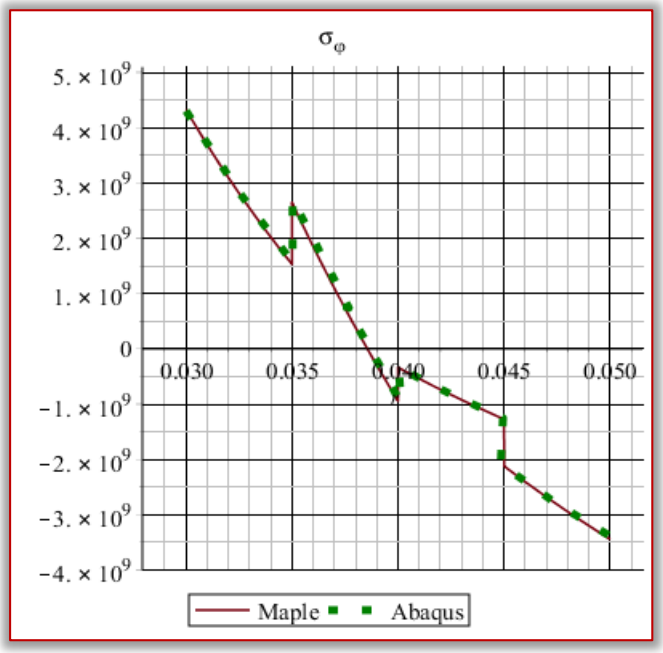


Figure 7. The normal stress distributions of the second problem with constant temperature and concentrated moment

SUMMARY

An analytical method was presented to determine the stresses and displacement in multilayered curved beam subjected to specific thermal and mechanical loads. The curvature of the beam was constant.

The developed method is based on the elasticity equations of plane stress state and Euler Bernoulli beam theory.

A method is presented to tackle the problem of radially graded beams subjected to constant temperature and concentrated moment.

The results were compared to solutions coming from finite element simulations.

References

[1] Timoshenko. S. P.: Analysis of bi-metal thermostats. Journal of the Optical Society of America, 11(3), pp. 233–255, 1925.

[2] Timohsenko. S. P.: The Collected Papers. McGraw Hill, New York, 1953

[3] Young W. C., Budynas R. G.: Roark's Formulas of Stress and Strain. 7th ed. McGraw Hill, New York, 2002.

[4] Boley, B. A. and Weiner, J. H.: Theory of Thermal Stresses. John Wiley & Sons Inc., New York, 1960.

[5] Carreci, E, Fazzolari, F, Cinefra, M.: Thermal Stress Analysis of Composite Beams, Plates, Shells. Academic Press, New York, 2017.

[6] Nowinski I.L.: Theory of Thermoelasticity with Applications. Sythoff and Noordhoff, Alpen aan den Rijn, 1978.

[7] Lekhnitskii, S. G.: Theory of Elasticity of an Anisotropic Body. Mir Publishers, Moscow, 1981.

[8] D. Ramos, I. Mertens, M. Callega, and I. Tamayo.: Study on the origin of bending induced by bimetallic effect on microcantilever. Sensors, 7(9), pp. 1757–1765, 2007.

[9] Rao, A. V., Prasad K. S. V., Avinash, M., Nagababu, K., Manohar, V., Raju, P. S. R. and Chandra, G. R.: A study on deflection of a bimetallic beam under thermal loading using finite element analysis. International Journal of Engineering and Advanced Technology, 2(1), pp. 81–82 2012.

[10] Aignatoaie. M.: FEA study on the elastic deformation process of a simple bimetal beam. Applied Mechanics and Materials, 371(8), pp. 448–452, 2013.

[11] Suhir. E.: Interfacial stresses in bimetal thermostats. Journal of Applied Mechanics, 56(3), pp. 595–600, 2013.

[12] Ecsedi, I., Gönczi, D.: Thermoelastic stresses in nonhomogeneous prismatic bars. Annals of Faculty of Engineering Hunedoara - International Journal of Engineering, 13(2), pp. 49-52, 2015.

[13] Kiss, L. P.: Nonlinear stability analysis of FGM shallow arches under an arbitrary concentrated radial force. International Journal of Mechanics and Materials in Design, 16(1), pp. 91-108, 2020.

[14] Babaei, H., Kiani, Y., Eslami, M.R.: Thermomechanical non-linear in-plane analysis of fix-ended FGM shallow arches on nonlinear elastic foundation using two-step perturbation technique. Int. J. Mech. Mater. Des. 15(2), 225–244, 2019.

[15] Kiss, L.P.: In-plane Buckling of Rotationally Restrained Heterogeneous Shallow Arches Subjected to a Concentrated Force at the Crown Point. Journal of Computational and Applied Mechanics, 9(2), pp. 171-199, 2014.

[16] Kiss, L. P.: Sensitivity of FGM shallow arches to loading imperfection when loaded by a concentrated radial force around the crown. International Journal of Non-linear Mechanics, 116, pp. 62-72, 2019.

[17] Gönczi, D.: Analysis of Rotating Functionally Graded Disks with Arbitrary Material Properties. Acta Technica Corviniensis – Bulletin of Engineering, 11, pp. 1-6, 2018.

[18] Chenyi Zheng, Xiaobao Li, Changwen Mi.: Reducing stress concentrations in unidirectionally tensioned thick-walled spheres through embedding a functionally graded reinforcement. International Journal of Mechanical Sciences, 152, pp. 257-267, 2019.

[19] Gönczi, D.: Thermoelastic analysis of thick-walled functionally graded spherical pressure vessels with temperature-dependent material properties. Journal of Computational and Applied Mechanics, 12(2), pp. 109-125, 2017.

[20] Pydah A., Sabale, A.: Static analysis of bi-directional functionally graded curved beams. Composite Structures 160: 867–876, 2017.

[21] Babaei, H, Kiani, Y, Eslami M.R.: Geometrically nonlinear analysis of functionally graded shallow curved tubes in thermal environment. Thin-walled Structured 123, pp. 48-57, 2018.

[22] Gönczi, D.: Analysis of curved bimetallic beam. Journal of Computational and Applied Mechanics, 41(1-2), pp. 41-51, 2019.

[23] Haskul, M.: Elastic state of functionally graded curved beam on the plane stress state subject to thermal load. Mechanics Based Design of Structures and Machines, 47., 2019.
[24] Ecsedi I., Baksa A.: A half circular beam bending by radial loads. Journal of Computational and Applied Mechanics, 12(1), pp. 3-18., 2017.
[25] Abaqus Standard User's Manual Version 6.13, 2017.

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

[1.]Biljana MILUTINOVIĆ, [2.]Petar S. DJEKIĆ

CONTRIBUTION OF LEAN PRODUCTION TO ENVIRONMENTAL PROTECTION IMPROVEMENT

[1.]College of Apllied Technical Sciences Niš, Niš, SERBIA

Abstract: Lean production is the most extended production concept currently applied in industry. Lean production is characterized by five principles (value, map the value stream, flow, pull and continuous improvement) and by the importance of reducing production waste (defects, waiting, unnecessary processing, overproduction, movement, inventory, unused employee creativity, complexity). Environmental concerns are a part of the Lean concept, although Lean production usually helps the environmental protection without really intending to. Emissions to air, water and soil, as well as waste generation, also represent a production waste (that is, no value to the customer). However, only recently conducted studies linked Lean production concept with environmental protection improvement. The main goal of the present study is to enlighten the contribution of Lean concept for achieving a better environmental performance of production systems.
Keywords: Lean production concept, environmental protection, waste

INTRODUCTION

Lean production became a leading production concept being applied in many sectors in the world, where improving product quality, reducing production costs, and being "first to market" and quick to respond to customer needs are critical to competitiveness and success [1]. Lean principles and methods focus on creating a continual improvement culture that engages employees in reducing the intensity of time, materials, and capital necessary for meetinga customer's needs. Fundamental focus of Lean production is on the systematic elimination of non-value added activity and waste from the production process. From this it can be concluded that the implementation of Lean principles and methods also results in improved environmental performance. However, only recently studies linked Lean production concept with environmental protection improvment. The relationship between Lean production concept and environmental protection has attracted much debate, and at the same time, the lack of empirical evidence leaves haphazard opinions on this matter [2]. A number of authors have proposed that the adoption of Lean production can directly improve the public good by improving the environmental performance of the adopting firms [3]. Some authors cited several organisations who have made economic savings through waste elimination and process improvements as part of their environmental programme [4]. They concluded that taking a Lean approach to waste elimination has considerable potential for environmental and economic sustainability. Also, other authors concluded that the pursuit of continuous improvement (Kaizen), created substantial opportunities for pollution prevention and waste and emissions reduction [5].

The main goal of the present study is to enlighten the contribution of Lean production concept for achieving a better environmental performance of production systems. Each of the production wastes that Lean attempts to reduce is somewhat associated with environmental performance. Hence, attention is focused on if and how Lean production creates more environment friendly production processes.

LEAN PRODUCTION CONCEPT

Lean production concept is developed as a generalisation of the Toyota Production System, which was an embodiment of previous production quality systems [6-7]. Generaly, This concept aims to reduce costs of production by eliminating waste and nonvalue-added activities and is a common underlying principle in many major businesses and production facilities around the world. In essence, Lean concept seeks to preserve value within an organisation with overall less work and thus maximising efficiency through the reduction of waste. Lean production paradigm can be accomplished by applying a wide variety of Lean production tools such as Heijunka, Six Sigma, Kanbans, First In-First Out (FIFO), Value Stream Mapping (VSM), Takt (from Taktzeit meaning cycle) time, Just In Time (JIT), Single Minute Dye Exchange (SMDE), and 5 S principles [7]. The essence of Lean production is to produce "more with les". This implies that Lean thinking organizations use less non-renewable resources in the form of raw materials and energy. This concept can be extended to determine whether Lean thinking can be applied to producing less pollution and emissions and whether Lean manufacturers are therefore more eco-friendly than traditional manufacturers [8].

Lean methods typically target eight types of waste: Defects, Waiting, Unnecessary processing, Overproduction, Movement, Inventory, Unused employee creativity, Complexity.

When companies implement several or all of these

Lean methods, several outcomes consistently result [1]:

- Reduced inventory levels (raw material, work-in-progress, finished product) along with associated carrying costs and loss due to damage, spoilage, off-specification, etc;
- Decreased material usage (product inputs, including energy, water, metals, chemicals, etc.) by reducing material requirements and creating less material waste during manufacturing;
- Optimized equipment (capital equipment utilized for direct production and support purposes) using lower capital and resource-intensive machines to drive down costs;
- Reduced need for factory facilities (physical infrastructure primarily in the form of buildings and associated material demands) by driving down the space required for product production;
- Increased production velocity (the time required to process a product from initial raw material to delivery to a consumer) by eliminating process steps, movement, wait times, and downtime;
- Enhanced production flexibility (the ability to alter or reconfigure products and processes rapidly to adjust to customer needs and changingmarket circumstances) enabling the implementation of a pull production, just-in-time oriented system which lowers inventory and capital requirements; and
- Reduced complexity (complicated products and processes that increase opportunities for variation and error) by reducing the number of parts and material types in products, and by eliminating unnecessary process steps and equipment with unneeded features.

LEAN PRODUCTION AND ENVIRONMENTAL PROTECTION

Successful implementation of the Lean concept undermines the elimination of production waste and which involves employees. While environmental waste (solid waste, hazardous waste, air emissions, waste waters, wastewater discharges) are not explicit targets or drivers for the implementation of the Lean concept, case studies and empirical evidence show that the environmental benefits deriving from the Lean concept are significant.

The application of the Lean production concept is often related to "flow and connectivity". Although not explicitly targeted, environmental benefits are embedded in the creation of this smooth and fast product flow through a production process with minimal defects, inventories, delays, and loss of movement.

For example, reducing defects eliminate negative environmental impacts associated with materials and processing used to create a defective product, as well as waste and emissions resulting from the processing or disposal of defective products. Likewise, reducing inventory and converting to a cellular production schedule reduces the need for space in the building, along with the use of water, energy and materials associated with heating, cooling, lighting and maintenance of the building.

Although negative environmental impacts, such as hazardous waste, air emissions and wastewater discharges, are often not directly identified in productive waste types that are targeted at Lean Initiatives, improvements in these areas are deeply embedded in other types of production waste. Table 1 lists the eight most common types of waste Lean concept works to eliminate, along with the environmental impact that often connects to each of them [1].

Table 1. Eight types of wastes targeted by Lean concept

Waste type	Examples	Environmental impacts
Defects	Production of off-specification products, components or services that result in scrap, rework, replacement production, inspection, and/or defective materials	— Raw materials and energy consumed in making defective products — Defective components require recycling or disposal — More space required for rework and repair, increasing energy use for heating, cooling, and lighting
Waiting	Delays associated with stock-outs, lot processing delays, equipment downtime, capacity bottlenecks	— Potential material spoilage or component damage causing waste — Wasted energy from heating, cooling, and lighting during production downtime
Unnecessary processing	Process steps that are not required toproduce the products	— More parts and raw materials consumed per unit of production — Unnecessary processing increases wastes, energy use, and emissions
Overproduction	Manufacturing items for which there are no orders	— More raw materials and energy consumed in making the unnecessary products — Extra products may spoil or become obsolete requiring disposal.

Table 1 (continuing). Eight types of wastes targeted by Lean concept

Waste type	Examples	Environmental impacts
Movement	Human motions that are unnecessary or straining, and work-in-process (WIP) transporting long distances	— More energy used for transport — Emissions from transport — More space required for WIP movement, increasing lighting, heating, and cooling demand and energy consumption — More packaging required to protect components during movement — Damage and spills during transport
Inventory	Excess raw material, WIP, or finished goods	— More packaging to store WIP — Waste from deterioration or damage to stored WIP — More materials needed to replace damaged WIP — More energy used to heat, cool, and light inventory space
Unused employee creativity	Failure to tap employees for process improvement suggestions	— Waste minimization opportunities
Complexity	More parts, process steps, or time than necessary to meet customer needs	— More parts and raw materials consumed per unit of production — Unnecessary processing increases wastes, energy use, and emissions

The cumulative effect of the concept of Lean production is a powerful means to reduce the overall environmental footprint of production and business operations, and at the same time is a significant driver for a sustainable and continuous improvement of the environment.

Figure 1 presents the relationship between Lean production's 8 types of waste and the 4 core dimensions to measure environmental performance.

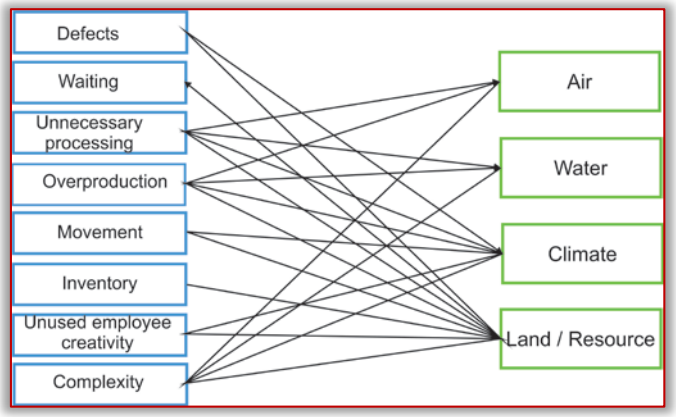


Figure 1. Relationship between Lean's 8 wastes and environmental performance measures

Some examples of positive contribution of Lean production towards environmental performance are:

— Usage of plastic pallet instead of wooden one was adopted under Lean due to short lifecycle and less durability of wooden pallet. This did improve environmental performance by utilizing reusable material (plastic) and preserving resources by not using wood and not burning it at the end of life cycle.

— Reduction in transportation of material has a dual effect. Positive effect by optimizing the operation time, reducing cost, as well as reducing emissions. But at the same time, lower inventory requires more frequent deliveries, thus an increase in emission, but it does balance itself by decreased/delayed resource extraction, and no stagnation of material in storage.

— The food industry greatly benefits from Lean concept, as by adopting JIT principles it minimize the obsolescence and wastage contributing to environmental pollutants.

— The indirect impact on environmental performance is through the utilization of Kanban systems to optimize information flow and reduce the usage of energy by avoiding over processing or incorrect processing.

— The design of assembly/production line affects efficiency. In general, a U-shaped assembly line system is given appraisal by participants, which is also highlighted by scholars [9]. It can improve efficiency by reducing motion within the processes, increase labor productivity by using less people to do the same work - so as to reduce the usage of natural resources and loss of other potential usage.

— By applying the TQM and Lean approaches, the possibility of defective product is minimized to the maximum possible extent, thus resulting in the preservation of natural resources and energy utilized for production.

In general, the environmental impacts of allocation of inventory, volume of production and defects have a strong linkage to the lean strategy [2].

CONCLUSION

Regardless of the lack of empirical data on the contribution of Lean production concept on environmental protection, but given that the essence of Lean production is to produce "more with less", implies that Lean thinking organizations use less non-renewable resources in the form of raw materials and energy and that Lean production is focused on the systematic removal of activities and waste that do not contribute to the value of the production process, which may imply that the application of Lean principles and methods also results in improved environmental performance.

Based on the presented analysis and avaliable examples from practice, it can be concluded that the Lean production concept contribute to the environmental protection. Generaly, two findings are imposed:

- Implementing Lean production concept does foster environmental protection.
- Environmental protection improvement is an added/bonus feature of Lean production.

Note:

This paper is based on the paper presented at DEMI 2019 – The 14th International Conference on Accomplishments in Mechanical and Industrial Engineering, organized by Faculty of Mechanical Engineering, University of Banja Luka, BOSNIA & HERZEGOVINA, co–organized by Faculty of Mechanical Engineering, University of Niš, SERBIA, Faculty of Mechanical Engeneering Podgorica, University of Montenegro, MONTENEGRO and Faculty of Engineering Hunedoara, Unversity Politehnica Timisoara, ROMANIA, in Banja Luka, BOSNIA & HERZEGOVINA, 24–25 May 2019

References

[1] EPA, US (2003). Lean Manufacturing and the Environment: Research on Advanced Manufacturing Systems and the Environment and Recommendations for Leveraging Better Environmental Performance, Ross & Associates Environmental Consulting, Ltd.
[2] Nadeem, S.P., Garza-Reyes, J.A., Leung, S.C., Cherrafi, A., Anosike, T., Lim, M.K. (2017). Lean manufacturing and environmental performance – exploring the impact and relationship. IFIP International Conference on Advances in Production Management Systems (APMS 2017): Advances in Production Management Systems. The Path to Intelligent, Collaborative and Sustainable Manufacturing, Hamburg, Germany, September 3-7, pp. 331-340.
[3] Florida, R. (1996), Lean and Green: The Move to Environmentally Conscious Manufacturing. California Management Review, vol. 39, no. 1, p. 80–105.
[4] Stern, N. (2006). The Economics of Climate Change: The Stern Review. Cambridge University Press, Cambridge
[5] Wallace, D. (1995). Environmental Policy and Industrial Innovation: Strategies in Europe, the U.S. and Japan. Royal Institute of International Affairs, Earthscan Publications Ltd., London.
[6] Deming, W. E. (1986) Out of the Crisis, MIT Press, Cambridge, Mass, USA.
[7] Womack, J., Jones, D., Roos, D. (1991) The Machine that Changed the World: The Story of Lean Production, Harper Perennial.
[8] Found P.A. (2009). Lean and Low Environmental Impact Manufacturing. POMS 20th Annual Conference Orlando, FL, USA.
[9] Sirovetnukul, R., Chutima, P. (2010). The Impact of Walking Time on U-shaped Assembly Line Worker Allocation Problems. Engineering Journal, vol. 14, no. 2, p. 53-78.

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

[1.]Nicoleta UNGUREANU, [2.]Valentin VLĂDUŢ, [1.]Sorin Ştefan BIRIŞ

EMERGING CONTAMINANTS IN WASTEWATER

[1.]University Politehnica of Bucharest, Faculty of Biotechnical Systems Engineering, ROMANIA
[2.]INMA Bucharest, ROMANIA

Abstract: Emerging contaminants are micropollutants found in wastewater, such as antibiotics widely applied to prevent or treat human and animal diseases, and steroid hormones used for animal fattening. Anaerobic processes are widely applied in the treatment of swine, cattle and poultry wastewater, but their performance can be diminished by the inhibition effect of antibiotics. Emerging contaminants cannot be entirely removed by conventional wastewater treatment. They accumulate in sludge and manure applied as fertilizers on the agricultural soil, resulting in localized contamination of surface and ground waters. Released in the environment, the emerging contaminants have eco-toxicological effects in aquatic and terrestrial organisms and human health: feminization of aquatic organisms, bacterial resistance, endocrine disruption, neurotoxicity and cancer. Emerging contaminants endanger the reuse of treated wastewater for irrigation of vegetable and energy crops, a regular practice among farmers trying to overcome water scarcity in arid and semiarid areas. The uptake and bioaccumulation of emerging contaminants in plants and fodders and their subsequent entry in the human food chain have been gaining attention over the last decade. This paper provides a review on the existence and the removal of antibiotics and steroid hormones in wastewater via different treatment technologies.
Keywords: emerging contaminants, antibiotics, steroid hormones, wastewater treatment

INTRODUCTION

In arid and semiarid areas, the reuse of wastewater for irrigation is regularly applied by farmers. Micropollutants in municipal wastewater, such as pharmaceutics, personal care products, pesticides, insecticides, surfactants, detergents, dyes, polymers, plastics, phthalates, flame retardants, industrial additives, and the micropollutants in livestock wastewater, such as antibiotics applied to prevent or treat animal diseases and steroid hormones used for farmed animal fattening, are known as emerging contaminants (ECs). Since they cannot be entirely removed by conventional wastewater treatment, the ECs are released into the receiving environments including rivers, fishponds, and crop fields.

Most commonly found molecules of human drugs in treated effluents and the environment include antibiotics, analgesics, contraceptives, anti-cancer agents, beta-blockers, lipid regulator agents, anti-inflammatory drugs, anticonvulsants, contrast agents, hormones and even disinfectants (Deblonde et al., 2011). Chemical, natural, or synthetic antibiotics are widely administered drugs in human and veterinary medicine and in aquaculture to block the multiplication of pathogenic microorganisms or to treat diseases caused by bacteria (Marcelino et al., 2017). More than 150 antibiotics are currently in use, of which over 90% are natural products of bacteria, fungi and semisynthetic modifications of natural compounds, and only a few are entirely synthetic (von Nussbaum et al., 2006). The increasing use of antibiotics and the subsequent development of multi-resistant bacteria pose severe risks to human and animal health (Grenni et al., 2018) and the environment (Pan and Chu, 2017).

The problem of ECs is the lack of knowledge of their impact in the long-term effect on human health and the environment. Antibiotic residues have been frequently identified in rivers, sediments and soils (Michael et al., 2013). Often, antibiotics manufacturers discharge illegally the wastewater in their neighboring environment, causing further contamination to groundwater, waterways, soil and local communities (Pan and Chu, 2017). A preliminary risk assessment database for common pharmaceuticals and their risk to the environment has been developed (Cooper et al., 2008). When these undesirable compounds end up in the environment, they pose risks to all living organisms: antibiotic-resistant bacteria, antibiotic-resistant genes, neurotoxicity, endocrine disruption, cancer, allergic reactions (Martinez et al., 2014) and feminization of aquatic organisms such as fish, alligators and frogs (Orlando and Ellestad, 2014). Endocrine-disrupting products (steroid hormones, antibiotics and other pharmaceuticals) interfere with normal functioning of hormone systems in wildlife and influence plant development (Habteselassie et al., 2013).

Antibiotics cannot be fully metabolized by humans and animals. During their transfer from ingestion by the animal to the environment and then in wastewater treatment processes, antibiotic molecules could undergo transition and degradation. Thus, various unknown metabolites could be produced through different physicochemical processes, i.e. oxidation, hydrolysis, photodegradation and reduction reactions, which might produce compounds with higher toxicity than those of the antibiotics (Cheng et al., 2018). Eighteen antibiotics have been detected in soil, and seventeen in animal manure and biosolids,

the most abundant of which was tetracyclines, with 2.68 µg/g in soil and 184 µg/g in manure, as well as ciprofloxacin with 3.26 µg/g in biosolids (Pan and Chu, 2017). Sabourin et al. (2012) have studied the uptake of antibiotics by different crops (potato, carrot, tomato and sweet corn) from field soils previously treated with municipal biosolids and reported sulfonamides, trimethoprim and quinolones with concentrations ranging from 0.02 to 14 ng/g (dw) in the edible parts of the crops. The residual antibiotics may be taken up by crops which can be used for animal or human consumption (Dolliver et al., 2007). Once transmitted in the water environment, the residual antibiotics are toxic to algal and cyanobacterial populations that have crucial roles in the health of aquatic ecosystems (Gonzalez-Pleiter et al., 2013). Long-term exposure to residual antibiotics generates antibiotic resistant bacteria and antibiotic resistant genes, and this is recognized as one of the most serious overall public health issues (Davies and Davies, 2010). The prevalence of resistance to old antibiotics (aminopenicillins, tetracyclines, sulfonamides, or erythromycin) can reach more that 50% of some bacterial populations discharged in the final effluents of WWTPs with conventional treatment (Rizzo et al., 2013). Antibiotics and antibiotic resistant genes are emerging environmental contaminants (Pruden et al., 2006) and they have been detected in soils at depth of 20–30 cm (He et. al., 2019) or 40–60 cm (Tang et al., 2015), showing the transfer of antibiotics and migration of resistance determinants to deeper layers of soil by long-term application of animal manure and biosolids. Antibiotic resistance gene levels in the soil increase after irrigation with wastewater (Dungan et al., 2018). Antibiotic resistant bacteria are considered to be ECs (Pruden et. al., 2006) and they can make their way from the farm environment to humans through occupational exposures on farms and at meat processing facilities, as well as by food borne exposures among consumers, use of animal manures as crop fertilizers, and contamination of surface water and groundwater at animal production facilities (Koch et al., 2017).

In recent years, biocides have also been seen as ECs, due to their widespread use in household products. Biocides have adverse effects on aquatic organisms, such as toxicity to algae, weak estrogenic activity, and potential role as endocrine disruptors due to aromatase inhibition (Oliveira et al., 2017). Exposure of aquatic organisms to ECs may cause sexual disruption, such as feminization, intersex, altered oogenesis (Kidd et al., 2007) and could interfere with their growth, aging, survival and reproduction at ng/L levels in aquatic environments (Biswas et al., 2017). Wastewater treatment plants (WWTPs) are the most important source of ECs in the water environment (Sim et al., 2011). Due to their high solubility, low volatility and low degradability, the ECs can survive wastewater treatment processes in WWTPs and be sorbed by biosolids, which are subsequently applied to agricultural lands as fertilizer.

HUMAN ANTIBIOTICS

In developed countries, the annual consumption of pharmaceuticals per capita is of 50–150 g (Zhang et. al., 2008). Human antibiotics are only metabolized partially and after use, their metabolites are excreted into the sewerage network with 30–90% of the parent compounds in feces and urine, and finally end up in the receiving environment (Zhou et al., 2013), not only in wastewater treatment plants (WWTP) but also in surface waters (Hussain et al., 2012), groundwater and soil. In addition, a significant percent is given by expired and unused medicines, inadequately disposed through sinks and drains (Kümmerer, 2009).

Antibiotics reach water and soil (Figure 1) by discharge of municipal sewage, animal husbandry, manufacturing industry, landfill leachates of antibiotic disposal, runoff from agricultural field containing livestock manure, aquaculture ponds (Ben et. al., 2019), hospital and pharmaceutical wastewater (Gadipelly et al., 2014), irrigation with treated wastewater in arid and semi-arid regions, application of biosolids - manure and sludge - to fertilize the soil (Pan and Chu, 2017; Grenni et al., 2018).

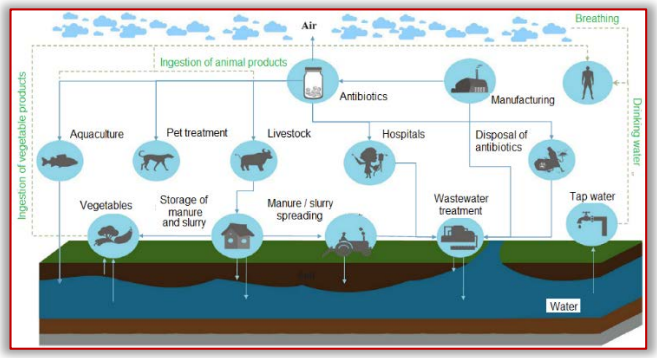


Figure 1 - Human exposure to antibiotic resistance due to antibiotic residues in environment (Ben et al., 2019)

When wastewater, animal manure or biosolids are used in the soil-plant system, the antibiotics might accumulate in irrigated soil, then can be taken up by crops and accumulate in different plant tissues. The uptake and bioaccumulation of pharmaceuticals active compounds in the edible parts of food crops and fodders and their subsequent entry into the human food chain have been gaining prominence over the last decade (Christou et al., 2017).

VETERINARY ANTIBIOTICS

Veterinary antibiotics are extensively used in prevention and treatment of animal diseases, but they are also administered on a large-scale basis, often in feed and water, to enhance productivity, which far

outweighs their use as animal therapeutics at present (Gelband et al., 2015). Common antibiotics used as growth promoters in animal breeding are ampicillin, tetracycline, sulfonamide, chlortetracycline and colistin (Tao et al., 2014). Other widely used veterinary antibiotics belong to the following four classes: oxytetracycline (OTC), sul-famethoxazole (SMX), tylosin (TYL), and monensin (MON) (Tasho and Cho, 2016; Pan and Chu, 2017). Globally, the annual usage of antibiotics has been estimated in the range of 100000 and 200000 tons (Kümmerer, 2003). China, the biggest swine (Liu et al., 2012) and poultry (Wei et al., 2011) breeding country in the world, is also the largest producer and consumer of veterinary antibiotics in the world, with annual usage of over 25000 tons in 2007 (Xu et al., 2007) and 84000 tons in 2015 (Zhang et al., 2015). In United States, about 11200 tons of antibiotics are used for non-therapeutic purposes, mostly to promote the growth of poultry, swine and cattle (Kümmerer, 2009). According to the European Center for Disease Prevention and Control (ECDPC), in 2014, the consumption of veterinary antibiotics in Spain, Italy, and Germany was of 2964, 1432, respectively 1306 tons; the lowest consumption and the lowest consumption were recorded in Luxembourg (2.1 tons) and Iceland (0.6 tons) (Pan and Chu, 2017). In 2030, China would still be the largest consumer of antibiotics in food-producing animals, followed by the USA, Brazil, India and Mexico (van Boeckel et al., 2015).

Given their over-dosage and low assimilation, 70–90% of veterinary antibiotics are excreted into the environment with animal wastes (urine and manure) and thus threaten the health of humans and other organisms by inducing the prevalence of antibiotics resistant bacteria and genes (Cheng et al., 2018). It was estimated that the antibiotics residue excreted from a swine was about 18.2 mg/day (Zhou et al., 2013). Moreover, antibiotics do not emerge in swine wastes individually, but with many other types of antibiotics or toxic pollutants, for example with hormones or heavy metals (Zhang et al., 2017).

Due to the effectiveness, broad-spectrum and favorable price, sulfonamides, tetracyclines, fluoroquinolones, macrolides (Chen et al., 2012) and other antibiotics (bacitracin, lincomycin, ormetoprim and trimethoprim) were extensively used in swine industry (Zhang et al., 2015). These antibiotics have different operation modes on microorganisms, such as interfering with the functions of cell membranes, blocking protein synthesis and preventing nucleic acid synthesis (Cheng et al., 2018). The maximum concentrations of sulfonamides, tetracyclines, fluoroquinolones and macrolides have ranged from 23.8 μg/L to 685 μg/L, with some varying from trace amounts to those as high as the ppm levels in manure slurry (Chen et. al., 2012). In liquid swine manure, concentrations of tetracycline from 14 to 41 mg/kg, chlortetracyclinefrom 0.9 to 1.0 mg/kg, and sulfamethazine at 7.2 mg/kg were reported (Hamscher et al., 2005). Tetracyclines from 0.05 to 15.7 μg/g and sulfonamides from 0.015 to 2.1 μg/g were discovered (Jacobsen and Halling-Sorensen, 2006). Oxytetracycline, erythromycin, florfenicol, sarafloxacin, premix, sulphonamides are commonly used antibiotics in aquaculture (Kumar and Pal, 2018).

The possible remanence of veterinary antibiotics in the environment is influenced by animal excreta, soil type, pH, temperature and UV light. Some antibiotics, for example fluoroquinolones and sulphonamides, are very strongly adsorbed by animal faeces and manure, and they remain unaltered even with increased aeration and temperature in the manure, thereby spreading into the environment in their original active form (Tasho and Cho, 2016). To reduce the environmental and health risk of antibiotics, their use as animal growth promoters has been forbidden in the E.U countries (Alban et al., 2008) and in the United States (FDA, 2003). Current legislation at European level does not contain an antibiotic concentration requirement for discharge from WWTPs to receiving water (Carvalho and Santos, 2016). However, the E.U Water Framework Directive 2015/495 requires those responsible for wastewater treatment to monitor the presence of emerging pollutants with the future aim of improving the quality of the effluent released to surface waters (Acheampong et al., 2019).

STEROID HORMONES

Steroid hormones can interfere with the endocrine function in organisms at low concentrations (Wu et al., 2017). Natural steroids are mainly originated from the feces and urine of human, livestock and aquaculture (Liu et al., 2009). Some natural and synthetic steroids have been used in human daily life for contraception and therapy, and in livestock production to prevent and treat diseases, to promote growth and to improve productivity (Liu et. al., 2012) and animal breeding control (Liu et al., 2015). Natural and synthetic steroid hormones, which are proved to induce biological effects on some organisms at part per trillion concentrations (ng/L), are poorly eliminated by conventional wastewater treatment processes (Fatta-Kassinos et al., 2011). Steroids are estrogens, androgens, glucocorticoids and progestagens. Estrogens, a group of endocrine disrupting compounds (Amin et. al., 2018), are natural (estrone, 17β-estradiol and estriol) when are produced in humans and animals, and synthetic (17α-ethynil estradiol) used as birth-control drugs (Zheng et al., 2008). Women daily excrete 10–100 μg of estrogen, and excretion increases up to 30 mg

during pregnancy. The average human excretion of estrone and 17b-estradiol was 10.5 μg/day and 6.6 μg/day (Tiwari et al., 2017). In influents, the concentrations of estrone, 17β-estradiol and 17α-ethynil estradiol were measured in ranges from 2.4–116, 4–150 and n.d-14.4 ng/L (Amin et al., 2018). In effluents, the concentrations of estrone, 17β-estradiol and 17α-ethynil estradiol were measured in ranges from n.d-96, n.d-30, and n.d-5 (Combalbert and Hernandez-Raquet, 2010). It was found that 10–100 ng/L concentrations of natural estrogens have an effect on the levels of the estrogenic exposure biomarker, vitellogenin, in fish (Cai et. al., 2013).

Dairy cows are the largest contributor of excreted estrogens in comparison to pig, sheep and chickens (Cai et al., 2013). Sewage and livestock wastewater are major pathways of estrogens in aquatic environment (Zheng et. al., 2008). Progestagens are growth promoters that improve the efficacy of feed conversion in animals through increasing bone density and muscular mass (Yang et al., 2009). The E.U, Netherlands and China have prohibited the administration of steroid hormones for farmed animal fattening due to adverse human health effects of hormone residues in animal meats (Liu et al., 2015).

REMOVAL OF EMERGING CONTAMINANTS FROM THE WASTEWATER

Different types of treatments are currently being tested to effectively remove the ECs from wastewater, with the lowest possible economic cost, before being discharged into the ecosystems. Tertiary treatment technologies (ozonation, chlorination, ultraviolet, membrane technologies, sand filters) are the most promising options for reducing ECs.

The conventional activated sludge (AS) and anaerobic digestion (AD) processes are ineffective for antibiotics and hormones removal, and they can still pose risks to the surrounding environment (Figure 2). Nevertheless, AD systems can degrade the antibiotics in swine wastewater to various degrees, depending on the initial concentrations and classes of antibiotics, type of bioreactor and operating conditions. More attention should be given to the toxic effect of antibiotics on micro-organisms involved in anaerobic processes of wastewater treatment. The presence of antibiotics in anaerobic processes changes the microbial structure by altering microorganisms to less sensitive ones to specific antibiotics or by promoting strains with antibiotic resistant genes (Angenent et al., 2008). In biological treatment, biosorption and biodegradation are two major mechanisms for antibiotics and hormones removal (Cheng et al., 2018). Biosorption and biodegradation followed by the removal of excess sludge can be considered for the removal of the estrogens in WWTPs (Luo et al., 2010), with reported removal rates between 19-98% for estrone, 62-98% for 17β-estradiol and 76-90% for 17α-ethynil estradiol (Mohagheghian et al., 2014).

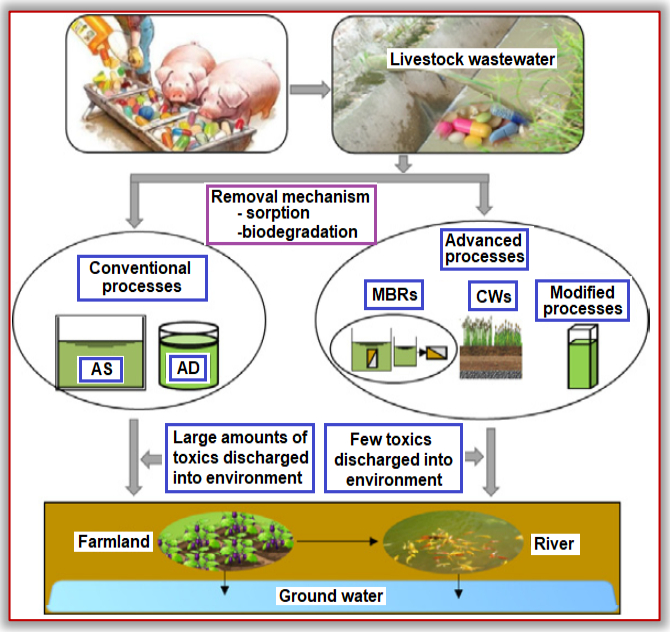


Figure 2 - Removal possibilities of antibiotics and hormones from swine wastewater (Cheng et al., 2018)

Membrane bioreactors (MBRs), constructed wetlands (CWs), stabilization ponds and modified processes perform better due to higher biodegradation of toxicants (Cheng et al., 2018). Microalgal-bacterial processes developed in photobioreactors have recently been recognized as environmentally friendly and cost-effective alternative for ECs removal from wastewater, especially at: high sludge retention time (4–20 days), enhanced penetration of UV light as a result of their high surface area to volume ratios, high daily variations of pH (between 7–11), 2–25 mg O_2/L dissolved oxygen concentration (Norvill et al., 2017). Ibuprofen, naproxen, salicylic acid, triclosan and propylparaben were removed by photodegradation in novel algal-bacterial photobioreactors (Lopez-Serna et al., 2019).

Lagoons as secondary or tertiary treatment have proved to be viable solutions for estrogens removal from livestock wastewater. Large-scale CW systems can effectively remove antibiotics, antibiotic resistant genes, non-steroidal anti-inflammatory drugs, analgesics, stimulants, psychoactive drugs, highly chlorinated compounds (Zhang et al., 2012). The presence of plants in CW improves the removal capacity for pollutants by direct absorption, by providing retention sites and by increasing microbial activities (Carvalho et al., 2014). Vertical subsurface flow CW obtained higher antibiotic removal efficiencies than horizontal subsurface flow and free water surface flow counterparts (Liu et al., 2014).

Antibiotic resistant genes (tetracycline and macrolide-lincosamide-streptogramin B) arising from swine-feeding operations can survive typical

animal waste treatment processes, because their levels remained high in swine wastes during composting (Wang et al., 2012), lime stabilization, anaerobic digestion (Tao et al., 2014), constructed wetlands (Liu et al., 2014) and lagoons (Brooks et al., 2014). Membrane processes (reverse osmosis and nanofiltration), have been effective in the removal of different ECs and allow the separation of divalent and monovalent ions from wastewater. In a feasibility study of removing antibiotics (norfloxacin, ofloxacin, roxithromycin and azithromycin) from a WWTP by secondary treatment followed by nanofiltration were obtained up to 98% removal rates (Liu et al., 2014). Photocatalytic oxidation, intermittent sand or coke filters can remove the ECs from wastewater (Egea-Corbacho et al., 2019).

Adsorption on activated carbon, ozone-based advanced oxidation, photooxidation, radiolysis and electrochemical oxidation have been tested at lab and industrial scale to remove the ECs from wastewater, but toxic by-products are formed and these technologies are quite expensive to be widely applied in WWTPs (López-Serna et al., 2019). Adsorption on multi-walled carbon nanotubes was studied to remove 1,8-dichlorooctane, nalidixic acid and 2-(4-methylphenoxy) ethanol (Patino et al., 2015). Indomethacin, diclofenac, betablockers (atenolol, metoprolol and propranolol), which are poorly removed in AS conventional treatment, showed large ozonation rates and were removed from treated wastewater using moderate ozone doses (Rosal et al., 2010). Electrooxidation using boron doped diamond electrodes is a promising technology to reduce Ecs in wastewater sludge (Barrios et. al., 2015). Acetaminophen and sulfonamide were removed from wastewater using spent mushroom compost of Pleurotus eryngii (Chang et al., 2018).

CONCLUSIONS

The presence of emerging contaminants, a category of micropollutants that include any chemical that is not usually monitored in the environment, was observed in treated wastewater effluents, aquatic environments and soil. Even at low concentrations, the emerging contaminants can increase the resistance among microorganisms and can have a significant impact on the aquatic ecosystems and human health. The development of antibiotic resistant bacteria and antibiotic resistant genes also pose an increasing concern. Although intensely studied, there are still knowledge gaps in the ecotoxicological effects of antibiotics and hormone steroids.

Conventional WWTPs, usually based on biological processes, are unable to fully remove the emerging contaminants from wastewater. Tertiary treatment technologies are the most promising options for reducing ECs. Future research must concentrate on developing sustainable and innovative treatment processes to increase the removal efficiency of emerging contaminants in WWTPs.

Note:

This paper is based on the paper presented at ISB–INMA TEH' 2019 International Symposium (Agricultural and Mechanical Engineering), organized by Politehnica University of Bucharest – Faculty of Biotechnical Systems Engineering (ISB), National Institute of Research–Development for Machines and Installations Designed to Agriculture and Food Industry (INMA Bucharest), Romanian Agricultural Mechanical Engineers Society (SIMAR), National Research & Development Institute for Food Bioresources (IBA Bucharest), National Institute for Research and Development in Environmental Protection (INCDPM), Research-Development Institute for Plant Protection (ICDPP), Research and Development Institute for Processing and Marketing of the Horticultural Products (HORTING), Hydraulics and Pneumatics Research Institute (INOE 2000 IHP) and "Food for Life Technological Platform", in Bucharest, ROMANIA, between 31 October – 1 November, 2019.

Acknowledgement

This work was supported by a grant of the Romanian Ministery of Research and Innovation CCDI - UEFISCDI, Project INNOVATIVE TECHNOLOGIES FOR IRRIGATION OF AGRICULTURAL CROPS IN ARID, SEMIARID AND SUBHUMID-DRY CLIMATE, project number PN-III-P1-1.2-PCCDI-2017-0254, Contract no. 27 PCCDI / 2018, within PNCDI III.

References

[1] Acheampong E., Dryden I.L., Wattis J.A.D., Twycross J., Scrimshaw M.D., Gomes R.L., (2019), Modelling emerging pollutants in wastewater treatment: A Case study using the pharmaceutical 17 α–ethinylestradiol, Computers and Chemical Engineering, vol. 128, pp. 477–487;

[2] Alban L., Nielsen E.O., Dahl J., (2008), A human health risk assessment for macrolide-resistant Campylobacter associated with the use of macrolides in Danish pig production, Prev. Vet. Med., vol. 83, pp. 115–129;

[3] Amin M.M., Bina B., Ebrahimi A., Yavari Z., Mohammadi F., Rahimi S., (2018), The occurrence, fate, and distribution of natural and synthetic hormones in different types of wastewater treatment plants in Iran, Chinese Journal of Chemical Engineering, vol. 26, pp. 1132–1139;

[4] Angenent L.T., Mau M., George U., Zahn J.A., Raskin L., (2008), Effect of the presence of the antimicrobial tylosin in swine waste on anaerobic treatment, Water Res., vol. 42, no. 10, pp. 2377–2384;

[5] Barrios J.A., becerril E., De Leon C., Barrera-Diaz C., Jimenez B., (2015), Electrooxidation treatment for removal of emerging pollutants in wastewater sludge, Fuel, vol. 149, pp. 26–33;

[6] Ben Y., Fu C., Hu M., Liu L., Wong M.H., Zheng C., (2019), Human health risk assessment of antibiotic resistance associated with antibiotic residues in the environment: A review, Environmental Research, vol. 169, pp. 483–493;

[7] Biswas S., Kranz W.L., Shapiro C.A., Snow D.D., Bartelt-Hunt S.L., Mamo M., Tarkalson D.D., Zhang T.C., Shelton D.P., van Donk S.J., Mader T.L., (2017), Effect of rainfall timing and tillage on the transport of

steroid hormones in runoff frommanure amended row crop fields, J. Hazard. Mater., vol. 324, pp. 436–447;
[8] Brooks J.P., Adeli A., McLaughlin M.R., (2014), Microbial ecology, bacterial pathogens, and antibiotic resistant genes in swine manure wastewater as influenced by three swine management systems, Water Res., vol. 57, pp. 96–103;
[9] Cai K., Phillips D.H., Elliott C.T., Muller M., Scippo M.-L., Connolly L., (2013), Removal of natural hormones in dairy farm wastewater using reactive and sorptive materials, Science of the Total Environment, vol. 461–462, pp. 1–9;
[10] Carvalho I.T., Santos L., (2016), Antibiotics in the aquatic environments: a review of the European scenario, Environ. Int., vol. 94, pp. 736–757;
[11] Carvalho P.N., Basto M.C.P., Almeida C.M.R., Brix H., (2014), A review of plant– pharmaceutical interactions: from uptake and effects in crop plants to phytoremediation in constructed wetlands, Environ. Sci. Pollut. Res. Int., vol. 21, no. 20, pp. 11729–11763;
[12] Chang V.-V., Fan S.-N., Tsai Y.-C., Chung Y.-L., Tu P.-X., Yang C.-W., (2018), Removal of emerging contaminants using spent mushroom compost, Science of the Total Environment, vol. 634, pp. 922–933;
[13] Chen Y., Zhang H., Luo Y., Song J., (2012), Occurrence and dissipation of veterinary antibiotics in two typical swine wastewater treatment systems in east China, Environ. Monit. Assess., vol. 184, pp. 1–13;
[14] Cheng D.L., Ngo H.H., Guo W.S., Liu Y.W., Zhou J.L., Chang S.W., Nguyen D.D., Bui X.T., Zhang X.B., (2018), Bioprocessing for elimination antibiotics and hormones from swine wastewater, Science of the Total Environment, vol. 621, pp. 1664–1682;
[15] Cheng D.L., Ngo H.H., Guo W.S., Chang S.W., Nguyen D.D., Kumar S.M., Du B., Wei Q., Wei D., (2018), Problematic effects of antibiotics on anaerobic treatment of swine wastewater, Bioresour. Technol., vol. 263, pp. 642–653;
[16] Christou A., Karaolia P., Hapeshi E., Michael C., Fatta-Kassinos D., (2017), Long-term wastewater irrigation of vegetables in real agricultural systems: Concentration of pharmaceuticals in soil, uptake and bioaccumulation in tomato fruits and human health risk assessment, Water Research, vol. 109, pp. 24–34;
[17] Combalbert S., Hernandez-Raquet G., (2010), Occurrence, fate, and biodegradation of estrogens in sewage and manure, Appl. Microbiol. Biotechnol., vol. 86, pp. 1671–1692;
[18] Cooper E.R., Siewicki T.C., Phillips K., (2008). Preliminary risk assessment database and risk ranking of pharmaceuticals in the environment, Sci Total Environ., vol. 398, pp. 26–33;
[19] Davies J., Davies D., (2010), Origins and evolution of antibiotic resistance, Microbiol. Mol. Biol. Rev., vol. 74, pp. 417–433;
[20] Deblonde T., Cossu-Leguille C., Hartemann P., (2011), Emerging pollutants in wastewater: A review of the literature, International Journal of Hygiene and Environmental Health, vol. 214, pp. 442–448;
[21] Dolliver H., Kumar K., Gupta S., (2007), Sulfamethazine uptake by plants from manure amended soil, J. Environ. Qual., vol. 36, pp. 1224–1230;
[22] Dungan R.S., McKinney C.W., Leytem A.B., (2018), Tracking antibiotic resistance genes in soil irrigated with dairy wastewater, Science of the Total Environment, vol. 635, pp. 1477–1483;
[23] Egea-Corbacho A., Gutiérrez S., Quiroga J.M., (2019), Removal of emerging contaminants from wastewater through pilot plants using intermittent sand/coke filters for its subsequent reuse, Science of the Total Environment, vol. 646, pp. 1232–1240;
[24] Fatta-Kassinos D., Kalavrouziotis I.K., Koukoulakis P.H., Vasquez M.I., (2011), The risks associated with wastewater reuse and xenobiotics in the agroecological environment, Science of the Total Environment, vol. 409, pp. 3555–3563;
[25] FDA, 2003. New Guidance for Industry on Antimicrobial Drugs for Food Animals. GFI#152. Released October 23. US Food and Drug Administration, p. 35;
[26] Gadipelly C., Pérez-González A., Yadav G.D., Ortiz I., Ibáñez R., Rathod V.K., Marathe K.V., (2014), Pharmaceutical industry wastewater: review of the technologies for water treatment and reuse, Ind. Eng. Chem. Res., vol. 53, pp. 11571–11592;
[27] Gelband H., Molly Miller P., Pant S., Gandra S., Levinson J., Barter D., White A., Laxminarayan R., (2015), The state of the world's antibiotics, Wound Heal. South. Afr., vol. 8, pp. 30–34;
[28] Gonzalez-Pleiter M., Gonzalo S., Rodea-Palomares I., Leganes F., Rosal R., Boltes K., Marco E., Fernandez-Pinas F., (2013), Toxicity of five antibiotics and their mixtures towards photosynthetic aquatic organisms: implications for environmental risk assessment, Water Res., vol. 47, pp. 2050–2064;
[29] Grenni P., Ancona V., Barra Caracciolo A., (2018), Ecological effects of antibiotics on natural ecosystems: A review, Microchemical Journal, vol. 136, pp. 25–39;
[30] Habteselassie M.Y., Xu L., Norton J.M., (2013), Ammonia-oxidizer communities in an agricultural soil treated with contrasting nitrogen sources, Front. Microbiol., vol. 4, 00326;
[31] Hamscher G., Pawelzick H.T., Höper H., Nau H., (2005), Different behavior of tetra-cyclines and sulfonamides in sandy soils after repeated fertilization with liquid manure, Environ. Toxicol. Chem., vol. 24, pp. 861–868;
[32] He L.-Y., He L.-K., Liu Y.-S., Zhang M., Zhao J.-L., Zhang Q.-Q., Ying G.-G., (2019), Microbial diversity and antibiotic resistome in swine farm environments, Science of the Total Environment, vol. 685, pp. 197–207;
[33] Hussain S.A., Prasher S.O., Patel R.M., (2012), Removal of ionophoric antibiotics in free water surface constructed wetlands, Ecological Engineering, vol. 41 (0), pp. 13–21;
[34] Jacobsen A.M., Halling-Sorensen B., (2006), Multi-component analysis of tetracyclines, sulfonamides and tylosin in swine manure by liquid chromatography-tandem mass spectrometry, Anal. Bioanal. Chem., vol. 384, pp. 1164–1174;
[35] Kidd K.A., Blanchfield P.J., Mills K.H., Palace V.P., Evans R.E., Lazorchak J.M., Flick R.W., (2007), Collapse of a fish population after exposure to a

synthetic estrogen, Proc. Natl. Acad. Sci., vol. 104, no. 21, pp. 8897–8901;
[36] Koch B.J., Hungate B.A., Price L.B., (2017), Food-animal production and the spread of antibiotic resistance: the role of ecology, Front. Ecol. Environ., vol. 15, pp. 309–318;
[37] Kumar A., Pal D., (2018), Antibiotic resistance and wastewater: Correlation, impact and critical human health challenges, Journal of Environmental Chemical Engineering, vol. 6, pp. 52–58;
[38] Kümmerer K., (2003), Significance of antibiotics in the environment, J. Antimicrob. Chemother., vol. 52, pp. 5–7;
[39] Kümmerer K., (2009), The presence of pharmaceuticals in the environment due to human use - present knowledge and future challenges, J Environ Manage, vol. 90, pp. 2354–2366;
[40] Kümmerer K., (2009), Antibiotics in the aquatic environment – a review – part I, Chemosphere, vol. 75, no. 4, pp. 417–434;
[41] López-Serna R., Posadas E., Garcia-Encina P.A., Muñoz R., (2019), Removal of contaminants of emerging concern from urban wastewater in novel algal-bacterial photobioreactors, Science of the Total Environment, vol. 662, pp. 32–40;
[42] Liu Z.H., Kanjo Y., Mizutani S., (2009), Urinary excretion rates of natural estrogens and androgens from humans, and their occurrence and fate in the environment: a review, Science of the Total Environment, vol. 407, no. 18, pp. 4975-4985;
[43] Liu S., Ying G.-G., Zhou L-J., Zhang R.-Q., Chen Z.-F., Lai H.-J., (2012), Steroids in a typical swine farm and their release into the environment, Water Research, vol. 46, pp. 3754–3768;
[44] Liu P., Zhang H., Feng Y., Yang F., Zhang J., (2014), Removal of trace antibiotics from wastewater: A systematic study of nanofiltration combined with ozone-based advanced oxidation processes, Chem. Eng. J., vol. 240, pp. 211–220;
[45] Liu L., Liu Y.H., Wang Z., Liu C.X., Huang X., Zhu G.F., (2014), Behavior of tetracycline and sulfamethazin with corresponding resistance genes from swine wastewater in pilot-scale constructed wetlands, J. Hazard. Mater., vol. 278, pp. 304–310;
[46] Liu S.-S., Ying G.-G., Liu Y.-S., Yang Y.-Y., He L.-Y., Chen J., Liu W.-R., Zhao J.-L., (2015), Occurrence and removal of progestagens in two representative swine farms: Effectiveness of lagoon and digester treatment, Water Research, vol. 77, pp. 146–154;
[47] Luo Y., Guo W., Ngo H.H., Nghiem L.D., Hai F.I., Zhang J., Liang S., Wang X.C., (2010), A review on the occurrence of micropollutants in the aquatic environment and their fate and removal during wastewater treatment, Science of the Total Environment, vol. 473–474, pp. 619–641;
[48] Marcelino R.B.P., Leao M.M.D., Lago R.M., Amorim C.C., (2017), Multistage ozone and biological treatment system for real wastewater containing antibiotics, Journal of Environmental Management, vol. 195, pp. 110–116;
[49] Martinez J., Coque T.M., Baquero F., (2014), What is a resistance gene? Ranking risk in resistomes. Nat. Publ. Group, 1–8;
[50] Michael I., Rizzo L., McArdell C.S., Manaia C.M., Merlin C., Schwartz T., et al., (2013), Urban wastewater treatment plants as hotspots for the release of antibiotics in the environment: a review, Water Res., vol. 47, pp. 957–995;
[51] Mohagheghian A., Nabizadeh R., Mesdghinia A., Rastkari N., Mahvi A.H., Alimohammadi M., Yunesian M., Ahmadkhaniha R., Nazmara S., (2014), Distribution of estrogenic steroids in municipal wastewater treatment plants in Tehran, Iran, J. Environ. Health Sci. Eng., vol. 12, pp. 1–7;
[52] [52] Nikolaou A, Meric S, Fatta D., (2007), Occurrence patterns of pharmaceuticals in water and wastewater environments, Anal Bioanal Chem., vol. 387, pp. 1225–1234;
[53] Norvill Z.N., Toledo-Cervantes A., Blanco S., Shilton A., Guieysse B., Muñoz R., (2017), Photodegradation and sorption govern tetracycline removal during wastewater treatment in algal ponds, Bioresour. Technol., vol. 232, pp. 35–43;
[54] Oliveira I.B., Groh K.J., Schönenberger R., Barroso C., Thomas K.V., Suter M.J., (2017), Toxicity of emerging antifouling biocides to non-target freshwater organisms from three trophic levels, Aquat. Toxicol., vol. 191, pp. 164–174;
[55] Orlando E.F., Ellestad L.E., (2014), Sources, concentrations, and exposure effects of environmental gestagens on fish and other aquatic wildlife, with an emphasis on reproduction, Gen. Comp. Endocrinol., vol. 203, pp. 241–249;
[56] Pan M., Chu L.M., (2017), Fate of antibiotics in soil and their uptake by edible crops, Science of the Total Environment, vol. 599–600, pp. 500–512;
[57] Patino Y., Diaz E., Ordonez S., Gallegos-Suarez E., Guerrero-ruiz A., Rodriguez-Ramos I., (2015), Adsorption of emerging pollutants on functionalized multiwall carbon nanotubes, Chemosphere, vol. 136, pp. 174–180;
[58] Pruden A., Pei R.T., Storteboom H., Carlson K.H., (2006), Antibiotic resistance genes as emerging contaminants: studies in northern Colorado, Environ. Sci. Technol., vol. 40, pp. 7445–7450;
[59] Rizzo L., Manaia C., Merlin C., Schwartz T., Dagot C., Ploy M.C., et al., (2013), Urban wastewater treatment plants as hotspots for antibiotic resistant bacteria and genes spread into the environment: a review, Science of the Total Environment, vol. 447, pp. 345–360;
[60] Rosal R., Rodriguez A., Perdigon-Melon J.A., Petre A., Garcia-Calvo E., Gomez M.J., Aguera A., Fernandez Alba A.R., (2010), Occurrence of emerging pollutants in urban wastewater and their removal through biological treatment followed by ozonation, Water Research, vol. 44, pp. 578–588;
[61] Sabourin L., Duenk P., Bonte-Gelok S., Payne M., Lapen D.R., Topp E., (2012), Uptake of pharmaceuticals, hormones and parabens into vegetables grown in soil fertilized with municipal biosolids, Science of the Total Environment, vol. 431, pp. 233–236;
[62] Sim W.-J., Lee J.-W., Shin S.-K., Song K.-B., Oh J.-E., (2011), Assessment of fates of estrogens in wastewater and sludge from various types of wastewater treatment plants, Chemosphere, vol. 82, pp. 1448–1453;
[63] Tang X., Lou C., Wang S., Lu Y., Liu M., Hashmi M.Z., Liang X., Li Z., Liao Y., Qin W., Fan F., Xu J., Brookes P.C., (2015), Effects of long-term manure applications on the occurrence of antibiotics and antibiotic resistance genes (ARGs) in paddy soils: evidence from

four field experiments in south of China, Soil Biol. Biochem., vol. 90, pp. 179–187;
[64] Tao C.-W., Hsu B.-M., Ji W.-T., Hsu T.-K., Kao P.-M., Hsu C.-P., Shen S.-M., Shen T.-Y., Wan T.-J., Huang Y.-L., (2014), Evaluation of five antibiotic resistance genes in wastewater treatment systems of swine farms by real-time PCR, Science of the Total Environment, vol. 496, pp. 116–121;
[65] Tasho R. P., Cho J. Y., (2016), Veterinary antibiotics in animal waste, its distribution in soil and uptake by plants: A review, Science of the Total Environment, vol. 563–564, pp. 366–376;
[66] Tiwari B., Sellamuthu B., Ouarda Y., Drogui P., Tyagi R.D., Buelna G., (2017), Review on fate and mechanism of removal of pharmaceutical pollutants from wastewater using biological approach, Bioresource Technology, vol. 224, pp. 1–12;
[67] van Boeckel T.P., Brower C., Gilbert M., Grenfell B.T., Levin S.A., Robinson T.P., Teillant A., Laxminarayan R., (2015), Global trends in antimicrobial use in food animals, Proceedings of the National Academy of Sciences of the United States of America- PNAS, vol. 112, no. 18, pp. 5649-5654;
[68] von Nussbaum F., Brands M., Hinzen B., (2006), Medicinal chemistry of antibacterial natural products exodus or revival? Angew. Chem. Int. Ed.. vol. 45, pp. 5072–5129;
[69] Wang L.L., Oda Y., Grewal S., Morrison M., Michel F.C., Yu Z.T., (2012), Persistence of resistance to erythromycin and tetracycline in swine manure during simulated composting and lagoon treatments, Microb. Ecol., vol. 63, no. 1, pp. 32–40;
[70] Wei R., Ge F., Huang S., Chen M., Wang R., (2011), Occurrence of veterinary antibiotics in animal wastewater and surface water around farms in Jiangsu Province, China, Chemosphere, vol. 82, pp. 1408–1414;
[71] Wu Q., Lam J.C.W., Kwok K.Y., Tsui M.M.P., Lam P.K.S., (2017), Occurrence and fate of endogenous steroid hormones, alkylphenol ethoxylates, bisphenol A and phthalates in municipal sewage treatment systems, Journal of Environmental Sciences, vol. 61, pp. 49-58;
[72] Xu W.H., Zhang G., Zou S.C., Li X.D., Liu Y.C., (2007), Determination of selected antibiotics in the Victoria Harbour and the Pearl River, South China using high performance liquid chromatography spectrospray ionization tandem mass spectrometry, Environ. Pollut., vol. 145, pp. 672–679;
[73] Yang Y., Shao B., Zhang J., Wu Y.N., Duan H.J., (2009), Determination of the residues of 50 anabolic hormones in muscle, milk and liver by very-high-pressure liquid chromatography-electrospray ionization tandem mass spectrometry, J. Chromatogr. B., vol. 877, no. 5, pp. 489–496;
[74] Zhang Y., Geißen S.U., Gal C., (2008), Carbamazepine and diclofenac: removal in wastewater treatment plants and occurrence in water bodies, Chemosphere, vol. 73, pp. 1151–1161;
[75] Zhang D.Q., Gersberg R.M., Hua T., Zhu J., Tuan N.A., Tan S.K., (2012), Pharmaceutical removal in tropical subsurface flow constructed wetlands at varying hydraulic loading rates, Chemosphere, vol. 87, no. 3, pp. 273–277;
[76] Zhang Q., Ying G., Pan C., Liu Y., Zhao J., (2015), Comprehensive evaluation of antibiotics emission and fate in the river basins of China: source analysis, multimedia modeling, and linkage to bacterial resistance, Environ. Sci. Technol., vol. 49, no. 11, pp. 6772–6782;
[77] Zhang R., Wang X., Gu J., Zhang Y., (2017), Influence of zinc on biogas production and antibiotic resistance gene profiles during anaerobic digestion of swine manure, Bioresour. Technol., vol. 244, pp. 63–70;
[78] Zheng W., Yates S.R., Bradford S.A., (2008), Analysis of steroid hormones in a typical dairy waste disposal system, Environ. Sci. Technol., vol. 42, pp. 530–535;
[79] Zhou L.J., Ying G.G., Zhang R.Q., Liu S., Lai H.J., Chen Z.F., Yang B., Zhao J.L., (2013), Use patterns, excretion masses and contamination profiles of antibiotics in a typical swine farm, south China, Environ. Sci. Processes Impacts, vol. 15, pp. 802–813;
[80] Zhou L.J., Ying G.G., Liu S., Zhang R.Q., Lai H.J., Chen Z.F., Pan C.G., (2013), Excretion masses and environmental occurrence of antibiotics in typical swine and dairy cattle farms in China, Science of the Total Environment, vol. 444, pp.183–195.

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

[1].J. VASWANI, [2].A. AGARWAL

A FOUR PORT, DUAL BAND ANTENNA FOR FIFTH GENERATION MOBILE COMMUNICATION AND WLAN SERVICES

[1,2].Electronics and Communication Engineering Department, Sangam University, Bhilwara, Rajasthan, INDIA

Abstract: This paper presents a dual-band four port antenna system for Fifth Generation devices and WLAN services. This antenna works on sub-6 GHz frequency bands with center frequencies as 3.6 GHz and 5.5 GHz. It is designed on FR-4 substrate of thickness of 1.6 mm. The simulations are performed on CST for 4 port configuration of the proposed antenna. It offers gain more than 3dB and radiation efficiency more than 60% for both bands of operation. Both operating bands can be controlled independently.
Keywords: 5G, WLAN, MIMO, Sub-6 GHz, Dual-band

INTRODUCTION

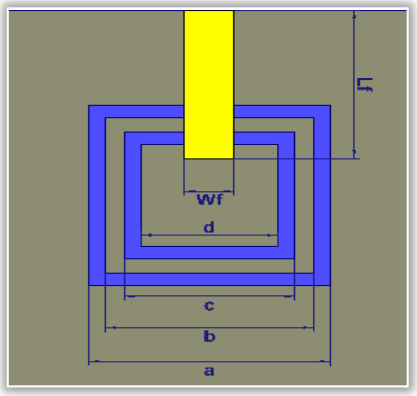
Multiple input, multiple output (MIMO) technology has been used to increase the data rate in fourth generation mobile device and will also be deployed in Fifth Generation (5G) user equipments with even higher data rate. In advanced wireless communication devices, MIMO, massive MIMO and multi-beam systems have been extensively deployed. [1] To get the superior data capacity, MIMO is almost certain to be used in 5G systems. [2] MIMO antenna systems have been proposed with different number of antennas. Two to four elements MIMO antennas are proposed in literature by various researchers. [3]-[4] MIMO with 8 elements is discussed in numerous research articles. [5]-[6] More than eight elements MIMO is also discussed by few researchers.[7]

Various types of antennas have been proposed for 5G devices by various researchers. Slot antenna have been proposed in [8], [9] Multi-band antenna is proposed by the author for GPS/2G/3G/4G and 5G NR Applications. [10] A compact ultra-wide band antenna with MIMO system for sub-6 GHz 5G services is also proposed with fractional bandwidth of 143%. [11] Parasitic layer-based pattern reconfigurable antenna is discussed by the author for 5G communication devices. [12] A '9' shaped patch antenna for 3.5 GHz band of 5G applications, designed on FR-4 substrate is presented by the author. [13] An eight antenna MIMO array with balanced open slot antenna operating at 3.5 GHz band with total efficiency greater than 62% and low ECC is presented. [14]

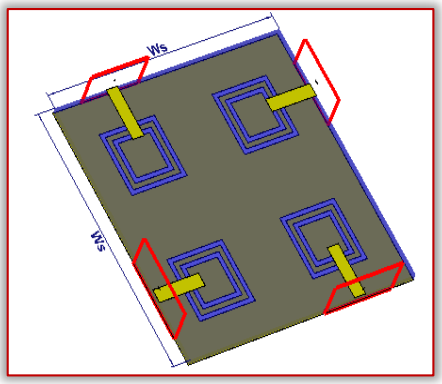
In this paper a dual-band 4 port MIMO antennas system is proposed on FR-4 substrate that operates on the sub 6 GHz frequencies allotted for fifth generation services. It is designed on a square substrate. The two operating bands are results of the two square loops etched on the ground plane. The antenna design and the simulation results in terms of S-parameter, gain, efficiencies and the surface current distribution pattern is discussed in the next section of the paper.

ANTENNA DESIGN

Figure 1 show a four port antenna designed on the FR-4 epoxy substrate with thickness 1.6 mm and the copper thickness of 0.035 mm. The overall dimensions of the antenna are 60mm x 60mm x 1.6mm. The proposed antenna has four identical antennas each designed in 30mm x 30mm area and packed together as shown in figure.



(a)



(b)

Figure 1: The proposed slot antenna configuration, (a) Front and Back View (b) Side-View

Each antenna has a feed element is fed by 50-Ω microstrip transmission line and two squared ring slots cut into the ground plane. The dimensions of feed element and of the slots are given the figure. Two slots are responsible for two resonating frequencies of the antenna, outer slot for lower frequency and the inner

slot for higher one. The length of the slots is responsible for the resonating frequency and the resonating frequency is inversely proportional to the length of the slot.

Table 1: The Values of Design Parameters

Parameter	Value (mm)
a	14.6
b	12.6
c	10.3
d	8.3
Wf	3
Lf	12
Ws	60
h	1.6

RESULTS AND DISCUSSION

The S-parameter results of the proposed antenna are shown in the figure 2. All the four antennas have almost identical S-parameter results with resonating frequencies at 3.6 GHz and 5.5 GHz. The band with 6 dB as the benchmarks is 450 MHz in 3.6 GHz band and more than 800 MHz in 5.5 GHz band.

The value of voltage standing wave ratio (VSWR) remains close to 2 as visible in figure 3 and it also verify the same about the operating frequencies of the antenna. The antenna is also having good isolation i.e. very less mutual coupling, more than 17 dB isolation from the neighboring antennas, verified from the figure 4.

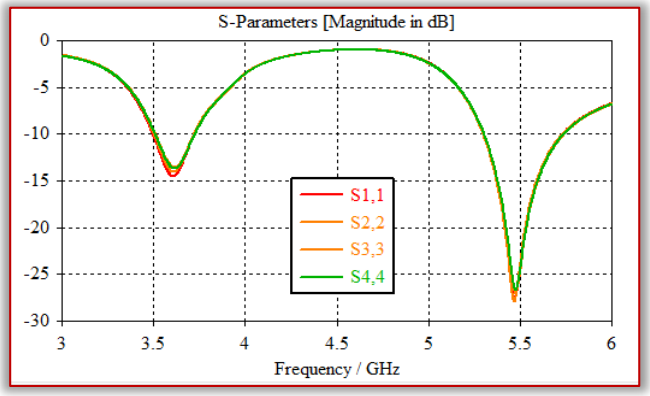


Figure 2: S-Parameter results of the proposed antenna for all four ports

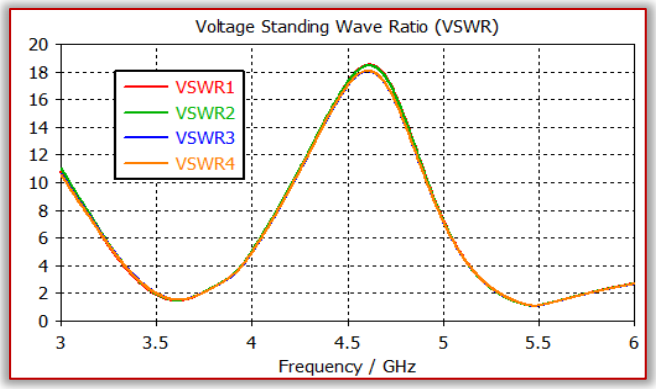


Figure 3: VSWR results of the proposed antenna for all four ports

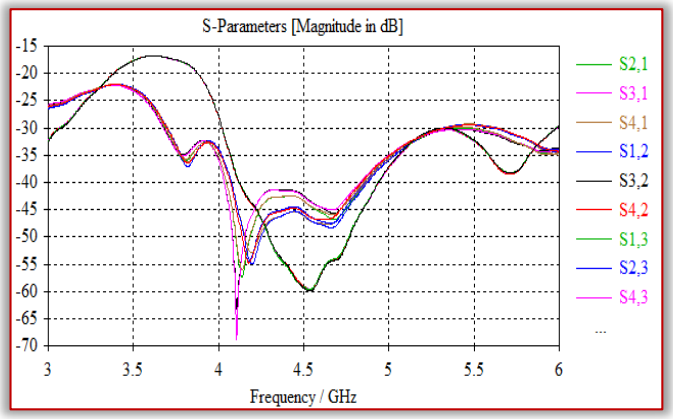


Figure 4: Mutual Coupling between the ports of antenna system

As seen in the figure 5, the plot of Radiation Efficiency v/s Frequency, the radiation efficiency of the antenna is more than 60% in the 3.6 GHz band and 55 to 74 % in the 5.5 GHz band. So, the antenna is radiating efficiently and is always more than 50%. The total efficiency of the antenna is more than 50% for both the operating bands.

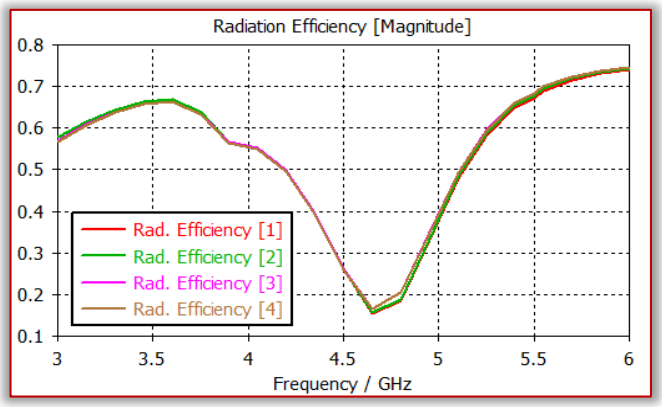


Figure 5: Radiation efficiency for all the four ports of the antenna.

Figure 6 and figure 7 shows the vector current for the both resonant frequencies of the proposed antenna. The outer slot is having high surface current density (111.3 A/m) for 3.6 GHz and the inner slot is having high surface current density (88.6 A/m) for 5.5 GHz.

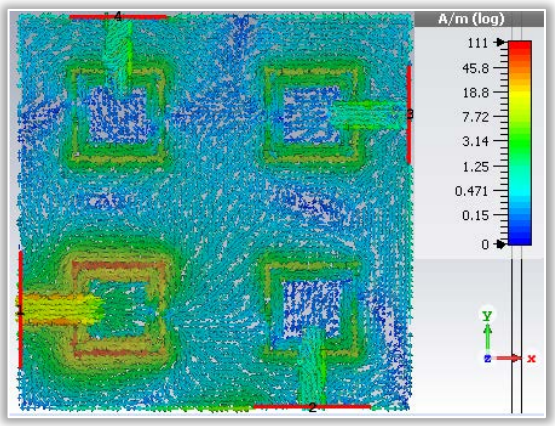


Figure 6: Surface Current at 3.6 GHz

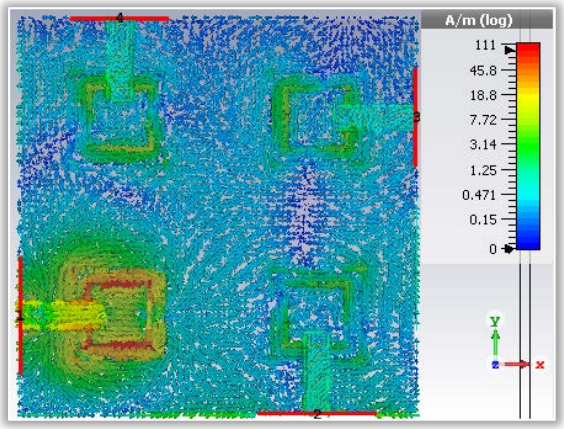
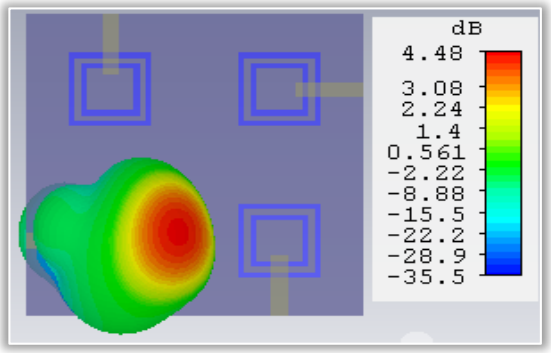
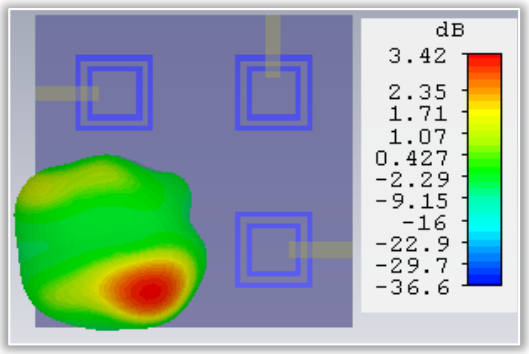


Figure 7: Surface Current at 5.5 GHz



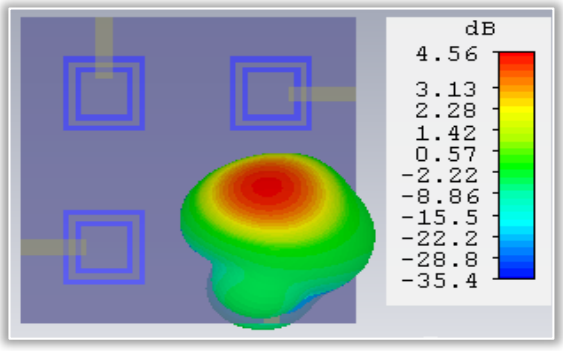
(a)



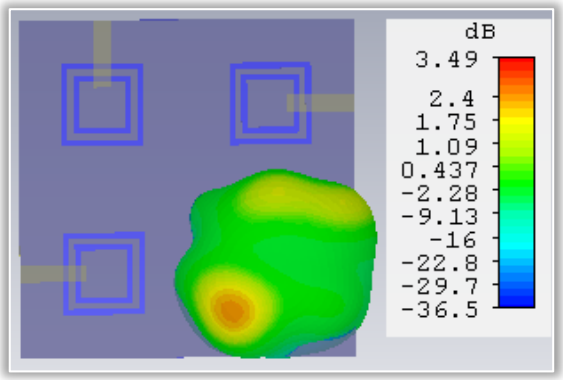
(b)

Figure 8: 3D Antenna Radiation Pattern for antenna 1 (a) At 3.6 GHz (b) At 5.5 GHz

As evident from the 3D gain plot of the proposed antenna shown in figure 8 and figure 9, the gain of the antenna at 3.6 GHz frequency is approx. 4.5 dB and for 5.5 GHz it is 3.5 dB. Further the polar plot in figure 10, show that the radiation pattern is bidirectional.

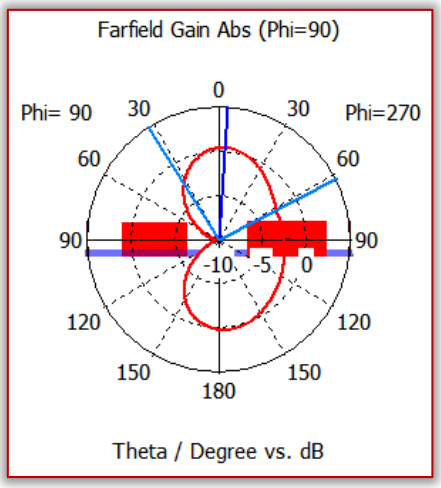


(a)

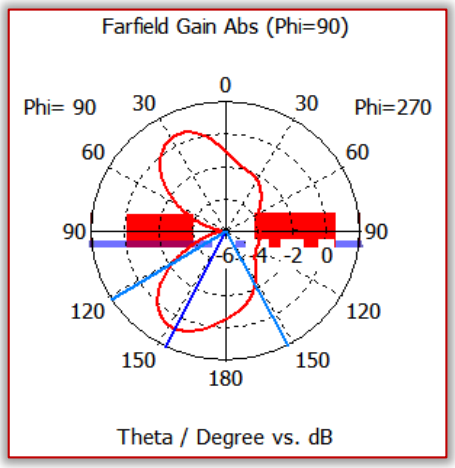


(b)

Figure 9: 3D Antenna Radiation Pattern for antenna 2 (a) At 3.6 GHz; (b) At 5.5 GHz



(a)



(b)

Figure 10: 2D Antenna Radiation Pattern for antenna 1 (a) At 3.6 GHz (b) At 5.5 GHz

Another important result to be observed is Envelope Correlation Coefficient (ECC). As visible in the figure 11, the value of ECC is below 0.02 for the complete range of frequencies from 3 GHz to 6 GHz for port 1 with other three ports. Similar results are obtained for port 2, 3 and 4.

Similarly, diversity gain is simulated for Port 1 with other three ports. The obtained diversity gain is more than 9.9 for the proposed two bands of operation of the antenna.

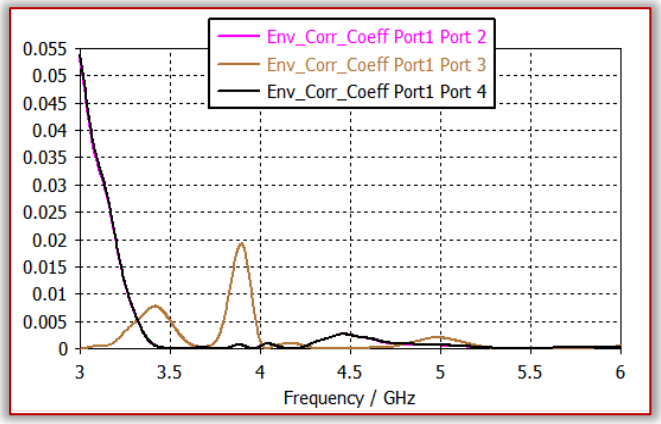


Figure 11: Envelope Correlation Coefficient for the port 1 of antenna system

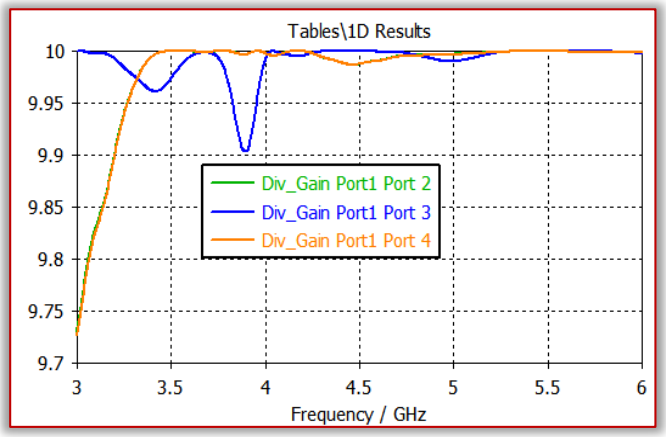


Figure 12: Diversity Gain for the port 1 of antenna system

CONCLUSIONS

In this paper, a four port dual band antenna is proposed for 5G communication systems. The proposed antenna has two concentric square slots for the two resonant frequencies at 3.6 GHz and 5.5 GHz, The proposed structure has sufficiently high gain, radiation efficiency and diversity gain with very small value of mutual coupling and Envelope Correlation Coefficient. The proposed antenna can be good candidate to be installed in future I-pads and wi-fi devices.

Acknowledgement:
We would like to acknowledge Dr. Sanjeev Yadav, Department of Electronics and Communication Engineering, GWECA and Mr. Sayyed Arif Ali, Scholar, AMU, for their suggestions and support in carrying out these simulations.

References:

[1] Z. N. Chen, D. Liu, H. Nakano, X. Qing, and T. Zwick, Handbook of Antenna Technologies, vol. 1–4. Singapore: Springer Singapore, 2016.
[2] W. Hong, "Solving the 5G Mobile Antenna Puzzle: Assessing Future Directions for the 5G Mobile Antenna Paradigm Shift," IEEE Microw. Mag., vol. 18, no. 7, pp. 86–102, Nov. 2017.
[3] H. Alsaif, M. Usman, M. T. Chughtai, and J. Nasir, "CROSS POLARIZED 2×2 UWB-MIMO ANTENNA SYSTEM FOR 5G WIRELESS APPLICATIONS," Prog. Electromagn. Res. M, vol. 76, no. October, pp. 157–166, 2018.
[4] S. Saxena, B. K. Kanaujia, S. Dwari, S. Kumar, and R. Tiwari, "MIMO antenna with built-in circular shaped isolator for sub-6 GHz 5G applications," Electron. Lett., vol. 54, no. 8, pp. 478–480, Apr. 2018.
[5] L. Y. Rao and C. J. Tsai, "8-Loop Antenna Array in the 5 Inches Size Smartphone for 5G Communication the 3.4 GHz-3.6 GHz Band MIMO Operation," in Progress in Electromagnetics Research Symposium, 2018, vol. 2018-Augus, pp. 1995–1999.
[6] A. S. Ruswanditya, Y. Wahyu, and H. Wijanto, "MIMO 8×8 antenna with two H-slotted rectangular patch array for 5G access radio at 15 GHz," in 2017 International Conference on Control, Electronics, Renewable Energy and Communications (ICCREC), 2017, vol. 2017-Janua, pp. 221–226.
[7] J.-Y. Lu, H.-J. Chang, and K.-L. Wong, "10-antenna array in the smartphone for the 3.6-GHz MIMO operation," in 2015 IEEE International Symposium on Antennas and Propagation & USNC/URSI National Radio Science Meeting, 2015, vol. 2015-Octob, pp. 1220–1221.
[8] J. L. Li, M. H. Luo, and H. Liu, "Design of a slot antenna for future 5G wireless communication systems," in 2017 Progress In Electromagnetics Research Symposium - Spring (PIERS), 2017, pp. 739–741.
[9] L. Han, C. Wang, W. Zhang, R. Ma, and Q. Zeng, "Design of frequency- and pattern-reconfigurable wideband slot antenna," Int. J. Antennas Propag., vol. 2018, pp. 1–7, 2018.
[10] A. Biswas and V. R. Gupta, "Design of penta-band MIMO antenna for GPS/2G/3G/4G AND 5G NR applications," Int. J. Recent Technol. Eng., vol. 8, no. 1, pp. 1935–1940, 2019.
[11] H. AL-Saif, M. Usman, M. T. Chughtai, and J. Nasir, "Compact Ultra-Wide Band MIMO Antenna System for Lower 5G Bands," Wireless Communications and Mobile Computing, vol. 2018, pp. 1–6, 2018.
[12] M. A. Hossain, I. Bahceci, and B. A. Cetiner, "Parasitic Layer-Based Radiation Pattern Reconfigurable Antenna for 5G Communications," IEEE Trans. Antennas Propag., vol. 65, no. 12, pp. 6444–6452, 2017.
[13] N. Ferdous, G. Chin Hock, H. A. S. Hamid, M. N. A. Raman, T. Sieh Kiong, and M. Ismail, "DESIGN of A SMALL PATCH ANTENNA at 3.5 GHZ for 5G APPLICATION," IOP Conf. Ser. Earth Environ. Sci., vol. 268, no. 1, 2019.
[14] Y. Li, C.-Y.-D. Sim, Y. Luo, and G. Yang, "High-Isolation 3.5 GHz Eight-Antenna MIMO Array Using Balanced Open-Slot Antenna Element for 5G Smartphones," IEEE Trans. Antennas Propag., vol. 67, no. 6, pp. 3820–3830, Jun. 2019.

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

[1.]Nadica STOJANOVIC, [2.]Oday I. ABDULLAH, [3.]Ivan GRUJIC,
[4.]Jasna GLISOVIC, [5.]Sasa VASILJEVIC

STUDY THE EFFECT OF VANES SHAPE ON THE CONVECTIVE COOLING OF THE VENTILATED BRAKE DISC

[1,3,4.]University of Kragujevac, Faculty of Engineering, Department for Motor Vehicles and Motors, SERBIA
[2.]Department of Energy Engineering, College of Engineering, University of Baghdad, Iraq, Hamburg University of Technology, GERMANY
[5.]High Technical School of Professional Studies, Kragujevac, SERBIA

Abstract: Today, the most brake systems used on vehicles are the disc brakes. During the braking process, the large amount of frictional heat is generated on the contact surfaces of disc brakes. In order to ensure the safety of the drivers and the traffic participants, the optimal performance of brake system of the vehicles under the different working conditions should be ensured. Therefore, it can be considered that the brake system an essential element in the vehicle. Practical experiences showed that the most important factor that affects performance of the brake system is the excessive heat that generated during the braking process. Therefore, it's necessary to pay high attention on the air cooling of the brake system. This is one of the reasons why the ventilated discs are used, besides that their usage provides the reduction of the inertial masses which meaning less cost. In order to provide a good cooling, it's necessary to find the optimal vanes shape to increase the degree of air cooling as much as possible. The aim of this research paper is to analyse the air flow through four different ventilated brake discs; each one has the shape of vane. Comparisons were made between the results of the selected models of the ventilated brake discs. The results presented the air flow currents through the disc, as well as the turbulences that occurred during the air flow around vanes.
Keywords: Ventilated disc brake, Convection problem, CFD, turbulences

INTRODUCTION

The first step in developing of a new product is the creation of the 3D model. Then, the same model is tested by numerical analysis, and if it meets the expectations, the part is fabricated and tested experimentally. If the experiment gives the positive results, more accurate the same results that are obtained by the numerical analysis, the part can be mass-produced. In this way, the costs are reduced, and the company that operates in this way becomes the market leader with its innovations.

When creating a new model of the ventilated brake disc, the experiment can be omitted, as the researchers have repeatedly confirmed many times, where the deviation between numerical analysis and the experiment is within the allowed limits [1, 2].

The shape of the vanes greatly influences the air flow speed through brake disc, as well as on the pressure that will occur due to air flow through it [3]. If a larger amount of the air passes through the brake disc, better cooling will be achieved. In order to achieve even better cooling, Galindo-Lopez and Tirovic [4] came to the conclusion that if one more vane is added between existing vanes, cooling would be better because there are a larger number of surfaces that cool down. In addition, the cooling rate would increase [5].

First of all, it is important to find such a shape and size of vanes in which the cooling will be more uniform and the mass flow value will be greater [1].

The air flow speed and turbulence are shown in this paper and the numerical analysis is performed in order to show which vanes are more suitable for use at the ventilated disc, more precisely, with which of them the higher velocity of the air flow will be achieved, with minimal turbulence. At the end, the values of the air mass flow are given, depending on the applied vanes on the brake disc.

MODEL AND BOUNDARY CONDITIONS OF VENTILATED BRAKE DISC

The basic role of the brake system is to slow down or stop the vehicle. However, during braking, a large amount of heat is generated on the brake disc, and this leads to the appearance of the thermal stresses, which further can lead to the occurrence of cracks and, at worse, to the fracture. Figure 1 shows typical damage patterns in brake discs.

(a) (b)

Figure 1. Disc damages because of thermal stress [6]: (a) Overheated brake disc; (b)Brake disc with hotspots

During braking process, the disc plays the role of a heat exchanger, but its capacity is limited. Therefore, this is one of the reasons why it is necessary to design discs with such vanes that will enable a good cooling. The second reason is to prevent the heat transfer to the

brake pads. In this way, braking components will be protected and the safety of the driver, who operates such vehicle, as well as the other participants in the traffic, will not be disturbed.
In this paper, a disc whose dimensions are the same, but with different shape of the vanes, is observed, Figure 2. The model has been created in CATIA software package, while the analysis is performed in ANSYS software package (Fluid Flow module).

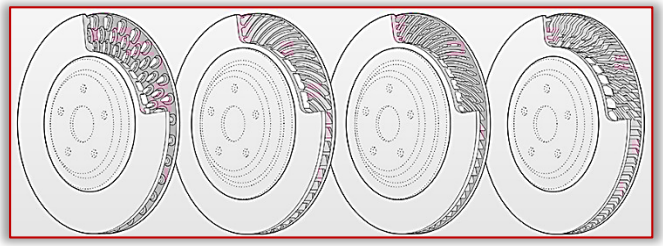
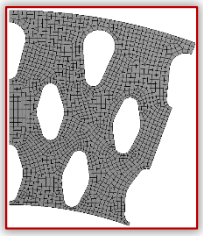
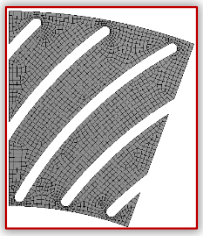
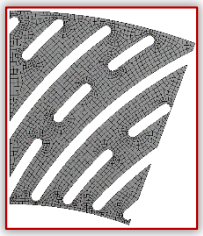
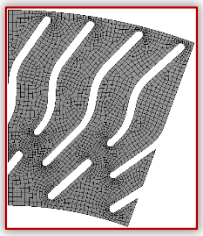


Figure 2. Four different ventilated brake discs [7]

In order to simplify the analysis, and reduce the time for calculation, only 1/18 of the disc will be observed, and considered for numerical analysis for all configurations due to the rotational symmetry [1, 2]. Table 1 shows the internal space of the disc, as well as vanes shape, and number of elements and nodes for each analysed model.

Table 1. Number of finite elements and nodes

		
Title	Pillar vane	48-vane
No. nodes	19052	30225
No. elements	15540	24556
		
Title	72-vane	72-vane flash
No. nodes	41378	48161
No. elements	33200	10128

The analysis was performed under the following boundary conditions:

- Vehicle speed is 120 km/h, more accurate the angular velocity of the disc is 107.26 rad/s,
- Air density is 1.225 kg/m^3,
- Environment temperature is 25 °C,
- Environment pressure is 101325 Pa.

The boundary conditions for each disc are the same. The applied model is k-ε. The reason for its application is widely used turbulence models as it provides robustness, economy and reasonable accuracy for a wide range of turbulent flows [8].

RESULTS AND DISCUSION

Airflow speed through the disc is shown in Figures 3 to 6, and the highest speeds occur in the disc with pillar vane. Furthermore, turbulence values for this disc are the lowest. The airflow is shown in the form of arrows so that the direction of movement of the air through the internal space of the disc can be seen. In addition, it can also be seen where the direction of air movement changes.
In addition, precisely because of those changes, the turbulence is appearing. Additionally, the occurrence of turbulence is also affected by the collision of air currents. The collision is happening after vanes trespassing. In addition, turbulences as well affected whether the vanes are made from one solid part or have discontinuities.
The disadvantage of higher turbulence values results in a lower air mass flow. As the air mass flow through the disc itself is smaller, a higher amount of heat remains on the disc. If there is a higher mass flow, more heat is dissipating to the environment.

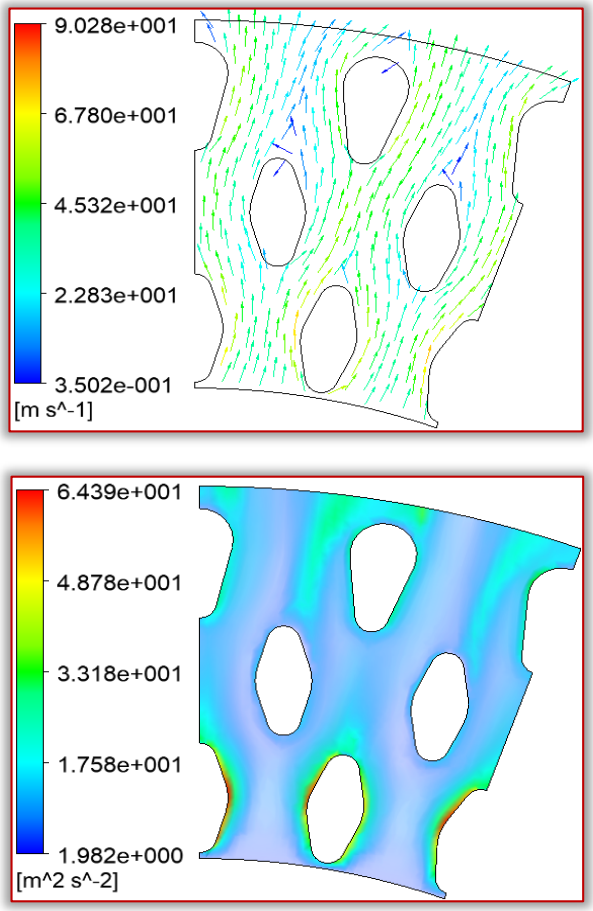


Figure 3. Air flow velocity and turbulences for disc with pillar vane

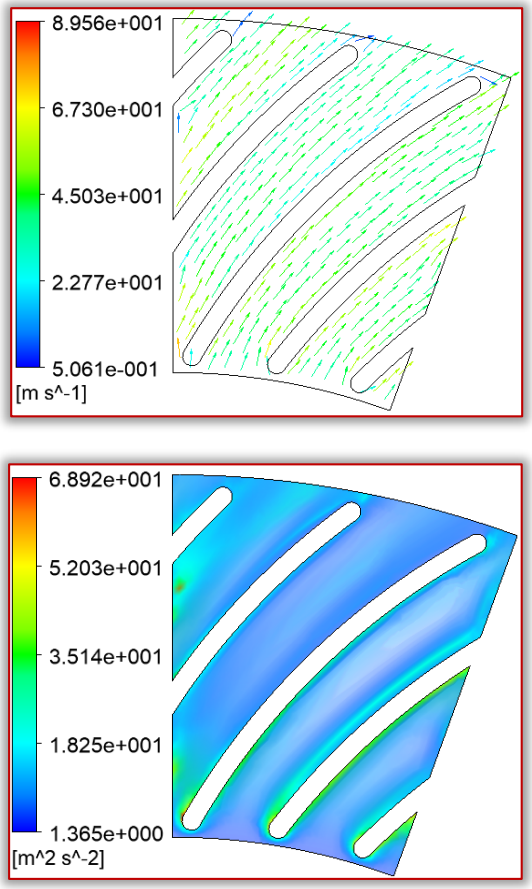


Figure 4. Air flow velocity and turbulences for disc with 48 vane

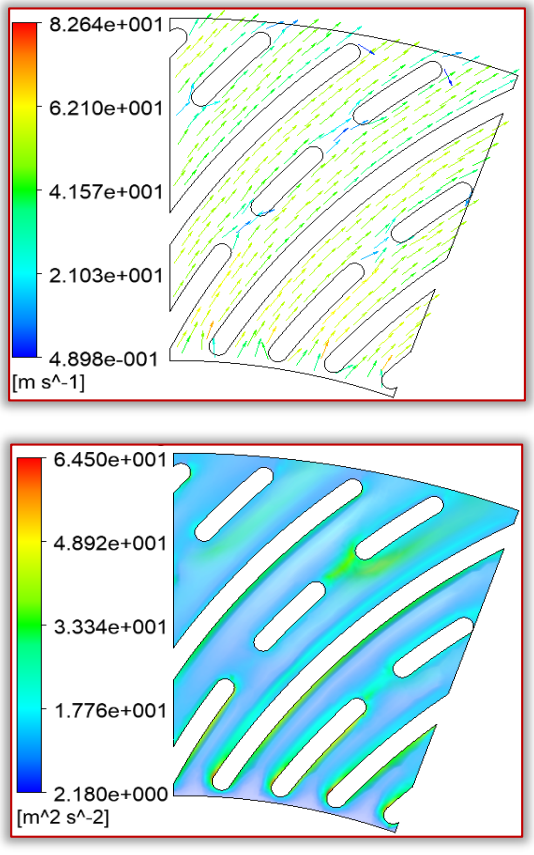


Figure 5. Air flow velocity and turbulences for disc with 72 vane

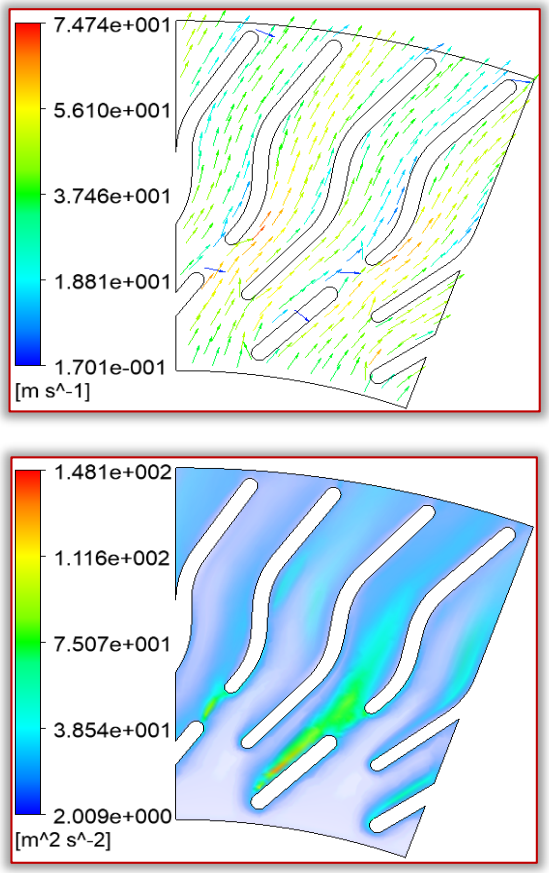


Figure 6. Air flow velocity and turbulences for disc with 72 vane flash

Regardless of the shape of vanes, turbulence occurs in each disc. The only difference is that they are the smallest in case of the disc with pillar vane, while for the disc with 72 vanes flash turbulence values are the highest. Table 2 shows the values of the air mass flow through the disc depending on the vanes shape.

Table 2. Mass flow rate for different ventilated brake discs

Title	Pillar vane	48-vane	72-vane	72-vane flash
Flow rate, gs^{-1}	0.977	0.971	0.971	0.973

CONCLUSION

The shape of the vanes has a great influence on the heat exchange with the environment i.e. the higher values of the air mass flow through the inner space of the disc, the greater the amount of heat will be dissipated into the environment. The air mass flow is the highest for disc with pillar vane, while the smallest is for the disc with 48-vane and 72-vane, which represents a difference of 0.61%.

The biggest changes in air flowing through the internal space of the disc occur with the disc with pillar vane, although due to the greater distance between vanes, it has the highest air flow. For future research, it is necessary to investigate how the distance between vanes for the remaining three cases affects the air mass flow, but it is important not to

disturb mechanical properties of the part. In addition to the CFX analysis, the structural analysis in terms of exploitation conditions is also necessary to be performed.

Acknowledgement

This paper was realized within the framework of the project "The research of vehicle safety as part of a cybernetic system: Driver-Vehicle-Environment", ref. no. TR35041 funded by the Ministry of Education, Science and Technological Development of the Republic of Serbia.

Note:

This paper is based on the paper presented at DEMI 2019 – The 14th International Conference on Accomplishments in Mechanical and Industrial Engineering, organized by Faculty of Mechanical Engineering, University of Banja Luka, BOSNIA & HERZEGOVINA, co–organized by Faculty of Mechanical Engineering, University of Niš, SERBIA, Faculty of Mechanical Engeneering Podgorica, University of Montenegro, MONTENEGRO and Faculty of Engineering Hunedoara, Unversity Politehnica Timisoara, ROMANIA, in Banja Luka, BOSNIA & HERZEGOVINA, 24–25 May 2019.

References

[1] Rajagopal, T.K.R., Ramachandran, R., James, M., Gatlewar, S.C. (2014). Numerical investigation of fluid flow and heat transfer characteristics on the aerodynamics of ventilated disc brake rotor using CFD – Thermal Science, vol. 18, no. 2, p. 667-675.

[2] Rajesh, A., Vedhagiri, K., Sivaprasanth, L., Vengatesh, R. (2015). Numerical analysis of fluid flow and heat transfer characteristics of ventilated disc brake rotor using CFD - International Journal of Engineering Inventions, vol. 4, p. 31-38.

[3] Stojanovic, N., Glisovic, J., Grujic, I. (2016). Influence of vanes shape on flow velocity of ventilated disc in heavy truck braking. The Ninth International Symposium KOD 2016, Machine and Industrial Design in Mechanical Engineering, p. 83-88.

[4] Galindo-Lopez, C.H., Tirovic M. (2007). Understanding and improving the convective cooling of brake discs with radial vanes - Part D: J. Automobile Engineering, vol 222, p. 1211-1229.

[5] Khivsara, S., Bapat, R., Lele, N., Choudhari, A., Chopade, M. (2015). Thermal analysis and optimisation of a ventilated disk brake rotor using CFD techniques - International Journal of Emerging Technology and Advanced Engineering, vol. 5, p. 59-64.

[6] Güllering, U., Jobelius, P., Rotter, R. (2017). Wartung und Diagnose von Bremsanlagen. Breuer, B., Bill K.H., Bremsenhandbuch Grundlagen - Komponenten ·Systeme · Fahrdynamik. Springer, Berlin, p. 747-759.

[7] Race Technologies, from https://www.racetechnologies.com/article/vane-design, 09.02.2019.

[8] Soe, T.M., Khaing, S.Y. (2017). Comparison of turbulence models for computational fluid dynamics simulation of wind flow on cluster of buildings in mandalay - International Journal of Scientific and Research Publications, vol. 7, p. 337-350.

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

[1.]N. MANJUNATHA

INTERNATIONALIZATION AND INNOVATION CAPABILITIES DETERMINES EXPORT PERFORMANCE OF INDIAN AUTO COMPONENT INDUSTRY

[1.]Department of Commerce and Management Studies, Government First Grade College, Srinivaspur-Kolar District, Karnataka, INDIA

Abstract: All countries in the world formulate export policies to promote exports and enable manufacturing firms to compete in international markets. The firms are striving to achieve desired level of export performances with the support of export policies and commitment towards entering into international business along with various dimensions of innovations. Manufacturing industries search for one or the other strategy to market their products in global markets to survive under cut-throat competition. In international markets, a common export practice includes internationalization and innovation abilities of a company determines the export performances. The objective of the research is to find out whether international and innovation capabilities of auto components manufacturers has significant relationship with export performance. There are 88 auto component manufacturing companies were selected in south India to collect the data related to export performance. Linear regression analysis was uses to test the hypothesis formulated. The results revealed that gathering export market information, capable of using export market information, role of export mode, relationships & networks, flexible to modify firm resource base, develop new service, technological up-gradation, in-house product designs, improvement in the existing products and re-align manufacturing system have found significant relationship with export performances of auto component manufacturing companies in India.
Keywords: auto components, internationalization, innovation, export performance

INTRODUCTION

Demand for auto components is primarily dependent on the requirement of Original Equipment Manufacturers (OEMs) across the globe. Initially the Indian auto component manufacturing industry faced many challenges, especially in technological expertise. Gradually, with rapid changes in the global automotive industry, the Indian auto component industry entered into technological alliance and joint venture with global automotive manufactures to meet the specific requirement of OEM's (Parhi, M. 2008g; Sahoo T., et al., 2010).

The origin of the Indian auto component manufacturing industry dates back to 1953, when the Indian Government decided to develop its own manufacturing base with the principal aim of import substitution (Sagar, et al., 2004; Torayeh, and Neveen, M. 2011). Gradually, with the support of the government, the auto component manufacturers started to find better opportunities for export across the international markets in spite of tough competition therein. In view of fluctuating market conditions in overseas markets, the auto component manufacturers had to formulate and constantly review the marketing strategies to gain strong market position and competitive edge (Kaleka, A. and Morgan, N.A. 2017; Dholakia, N. and Khurana, R, 1976). They also needed to focus on investment in developing state-of-the-art technology to serve a number of vehicle models in domestic and overseas markets. (Torayeh, and Neveen, M. 2011; Tang, R.Y. 2011). Many researches have been conducted to streamline export strategy. The present investigation attempts to identify the significant relationship between firm's internationalization, Innovation and export performance of auto component manufacturing firms. The success of auto component industry is determined by firm characteristics such as firm's internationalization capabilities and innovation capabilities.

Firm characteristics such as firm size, nature of the business, capital investment and technological capabilities are key factors that are playing an important role to decide the successfulness of export operation of the company (Kahia, M. 2017). Firm characteristics such as firm size, firm's assets, firm's financial stability, firm's product line are considered as an important determinants of export success. The larger the firm in size, the better chances of firm having an ability to innovate and produce products with new features along with service after sales by gaining the status of leader in technology through R&D. The same can be used as a strategy for export orientation (Erdila, S.T. and Ozdemir, O. 2016). Many of the research results showed that the firm characteristics, environmental characteristics and export commitment are positively influence on export performance. Many researchers have addressed export performance without considering the export marketing strategy implementation. The firm's export performance is determined by the formulation of appropriate export orientation (Jalali, S.H. 2012). Many studies related to identifying differences among the firm characteristics and export performance of

the companies operating domestically. Firm size, firm's technological intensity, firm's vertical and horizontal integration, capital investment, extent of imports and export policy of the country are found to be key determinates of export performance (Sahoo, T, 2010). Researchers have done Classification of firm's internal factors to test significant impact on export performance of small scale enterprises. The firm characteristics, export market characteristics and managerial characteristics are the factors found as key determinants of export performance. It is also found that international market information, marketing research, export market segmentation, targeting, positioning and product characteristics are playing significant role in enhancing export performance of the small scale enterprises (Nazar, M. et al.,2009). The firm characteristics such as product quality through product and process improvement, firm age, firm's extent of international exposure, technical expertise, continuous export engagement, firm size, cost of export operation, export operational efficiency and seriousness of export marketing are considered as key determinants to attain export goal (Balakrishnan, K et al., 2007). There is a significant impact of size of the firm on export performance because as the size of the firm is large, company will have an ability to sustain the risk associated with international markets due to sophisticated resources available which also leads to achieve low cost advantage through large scale production which enhances the export success of the firm (Saripalle, M, 2008).

LITERATURE REVIEW

— Firm's internationalization capabilities

Internationalization capabilities of the firm have significant effect on export growth which also is a key indicator of company's continuous improvement, survival in international markets, ability to keep competitors away along with economic growth of the nation (Alen, L. 2017). It is understood that investing on state of art technology, well designed distribution network, research and development partnership are going to be a greater advantage to enhance export performance in automotive/auto component industry keeping long run revenue in mind. Sophisticated infrastructure facilities creates attractive space to cope up with frequently changing customer requirements and foreign market trends. This can be achieved through increasing production with help of upgraded technology. Strategic alliances also will assist auto and auto component industry in Indian to access latest technical requirements/technology to serve international markets with global quality standards which enhances the export performance (Arora, V.2014). Firm characteristics such as firms experience and image are the indicators of export success of any organization. Besides firm's export competitiveness and firm's export exposure are the indicators of internationalization capabilities leading to successful export performance. Experienced firms are able to understand export markets better and attract customers through adaptation of marketing strategies in the light of environmental conditions in the international market (Kahia, M. 2017). Along with exporting of traditional mechanical parts such as engine parts, gear boxes and brakes parts, the company need to export high end/critical/advanced electronic parts which exhibit the strength of Indian exporters and also enhances the export profitability of the company. The report concludes that there is a need for focusing on exporting of higher value added products to achieve desired level of export success (Kumar, A, and Dubey, S, 2017). In the near future the auto component industry in India export sales is expected to increase gradually. due to positive regulatory policies in the country. The domestic companies are able to manufacture product which meets global quality standards through technical collaborations along with low cost as a competitive advantage which is helping Indian companies to achieve robust export growth (CRISIL Report, 2017). With the combination of firms internal and external knowledge, a firm can innovate products rapidly. The firm knowledge can be created by experiments, learning by theory of experience curve, learning by organized and unorganized networks within the innovation environment. Communication with outside innovation sources helps to have continuous link to become strong in technology which was not addressed internally. Therefore, firm's technological innovation can be termed as firm's ability to communicate, learn and process and utilize the knowledge base. This technological innovation is possible through importing required technology, sharing, integrating, interacting and adopting them in an organization which helps in enhancing export performance too (More, R.Z. and Jain, K. 2013). Internationalization process involves lot of risk in terms of financial losses, market failures due to lack of resources and high transactional cost may affect negatively on firm's long term survival. In addition to this firm should go through more managerial complexities, liability towards foreign customers due to scarcity of resources etc. Therefore, transactional cost, resources of the firm and risk associated with foreign markets are considered as an influential factor on firm's export performance (Musuva, A. M. et al., 2013). In order to achieve export success, firms should be strong enough with sufficient export market information and that is to be shared among the needy people and the departments in an organization for the appropriate decision making to respond to changing market conditions and to face challenges immediately. In this study he found marketing

intelligence has significant relationship with firm's export performance (Benoit Battistelli 2013). After liberalization process took place in the year 1991 the auto component manufacturing firms in India were exporting moderate quality products in smaller quantity to underdeveloped countries such as Middle East, South Africa and also exporting less critical components for after markets requirement to moderately developed countries. Gradually Indian auto component manufacturing firms have learnt to upgrade their technology and acquired competencies slowly, but some auto component manufacturers had greater shift to provide high quality products to meet the demands of global OEMs (Kumaraswamy, A 2012). Liberty should be given by the firms to the foreign branches which are big in size in the form of independent decision making with respect to deciding marketing strategies in foreign markets as method of control over the distribution system. Degree of decentralization is also considered as one of the mode of having control over foreign branches operating globally. Therefore, decentralization and providing the power of making independent decisions by firm's foreign branches are the factors significantly affecting export performance of the firm (Henry F.L 2012). Choosing appropriate export mode for the business organization to operate internationally is very crucial for achieving desired level of export success. Strategy of export market entry by manufacturing firm has significant impact on export performance. Most of the manufacturing firms begins operating internationally through direct exports which is considered as safe mode in terms of reducing risk and simple way to process international transactions and also helps in facing global market challenges by meeting the changing demands of overseas customers gradually (Sadaghiani, J.S. and Dehghan, N. 2011). The firms export knowledge, stage of export, firms experience in domestic markets and firm's resources are found positive influence on export performance (Mohamad, O et al., 2011). The influence of export transaction overheads and firm's resources capabilities on internationalization process of manufacturing firms in Kenya, Mombasa countries. The results show that export processing overheads such as export decision implementation cost, cost incurred due to information less trade, market timing cost, opportunity cost and firm characteristics and firms' resources capabilities are the factors positively impact on internationalization process such as market size, number of export intermediaries, direct/indirect trade barriers, county risk and market growth of manufacturing firms (Stoian, M.C 2010). The factors affecting the extent of internationalization capabilities of small scale enterprises of South Korea has been studied it shows that, International capabilities such as ownership characteristics, human resources, technological capabilities and external factors determines the extent of internationalization capabilities of small scale enterprises in South Korea are tested on export performance. The results found that ownership pattern, firm's human resources, and technological capabilities and export market standardization strategies are the significant factors that determines the export performance. Further it is understood that firms internal and external factors cannot be ignored while framing strategy for overseas markets (Ivan Damir Anic, I. D, 2009).

— Firm's innovation capabilities

Advanced technology in automatic and manual transmissions, well designed engine structure, electric and electronic parts/sensors, anti-lock braking systems have attractive export growth potential. Need for the customer safety such as distance control, lane assistance, vehicle to vehicle communication also have increased the growth potential for exports (CRISIL Report, 2017). The export prospects and rising consciousness of original equipment manufacturers on product quality leading to rise in innovation capabilities of auto component manufactures (Tiwari, R. and Kalogerakis, K. 2017).

The various forms of innovations such as managerial and organizational innovation, product and process innovation and market innovation have been tested on export performance. The results showed that product and process innovations have significant influence on export profit. There is no considerable impact of managerial and organizational innovation on export performance of companies operating in Malaysian Manufacturing Sector (Kim, M.M., and Azizi, 2009). In this report, it is understood that, to reduce weight of vehicle, the OEMs are using alternative materials. Usage of electronic products, fiber/ plastic materials and adherence to environmental policies and technology with respect to customer safety in the vehicle are the major divers of demand for auto component industry.

Innovation through R&D activities in India has better export opportunities to exploit global market. India is opening number of R&D centers across the world which also serves headquarters locating locally to produce advanced and innovative products and launch them in international markets (E&Y Report, 2016). Process innovation plays key role in increasing product quality in manufacturing industry. Therefore, firms should invest substantial funds on research and development activities which strengthen the firms long term survival by sustaining export profits which also enhances the reputation of the firm in international markets (Mitra, A.K and Joshi, B.P. 2014). Standardization and adaptation of export marketing strategies are important variables for technological oriented industries. In the literature review on export marketing, it is understood that,

export marketing strategy adaptation have negative correlation with technology orientation. High degree of standardization of export marketing strategies can be found in industries which are technological oriented for example photocopier industries, equipment manufactures for medical field, aircrafts, computers manufacturing industries and auto/Auto component manufacturing industries (Mersid Poturak Teoman Duman, 2014). Auto component industry should understand the changing requirements of OEMs regularly in foreign markets for its long term survival. Both automotive and auto components manufacturing firms should focus on innovation through research and development to meet changing market conditions in the export markets which also helps in keeping competitors away. Improved reliable quality standards reduce the cycle time and cost which is a key strategy for facing highly changing business environment due to changing customer preferences. In order to match this fluctuations, auto component manufacturers should work closely with OEMs by collaborative partnerships to enhance export performance (Arora, V.2014). Auto component manufacturing firms locating in the same clusters should have capability of innovation and advanced technological competitiveness apart from R&D capabilities. Sometimes having in house R&D facilities alone cannot be sufficient unless having technical support from outside sources through technological collaborations and joint ventures. Combination of both internal and external R&D efforts with technical support the Indian auto component manufactures can face the challenges posed in foreign markets. It is found that firms' competitive advantage such as low cost, favorable exchange rates, support by government in duty drawback are inadequate. The export success is dependent on how well auto component industry is able to manage its technology as an export business strategy (More, R. Z. and Jain,K. 2013). Product quality oriented competition can be seen in Indian auto component manufacturing industries. Due to highly skilled labors with low- cost advantage of Indian auto components, global OEMs are looking at India as auto component hub. Along with this, information technology and software developments made Indian auto component firms as an emerging sector which suppliers embedded product models to OEMs. Gradually Indian component manufacturers are improving products with global quality standards through strategic alliances and technical collaborations while other companies are planning to enter export markets (Chisthy, S. K. and Asadullah 2013).

Firm's operating in technological oriented environment, should use adaptation pricing strategy to capture more market share in export market in order to get immediate return on investment on advanced technology. Once the technology becomes obsolete, there is no guarantee to recover initial investment. Therefor he advocates that price adaptation strategy and export performance have found significant influence on export performance (Alshammari, S. D. and Islam, R. 2014).

To examine relationship between firm's manufacturing productivity and export performance from the period of 2003 to 2015 using the information available at firm level has been studies. The earlier studies show that product innovation enhances the export performance of the company which is also a contributing factor for the economic development of the nation. Productivity through product innovation, research and development, resources reallocation, strategies related to integrate marketing commutation are considered as key elements which influence positively on export performance (Yan A.W et al, 2007).

— Problem statement

Although Indian auto component industry has been fairly successful in penetrating global markets, the importance of export strategies in foreign markets to find better export prospects has not been addressed in any research adequately. Such a study therefore could throw more insights on the critical drivers which could be addressed to accelerate export growth. There is a need for understanding and fine tuning the export orientation followed by Indian auto component manufacturers due to the changing global market scenario. The success of export performance is dependent on various factors. However, firms have little understanding about the specific nature and drivers that contribute to effectiveness of export performance. There is a need to understand the Indian auto component manufacturing company's internationalization and innovation capabilities. Rising competition, complexities and foreign market uncertainties are posing challenges for the Indian auto component manufacturers in foreign markets. To tackle these challenges, the firms should increase their export efficiency through internationalization and innovation capabilities to achieve desired level of export performance.

— Objectives of the study

- To study the factors related to internationalization of auto component firms and its relationship with export performance.
- To examine the innovation capabilities of auto component firms leading to rise in export performance.

— Hypothesis of the study

- **H1:** Firm's internationalization capabilities have significant relationship with Export Performance.

≡ **H2:** Firm's innovation capabilities have significant relationship with Export Performance

— Research methodology

The research methodology is adopted based on the descriptive analytical research approach. Each objective has been addressed in the study systematically to understand auto component manufacturing company's internationalization and innovation capabilities. Consequently, study continues to find out influence of these capabilities on export performance leading to develop systematic knowledge for export performance of Indian auto component manufacturers.

— Scope of the study

This research has been narrowed down to study how auto component manufacturers are modifying their firm's internationalization and innovation capabilities, and how these approaches are influence the export performance. The geographic area covered for the study is Tamilnadu, Karnataka and few companies in Andhra Pradesh.

— Sample size

The total number of auto component companies operating in India is 647 with these firms being members of ACMA (Automotive Component Manufacturers Association of India). Of these companies (Table:1) 146 auto component companies are located in South India, of which, 119 companies are component exporting companies and are actively involved in both export and domestic business out of 119 companies 88 auto component manufacturing companies in south India.

Table1: Number of Respondents (Auto component Manufacturing Units/Product wise)

Product Category	Total Companies in South India	Total Population (Exporters) in South India	Number of Respondents	Percentage of respondents
Engine components	53	42	27	30%
Drive Transmission & Steering components	19	18	6	7%
Suspension & Braking components	8	6	5	6%
Body & Chassis components	10	8	8	10%
Equipments/ Tools and accessories	23	20	20	22%
Electrical components	16	12	9	10%
Other products	17	13	13	15%
Total	146	119	88	100%

Source: Primary Data through Survey and CAMA Data Base-Buyer Guide

— Respondents

The target respondents for the survey were the managers who have occupied the positions of Export In-charge/Export Manager/Vice-president Marketing. The interaction was made with senior level people who have knowledge about export operations.

This survey was implemented by personal visit to auto component manufacturing firms. Managers were requested to give their appointment for the discussion and a scheduled questionnaire was issued collect data. Questionnaire has been sent through online to the respondents but the response was very poor due to their busy schedule. In the present research out of the 119 auto component manufacturers which contributed the population 88 companies have responded indicating response rate 74%.

— Data collection

≡ Primary data

The first time data has been through self-administered structured questionnaire which was developed and asked to fill. Personal interviews were also done with respondents to discuss about foreign market familiarity, awareness, or understanding of export marketing strategies, industry profile, facts and figures, information, descriptions about international operations etc.

≡ Secondary Data

The following are the sources that the secondary data was collected and in chapter 1 and chapter.

- Automotive Component Manufacturers Association (ACMA)
- Database of ACMA "Buyers Guide"
- Export-Import Bank of India
- Society of Indian Automobile Manufacturers (SIAM)
- Mysore University Off-Campus Wide Access Online E-Sources
- Companies' Annual Reports
- Journals, Thesis, Magazines, research articles, Newspapers etc.

— Data collection instrument

Basic outline of the approaches used in various research articles has been helpful to develop questions for studying export behavior of Indian auto component manufacturers. A structured questionnaire is developed according to the respondent's familiarity, awareness, or understanding of concepts which is related to their industry, such as facts, information, descriptions, or strategies or export practices etc.

— Data measurement

All the variables of firm's internationalization, firm's innovation capabilities and export performance of auto component manufacturers were measured by using Likert's five point scales.

Export performance has been defined as export satisfaction of managers who are engaging in export activities in auto component manufacturing companies.

ANALYSIS AND RESULTS

— Gathering Export Market Information

In order to enter into international business, the auto component manufacturing firms should conduct regular market research to gather information on factors affecting international business operation. The information may be on specific requirement of original equipment manufacturers abroad, political stability, economic conditions of the host country, competition intensity, entry barriers such as tariff and taxes, foreign customer's perceptions etc. The auto component manufacturers may go for periodic market research or gather required export information.

— Capable of using export market information

The results of market research and the information available on export market conditions should be disseminated among all the department and strategic business units of the company for making effective export decisions. In this connection company should be in a position to use available information effectively because mere collection of information does not serve the purpose.

— Role of Export Mode

South Indian auto component firms find direct export mode as simple way of export to enter international business due to less risk involved in meeting OEMs demand. Firm's with small export commitment would choose direct export as an entry mode considering the advantages such as rising export sales, grater export market control, access to export market information, opportunity to gain international experience. Out of 88 companies surveyed 40 companies have chosen direct export at the initial stage at present the 47 companies are engaging in direct export.

— Flexible to Modify Firm Resource Base

Resource base in the context of export can be defined as the firm's adequate financial and human resources to meet requirements of original equipment manufacturers abroad. Substantial physical resources such as state of art with respect to technology, premises, facilities for physical distribution, separate export oriented units. R&D facilities are also found significant for successful export operations.

Firm's internationalization capabilities of South Indian auto component manufacturing firms such as gathering export market information, capable of using export market information, role of export mode, relationships & networks, strive to be the pioneer, flexible to modify firm resource base, are the variables used to test the significant relationship with export Performance.

Table 2: Relationship between Firm's internationalization capabilities and export performance

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.918a	.842	.831	.44826

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	86.937	6	14.489	72.110	.000[a]
	Residual	16.276	81	.201		
	Total	103.212	87			

a. Predictors: (Constant), Flexible to Modify Firm Resource Base, Strive to be the Pioneer, Relationships & Networks, Gathering Export Market Information, Capable of using export market information, Role of Export Mode

b. Dependent Variable: Export Performance

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.632	.218		-2.892	.005
	Gathering Export Market Information	.325	.083	.307	3.907	.000
	Capable of using export market information	.220	.066	.258	3.350	.001
	Role of Export Mode	.333	.102	.265	3.260	.002
	Relationships & Networks	-.005	.068	-.005	-.077	.939
	Strive to be the Pioneer	.093	.069	.091	1.356	.179
	Flexible to Modify Firm Resource Base	.184	.060	.179	3.042	.003

[a] Dependent Variable: Export Performance

The analyses show that, the value of R indicating Firm's internationalization capabilities and export performance have high degree of correlation (.918) and R^2 is .842 indicates the variables selected fits the data to the model well. The significant of F change is less than 0.05 which indicate that Firm's internationalization capabilities have found significant relationship with Export Performance. All the six variables were considered to predict export performance.

In this case Gathering Export Market Information (t =3.907, p =.000), Capable of using export market information (t =3.350, p =.000) Role of Export Mode (t =3.260, p =.002) and Flexible to Modify Firm Resource Base (t =3.042, p =.003) are the factors have significant relationship with Export Performance.

Regression model for Export Performance is

$$Y=b0+b1\times1+b2\times2\ldots+ bk \times k + n$$

Y= dependent variable, β0=Constant, β1=Beta1, β2=Beta 2, 1= Independent variable 1 2=Independent variable 2.

Export Performance = -.632+ (.325×Gathering Export Market Information) + (.220×Capable of using export market information) + (.333×Role of Export Mode) + (-.005×Relationships & Networks) + (.093×Strive to be the Pioneer) + (.184×Flexible to Modify Firm Resource Base)

Since the gathering export market information, capable of using export market information, role of export mode, relationships & networks and flexible to modify firm resource base significant value is less than the 'p' value of 0.05 respectively. Therefore, hypothesis statement number 1 that is Firm's internationalization capabilities have significant relationship with Export Performance is accepted.

INNOVATION CAPABILITIES OF AUTO COMPONENT MANUFACTURING FIRMS

- **Develop New Service:** New services like providing credit facilities, logistics services, warehousing service, installation, rework and replacement, payment of export insurance premium on behalf of clients, services with respect to customized products manufacturing, product and process improvement for the benefit of export customers, R&D facilities, services related to information and communication technology, development of system models for original equipment manufacturers abroad are considered as key elements for enhancing export performance.
- **Technological Up-gradation:** Process and product improvement, collaboration with research institution to develop new technology, setting up of R&D facility, obtaining of quality certifications (Product quality improvement), having state of the technology, flexible manufacturing facilities, technical collaboration with clients, ability of manufacturing cross deployment products, technological upgradation in the form of implementation of CNC machines, automations, robotics are the key elements can be considered essential to achieve desirable export performance.
- **In-house Product Designs:** Product design may change due to varied customers' demands, in order to address this issue, the auto component manufacturers need to adopt product strategy with the help of engineering /R&D Department of the company. This can be achieved through process and product innovation.
- **Improvement in the Existing Products:** The concept called cross deployment can be adopted by the Indian auto component manufacturers. For example, the component manufactured supplied for on-road vehicles can be supplied for off-road machineries. More specifically, the engine valves manufactured for buses and trucks can be supplied for locomotives and excavators, generators and in the aerospace industry.
- **Re-align Manufacturing System:** Well-designed manufacturing layout, process design, outsourcing non-core products, just in time management, having well trained technical team, in-house research and development, setting up of strategic business units (Export oriented units), transformation of tradition manufacturing process to advanced technology are the factors considered as key elements for the successful export business.

Firm's innovation capabilities of South Indian auto component manufacturing firms such as associate with research institutions, new product development, develop new service, technological up-gradation, protect intellectual property rights, in-house product designs, in-house testing capabilities, improvement in the existing products, re-align manufacturing system, leads to improvement in export Performance.

The analyses of this research show the value of R indicating Firm's innovation capabilities and export performance have high degree of correlation (.960) and R^2 is .921 indicates the variables selected for the study fits the data to the model well. The significant of F change is less than 0.05 which indicate that firm's innovation capabilities have found significant relationship with export performance. All the ten variables were considered to predict export performance.

In this case Develop New Service (t =3.973, p =.000), Technological Up-gradation (t =2.645, p =.010), In-house Product Designs (t =4.098, p =.000), Improvement in the Existing Products (t =2.960, p =.004), and Re-align Manufacturing System (t=1.931, P=.057) are the factors have significant relationship with export performance.

Regression model for Export Performance is

$$Y=b0+b1\times1+b2\times2\ldots+ bk \times k + n$$

Y= dependent variable, β0=Constant, β1=Beta1, β2=Beta 2, 1= Independent variable 1 2=Independent variable 2.

Export Performance =-.532+ (-.058× Usage of Information and Communication Technology) + (-.080×Associate with Research Institutions) + (.107×New Product Development) + (.267×Develop New Service) + (.213×Technological Up-gradation) + (-.134×Protect Intellectual Property Rights) + (.199×In-house Product Designs) + (.037×In-house Testing Capabilities) + (.344×Improvement in the Existing Products) + (.139×Re-align Manufacturing System).

Since the variables such as development of new service, technological up-gradation, in-house product designs, improvement in the existing products, re-align manufacturing system's significant values are less than the 'p' value of 0.05 respectively.

Table 3: Showing Innovation Capabilities of Auto Component Manufacturing Firms

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.960[a]	.921	.911	.32517

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	95.071	10	9.507	89.913	.000[a]
	Residual	8.142	77	.106		
	Total	103.212	87			

a. Predictors: (Constant), Re-align Manufacturing System, In-house Product Designs, Technological Up-gradation, Collecting market information from various sources, New Product Development, Protect Intellectual Property Rights, Develop New Service, Associate with Research Institutions, In-house Testing Capabilities, Improvement in the Existing Products

b. Dependent Variable: Export Performance

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.532	.173		-3.071	.003
	Usage of Information and Communication Technology	-.058	.052	-.059	-1.121	.266
	Associate with Research Institutions	-.080	.073	-.099	-1.096	.276
	New Product Development	.107	.059	.131	1.819	.073
	Develop New Service	.267	.067	.373	3.973	.000
	Technological Up-gradation	.213	.081	.171	2.645	.010
	Protect Intellectual Property Rights	-.134	.096	-.124	-1.394	.167
	In-house Product Designs	.199	.049	.195	4.098	.000
	In-house Testing Capabilities	.037	.091	.041	.406	.686
	Improvement in the Existing Products	.344	.116	.324	2.960	.004
	Re-align Manufacturing System	.139	.072	.130	1.931	.057

a. Dependent Variable: Export Performance

Therefore, hypothesis statement number 2 i.e., firm's innovation capabilities have significant relationship with export performance has been accepted.

Findings:

- It is found that there is a significant relationship between gathering export market information and export performance of auto component manufacturing companies in India.
- The research findings reveal that the capable of using export market information and export performance of auto component manufacturing firms has direct relationship.
- Most of the auto component manufacturers adopt direct export strategy to enhance export performance.
- It is identified that, the auto component manufacturing companies are inculcating the practice of allocating substantial financial and human resources to achieve desired level of export performance.
- There is a drastic change has been identified with regard to services connected with auto components such as credit facilities and logistics services to its foreign customers has been considered as significant with export performance.
- The auto component manufacturing companies are acquiring required technologies through technological collaboration along with internal R&D capabilities to rise the exports.
- The core products are designed and manufactured in-home according to original equipment manufacturers requirement and non-core products are outsourced to save the cost of manufacturing. The engineering and R&D department may take care of product design and development. It is identified that the foreign clients send their products or components designs or drawing (Blue print) through mail. The Indian auto component manufacturing companies have such capability of designing and development of products in-house based on component drawings sent by OEM's.
- The Indian auto component manufacturers are using the strategy of cross deployment which means the components used for one vehicle models can used as an application component in the other vehicles or other industry with little modification.
- It is found that the component manufacturers are able to use flexible manufacturing system through CNC, Automation and robotic technologies, by that these companies are able to meet changing demand of OEM's as and when technology changes.

Suggestions

- In order to internationalize the auto component manufacturers can opt for three options to source foreign market information
  - the firm should make periodical international market research as a habitual process.
  - market information can be obtained from market research agencies.
  - based on the data available within the company the export manager can predict the future export operation.
- Effective utilization of market research information makes the company to take appropriate export decisions. Each export case

should be properly recorded kept for the future references.

≡ South Indian auto component firms find direct export mode as simple way of export to enter international business due to less risk involved in meeting OEMs demand.

≡ Auto component manufacturing firms should have substantial financial and human resources along with manager's export strategic planning to face the challenges posed in international business.

≡ Services related to logistics, finance and technological support has been considered as an important service in the industry.

≡ Technological Up-gradation through technical collaborations and joint ventures with original equipment manufacturers are considered as significant elements for export performance.

≡ Having own or in-house research and development facilities enables auto component manufacturers to come out with new and unique products to meet foreign customers.

≡ It is advisable to the auto component manufacturers to implement the concept called product cross deployment where the products of one client can be supplied for the other clients with little modification, by that cost of product development and setup cost can be reduced.

≡ Installation of new technology is very essential to meet changing technological requirement of original equipment manufacturers, so that the firms need to implement Total Quality Management (TQM) to meet the demands of foreign customers with global standards.

— Limitations of the study

≡ The present research is confined to test relationship of internationalization and innovation capabilities of auto component manufacturing companies with export performance only.

≡ The present research includes only linear regression analysis to find out significant relationship among the variables selected.

≡ The study is limited to the geographic areas such as Karnataka, Andhrapardesh and Tamilnadu.

≡ Only 88 auto component manufacturing companies were selected as samples size due to limited population size.

≡ The variables are measured only on the basis of subjective measures.

— Directions for the future research

≡ Comparative analysis can be done to test the influence on export performance of other industries.

≡ The marketing elements or variables such as product, price, place, promotion strategies and service marketing strategies such as people, process, physical evidence can be tested on export performance of auto component industry in India.

≡ Advanced statistical tools can be used to test the impact of multi-dimensional variables of international and innovation capabilities on export performance.

≡ Firm's Internal and external factors that influence export performance of Indian auto component manufacturing companies can be studied.

≡ The researchers can explore the export marketing strategies which can improve the export performance.

CONCLUSIONS

The present study is to understand the significant relationship of internationalization and innovation capabilities with export performance of Indian auto component manufacturing companies. It is understood that gathering export market information, capable of using export market information, role of export mode, relationships & networks, flexible to modify firm resource base, develop new service, technological up-gradation, in-house product designs, improvement in the existing products and re-align manufacturing system have found significant relationship with export performances of auto component manufacturing companies in India. Appropriate foreign market information, direct export mode and technological upgradation is advisable to the auto component manufacturing companies where they can achieve desired export performance.

References:

[1] Alen, L. (2017), "Internationalization: Entering the Russian Market, Lahti University of Applied Sciences Ltd, Faculty of Business and Hospitality Management Degree Programme in International Trade, Bachelor's Thesis.

[2] Alshammari, S. D. and Islam, R. (2014), Impact of The Antecedent Factors on the Performance of Malaysian Export Companies, American Journal of Economics and Business Administration, Published Online Vol.6, No.2.

[3] Arora, V. (2014), Step On the Gas, Future Thought of Business, A Wipro Thought Leadership Initiative, Working Paper, 5th Edition, Jun.

[4] Balakrishnan, K., Seshadri,S. and Sheopuri, A. (2007), "Indian Auto-Component Supply Chain at the Crossroads", INFORMS Journal on Applied Analytics, Vol. 37, No. 4, pp. 310–323.

[5] Chisthy, S. K. and Asadullah (2013), "Issues and Challenges in the Indian Auto Component Industry with Special Reference to Indo Thailand FTA", Indian Journal of Management Science, Vol. 3, No. 2, pp. 10-21.

[6] CRISIL Report (2017), An S&P Global Company, Research Article on Automotiv Components, September.

[7] Dholakia, N. and Khurana, R. (1976) "A Strategy Model for Export Marketing", Vikalpa, Vol.1, No.3. pp. 35-43.

[8] Erdila, S.T. and Ozdemir, O. (2016), "The Determinants of Relationship between Marketing Mix Strategy and Drivers of Export Performance in Foreign Markets: An Application on Turkish Clothing Industry", - Social and

Behavioral Sciences 12th International Strategic Management Conference, Antalya, Turkey.
[9] Henry F.L. Chung., Wang C.L and Huang, P. (2012), "A contingency approach to international marketing strategy and decision-making structure among exporting firms, International Marketing Review,Vol. 29 No. 1, pp. 54-87.
[10] Ivan Damir Anic, I. D., Rajh, E. and Teodorovic, I. (2009), "Firms' Characteristics, Strategic Factors and Firms' Performance in the Croatian Manufacturing Industry", Ekonomski Pregled, Vol. 9, No.10, pp. 413-431.
[11] Jalali, S.H. 2012, "Appraising the Role of Strategy Implementation in Export Performance: a case from middle east", Business Intelligence Journal, July, Vol.5 No.2. pp. 282-291.
[12] Kahia, M. (2017), MPRA Paper No. 77278, University of Tunis E1 Manar, (2017), https://mpra.ub.uni-muenchen.de/77278/.
[13] Kaleka, A. and Morgan, N.A. (2017), "How Marketing Capabilities and Current Performance Drive Strategic Intentions in International Markets", Industrial Marketing Management, Vol.10, No.10, pp.1-13.
[14] Kim, M.M., and Azizi, (2009), The Relationship Between Innovativeness, Strategy Types, Environment and the Export Performance of Small and Mediumsize Enterprises (SMEs) of Malaysian Manufacturing Sector, The Business Review, Cambridge, Vol. 13, No.2, pp.154-145.
[15] Kumar, A, and Dubey, S (2017)." The Indian Automotive Industry: An International Trade Perspective" Working Paper Export-Import Bank of India.
[16] Kumaraswamy, A., Mudambi, R., Saranga, H. and Tripathy, A. (2012), Catch-up Strategies in the Indian Auto Components Industry: Domestic Firms' Responses to Market Liberalization, Journal of International Business Studies, Vol. 43, No.1, 368–395.
[17] Mersid Poturak Teoman Duman 2014, The Role of Marketing Standardization/Adaptation Strategies on Managers' Satisfaction with Export Performance: Proposal of a Conceptual Framework, European Journal of Economic Studies, Vol. 10, No. 4, pp. 252-262.
[18] Mitra, A.K and Joshi, B.P. (2014), "International Competitive Advantage of India in Auto-Component 'Bumpers and Parts Thereof (ITC HS - 870810)' With Selected and Economically Most Important Countries of the World", International Journal of Engineering Research & Management Technology, Vol. 1, No. 5, pp.116-126.
[19] Mohamad, O. Ramayah, T. and Puspowarsito, H, (2011), "Incidence of Marketing Activities in Medium-Sized Manufacturing Firms in Indonesia: Comparing Export Intenders and Non-Export Intenders", International Journal of Business and Society, Vol. 12, No. 1, 89-102.
[20] More, R. Z. and Jain,K. (2013), "Innovation and competitiveness among the firms in the Automobile Cluster in Pune", Knowledge Forum: Annual International Conference Paper @ Pune
[21] Musuva, A.M, Ogutu, M. Zachary Awino, B. Yabs, J (2013), "The Influence of FirmCapabilities on the Internationalisation and Performance of Publicly Quoted Companies in Kenya"DBA Africa Management Review, Vol. 3 No. 2. Pp. 40-58.
[22] Nazar, M. S., Mujtaba, H. and Saleem, N (2009), "Firm-Level Determinants of Export Performance", International Business & Economics Research Journal – Vol. 8, No. 2, pp.105-112.
[23] Parhi, M. (2008), "Indian Automotive Industry: Innovation and Growth, India, Science and Technology, Working Paper, S&T and Industry.
[24] Sagar, Ambuj, D. and Chandra, P. (2004), "Technological Change in the Indian Passenger Car Industry" BCSIA Discussion Paper (2004)-05, Energy Technology Innovation Project, Kennedy School of Government, Harvard University.
[25] Sahoo T, Banwet, D.K. and Momaya, K. (2010), Strategic Technology Management in Practice: Dynamic SAP-LAP Analysis of an Auto Component Manufacturing Firm in India, Global Journal of Flexible Systems Management, Vol.11, Nos.1 & 2, pp. 13-24.
[26] Sahoo T, Banwet, D.K. and Momaya, K. (2010), Strategic Technology Management in Practice: Dynamic SAP-LAP Analysis of an Auto Component Manufacturing Firm in India, Global Journal of Flexible Systems Management, Vol.11, Nos.1 & 2, pp. 13-24.
[27] Saripalle, M (2008), The Indian Auto Component Industry: Competing through Costs or Capabilities? working Paper, IIMB Management Review.
[28] Stoian, M.C (2010), "Internationalization and International Marketing –Export Behavior, International Marketing Strategy and Export Performance in Spanish Amall and Medium Sized Enterprises", PhD thesis, Department of Business Economics Autonomous University of Barcelona.
[29] Tang, R.Y. (2011), "An Empirical Study on The Factors Influencing International Marketing Strategy Development Among Successful Exporters in Australia", DBA thesis, Southern Cross University, Lismore, NSW. Tenneco Inc, 2017, Annual Report.
[30] Tiwari, R. and Kalogerakis, K. (2017), "Innovation Pathways and Trajectories in India's Auto Component Industry", Working Paper Number 98, Hamburg University of Technology (TUHH) Institute for Technology and Innovation Management Am Schwarzenberg-Campus 4.
[31] Torayeh, and Neveen, M. (2011), "Manufactured Exports and Economic Growth in Egypt: Cointegration and Causality Analysis", Applied Econometrics and International Development, Vol. 11, No,1. Pp.111-135.
[32] Yan A.W, B.A., Roberts, M.J. and Winston, T. (2007), "Export Market Participation, Investments in R&D and Worker Training, and the Evolution of Firm Productivity", The World Economy, doi: Blackwell Publishing Ltd.

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

[1.]Saša RANĐELOVIĆ, [2.]Mladomir MILUTINOVIĆ, [3.]Dejan TANIKIĆ, [4.]Vladisalav BLAGOJEVIĆ

THE TECHNOLOGY OF TUBE HYDROFORMING AND PARAMETERS PROCESS

[1,4.]University of Nis, Faculty of Mechanical Engineering, Nis, SERBIA
[2.]University of Novi Sad, Faculty of Technical Science, Novi Sad, SERBIA
[3.]University of Belgrade, Technical Faculty in Bor, Bor, SERBIA

Abstract: The tube plastic deformation technology represent metal forming technology that involves flexible production process that can be realized through various technological solutions and the tool design itself. Each additional requirement to fulfill some special requirements, in terms of tube shape and geometry, almost always implies non-standard technologies that significantly price increase of the finished product. For these reasons, the application of incompressible fluid in these processes, with certain limitations, can greatly improve and fulfill the requirements that are placed before the finished product. The paper presents a geometric tool model, with a preliminary analysis of the mechanical parameters of the design process, with the possibility of designing the technology itself.
Keywords: hydroforming, stress, strain, tool, pressure

INTRODUCTION

The proposed technology of supplying compensating tubes first of all requires a detailed analysis of the parameters of the tube manufacturing process, because it is a complex metal forming process of plastic deformation where the desired tube profile is obtained by means of an incompressible fluid [1].

For these reasons, the required pressure of the fluid inside the tube, or the entire installed hydraulic unit, is to be analyzed, which should allow the working pressure of the fluid [2]. It starts from the Laplacian equation for the deformation of the sheet according to the instantaneous without moment theory and the geometric conditions that are set by the tool geometry itself to get pressure inside the pipe. In order to make deformation possible at all, the axial compression force of the tube in the tool is also provided to allow plastic deformation against the removable and moving tools walls [3,4]. Such a detailed analysis was used for construction and tool design for the mentioned technology which, based on 3D models and complete technological documentation, were realized to the exploitation conditions of the production itself.

MECHANICAL PARAMETERS DEFINE

The most important task in analyzing the design of the tubular compensator by the hydraulic design method is the correct determination of the value of the required pressure of the fluid in the tube itself during the design process [2].

Based on the pressure value obtained, the calculation of the most important construction and structural elements of the tool sets and the selection of materials for individual parts of the tool is carried out. The required pressure can be determined from Laplace's equation

$$\frac{\sigma_\rho}{R_\rho}+\frac{\sigma_\theta}{R_\theta}=\frac{p}{s} \tag{1}$$

where is: $R_\theta=\frac{\rho}{\cos\alpha_i}$, R_r – radius of curve in the tangential and meridian direction respectively,

Solving Laplace's equation by an unknown size of internal pressure p is obtained:

$$p=\frac{s}{R_\rho}\sigma_\rho+\frac{s}{R_\theta}\sigma_\theta \tag{2}$$

If the expressions for radial and tangential stress σ_ρ and σ_θ are entered in the above expression, a general expression for determining the pressure in the form is obtained:

$$p=\frac{s\cdot\beta K\left(\frac{1-\frac{R_0}{\rho}}{R_\rho}+\frac{1}{R_\theta}\right)-\frac{s}{R_\rho}\frac{R_0}{\rho}\frac{F_a}{A}}{1+\frac{s}{R_\rho}\left(1+\frac{R_0}{\rho}\right)+\frac{s}{R_\theta}} \tag{3}$$

Instead of the variable radius R_ρ and R_θ, the variable can be included in the obtained expression α_i , if the radius are replaced by the terms given in the deformation state analysis. From the general expression (3) it can be seen that the pressure is higher if the thickness of the tube wall is larger and the tube diameter is smaller [2]. By increasing the axial compression force, the required pressure decreases. When the coordinate ρ is increased, i.e. the height of the ribs, the necessary pressure is growing. Based on the above, it follows that the internal pressure in the tube is variable value and changes during the metal forming process. However, it is much conviniant process to metal forming with constant pressure, in which case the axial

compression force is variable during the time of metal forming [5]. The value of the required pressure is determined from the condition that the internal pressure is the same at any time in the metal forming process, even at the beginning. If the initial conditions are:

$$\rho = R_0 \qquad R_\rho = \infty \qquad R_\theta = \frac{\rho}{\cos 0} = R_0 \qquad K = K_0$$

by replacement into expression (3) gives a simplified expression for determining the required pressure in the form:

$$p = \frac{s \cdot \beta \cdot K}{R_0 + s} \tag{4}$$

which indicates that the internal pressure depends only on the type of tube material and the dimensions of the tube. As the thickness of the tube wall increases, the pressure increases, and with the increase in the tube diameter it decreases [6].

Unless the curves of hardening for the given material are available, one of the empirical aproximation can be used to evaluate the actual curve of hardening. In this case, the most commonly used is the linear approximation according to the expression:

$$K = K_0 + \Pi \cdot \varphi_i \tag{5a}$$

and exponential aproximation curve:

$$K = C \cdot \varphi_i^n \tag{5b}$$

In previous expresion labels K_0, n, C, Π represent constants that depend on the type of material, while with φ_i the intensity of the deformation is determined by the expression:

$$\varphi_i = \frac{\sqrt{2}}{3}\sqrt{(\varphi_\rho - \varphi_\theta)^2 + (\varphi_\theta - \varphi_n)^2 + (\varphi_n - \varphi_\rho)^2} \tag{6}$$

and in the conditions of the axe symetric deformation state:

$$\varphi_i = \frac{\sqrt{2}}{3} \cdot 2\varphi_\theta \approx \varphi_\theta \tag{7}$$

The results of the theoretical analysis presented in this paper were obtained according to the expressions (5b) and (6) where the values of the true stress were obtained from the empirical expression for stainless steel:

$$K = K_0 + 3{,}2(100 \cdot \varphi_i)^{0{,}84} \tag{9}$$

where is: $K_0 = \sigma_v$ - stress at the yield point. When carrying out metal forming experiments in this investigation process was done with constant pressure values for even during the process of forming.

THE AXIAL FORCE OF UPSETTING DETERMINATION

When grouping ribs forming in a tool sets with moving mold segments, the axial force of upsetting appears as the only unmanageable size that changes values depending on other, controlled values such as fluid pressure in the tube, tool stroke etc.

However, the dependence of the axial force on various influential factors can be determined in analytical form [2,5]. The correct determination of the axial force is the basis for the selection of the press equipment on which the forming can be carried out. Generally, the axial force of upsetting can be presented as the sum of the following components:

- Fa_1 - the force required to overcome resistance to plastic deformation occurring in the tube material;
- Fa_2 - the force required to overcome the friction resistance occurring between the tube and the mold;
- Fa_3 - the force required to overcome the pressure of the fluid in the tube on the surface of the punch;

The component Fa_2 is equal to zero because there is no displacement of tube parts inside the mold, i.e. coefficient of friction is zero. The Fa_1 component can be determined by integrating the stress in the meridian direction along the front surface of the tube (circular ring) through which the axial force of upsetting is transmitted:

$$F_{a1} = \int_{R_u}^{R_u + s_0} \sigma_\rho \cdot 2\pi\rho d\rho \tag{9}$$

where is integral limits: R_u internal radius of tube , $R_u + s_0 = \frac{d}{2}$ outer radius of tube ,

Radial stress σ_ρ can be define in the form:

$$\sigma_\rho = \frac{\beta K}{2} - p \tag{10}$$

which is obtained from the conditions of the axe symetric deformation state:

$$\sigma_\rho = \frac{\sigma_\theta + \sigma_n}{2}$$

where is σ_ρ and σ_n normal stress in radial and tangential direction of the compensation tube wall respectively [5,6].

The axial force upsetting get the form:

$$F_{a1} = \pi\left(\frac{\beta K}{2} - p\right)\left(s_0^2 + 2s_0 R_u\right) \tag{11}$$

By analyzing the expression (11), it is concluded that the axial force upsetting depends on the type of material of workpiece and dimensions of the tube, as well as the pressure of the fluid during process of metal forming. With the increase in pressure in the tube, the required axial force is reduced, which could be expected. As the dimensions of the tubes increase, the required axial force is also increased.

If all the parameters are fixed at one level, the axial force during the process must increase because it also depends on the true stress of material of workpiece K that changes during the process deformation. Component Fa_3 is defined by the expression:

$$F_{a3} = p \cdot A = p \cdot R_u^2 \cdot \pi \qquad (12)$$

This component of the axial force increases in proportion to the increase in the pressure of the fluid in the tube and the inner diameter of the pipe [6]. The total axial force upsetting is:

$$F_a = F_{a1} + F_{a3}$$

ie. by inserting an expression (11) i (12) :

$$F_a = \pi\left(\frac{\beta K}{2} - p\right)\left(s_0^2 + 2s_0 R_u\right) + \pi \cdot p \cdot R_u^2 \qquad (13)$$

Since the metal forming takes place with constant working pressure in the tube, the axial force upsetting during the formation is monotonous due to the effect of hardening, i.e. an increase in the true stress K, which the experiments confirmed.

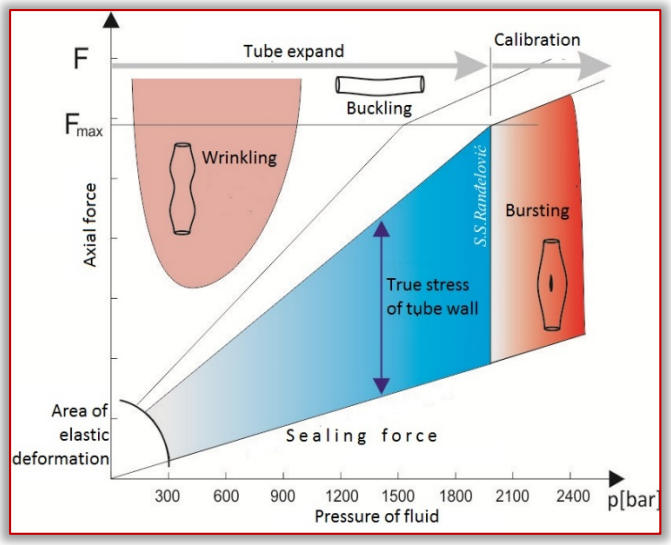


Figure 1. The defect type at hydroforming process

As with any metal forming process, there are certain limitations on the degree of deformation achievable in tube hydroforming process such that parts with desired specifications (like expansions) may not be formed without any defects [8].

Depending on the defect type observed, failure types or instability modes can be grouped as wrinkling, buckling and bursting (Figure 1). Instability modes, which limit the extent of formability in tube hydroforming process, occur when stress and strain state in a part reach a critical level that equilibrium can't be sustained any longer between external forces applied and the internal resistance of the material (i.e. strength).

TECHNOLOGICAL SOLUTION REALISATION

All the complexity of the previously described mathematical procedure gets important when considering the preparation and the finished part after deformation (Figure 1).

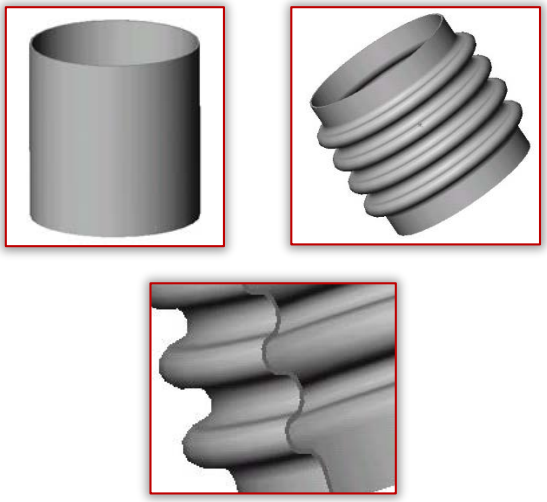


Figure 2. Workpiece a) and finished part b) with geometry of final cross section

The conclusion is immediately drawn that the finished part in Figure 1b, c is almost impossible to obtain by conventional deformation procedures. However, a partial answer to this question is already shown in Figure 2, which only shows the outer appearance of the tool enclosure in a 3D presentation where clearly the outer contours of the tools with the inlet and outlet pipes of the working fluid, that is, the adjoining tools for the press workpiece can be clearly seen.

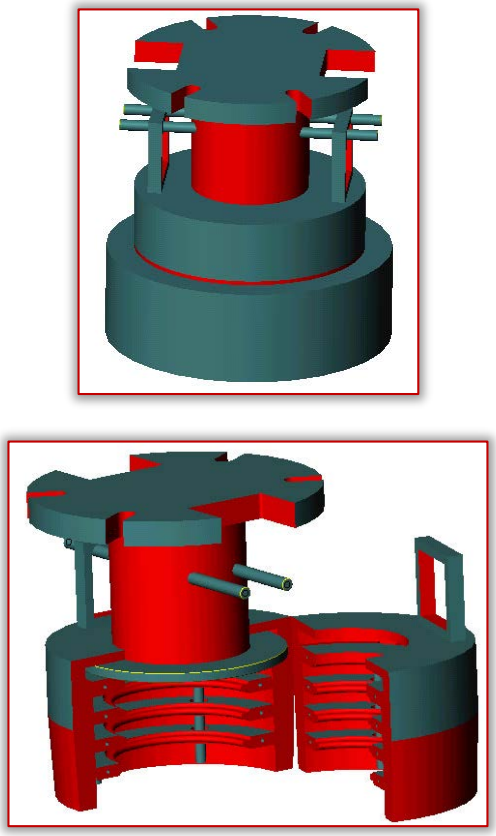


Figure 3. 3D model of tool for compensation tube and flat opening

The very essence and constructive solution of the interior of the tool is clearly seen in Figure 3 which provides an answer to many questions regarding the

work of the tool itself. In order to clarify many dilemmas, the same pisture shows the internal geometry of the tool and gives answers to almost all of the reader's questions. This approach and display of tools in many ways helps in understanding the technological method of closing the tool and the deformation process that takes place inside its interior.

CONCLUSION

The production of a compensation tube with an incompressible fluid has a number of advantages over the production of solid tools. A process with movable mold segments is particularly suitable. The paper was intended to provide basic notions and settings of theoretical analysis, thus obtaining the expressions for calculating the required pressure and axial compression forces. In order to verify the theoretical results, complete experimental tests and checks of all parameters were performed.

Note:

This paper is based on the paper presented at DEMI 2019 – The 14th International Conference on Accomplishments in Mechanical and Industrial Engineering, organized by Faculty of Mechanical Engineering, University of Banja Luka, BOSNIA & HERZEGOVINA, co–organized by Faculty of Mechanical Engineering, University of Niš, SERBIA, Faculty of Mechanical Engeneering Podgorica, University of Montenegro, MONTENEGRO and Faculty of Engineering Hunedoara, Unversity Politehnica Timisoara, ROMANIA, in Banja Luka, BOSNIA & HERZEGOVINA, 24–25 May 2019

References

[1] B. Musafija, Primjenjena teorija plastičnosti I i II (1973), Sarajevo, str. 684.
[2] Koc M.¸ Altan T., Prediction of forming limits and parameters in the tube hydroforming process, Machine tools & Manufacture, 2001. p.123-128
[3] Slater R.A.C., Engineering Plasticity, Theory and application to metal forming processes, 1977., London
[4] Marciniak, Z., Duncan J.L., Hu S.J., Mechanics of Sheet Metal forming (2002), Butterworth-Heinemann (p. 211)
[5] Jansson, M, Nilsson, L., Simonsson, K., The use of biaxial test data in the validation of constitutive descriptions for tube hydroforming applications, Journal Material Processing Technology, 2007, 184, p. 69-76
[6] Hartl, Ch., Research and advances in fundamentals and industrial applications of hydroforming, Journal Material Processing Technology, 2005, 167, p. 383-292
[7] Manabe, K., Amino, M., Effects of process parameters and material properties on deformation process in tube hydroforming. Journal Material Processing Technology, 2002, 123, p. 285-291
[8] Ranđelović S., Marinković V., Proizvodne tehnologije, Mašinski fakultet u Nišu, 2017. p. 356.

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

[1.]Georgeta GĂGEANU, [2.]Iuliana GĂGEANU, [3.]Dan CUJBESCU, [4.]Ioan Cătălin PERSU

EXPERIMENTAL RESEARCHES FOR DETERMINING THE PHYSICAL-CHEMICAL PROPERTIES OF BIOMASS PELLETS

[1-4.] INMA Bucharest, ROMANIA

Abstract: Human activity will always require the existence of a large volume of energy to support it. Due to climate change and the rapid depletion of conventional fuels, it is necessary to use renewable sources to provide the necessary energy. Biomass heating is the oldest and most well-established form of energy supply in the world, being intrinsically linked to the development of the human race. However, it was made redundant by the high energy density of fossil fuels, and its application in modern energy systems, especially in industrialized countries, has until recently been declining. A renewed interest in biomass-based energy systems comes from a variety of reasons. They are dominated by the interest in reducing greenhouse gas emissions, the emergence of new efficient biomass conversion technologies, as well as rising prices of fossil fuels. By pelleting, it is important preserve or enhance the physical-chemical properties of biomass that make this type of biofuel suitable for large scale use. The article presents a series of experimental researches in the field of solid biofuels, namely pellets from biomass for determining their physical-chemical properties, determinants for their use as solid biofuels.
Keywords: biomass, pelleting, calorific power, volatile matter

INTRODUCTION

The need to limit the use of conventional (fossil) fuels and replace them with fuels obtained from renewable energy has led to the intensification of researches in the field of obtaining biofuels from renewable energy such as biomass (Mani et al., 2003; Tabil et al., 2011). The benefits of biofuels compared to traditional fuels aim to lead to greater energy security, lower environmental impact, financial savings and socio-economic aspects related to the rural sector.

Given that biomass is the most abundant renewable resource in the world being represented by any plant component, including manure and sewage sludge. Under proper processing, freshly harvested biomass can be converted into products similar to natural gas or liquid or solid biofuels (Stelte, 2012).

Biomass heating is the oldest and most well-established form of energy supply in the world, being intrinsically linked to the development of the human race. However, it was made redundant by the high energy density of fossil fuels, and its application in modern energy systems, especially in industrialized countries, has until recently been declining.

A renewed interest in biomass-based energy systems comes from a variety of reasons. They are dominated by the interest in reducing greenhouse gas emissions, the emergence of new efficient biomass conversion technologies, as well as rising prices of fossil fuels.

Except in cases where direct combustion is appropriate, crude biomass requires the conversion into solid, liquid or gaseous fuels that can be used to produce heat, electricity and as fuel for vehicles. This conversion is accomplished through a series of physical, biological, thermal and chemical processes (Ion, 2006).

In order to obtain solid biofuels that can replace fossil fuels such as coal from biomass is necessary to undergo a compaction process, such as pelleting. The process of producing the pellets involves subjecting the biomass material (sawdust from woody biomass, grinded agricultural biomass or combinations between the two types, with or without using additives) to high pressures and forcing it to pass through the cylindrical orifices of a flat or cylindrical die. Due to the temperature and the friction forces that develop inside the machine, the biomass "fuses", resulting in compact and uniform pellets (Artemio et al., 2018; Smaga et al., 2018, Wu et al., 2011).

Pelleting materials of forest or agricultural origin have the following advantages: a considerable reduction in the waste of wood material; higher capitalization of the by-products of agriculture and forestry; reduction of handling and storage costs.

By pelleting, it is important preserve or enhance the physical-chemical properties of biomass that make this type of biofuel suitable for large scale use. This paper shows a series of experimental researches conducted on biomass pellets to determine their physical-chemical properties, in comparison with those of the raw material.

MATERIAL AND METHOD

For conducting the experimental researches, sawdust and pellets obtained from fir tree, oak and alder sawdust were used. All sawdust samples had the same granulation (2 mm) and all pellets were obtained in the same conditions (using a single pellet device with an 8 mm diameter die, at 80°C). Table 1 shows the samples used for experiments.

Table 1. Samples for analysis

Sample no.	Type
1	Fir sawdust
2	Fir pellets
3	Oak sawdust
4	Oak pellets
5	Alder sawdust
6	Alder pellets

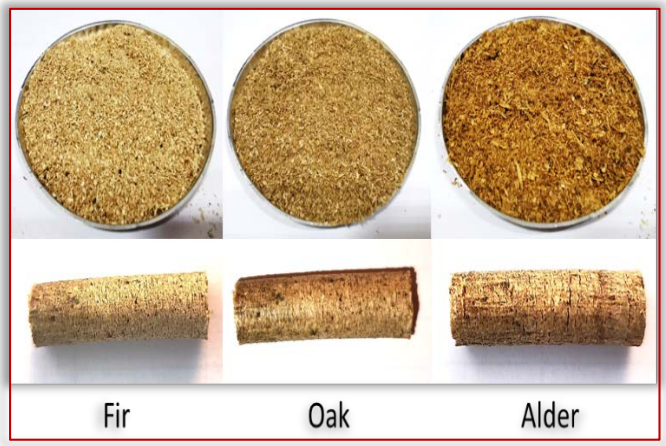


Figure 1. Sawdust and pellet samples used for experiments

The following equipment were used during the researches, presented in Table 2.

Table 2. Equipment used for determining the physical-chemical properties of pellets

Equipment/type	Measure domain / division
Precision weighing scales /AW 220 M, with self-calibration (Shimadzu - Japan)	0÷200 g / 0.1 mg
Furnace with temperature adjustment / -UFE 500 (Memmert - Germany)	0÷260°C / 1°C
Calorimeter /CAL 2k (DDS Calorimeters - South Africa)	0.001 MJ kg^{-1}
Calcination oven, with P 320 controller (Naberterm - Germany)	0 ÷ 1400°C / 10°C

All biomass and pellet samples for analysis were prepared according to the specifications found in standard ISO 14780:2016 – Solid biofuels: Sample preparation.

METHODS OF ANALYSIS USED

— Moisture content

Moisture content (%) was determined on a wet basis, according to the method described in standard ISO 18134-1:2015 – Solid biofuels – Determination of moisture content – Oven dry method – Part 1: Total moisture – Reference method.

— Energy content

The energy content (MJ/kg) of pellet samples was determined using the calorimeter bomb, according to the specification found in ISO 18125:2016 standard – Solid biofuels – Determination of calorific power.

— Ash content

The ash content (%) of sawdust and pellets samples was determined using the calcination oven, at 550°C, according to the provisions of standard ISO 18122: 2015 – Solid biofuels – Determination of ash content.

— Volatile matter

The content of volatile matter (%) was determined by introducing the samples at 900 °C in the calcination oven, according to the provision found in standard ISO 18123: 2015 – Solid biofuels – Determination of the content of volatile matter.

— Sawdust and pellet density

Sawdust density (kg/m^3) was determined using a cylinder that has a known volume and a precision scale for weighing the samples, according to the provisions of standard ISO 17828:2015 – Solid biofuels – Determination of bulk density.

Pellet density was determined by giving the pellet samples a cylindrical shape by sanding the irregularities resulted from the pelleting process and weighing each sample.

Figure 2. Aspect during the experiments

RESULTS

Using the methods previously mentioned, after conducting the analysis, the following results were obtained, presented in table 3.

Table 3. Results obtained from the analysis of pellets

Sample no.	Moisture content [%]	Energy content [MJ/kg]	Ash content [%]	Volatile matter content [%]	Density [%]
1	13	16.589	4.22	73.50	142.18
2	9.21	15.981	4.18	72.58	1001.47
3	13	15.788	5.21	73.48	184.75
4	9.53	16.021	5.18	73.42	1124.31
5	13	15.521	5.88	74.23	178.91
6	9.86	15.470	5.76	72.81	1024.31

It can be observed that the moisture content of pellets registered values ranging between 9.21 % and 9,86 % for pellets obtained, indicating that coniferous sawdust loses water more easily during the pelleting process.

The moisture obtained for the pellets is under 10%, indicating good storage combustion attributes.

Calorific power registered small increases for all samples after compaction, while volatile matter had small decreases for pellets compared with sawdust, indicating that volatiles are released during the process, due to the high temperature used. The ash content of pellets had small variations compared to sawdust.

Bulk density was found to increase greatly (7.04 times for fir, 6.08 times for oak and 5.72 times for alder sawdust).

CONCLUSIONS

The experimental researches showed that the compaction of sawdust had an overall beneficial effect, mainly on the stability of the biomass, storage characteristics and energy content, but also gives a solution for ensuring quality solid biofuel. Therefore, this study has shown that the pelleting process is a represents a good solution for valorizing the residues from silviculture, tree grooming, etc.

Acknowledgement

This work was supported by the Romanian Research and Innovation Ministry, through NUCLEU Programme, Project "Researches on the intensive polyculture growth of fish and the complex valorization of aquatic bioresources (plants)", code PN 19 10 02 03, contract no. 5N/07.02.2019.

Note:

This paper is based on the paper presented at ISB–INMA TEH' 2019 International Symposium (Agricultural and Mechanical Engineering), organized by Politehnica University of Bucharest – Faculty of Biotechnical Systems Engineering (ISB), National Institute of Research–Development for Machines and Installations Designed to Agriculture and Food Industry (INMA Bucharest), Romanian Agricultural Mechanical Engineers Society (SIMAR), National Research & Development Institute for Food Bioresources (IBA Bucharest), National Institute for Research and Development in Environmental Protection (INCDPM), Research-Development Institute for Plant Protection (ICDPP), Research and Development Institute for Processing and Marketing of the Horticultural Products (HORTING), Hydraulics and Pneumatics Research Institute (INOE 2000 IHP) and "Food for Life Technological Platform", in Bucharest, ROMANIA, between 31 October – 1 November, 2019.

References

[1] Artemio C.P., Maginot N.H., Serafin C.U., Rahim F.P., Guadalupe R.Q.J., Fermin C.M., (2018), Physical, mechanical and energy characterization of wood pellets obtained from three common tropical species. PeerJ 6:e5504; DOI 10.7717/peerj.5504;

[2] Ion V. I., Ion D. I., (2006) Consideraţii teoretice energie, Universitatea „Dunărea de Jos" din Galaţi, nr. 7/2006;

[3] Mani S., Tabil L.G., Sokhansanj S. (2003), An Overview of Compaction of Biomass Grinds, Powder handling & processing, vol. 15, no.2, pp. 1-9;

[4] Smaga M., Wielgosinski G., Kochanski A., Korczak K. (2018), Biomass as a major component of pellets, Acta Innovations, no. 26, pp. 81-92;

[5] Stelte W. (2012), Guideline: Storage and Handling of Wood Pellets, Report, Danish Technological Institute;

[6] Tabil L., Adapa P., Kashaninejad M. (2011) In biomass feedstock pre-processing: densification, Biofuel's Engineering Process Technology, M. A. Dos Santos Bernardes, Ed., pp. 439–464, InTech, NY, USA;

[7] Wu M.R., Schott D.L., Lodewijks G. (2011), Physical properties of solid biomass, Biomass and bioenergy 35, pp. 2093 – 2105;

[8] ISO 14780:2016 – Solid Biofuels. Sample preparation;

[9] ISO 18134-1:2015 - Solid biofuels - Determination of moisture content - Oven dry method - Part 1: Total moisture – Reference method;

[10] ISO 18125:2016 – Solid biofuels – Determination of calorific power.

[11] ISO 18122:2015 - Solid biofuels - Determination of ash content;

[12] ISO 18123:2015 - Solid biofuels - Determination of the content of volatile matter;

[13] ISO 17828:2015 - Solid biofuels - Determination of bulk density.

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

Fascicule 4

[October – December]

tome [2020] XIII

ACTA Technica CORVINIENSIS
BULLETIN OF ENGINEERING

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

http://acta.fih.upt.ro

[1.]Olakunle F. ISAMOTU, [2.]Oluwafunmilola I. OGUNLARI

OPTIMAL DESIGN AND PERFORMANCE OF A SELF- INDUCTING POWERED BICYCLE GENERATOR

[1,2.]Mechanical Engineering, Engineering, Federal University of Technology, Minna, NIGERIA

Abstract: The insufficiency of energy is a global challenge so also is the effect of burning fuel to generate power a threat to the earth. Hence, the need for a sustainable and renewable source of energy that can be used to supplement and with time substitute the burning of fuels to generate power. The research work is focused on optimizing on existing design models of the Chas Campbell free energy generator by incorporating a bicycle system for initial excitation as opposed to electric power. The system is supported with a flywheel which will store kinetic energy to keep the system working before the motor is connected to the generator. The system generated a power of 96w and stayed self-inducting at maximum cyclist speed of 58rpm for a period of 35 seconds. The kinetic energy stored in the flywheel as a result of the flywheel is the major determinant of the duration of self-inducting for the system.
Keywords: clean energy; free energy; flywheel technology; power generation; performance evaluation

INTRODUCTION

The need for a clean, cheap and sustainable power source has been a key area where researchers have directed their efforts over the years in order to counter and minimize the effect and dependence on fossil fuels for both domestic and industrial applications. Demand for energy storage in flywheel have increased because of it high power and efficiency which are of essence in commercials areas of application includes Uninterrupted Power Supply (UPS) systems for backup to temporarily provide power until another source of power is switched to during power outage, sustaining and regulating frequency of power channeled to the power grid, provide power for acceleration in automotive engines [1]. The use of flywheel for energy storage can be dated to 1973 when Dr Richard Post proposed the construction of a 200-tonne, 10 megawatt-hour flywheels for electricity storage for the United States power grid.

The material used for the flywheel were of composite materials thus making it difficult to achieve dynamic stability and structural integrity made difficult with high cost production.

Technology has improved and other electricity storage devices have been made such as: fuel cells, pumped hydro, compressed air energy storage (CAES), ultra-capacitors also referred to as super capacitors batteries, super-conducting magnetic energy (SMES) and flywheel [2].

Several works have been done as to generating electricity through the motor-generator mechanism. Some of the notable arrangements for this systems that will be further discussed in this research work include Chas Campbell's Power Generation System which he demonstrated at a science community in Australia [3], The Tesla Switch popularly called the 'cigar box' which was built by John Bedini at the Tesla Tech Conference in 1984, The Ronald Brandt converter constructed in 1983, The Phi Transformer, The Clem motor built by Richard Clem in 1992 at his residence in Texas, The Papp Engine [4].

From history, human power has been used to power devices. The first human powered device recorded to give a rotary motion is the potter's wheel around 3,500 B.C. Pedal power and Cranks became one of the most devices to couple human power to applications and in the 19th Century, the use of bicycle pedal with the electric dynamo for self-transportation and to generate electric power [5]. This research will be integrating and making modifications to the Chas Campbell Power Generation System by applying the flywheel technology to save energy and the system which will be initially driven by a cyclist on a bicycle and the flywheel is being connected to the generator for electricity generation.

The aim of this work is to develop a simple and easy to use power generating system that is safe for the environment, sustainable and cheap. This research work is a modification to the existing designs of motor-generator systems incorporating human power by using a bicycle pedal cycling to give initial excitation to the flywheel before connecting the AC motor to the output from the generator.

MATERIALS AND METHOD

The following materials were used to carry out this research work: Flywheel, System support frame, Shaft, Bicycle frame, 18V, 3.2A DC motor with rotational speed of 300 rpm,12V, 8A, 350rpm DC motor, Ø60mm single groove pulley, Double groove Ø130mm pulley.

Table 1 shows the materials and ratings of the components employed for the powered bicycle generating system.

Table1: Summary of materials with their rating/properties

S/N	Component	Material	Rating/Specifications
1	Flywheel	Cast Iron	18 Kg, 350mm rim with web
2	Shaft	High carbon steel	400mm, Ø30mm
3	DC Motor	-	57.6W, 18V, 3.2A, 300rpm
4	Generator DC	-	96W, 12V, 8A, 350rpm
5	Pulleys	Cast steel	Ø150mm, Ø130mm, Ø60mm
6	Bicycle Frame	Mild steel pipe	500mm rim size
7	Belt	Synthetic rope	1200mm long

— Free Energy

Free energy refers to a method of generating power without fuel combustion from the environment. Furthermore, free energy can be generated through the following methods; Battery-Charging Pulsed Systems, Moving Pulsed Systems, Energy- Tapping Pulsed Systems, Aerial Systems and Electrostatic Generators, Motionless Pulsed Systems, Fuel-less Motors, Magnet Power, passive Systems and Gravity Powered Systems [3].

— Flywheel Technology

A flywheel serves as an energy reservoir in the form of inertia which has a motor/alternator attached to feed it [6], [7]. It is a mechanical battery that typically consists of a high speed inertia composite rotor to store kinetic energy consisting of a control system and magnetic bearing support, a vacuum support housing and containment, compact heat removal and exchangers, instrumentation monitoring and control, an electrical machine that can run either as a motor or a generator to undertake the energy transfer to and from the flywheel and power electronics for electrical conversion as represented in Figure 1 [8]

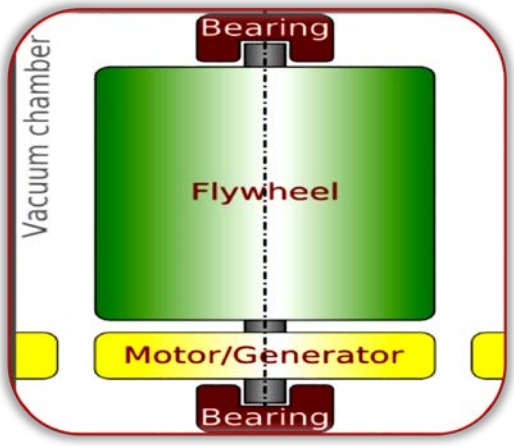


Figure 1: Schematic diagram for a flywheel's storage system [8]

Unlike the failings of all chemical batteries, a flywheel has the ability to discharge cyclically to zero energy without any degradation whatsoever [9].

Flywheel energy storage systems are attractive for the types of applications for which a designer might not want to consider the common conventional electrochemical batteries or superconducting magnetic energy storage [8] Flywheel is a storage device which stores mechanically generated energy in the flywheel and the energy stored is then converted to drive a device which most times produce electrical power or to stabilize the electricity produced. With lower energy densities compared to batteries but the density is sufficient to meet the requirements for many high power applications and still give better performance than batteries [10], [11].

Several researchers have proposed methods and ideas to alleviate these problems, but a fundamental limitation remains in all present designs which are that the rotating mass is far from the axle while the stabilization system (bearings and actuators) operates directly on the axle.

If the harbor or spokes are flexible enough to expand as rotational speed increases, then the stabilization system must transmit control forces to the rim through a "floppy" structure – an impossible task – but if the structure is rigid it will delaminate under high radial stress. So far, the only way to resolve this conflict has been restricting the composite flywheels to small diameters [2].

Energy stored in a flywheel is based on the rotating mass principle which is stored in the device as rotational kinetic energy and the source of its input energy is usually electrical [12].

The energy that is stored in a flywheel can be expressed by equation (1), where E is the kinetic energy stored in the flywheel in N-m, ω is the velocity of the flywheel in rad/s and I is the moment of inertia.

$$E=\frac{1}{2}\cdot I\cdot\omega^2 \quad (1)$$

The moment of inertia I for a flywheel can be expressed as the product of the mass of the flywheel, m the radius of the flywheel, r and the shape-factor for the flywheel geometry, k as expressed in equation (2).

$$I=kmr^2 \quad (2)$$

For a hollow flywheel, the moment of inertia can be expressed as,

$$I= km(r_2^{\,2} - r_1^{\,2}) \quad (3)$$

where, r_1 and r_2 are the internal and external diameters respectively.

Table 2: Shape-Factor for different planar geometry [13].

FLYWHEEL GEOMETRY	CROSS SECTION	SHAPE FACTOR. K
Disc		1.000
Modified constant stress disc		0.931
Conical disc		0.806
Flat unpierced disc		0.606
Thin film		0.500
Shaped bar		0.500
Rim with web		0.400
Single bar		0.333
Flat pierced bar		0.305

Possible applications for a highly efficient flywheel energy storage system include: In road vehicles, as well as other applications, flywheels are being considered as a replacement for electrochemical batteries [14]-[15]. Flywheels have high energy per kilogram, are light weighted, low charging times and have been found to have a longer lifetime than batteries.

Batteries need to be replaced during the life of a hybrid vehicle, which can be costly and hazardous to the environment, the flywheel's main use in cars is to convert the power from the engine and transfer it to the clutch plate, dealing with intermittency, providing ride-through for fast instantaneous events such as demand spikes or clouds with PV, renewable integration. Storing during generation and extracting it during demand; in train systems which extracts energy from the flywheel during acceleration and returns the braking energy to the flywheel during deceleration [16].

— Bicycle cycling for power generation

Human rotational performance is a function of the skeletal muscle to generate power and also sustain the power generated which can be possible by resisting fatigue [17]. While riding bicycle, humans are capable of generating approximately 150W of electrical power which goes waste without being put to use. This power can be used to power many electrical devices by incorporating a dynamo or alternator to harvest the energy generated by the pedaling cyclist and the energy can also be stored in a battery [18]. As long as there is continuous pedaling and the system is working fine, we can get power whenever needed. Generating power through this medium is free and eco-friendly [19].From an experiment carried out for three people at average physical condition during an indoor cycling experiment conducted and each session lasted for 50 minutes. The result reveals a dominant range of speeds of 200rpm to 250rpm. The average speed from the experiment is close to 242 rpm, and the rotational speed will be above 200 rpm for 80% session of the time [20].

The idea of adding a flywheel to a bicycle is very appealing because it can increase the efficiency of what is already considered a very efficient machine. This means at its peak, the flywheel is only making up for the efficiency lost by its additional weight [9].

— Shaft Design

The design calculation for the selected shaft for the system as shown in Figure 2

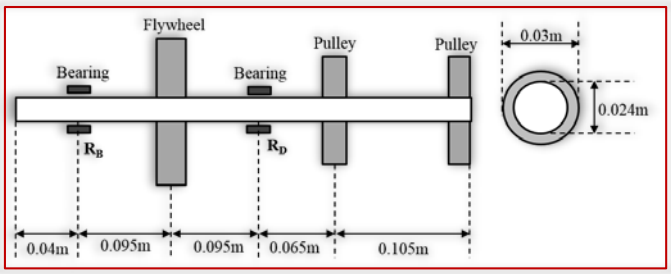


Figure 2: Schematic diagram of loads on the shaft

The direction and magnitude of the forces acting on the shaft are shown in the schematic diagram of the loaded in Figure 2

The Reaction Forces R_B and R_D from the supporting bearing system are calculated as;

Summing the forces in one direction about point B,

$$(0\times0.04) + (180\times0.095) - (R_D\times0.19) + (20\times0.255) + (20\times0.36) = 0$$

$$0 + 17.1 - 0.19R_D + 5.1 + 7.2 = 0$$

Rearranging,

$$0.19R_D = 17.1 + 5.1 + 7.2$$

$$0.19R_D = 29.4$$

Divide through by 0.19

$$R_D = 154.74\ N$$

Summation of upward forces = Summation of downward forces

$$R_D + R_B = 180 + 20 + 20$$

$$154.74 + R_B = 180 + 20 + 20$$

$$R_B = 180 + 20 + 20 - 154.74$$

$$R_B = 65.26\ N$$

The Shear Force, F acting at each point of the shaft loading is calculated,

$$F_A = 0$$

$$F_B = 65.26N$$

$$F_C = 65.26N - 180N$$

$$F_C = -114.74N$$

$$F_D = -114.74N + 154.74N$$

$$F_D = 40N$$

$$F_E = 40N - 20N$$

$$F_E = 20N$$
$$F_G = 20N - 20N$$
$$F_G = 0$$

The Shear force diagram is represented in Figure 3.
The Bending Moment, M at each point of the shaft loading is calculated,

$$M_A = 0$$
$$M_B = 0$$
$$M_C = 62.26 \times 0.095$$
$$M_C = 6.2Nm$$
$$M_D = 0$$
$$M_E = 154.74 \times 0.065$$
$$M_E = 10.06Nm$$
$$M_G = (154.74 \times 0.17) - (20 \times 0.105)$$
$$M_G = 24.21Nm$$

The Bending Moment diagram is shown in Figure 3.

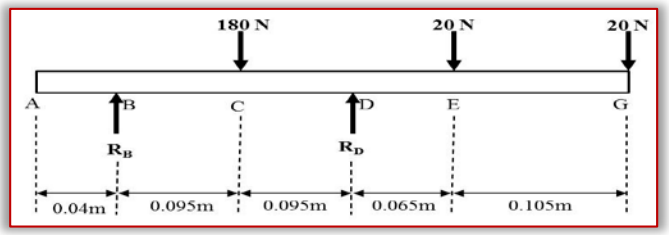


Figure 3: Direction and magnitude of the forces acting on the shaft

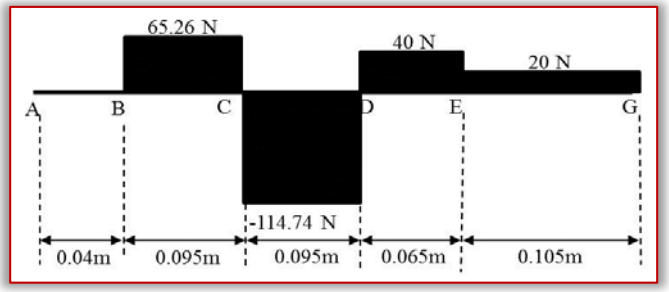


Figure 4: Shear force diagram for the shaft

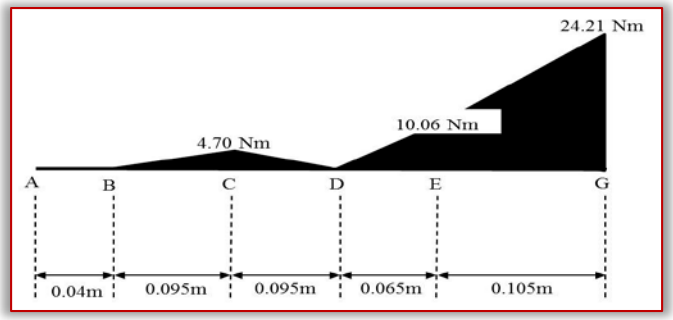


Figure 5: Bending Moment diagram for the shaft

Diameter of shaft

$$r = \frac{\sigma_a \times I}{M} \quad (4)$$

where:
σ_a = maximum allowable stress = 40 MPa
I = Moment of inertia
M = Maximum bending moment,
$I = \pi \times r^4 \times 0.25$
$I = 0.785r^4$

$$r = \frac{\sigma_a \times I}{M}$$

r = 10.9mm
D = 22mm
The Maximum Bending moment is M_G = 24.21Nm

$$\text{The Bending Stress, } \sigma_b = \frac{32M}{\pi d_0^3(1-\emptyset^4)} \quad (5)$$

where,
M = Maximum Bending Moment = M_G = 24.21Nm
d_o = shaft outer diameter = 0.30
Ø = ratio of shaft inner to outer diameter

$$\emptyset = \frac{0.024}{0.030}$$
$$\emptyset = 0.8$$

$$\text{The Bending Stress, } \sigma_b = \frac{32 \times 24.21}{\pi 0.03^3(1-0.8^4)}$$

The Bending Stress, σ_b= 9.13MPa
For commercial steel, allowable design stress to steel shafting is 40MPa (Kharagpur, 2010)
The shaft cannot fail by bending since the Bending stress σ_b is less than allowable design stress for steel, that is, 9.13MPa<40MPa

$$\text{The Stress due to Torsion, } \sigma_b = \frac{16T}{\pi d_0^3(1-\emptyset^4)} \quad (6)$$

T = Torque on shaft
d_o = shaft outer diameter = 0.30
Ø = ratio of shaft inner to outer diameter = 0.8
Torque on Shaft, T = load on shaft × radius of shaft
T = 220N × 0.03m
T = 6.6Nm

$$\text{The Stress due to Torsion, } \sigma_t = \frac{16T}{\pi(0.03^3)(1-0.8^4)}$$

σ_t = 2.11MPa
The shaft cannot fail from torsional stress since the torsional stress σ_t is less than allowable design stress for steel, that is, 2.11MPa < 40MPa.
Maximum shear stress the shaft is subjected, σ_{max} = Bending stress, σ_b + Torsional Stress, σ_t

$$\sigma_{max} = 9.13 + 2.11$$
$$\sigma_{max} = 11.24 \text{ MPa}$$

The shaft cannot fail from shear stress since the maximum stress, σ_{total} is less than allowable design stress for steel, that is, 11.24MPa < 40MPa.

RESULT AND DISCUSSION

Considering the ambiguity and need for external electrical source of power for existing self-inducting generator, this system was designed to be powered using the rotational power from a cyclist for initial excitation. Locally sourced materials were used and the construction was done at a workshop. The design process was carefully done ensuring the alignment of every part to one another to avoid power losses due to friction and skidding of belt from the pulley while the

flywheel was checked to be parallel to the axial direction of rotation.

A load/indicator (electric bulb) of 4 watt was connected to the generator to signal when the generator is drive above it synchronous speed when it starts generating useable power by lighting the bulb.

Six cyclists tested the system by riding the bicycle system until the indicator bulb powers on and the bulb lightening is stable. The speed of the cyclist is measured, the time taken for the bulb lightening to become stable (12v generated) and the time taken for the system to go off when the cyclist stops pedaling.

The result obtained from the experiment is shown in table 2.

Table 2: Time result from varying speed of cycling

Cyclist speed	Time taken to reach 12v output (sec)	Time taken for system to shutdown (sec)	Flywheel Max Speed (rpm)
40	251	30	315
43	225	31	315
45	218	31	318
49	205	32	320
55	185	33	345
58	165	35	352

The main observation from this result is that the more the speed of cycling, the lesser time it will take for the system to become stabilized in generating electricity and the longer it will take for the system to shut down after the cyclist stops pedaling as seen with the sixth cyclist with 58 rpm. Cyclist with 58 rpm speed of cycling took less time to power the system to a point whereby the bulb lightning was stable.

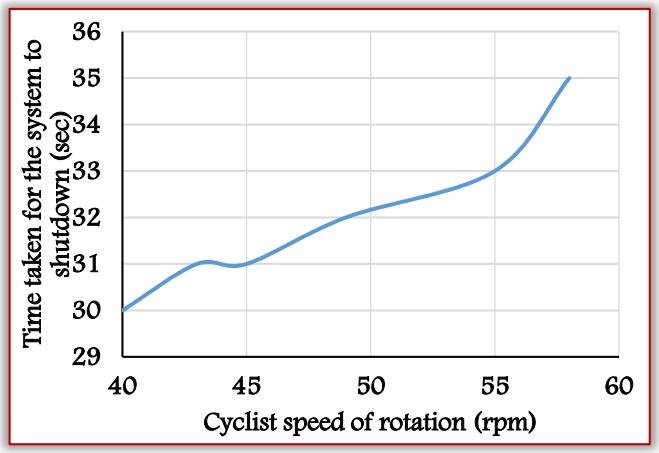


Figure 3: Graph showing relationship between the cyclist speed and time taken before the system shutdown

As shown in figure 3, the cyclist speed of rotation is very critical to the self-inducting duration of the system as the relationship is a linear one such that as the speed of the cyclist increases, the duration for self-inducting for the system also increases.

CONCLUSION

The performance evaluation of this experiment has proved the possibility of integrating a bicycle system into a self-inducting system for initial excitation rather than the existing designs using electrical power. The power out from the system is determined by the capacity of the generator in this case is a 96w DC generator. The duration for self-inducting for the system is a function of the cyclist speed which in turns affects the kinetic energy the flywheel can store in order to keep the system running.

References

[1] Severson, E., Nilssen, R., Undeland, T., & Mohan, N. (2014). Outer-rotor ac homopolar motors for flywheel energy storage.

[2] Fiske, O. J., & Ricci, M. R. (2006). Third Generation Flywheels For High Power Electricity Storage. California, USA.

[3] Maji, S. U., Mane, M. ., Kshirsagar, C., Jagdale, A., & Malgar, D. (2016). Conventional Free Energy using Flywheel. International Journal for Scientific Research and Development, 4(2), 1259–1265.

[4] Kelly, P. (2009). Chapter 4: Gravity-Powered Systems Author: In A Practical Guide to Free-Energy Devices (pp. 4-1-4–60).

[5] Mankodi, H. (2012). Analysis of a Treadmill Based Human Power Electricity Generator. University of Minnesota, Twin Cities.

[6] Badcock, R., Kalsi, S., Buckley, R., Storey, J., & Hamilton, K. (2017). An AC Homopolar HTS Generator for Flywheel Energy Storage. In Cryrogenic Engineering Conference and International Cryrogenic Materials Conference (pp. 1–22). New Zealand: Robinson Research Institute.

[7] Barwahe, A., Kumar, A., Domde, A., Dhakad, D., & Dhadse, M. K. (2016). Electricity Generation Using Flywheel. International Journal for Research in Applies Science and Engineering Technology, 4(Iv), 750–753.

[8] Marques, M. I. L. (2008). Design and Control of an Electrical Machine for Flywheel Energy- Storage System. Universidade Tecnicia de Lisboa.

[9] Ludlum, K. (2013). Optimizing Flywheel Design for use as a Kinetic Energy Recovery System for a Bicycle. International Journal of Innovative Research in Advanced Engineering, 1–24.

[10] Tsao, P. I.-P. (2003). An Integrated Flywheel Energy Storage System with a Homopolar Inductor Motor/Generator and High-Frequency Drive. University of California, Berkeley.

[11] Cibulka, J. (2009). Kinetic Energy Recovery Syatem by means of flywheel energy storage. Journal of Advanced Engineering, 3, 27–38.

[12] Amiryar, M. E., & Pullen, K. R. (2017). applied sciences A Review of Flywheel Energy Storage System Technologies and Their Applications. MDPI Applied Sciences, 7(286), 1–21

[13] Kharwade, A. U., Meshram, S. D., Karemore, J. P., & Jibhkate, B. M. (2017). Review of Free Energy Generator using Flywheel. International Journal of Recent Trends in Engineering and Research, 3(3), 90–

96.
[14] Jordan, H. E., Herbst, J. ., & Hayes, R, J. (2002). PN_267_Jordan.pdf. In SMMA 2002 Fall Technical Conference, St Louis (pp. 1–5). St Louis, Missouri: Centre for Electromechanics, The University of Texas, Austin.
[15] Östergård, R. (2011). Flywheel energy storage - a conceptual study. Uppsala.
[16] Badcock, R., Kalsi, S., Buckley, R., Storey, J., & Hamilton, K. (2017). An AC Homopolar HTS Generator for Flywheel Energy Storage. In Cryrogenic Engineering Conference and International Cryrogenic Materials Conference (pp. 1–22). New Zealand: Robinson Research Institute.
[17] Zoladz, J. A., Rademaker, A. C. H. J., & Sargeant, A. J. (1999). Human muscle power generating capability during cycling at different pedalling rates. Journal of Physiological Society, 85(1), 117–124.
[18] Megalingam, R. K., Veliyara, P. S., Prabhu, R. M., & Katoch, R. (2012). Pedal Power Generation. In Research Gate (pp. 1–5). Retrieved from https://www.researchgate.net/publication/259980152
[19] Pelz, B., & Feiereisen, J. (2010). Bicycle Powered Generator for the University Farm. Washington Univeristy, St. Loui
[20] Flórez, J., Flórez, C., Osma, G., & Ordóñez, G. (2014). Design of energy generation system by using spinning bikes. In The International Congress of Mechanical Engineering and Agricultural Sciences (pp. 1–9)

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

[1.]Tihomir MAČKIĆ, [2.]Milan TICA

ANALYSIS OF SPEED RATIOS OF SIMPLE CYCLOID DRIVE WITH STEPPED PLANETS

[1,2.] Mechanical Faculty of Banja Luka, Banja Luka, BOSNIA & HERZEGOVINA

Abstract: Due to the complicated and costly construction, the use of drive train with cycloid gears was avoided in the past. With the development of the modern CNC machining centers, it is possible to make the production process of these gears cheaper and simpler. The drive trains with cycloidal profile gears are mainly planetary drive trains, which are used today as speed reducers. They can achieve high speed ratio in single stage and have many advantages, as compactness and simplicity of production. Simple cycloid drive with stepped planets is a special variant of planetary drive train. It is a type of high sensitivity dive train which can realize high speed ratio in single stage. In this paper are shown the basic equations of speed ratios for different working conditions. By theoretical analysis, it can be noticed that a simple cycloid drive with stepped gear can achieve very high speed ratio while achieving small overal dimensions.
Keywords: cycloid drive, speed ratio, planetary drive train

INTRODUCTION

The drive trains with cycloidal profile gears are mainly planetary drive trains, which are used today as speed reducers. They can achieve high speed ratio in single stage and have many advantages, as compactness and simplicity of production. In addition, by using special cycloid stepped planets (figure 1), the total weight of drive trains can be further reduced.

Figure 1. Small cycloid stepped planets

Due to the complicated and costly construction, the use of drive train with cycloid gears was avoided in the past. With the development of the modern CNC machining centers, it is possible to make the production process of these gears cheaper and simpler. Because of very wide area of application, production of cycloid drives has growing character and wide area of application: processing equipment, conveyors, presses, mixers, food industry, robots, automotive plants, spinning machines, cranes, etc.
Despite the very common use of cycloid drive trains as speed reducers, they can also be used as speed increasers. Therefore, it is necessary to examine all the possibilities of the cycloid drive train with stepped planets, in order to get a clear picture of its transmission capabilities.

SIMPLE CYCLOID DRIVE

In the analysis of a simple cycloid drive, it can be started from an elementary planetary mechanism with internal coupling, replacing, for example, classic involute gears with cycloid gears (figure 1a). Members of the planetary mechanism whose axis coincides with the central axis and receive the external torques are called the *basic members* [1].

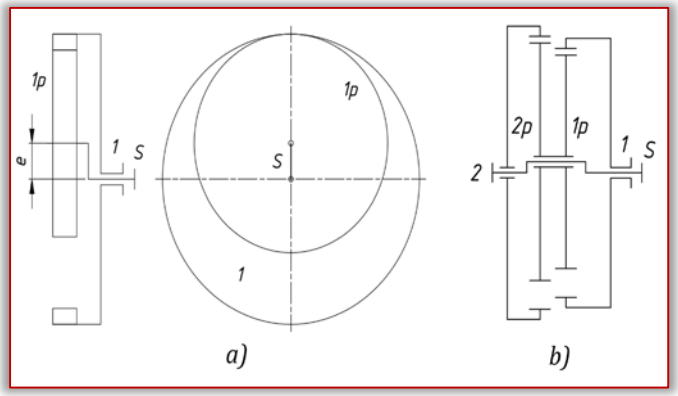


Figure 2. Transformation from elementary mechanism to simple cycloid drive with stepped planets

The members of the elementary mechanism, the central gear (*1*) and the carrier (*S*), whose axes of rotation coincide with the base axis, can't be used in this case for the transfer of energy. In order to achieve this, one elementary member must be added to the elementary planetary mechanism. This gives a *simple cycloid drive* or *three-shaft cycloid drive*.
This can be accomplished by adding another central ring gear (*2*) with the pins placed on the periphery, which meshes with the second cycloid gear (*2p*) (figure 1.b). The cycloid gears (*1p*) and (*2p*) are tightly connected in this case. In literature, such planets are called *stepped planets* [2, 3].

SPEED RATIOS

It will be analyzed only drives with the numbers of pins of ring gear by one greater than the numbers of teeth of cycloid planet gear. The gear drives shown in figure 2b have two degrees of freedom (DOF). By blocking one of the basic members, a *two-shaft cycloid drive* is provided, which has only one DOF.

When denoting the speed ratio, it is necessary to make a difference when denoting the speed ratios of three-shaft cycloid drive with two DOF from two-shaft cycloid drive with one DOF. Therefore, in this study, will be used proposal [4], that the symbol "*i*" means only a constant, design dependent speed ratios (with one DOF).

The order of two subscripts denote the order of input and output members. For the speed ratios of simple cycloid drive train with two DOF, will be used the symbol "*k*", so that, for example,

$$k_o = k_{12} = \frac{n_1}{n_2} = \frac{1}{k_{21}}, \tag{1}$$

represents the speed ratio between shafts 1 and 2.

The cycloid drive works as classical gearbox (with a fixed axle) when the eccentric shaft is stopped. This simple working mode can be termed as *the basic mode* whereby the *basic speed ratio* is realized:

$$i_o = i_{12} = \left(\frac{n_1}{n_2}\right)_{n_S=0}, \tag{2}$$

where is: n_1 - speed of ring gear shaft *1*,
n_2 - speed of ring gear shaft *2*,
n_S - speed of eccentric shaft *S*.

The complex general state of motion of a simple cycloid drive can be explained as the superposition of two partial motions. The first partial motion is the rotation of central ring rear (turning and meshing with planets), relative to the carrier. The second partial motion is an equal rotation of all shafts of basic members and it is same as rotation of carrier (eccentric shaft *S*).

If the two partial motion are superimposed, the total speed of each shaft is obtained as the algebraic sum of its partial speed. Thus the basic speed ratio become [3, 5]:

$$i_o = \frac{n_1 - n_S}{n_2 - n_S}, \quad \text{so that} \qquad n_1 - i_o n_2 + (i_o - 1) n_S = 0, \tag{3}$$

From the equation (3), the shaft speed of a simple cycloid drive is obtained as follows:

$$n_1 = i_o n_2 + (i_o - 1) n_S, \qquad n_2 = \frac{n_1 - n_S (1 - i_o)}{i_o}, \qquad n_S = \frac{n_1 - i_o n_2}{1 - i_o}. \tag{4}$$

It is possible to derive the equations for all speed ratios of simple cycloid drive with stepped gear (Table 1).

Table 1. Equations of speed ratios of simple cycloid drive

Reduced notation	Speed ratio *f*(k_o)
$k_{12} = i_o + (1 - i_o) k_{s2}$	$k_{12} = k_o$
$k_{21} = \frac{1}{i_o} + \left(1 - \frac{1}{i_o}\right) k_{s1}$	$k_{21} = \frac{1}{k_o}$
$k_{1S} = (1 - i_o) + i_o k_{2S}$	$k_{1S} = \frac{1 - i_o}{1 - \frac{i_o}{k_o}}$
$k_{S1} = \frac{1 - i_o k_{21}}{1 - i_o}$	$k_{S1} = \frac{1 - \frac{i_o}{k_o}}{1 - i_o}$
$k_{2S} = \frac{k_{1S} - (1 - i_o)}{i_o}$	$k_{2S} = \frac{1 - i_o}{k_o - i_o}$
$k_{S2} = \frac{k_{12} - i_o}{1 - i_o}$	$k_{S2} = \frac{k_o - i_o}{1 - i_o}$

TWO-SHAFT CYCLOID DRIVE SPEED RATIOS

If the numbers of pins of ring gear by one greater than the numbers of teeth of cycloid planet gear, then:

$$i_o = i_{11p} i_{2p2} = \frac{n_1}{n_{1p}} \frac{n_{2p}}{n_2} = \frac{n_1}{n_2} = \frac{z_{1p}}{z_1} \frac{z_2}{z_{2p}} = \frac{z_2 (z_1 - 1)}{z_1 (z_2 - 1)}, \tag{5}$$

where is: $n_{1p} = n_{2p}$ – speed of stepped planets,
z_{1p} - the number of teeth on a cycloid gear *1*,
z_{2p} - the number of teeth on a cycloid gear *2*,
i_{11p} - speed ratio between gear *1* and cycloid *1*,
i_{2p2} - speed ratio between cycloid 2 and gear 2.

The speed ratios of the tree possible two-shaft cycloid drive can be obtained using equations from Table 1, by setting appropriate speed ratios equal to zero if shaft was stopped (Table 2).

Table 2. Speed ratios of two-shaft cycloid drive

Working mode	Speed ratio *f*(z_1, z_2)
Minimum increase	$i_{12} = \frac{z_2 (z_1 - 1)}{z_1 (z_2 - 1)}$
Minimum reduction	$i_{21} = \frac{z_1 (z_2 - 1)}{z_2 (z_1 - 1)}$
Maximum increase	$i_{1S} = \frac{z_2 - z_1}{z_1 (z_2 - 1)}$
Maximum reduction	$i_{S1} = \frac{z_1 (z_2 - 1)}{z_2 - z_1}$
Reversible increase	$i_{2S} = \frac{z_1 - z_2}{z_2 (z_1 - 1)}$
Reversible reduction	$i_{S2} = \frac{z_2 (z_1 - 1)}{z_1 - z_2}$

Equations that determine the speed of the shafts of the basic members, for two-shaft cycloid drive, can also be written in matrix form. If e.g. shaft 1 is input shaft, and shaft 2 is locked, then the following system of equations are valid:

$$n_1 - i_o n_2 + (i_o - 1) n_S = 0$$
$$n_1 = n_{in} \quad (6)$$
$$n_2 = 0$$

where is: n_{in}- speed of input shaft *1*,

This system of linear equations can be written in matrix form:

$$\begin{bmatrix} 1 & -i_o & (i_o - 1) \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} n_1 \\ n_2 \\ n_S \end{bmatrix} = \begin{bmatrix} 0 \\ n_{in} \\ 0 \end{bmatrix} \Rightarrow [C_N]\vec{n} = \vec{e_n} \quad (7)$$

where is: $[C_N]$ - coefficient matrix,

$\vec{n}$ - vector of unknown shaft speeds,

$\vec{e_n}$ - input shaft speed vector.

System (7) can be solved using mathematical programs for working with matrices. In order to obtain values of unknown speeds, the system must be set up as follows:

$$\vec{n} = [C_N]^{-1} \vec{e_n} \Rightarrow \begin{bmatrix} n_1 \\ n_2 \\ n_S \end{bmatrix} = \begin{bmatrix} n_{in} \\ 0 \\ \dfrac{n_{in}}{1 - i_o} \end{bmatrix} \quad (8)$$

ANALYSIS OF SPEED RATIOS

Basic speed ratio, given in equation (2), shows, if the condition $z_1 < z_2$ is satisfied, then $i_o < 1$. Also, simple cycloid drive is a positive drive train ($i_o > 0$) [5].

The analysis of speed ratios will be considered regardless of the possibility of self-locking, which is present in high-sensitivity planetary gear trains [6].

Self-locking can occur if the teeth numbers are equal $z_1 = z_2$ (the gearbox acts as a coupling) and if $i_o \geq \eta_o$ [7], where η_o is *basic efficiency.* The last case can occur when $z_2 - z_1 = 1$, but because $\eta_o \approx 1$ it is possible only for higher values of z_1.

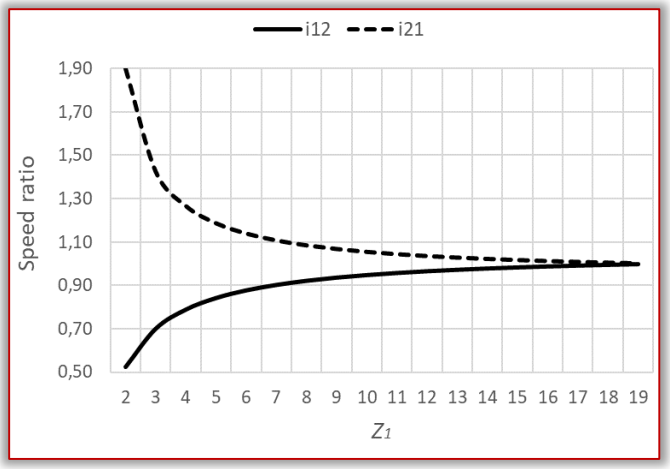


Figure 3. Basic speed ratios

In order to understand the nature of the change in speed ratios, the theoretical model of a simple cycloid drive with stepped planets will be considered, where $z_2 = 20$, while the number of pins of ring gear *1* are changing from $z_1 = 2 \div 19$.

In figure 3, the function of the change of the basic speed ratios is shown. It can be noticed that by approaching the number of pins z_1 to z_2, the basic speed ratio tends to $i_o = 1$ (self-locking occur).

— Reduction speed ratios

Cycloid drive train are mainly used as speed reducers. The variant with stepped planets is not used in practice for now, so it is very interesting to examine its possibilities.

Figure 4 shows the changing in speed ratios for maximum reduction (i_{S1}) and reversible reduction mode (i_{S2}). Number of pins of ring gear 2 is constant $z_2 = 10$ and number of pins of ring gear 1 are changing $z_2 = 2 \div 19$.

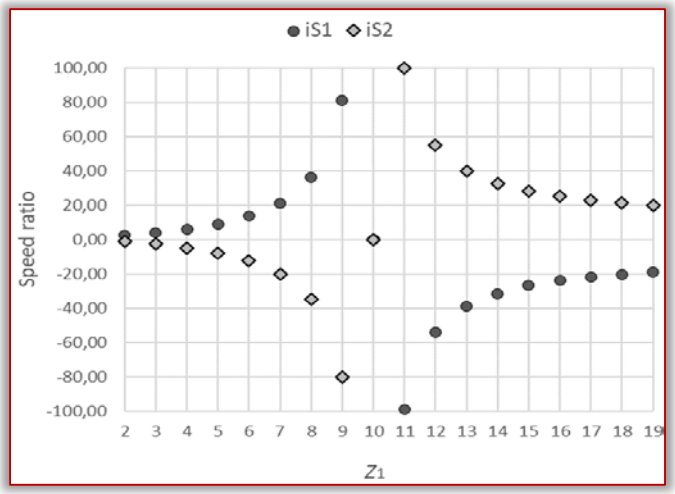


Figure 4. Reduction speed ratios

One can notice a sudden increase in the speed ratio, when number of pins z_1 is approaching to z_2.

— Increasing speed ratios

For the analysis of speed ratios in increase modes, the same settings will be used as for reducer modes, i.e. number of pins of ring gear 2 will be constant, while number of pins of ring gear 1 will change.

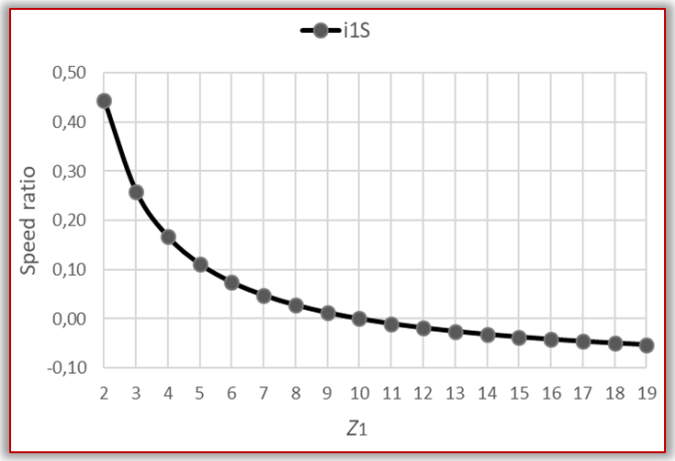


Figure 5. Maximum increase speed ratios

On figure 5 is shown the changing in the speed ratios for maximum increase mode (i_{1S}).
In figure 6, the function of the change of the speed ratios for reversible increase mode (i_{2S}) is shown.

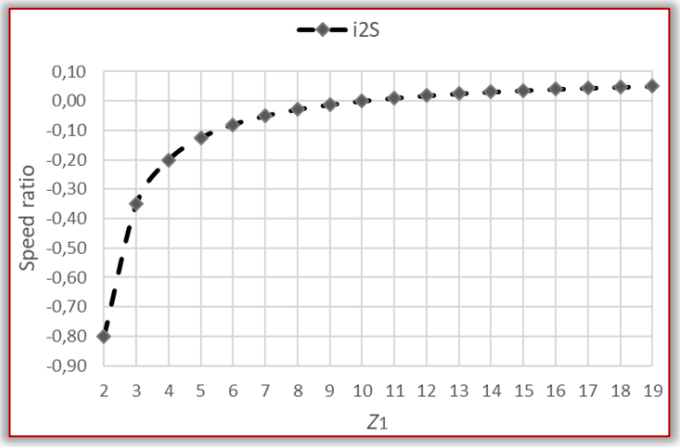


Figure 6. Reversible increase speed ratios

The speed ratio is equal to zero if $z_1 = z_2$. When $z_1 > z_2$ the sign of speed ratio is changing and shaft of ring rear 2 become summation shaft [7].
If the pins number of ring gear 2 is constant, it can be noted from an analysis, that there is no significant increase of speed ratio with increasing the pins number of ring gear 1. However, if the cycloid drive is loaded with higher torque, then it is desirable to use larger numbers of pins due to a more even distribution of forces on the ring gear.

CONCLUSION

The cycloid drive with stepped planets can achieve very large speed ratios, while using ring gears with a relatively small number of pins. This makes it possible to design high speed ratio cycloid drive train of small dimensions and mass.
Increasing the number of pins of ring gear 1, with a constant number of pins on the other ring gear, does not significantly increase the speed ratio. Therefore, when designing these drive train, it is necessary to first consider variants with smaller numbers of pins, with checking the total load capacity.

References

[1] Tanasijević, S., Vulić, A., „Mehanički prenosnici“, Jugoslovensko društvo za tribologiju, Kragujevac, 1994.
[2] Looman, J., Zahnradgetriebe: Grundlagen, Konstruktion, Anwendung in Fahrzeugen; Berlin: Springer-Verlag (1996).
[3] Müller, H. W, Die Umlaufgetriebe; Berlin: Spinger-Verlag (2001).
[4] Wolf, A.: Die Umlaufgetriebe und ihre Berechnung; VDI-Z. (91/22); pp. 597–603 (1949)
[5] Willis, R, Principles of Mechanism. London: Parker 1841.
[6] Sensinger J.: Efficiency of high-sensitivity gear trains, such as cycloid drives. ASME J Mech Des 2013; 135: 071006.
[7] Mačkić, T., Tica, M., Šuba, R.,: Transmission characteristics of simple cycloid drive with stepped planets. IOP Conference Series Materials Science and Engineering 659 (2019) 012071

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

[1.]Radu CIUPERCĂ, [2.]Ancuţa NEDELCU, [3.]Lucretia POPA, [4.]Ana ZAICA, [5.]Vasilica ŞTEFAN

RESEARCH ON HEAT RECOVERY IN THE COMPOSTING PROCESS

[1-5.]National Institute of Research – Development for Machines and Installations Designed to Agriculture and Food Industry (INMA) – Bucharest, ROMANIA

Abstract: The current trend manifested globally is to find new solutions using non–conventional energy and renewable energy (solar, wind, flowing waters, biological processes and geothermal heat) in socio–economic activities, as an alternative to classical energies. In this paper we intend to present some research on how to recover the thermal energy released in the biological process of composting biodegradable waste, research which will be finalized by creating and testing a composting container, equipped with recovery plant heat resulting from the aerobic fermentation (composting) of biodegradable waste.
Keywords: heat recovery from compost

INTRODUCTION

Mainly, known three types of heat recovery systems results from the fermentation of aerobic (composting) of biodegradable waste, as follows:

- heat recovery system in open compost pile formed, with natural ventilation;
- heat recovery system in compost open heaps achieved (dumps), aerated forced;
- heat recovery system made compost in closed container achieved, forced aerated.

Known limited studies on the heat recovery of composting have shown that it is a critical condition to strictly control the temperature in the heap. To prevent the temperature from falling below the temperature required for high–temperature composting, too much heat can't be removed during composting (Chroni et al., 2009). On the other hand, losing a large amount moisture is not conductive to heat accumulation, but also slow down the composting process, so keep the entire composting process from over–ventilation.

The current method of controlling the temperature of the composting process is usually to maintain the oxygen content of the reactor or to control the air content of the reactor by adjusting the temperature (Xiao et al., 2009).

In principle, two methods known of composting heat recovery, respectively, direct and indirect methods.

Direct recovery method

First direct method is to extract heat from the composting material in the form of heated water.

This method is by circulating water pipes inside the heap or in the concrete slab. This method is more suitable for personal use. The process of piling up and disassembling requires installation and removal of pipelines, and the time and labor available to them for help. This is not the case for commercial use for the waste of time and labor (Smith and Aber, 2014).

Another downside is the lack of mechanical agitation. But also easy to take away some of the heat in the cold water in the pipeline. The above situation is not conducive to the growth of microorganisms, and may also lead to corrosion (Smith and Aber, 2014).

The method of extracting heat directly from manure is a simple and effective method pioneered by Jean Pain. One of the heaps is to set water pipes in them, with pipes in 10 inches. When there is air through the heap will produce heat, water is taken away by the water pipes, as a radiation source for greenhouse.

Studies conducted by (Lekic, 2005) showed that the water temperature increases as it passes through the entire pipeline, theoretically 73% of the heat is absorbed by the water. The limitation of this study is the laying of pipes (Lekic, 2005). A solution proposed by (Seki and Komori 1992) is to use packed column heating tower to concentrate the heat discharged into water.

The second method in direct composting heat recovery is use air heating, where air is pushed out (forced aeration) or pulled through (negative aeration) a composting heap. Most commonly accomplished by placing the compost pile on a well–ventilated and level floor, pouring the perforated PVC pipes into the concrete, covering it with a perforated cover and finally covering it with 8–inch sawdust. By moving the whole body mechanically, air enters the heap, removing excess heat while generating heat (Rynk, 2000; Epstein, 2011; Smith and Aber, 2014).

However, this method requires that there be a strong microbial population in the heap and that it is difficult to collect the heat with a mere 13.4% availability, thus it has some limitations (Themelis, 2005). The invention was originally derived from the New Alchemy Institute, they warmed a greenhouse with compost vapor by biofilter in the winter (Fulford, 1986). Although this study is

mostly used for horticulture, it plays an important role in prolonging the season time and reducing greenhouse energy loss under cool climatic conditions.

Indirect recovery method

An indirect recovery method involves harvesting the heat indirectly by altering the form of the bio–waste material itself (Lee et al. 2014) reformed an Advanced Compost and Energy System (ACES).

In the ACES, technically speaking, the moisture in the feedstock is evaporated by the biological response of a specific set of well–fed fermenting microorganisms that produces heat above 80°C and thus evaporates residual materials and food waste were compared,18.82 MJ/kg, in a heating value test. One of the advantages of ACES is that it does not require the removal of waste water compared with the traditional method, ACES is more like a method does not need to rule out any substance, but does not require additional energy. Microbials can consume organic matter in the raw material and emit heat, and can be the temperature reached 80°C–90°C.

The use of heat generated, the raw water can be volatile out, which is the rest of the traditional methods can't be achieved (Lee et al., 2014).

About how to handle the liquid in livestock excrement. How to deal with these liquids is the biggest problem converting raw materials into heat. Because raw materials are mixed with up to 90% moisture, the remaining solids have very high potential for energy production, such as 10.46–14.64 MJ kg^{-1} (Lee et al., 2014), which requires reasonable treatment of the liquid. The usual approach is to evaporate. If electricity or natural gas is used for evaporation, the cost of the project will be increased. In addition, since the moisture inside the raw material itself is not easily dried, it takes a long time to evaporate, and the dried material also has unpleasant odor (Shin, 2002; Kim, 2012).

Direct recovery method is the most used in the industrial composting due to its simplicity. The heat transfer calculation models normally could be used to simulate the specified composting process. There are many more to do for the heat recovery both in research and application, such as more simplified models for heating predictions of potential heat from composting, and high efficient heat recovery method.

MATERIAL AND METHODS

Regarding heat energy recovery results in the composting of biodegradable waste in the world have made significant progress for the development of such systems, most being mounted in conventional systems composting (in the pile, rick, dumps composting) but also tanks (containers) composting or complex industrial systems.

Heat recovery system in open compost pile formed with natural ventilation

The ingenious system is constructed as a heat generator based on the natural fermentation of biodegradable waste and can provide thermal energy required for heating or hot water for a period of 12–16 months (**** 2). In general compost pile has a diameter of approx. 5 meters and a height of approx.2.5 meters. Some sources give much larger, 10 x 6 meters. In any case, they are major cylindrical shape and a ratio of 1:2 between height and diameter, Figure 1.

Figure 1 – Heat recovery system achieved in compost heap

The main disadvantage of this system is that the fermentation process requires a period between 70 and 90 days.

Not insignificant advantage of this system is that the starting materials – pipe, pump, and fence, can be reused for 10–15 years, with the same efficiency and costs are relatively low.

Composting system in open dumps static aerated forced with heat recovery system

This system was well documented in the extensive research conducted at the University of New Hampshire Department of Natural Resources, US, (Matthew M. Smith, John D. Aber, 2018).

Research shows operational information for aerated composting system developed on a commercial scale ASP (static aerated cells) with energy recovery, one of the few currently in operation worldwide.

The heat was captured directly and predictably related to the difference between the vapor temperature of the compost and the heat sink, a vapor temperature range of 51–66°C compost.

There is a lag time of 5 days, the heap of compost to the formation of vapor until the temperature of the compost has been sufficiently large for energy recovery (≥50 °C).
A second temperature difference existed also during each cycle of aeration, where the inlet temperature vapor, immediately after coming out of the compost heap, differs from reaching the heat exchanger, a difference of almost 4.4°C after the first minute of aeration and 1.3°C after six minutes.
Following these gaps, composting plant operators may reconsider energy recovery ventilation system design and aeration cycles to achieve maximum energy capture.
In Figure 2 is shown such a system for recovering heat energy from the high–capacity compost.

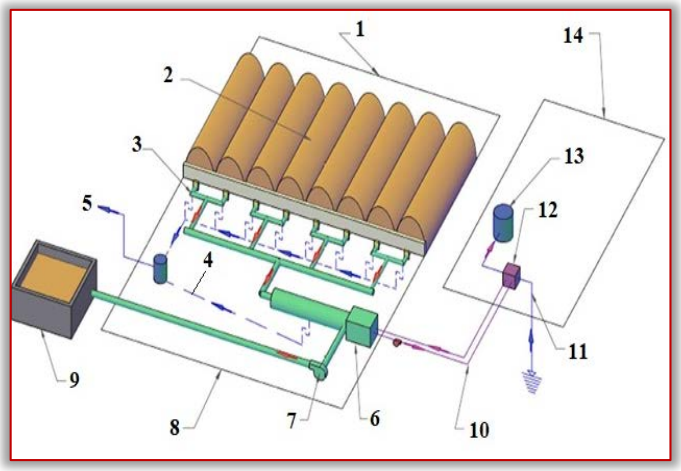


Figure 2 – Heat recovery of high capacity composting system – Schematic diagram –
1 – composting chamber; 2– compost; 3 – pipeline for collecting equipped with automatic valves; 4 – condensation collection circuit; 5 – condensing water outlet pump; 6 – isobaric heat exchanger; 7 – fan; 8 – mechanical room (the location of the heat recovery system); 9 – bio–filter to eliminate odors; 10 – hot water circuit; 11 – preheating water network; 12 – heat exchanger with flat elements; 13 – hot water tank; 14 – space for end use hot water.

The results of experiments in which the parameters measured are identified, are shown in the diagrams of Figure 3. The efficiency of energy capture and predictably varies strongly with the temperature difference between Vapor Heat Exchanger and Heat Sink Tank.

Heat recovery system in industrial composting system

This system was implemented at Diamond Hill Custom Heifers by Agrilab Technologies Inc. and the composted waste is manure and bedding material used in cattle (**** 5), Figure 4.
The system is essentially self–powered, with the exception of a small amount of electricity needed to power at 120 VAC four fans in line, 1/8 hP motor systems.

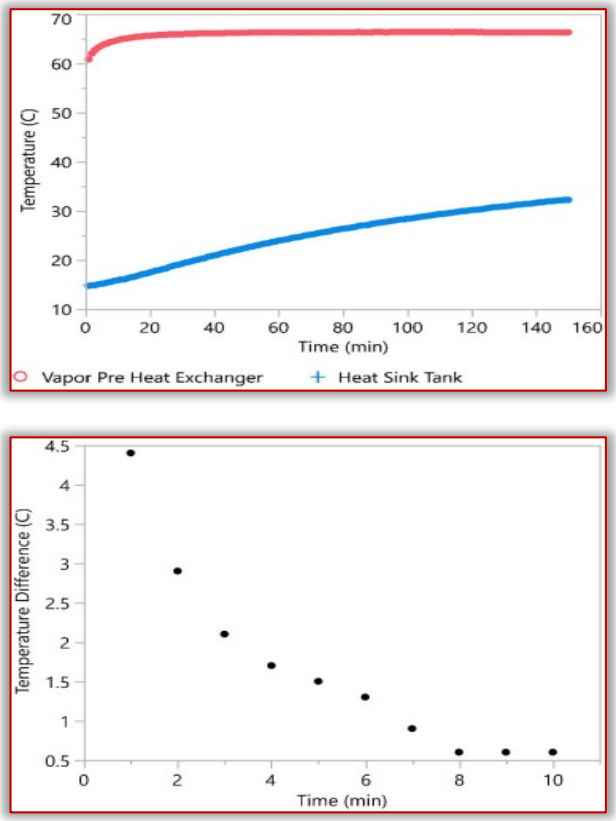


Figure 3 – Parameters variation in the composting process

Figure 4 – Industrial system implemented at Diamond Hill Custom Heifers

The system consists of two separate composting hall through a central gallery closed. Each of the waste composting heaps is approximately 15.5 m wide and 18 m in length allows the active composting between 700 and 800 tons of materials concomitantly itself. In each hall may form four piles (furrow) where the current can reach and maintain a temperature of 120 to 165 degrees F for four to eight weeks after the initial training.
The floor is made of reinforced concrete with a thickness of 6 "to 10" poured over the sand compacted to apply the foam of the type used in the installation of electrical systems in floor heating.

Semi–concrete and embedded in the insulation installed over a network of pipes made of PVC. In addition, these pipes are insulated with a material is coated "Techfoil" that increases the amount of insulation around the pipes. The connecting pipes are, in fact, the collection of vapor, have a diameter of 10 "and are vertically mounted fan by a record flexible 10", after which they are attached a pipe greater corrugated PVC, diameter 24 " in which are arranged six conductors Isobar superthermal.

The conductors of the isobaric superthermal devices are defined technically heat exchange in two phases, in this application are accomplished of the stainless steel tubes 3", sealed at each end and loaded with a fluid for work.

Isobars are insulated devices, which constant achieving uniform temperature on the surface of the heat contributions due to random. In this particular application, hot water vapor condensed on Isobars are immediately transferred to that part of Isobar which is in contact with water in the tank

As long as the bulk water in the tank is at a lower temperature than the water vapor in the hot compost, the transfer will take place. Isobars are self–powered, they do not need electricity or other external power source to activate only a temperature difference from one location to another on its surface.

The advantage of the transfer Isobar Agrilab is that it provides the supply of hot water accumulated in an insulated tank of bulk storage to be used directly, most often by providing all the necessary hot water, or as an adjunct to heating classical hot water

Heat recovery from the compost made in tunnel vessel (containers)

Investigations have been conducted by a group of researchers in Scotland, on the recovery of thermal energy from the system composting tunnel, composting system Deerdykes Facility (Irvine G., et. Al, 2010).

The achievement was completed in 2006 and supports the location of green waste, industrial sludge and liquid wastes. Main components are offices, tunnel composting vessels, the aeration of compost and the compost material mixing.

There are 8 tunnel composting vessel sizes, as follows: 1–4 tunnels is 5 m wide and 25 m long; tunnels 5 and 6 are 5.3 m wide and 35 m long; 7 and 8 tunnels is 5 m wide and 35 m long (SD Last, et.al, 2005).

The tunnels are approximately 5m high, however, the height of the compost loading was about 3m, Figure5. Vessel composting process was fully controlled by a computer software package designed specifically for the trial. Air flows for all fans of the air were varied automatically depending on the measured levels of temperature, pressure and oxygen within the tunnel.

The hot air extracted from the vessel by the fan pos. 6, is directed to a heat exchanger to recover heat from it, before being passed through the biofilter.

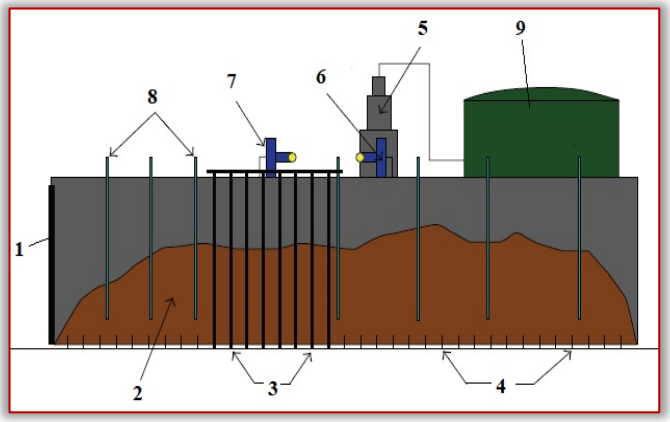


Figure 5 – Section through the composting vessels tunnel
1 – composting unit; 2 – compost; 3 – recirculation; 4 – holes aeration of the compost; 5 – noxious wet scrubber; 6 – ventilator circuit to the bio–filter; 7 – suction fan; 8 – measuring system of the composting temperature; 9 – bio–filter.

For the dimensioning of the recovery of heat from the compost made in the container, which is necessary in a livestock farm, is based on the amount of waste (manure) in a one–year on the farm itself, C_d, which is determined by the relationship (1).

$$C_d = n_a \cdot q \quad [m^3] \qquad (1)$$

where:

na – the number of animals on the farm;

q [m3] – the amount of manure produsăde an animal in a year.

Also determine the volume of the container for composting V_c occupied by the material subjected to the process of composting, depending on the amount of waste in the holding and the expected duration of the ongoing phase fermentation process in a composting container, so that the system compost all of waste produced of a year, to which are added the energy material required by composting process, C_e, according to the equation (2).

$$V_c = (C_d + C_e) \cdot \frac{t}{365} \quad [m^3] \qquad (2)$$

where:

C_e[m³] – the amount of energy material required composting;

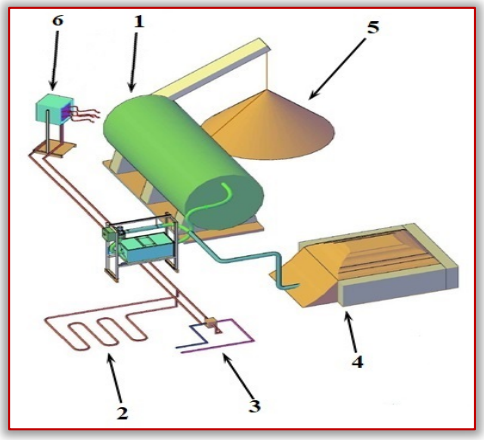
t [days] – estimated period of performance of the fermentation phase in a process of composting.

Depending on the volume of air generated by the fan, air temperature and water consumption needs, to be estimated size of the heat recovery unit of the compost.

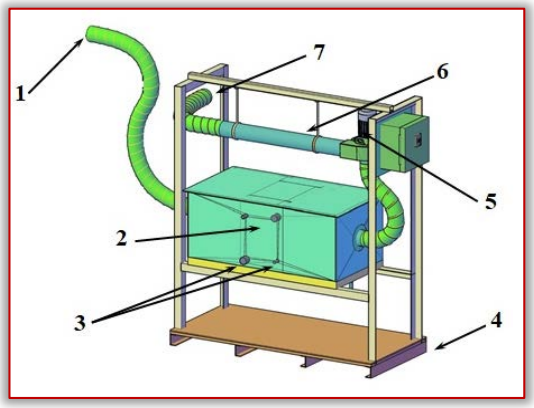
RESULTS AND DISCUSSION

Heat recovery from compost system proposed is composting container fitted with the recovery of thermal energy from the hot air generated in the process of composting biodegradable waste.

The heat sources in the form of wet vapor captured in the warm compost is conducted through specialized heat exchangers in which water is heated.
The exhaust air can be sent back automatically to optimize compost moisture and the entire process or directly into a bio–filter to eliminate odors.
The hot water can be used in industrial installations for washing farms as water or for space heating.
Schematically, the complete composting system, with heat recovery, is shown in Figure6a and the heat exchanger in Figure 6b.



a)



b)

Figure 6 – Container composting system with heat recovery facility – Schematic diagram
a) 1 – composting container; 2 – heat sink; 3 – water preheating system; 4 – bio–filter for odor reduction; 5 – finished compost; 6 – heating installation with energy recovered;
b) 1 – the hot air inlet hose connected to the compost; 2 – stainless steel heat exchanger is thermally insulated; 3 – connector of hot water and condensate drainage connector; 4 – stainless steel frame covered with epoxy resin; 5 – Fan; 6 – oxygen, temperature and flow of the vapor sensors; 7 – drain hose to the bio–filter.

The calculation of the thermal load for heating domestic hot water using heat recovered from the compost will be achieved, in the case of paper, a small family farm livestock with 5 dairy cows.
According to [**** 4], the amount of manure for a dairy cow in a week is about 0.315 m^3, or about 17 m^3 /year.
In this case the amount of manure produced in a year by the 5 dairy cows, complies relationship (3).

$$C_d = 5 \cdot 17 = 85 m^3 \quad (3)$$

For proper development of the composting process, in addition to the base material, using energy material.
The amount of energy material necessary for composting, from case to case, is about5–15% of the basic amount of biodegradable waste, in this case the manure and is calculated according to the relationship (4), considering an average of 10%.

$$C_e = 85 \cdot \frac{10}{100} = 8.5 \ \ m^3 \quad (4)$$

We consider a fermentation period, t = 30 days [**** 3], for the situation that the composting process is carried out in forced aeration system.
Substituting the values considered in (2), result the volume of the container occupied by the composting materials will be developed and tested, according to the relationship (5).

$$V_c = \frac{(85+8.5)\cdot 30}{365} = 7.68 m^3 \quad (5)$$

The container volume will be about 10 m^3 because it will not be completely filled with the composting material.

CONCLUSIONS

In principle, two methods known of composting heat recovery, respectively, direct and indirect methods:

- first direct method is to extract heat from the composting material in the form of heated water;
- the second direct method in composting heat recovery is use air heating, where air is pushed out (forced aeration) or pulled through (negative aeration) a composting heap;

An indirect recovery method involves harvesting the heat indirectly by altering the form of the bio–waste material itself namely Advanced Compost and Energy System (ACES). In the ACES, technically speaking, the moisture in the feedstock is evaporated by the biological response of a specific set of well–fed fermenting microorganisms that produces heat above 80°C and thus evaporates residual materials and food waste were compared,18.82 MJ/kg, in a heating value test;
Heat recovery systems results from the fermentation of aerobic (composting) of biodegradable waste is classified according to the embodiment of compost and known: heat recovery system in open compost pile formed with natural ventilation; heat recovery system of the compost piles open achieved (dumps) aerated forced; the heat recovery system of composting carried out in closed vessels, container aerated force;
The recovery of heat resulting from the fermentation aerobic (composting) of biodegradable waste proposed in the present work, has been designed for a family farm agro–zootechnical with 5 dairy cows and resulting a construction volume necessary of the container of 10 m^3.

Acknowledgements
This work was supported by:
— Integrated management of work in farms, vineyards and orchards, contract no. 5/ 07.02.2019, Project: PN 19 10 01 05.
— Development of the national research–development system, subprogramme 1.2 – Institutional performance – Projects for financing excellence in RDI, contract no. 16PFE.

Note:
This paper is based on the paper presented at ISB–INMA TEH' 2019 International Symposium (Agricultural and Mechanical Engineering), organized by Politehnica University of Bucharest – Faculty of Biotechnical Systems Engineering (ISB), National Institute of Research–Development for Machines and Installations Designed to Agriculture and Food Industry (INMA Bucharest), Romanian Agricultural Mechanical Engineers Society (SIMAR), National Research & Development Institute for Food Bioresources (IBA Bucharest), National Institute for Research and Development in Environmental Protection (INCDPM), Research-Development Institute for Plant Protection (ICDPP), Research and Development Institute for Processing and Marketing of the Horticultural Products (HORTING), Hydraulics and Pneumatics Research Institute (INOE 2000 IHP) and "Food for Life Technological Platform", in Bucharest, ROMANIA, between 31 October – 1 November, 2019.

References

[1] Chroni, C.,A. Kyriacou, I. Georgaki and T. Manios, (2009), Microbial characterization during composting of biowaste. Waste Manag, Oxford 29, pp.1520–1525, UK;
[2] Epstein, E, (2011), Industrial composting: Environmental engineering and facilities management, Boca Raton, FL: CRC Press. pp 334;
[3] Fulford, B, (1986), The composting greenhouse at new alchemy institute: A Report on Two Years of Operation and Monitoring, New Alchemy Institute, Research Report No. 3;
[4] G. Irvine, E. R. Lamont, B. Antizar–Ladislao,2010, Energy from Waste: Reuse of Compost Heat as a Source of Renewable Energy, Hindawi Publishing Corporation International Journal of Chemical Engineering, Volume 2010, Article ID 627930, 10 pages;doi:10.1155/2010/627930 Edinburgh UK;
[5] Kim, S. J, (2012), Domestic and international technology trend of RDF, Monthly Hazard Waste 13:45–50;
[6] Lee, H. S., D. Kim, J. S. Park, G. V. Chilingar, (2014), Advanced compost and energy (ACE) system converting livestock wastes to resources by exothermal microbial reactions: a case study, Energy Sources, Part A. 36, pp.1507–1516;
[7] Lekic, S.,(2005), Possibilities of Heat Recovery from Waste Composting Process, Centre for Sustainable Development, Department of Engineering, University of Cambridge, Cambridge, UK;
[8] Matthew M. Smith, John D. Aber, (2018), "Energy recovery from commercial–scale composting as a novel waste management strategy", Applied energy 211, pg. 194–199;
[9] Rynk, R.,(2000), Fires at composting facilities: causes and conditions, Bio Cycle 41(1), pp.54–58;
[10] Seki, H. and T. Komori, (1992), Packed–column–type heating tower for recovery of heat generated in compost, Journal of Agricultural Meteorology 48, pp.237–246;
[11] S.D. Last, D. MacBrayne, A. J. MacArthur, (2005), "Deedykes Composting Facility: a case study of the conversion of a conventional activated sludge sewage works to in–vessel composting, with sludge co–composting facility", Proceedings of Kalmar Eco–Tech and The 2nd Baltic Symposium on Environ–mental Chemistry, Kalmar, Sweden;
[12] Shin, P. C. (2002), Application and prospective on RDF from hazardous waste, High Mol. Sci. Technol. 13, pp.307–314;
[13] Smith M M, Aber J D., (2014), Heat Recovery from Compost: A guide to building an aerated static pile heat recovery composting facility, UNH cooperative Extension;
[14] Themelis, N. J.,(2005), Control of heat generation during composting, Biocycle, 46(1), pp.28–30;
[15] Xiao, Y., G. M. Zeng and Z. H. Yang.,(2009), Continuous thermophilic composting (CTC) for rapid biodegradation and maturation of organic municipal solid waste, Biores Technol 100, pp.4807–4813;
[16] ****1 http://www.icpa.ro/documente/coduri/Compostarea.pdf;
[17] ****2 http://www.100construct.ro/index.php?section=detalii–articol&id=1603&cat_id=36)
[18] ****3 https://www.slideshare.net/AdrianCrasnobaev/metode–i–tehnologii–de–gestionare–a–deeurilor
[19] ****4 Order no.1182 / 20.11.2005 / 1270 / 30.11.2005 of the Minister of Environment and Water and the Minister of Agriculture, Forests and Rural Development approving the Code of Good Agricultural Practice for protection of waters against pollution caused by nitrates from agricultural sources, pp.44
[20] ****5 Agrilab Technologies, Inc din Vermont– Canada.

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

[1.]Raina JAIN, [2.]Reshmita SHARMA, [3.]Abhishek MISHRA

MODELING OF WIND POWER PLANT USING ARTIFICIAL NEURAL NETWORK

[1.]Dept. of Electrical Engineering, SSGI, Bhilai, INDIA
[2.]Dept. of Electrical and Electronic Engineering, SSGI, Bhilai, INDIA
[3.]Dept. of Electrical Engineering, Bilaspur, INDIA

Abstract: The Wind Power Generation in the Power System Increases Rapidly in present and in the later trifling years. The fluctuation of electric power produced by wind power plants, will build, prompting greater expenses associated with the balance of generation and demand. This paper presents an application of artificial neural network for Modelling of Wind Power plant. The proposed algorithm is based on three parameter i.e. blade diameter, wind speed, and the blade pitch angle. The yield will be the power flow. The algorithm has been skilled with the collected data and then we are able to establish a model of wind Power plant. The proposed scheme is capable of modeling the parameters of wind power plant. The appearance of tested outcome is that the neural net trained data give more accurate result.
Keywords: Artificial neural network, Blade Diameter, Blade Pitch angle, Wind Speed

INTRODUCTION

Energy is avenue for human well-being, growth, development. To certify everybody has adequate access to power is challenge for worldwide development. The source for the blossoming of energy are coal, wind, solar, water etc. Production of energy affects the climate. Authentic and modern way of energy generation are influenced by fossil fuel (coal, gas, and oil) which produce harmful substances like carbon dioxide, greenhouse gases. These substances are the heart for global warming. The Environment is on fatal line. To redeem the aura, the world needs to transit the energy sources. Taking a deviation from non-renewable energy source to sustainable energy source for generation of energy will be a huge contribution to save the environment [18,19]. Wind power has been utilized for a sustained time for processing grains, siphoning water, and cruising the oceans. In the evolution of recent decades, an assortment of wind control advancements have been created, which have improved the change effectiveness of and diminished the expenses for wind power generation. But the progress of large capacity power plants (wind, solar etc.) requires new approaches to analyze plant dynamics for control purposes. It is a challenge to design a new model without specification of components. In order to design a control system for a power plant, it is necessary to develop a model in advance [1]. In the ancient time the technique which has been used in the electrical power industry is the mathematical optimization for many power systems operations, planning, and control problems. Mathematical formulations of real-world problems are derived under certain presumption and even with these presumptions; the result of modern power systems is not simple. Then again, there are numerous vulnerabilities in control framework issues due to their huge, complex, and topographically broadly dispersed nature. Simple model are easy to manage with mathematical modeling but if we see complex structure (solar, wind, thermal power plants etc) mathematical modeling is not a solution. Mathematical model is the simplification of the real problems and does not include all aspect of the problems. The mathematical model may work only in certain situation and with specified range. These facts make it complicated to deal effectively with many problems in this area through strict mathematical formulation alone [2]. In this manner, artificial intelligence techniques which ensure a worldwide ideal or about along these lines, for example, master frameworks, genetic algorithm, fuzzy logic, and Artificial neural network have risen as of late as a supplement apparatus to regular numerical procedures [3].

The paper is split into different sections as follow. In SECTION II, the detail of artificial neural network has been provided. In SECTION III the methodology which has been used is explained in detail. Further the SECTION IV and SECTION V justify the result and conclusion obtains with future scope.

OUTLINE OF ARTIFICIAL NEURAL NETWORKS

The investigation of Artificial neural systems (ANN) is roused by their closeness to effectively working biological system, which in contrast with the general system comprise of extremely basic however various nerve cells that work enormously in resemble and have the skills to grasp from training samples .One outcome from this learning strategy is the capacity of neural systems to sum up and partner information. After fruitful preparing a neural system we can find sensible answers for comparative issues of a analogous class that were not especially trained. This thusly brings about a high level of adaptation to internal failure against input data. The cerebrum is

tolerant against interior blunders and furthermore against outer mistakes. Our modernized society, in any case, isn't consequently shortcoming tolerant. Hence artificial neural network is used. Artificial Neural Network is nonlinear information driven self-versatile methodology instead of traditional model based technique. They are amazing asset for demonstrating particularly when the basic information relationship is unknown. ANN can recognize learn connect design between input informational index and target information. In the wake of preparing the ANN can be utilized to visualize the new free data. ANN copies the learning procedure of the human cerebrum and can process the issues including non-straight and complex information if the information are uncertain and loud. The wording of artificial neural system has created from organic model of the mind. The human cerebrum gives proof of the presence of huge neural systems that can prevail at those psychological, perceptual, and control assignments in which people are fruitful. The cerebrum can do computationally mentioning perceptual acts and control exercises. Treelike systems of nerve fibers called dendrites are associated with the cell body or soma, where the cell core is found. Reaching out from the cell body is a solitary long fibers called the axon, which inevitably branches into strands and sub strands, and are associated with different neurons through synaptic terminals or neurotransmitters [4]. With the help of Table 1 we can easily correlate the terminology of biological and artificial neural network.

Table 1-Terminologies of biological and artificial neural network

Biological Neural Network	Artificial Neural Network
Cell Body	Neurons
Dendrite	Weights
Soma	Net input
Axon	Output

The architecture of artificial neural network is described in Fig-1. There are three different layers, the input layer in which the input parameters are provided which are denoted by $x_1, x_2 \ldots x_n$, the output layer from which we get the desired output as y and the hidden layer. The purpose of hidden layer is to apply weights so that the desired output is obtained. The improvement of ANN includes two stages: preparing or learning stage and testing stage. During preparing, the synaptic loads get altered to show the given issue. As soon as the system has taken in the issue it might be tried with new obscure examples and its effectiveness can be checked. Most utilizations of ANN show that the back-propagation system is an incredible asset for developing nonlinear functions among several esteemed sources of info and at least one continuous esteemed output. Due to their capability to map complicated and nonlinear relationships of input-output patterns, ANN has become a powerful computing technique, and has thus inspired many people to apply them to various system problems.

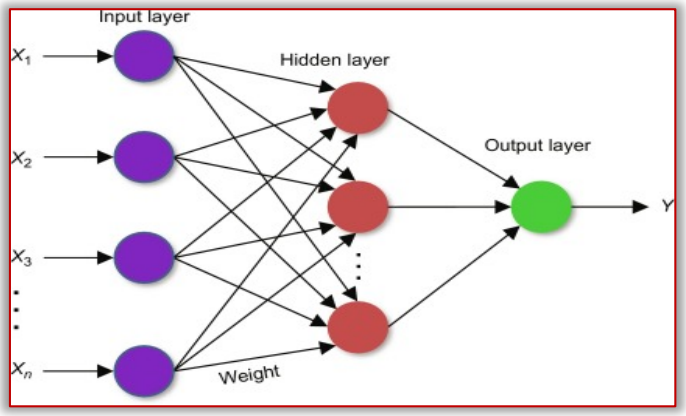


Figure 1-Architecture of Artificial Neural Network

Learning can be characterized as the capacity to perform better at a given assignment with experience. The learning procedure of the mind includes modifying organic neural structure, evolving the quality of associations relying upon activity. This learning procedure can be demonstrated by changing the loads of the associations between nodes in the structure. Learning calculations are incredibly valuable when it comes to complex perceptual issues which are hard to be composed by a developer [6]. Depend upon the training Imparted, ANN can be classified as supervised ANN, unsupervised ANN and Re-enforcement ANN.

A. Supervised ANN:

The managed ANN requires the arrangements of information sources and the output for its preparation. During the preparation, the output from the ANN is analysed and the ideal yield (target) and the error (mistake) is diminished by utilizing some method. This preparation is rehashed till the real yield secures a satisfactory level. Supervised ANN might be a forward or non-recurrent system.

B. Unsupervised ANN:

The artificial neural system which doesn't require a predominant or instructor for preparing is known as unsupervised ANN. In aggressive or unsupervised learning units of the output layer seek the opportunity to react to a given info design.

C. Re-enforcement ANN:

In this learning system, the learning of a data yield mapping is performed through continued with nature in order to constrain a scalar record of performance. The expert changes over a primary re-source signal got from the environment into a higher re-witness signal called the heuristic re-source signal, the two of which are scalar data sources [3].

ANNs are utilized in fields because of their various points of interest, for example medication, science,

mechanical technology, geospatial investigation, and so forth. ANNs can be utilized to produce capacities to clarify a specific marvel when the information doesn't enable such capacities to be made by hand. The primary favourable circumstances are:

- Adaptive learning: They can figure out how to perform undertakings through a preparation procedure.
- Self-association: ANNs can make their very own structure to speak to the data through a preparation procedure
- Fault resilience: The ANN can in any case work when its structure is harmed (resistance to debasement), and twisted or deficient when the information are loud (resistance to information).
- On-line activity: They can be executed in parallel and work quickly. Subsequently, they are uniquely modified to complete on-line forms.
- Easy usage into the frameworks: There are particular chips that can encourage the incorporation of ANNs into the framework

The NNs are helpful for taking care of a wide scope of issues from seven classes:

- Pattern order: The ANNs can recognize designs in a dataset through administered learning.
- Clustering: The information similitude, or dissimilarities, is distinguished through unaided learning. The system will dole out comparative information to a similar gathering (or group).
- Function estimation: ANNs can be applied to issues where a hypothetical model can't be applied. They can rough the info information to a capacity with a specific level of detail.
- Forecasting: A NN can be prepared by time arrangement to get an expectation of things to come conduct.
- Optimization: An answer that amplifies, or limits, a capacity subject to various requirements can be found.
- Association: A cooperative system can be utilized to remake adulterated information by building up an affiliated example.
- Control: It is conceivable to decide the sources of info that will cause an ideal framework conduct. This exploration work thinks about the accompanying order, concentrating on the investigation of the most compelling and considered issues.[5]

DATA PREPARATION

The data preparation plays a crucial role in modeling of plant as the quality and quantity both has the impact on modeling. Modeling of wind power plant has been done on the basis of three parameters, Rotor Diameter, Wind Speed, and Blade Pitch Angle. The data is collected from different sites and trained using MATLAB Neural network toolbox. Levenberg-marquadt (trainlm) is the training algorithm, used; it is the back propagation technique. Back propagation is a supervised training technique for artificial neural systems. It assesses the error commitment of every neuron after a lot of information is handled. The objective of back propagation is to alter the loads in order to prepare the neural system to accurately map arbitrary inputs to yields [6]. The transfer function used is sigmoid symmetric (transig) and the simulink model is prepared with the help of gensim. After training the performance graph is plotted. The y axis shows the mean square error and the x axis shows the epochs. From the total readings taken of all the three parameters, 25% will be used for testing and 25% will be used for validation and remaining will be used in training.

- ≡ Training - In training, network is arrange and adjusted according to the error.
- ≡ Validation - They are used to measure the system speculation and to end preparing when speculation quits improving.
- ≡ Testing - Testing has no effect on training and so provide an independent measure of network performance during and after training.

A.ROTOR DIAMETER

Rotor blade radius maximizes the power output. Larger blade allows the wind turbine to acquire more kinetic energy but required more space. Modernized wind turbine have diameter of 40m to 90m and are rated between 500 KW to 2MW. In 2019 the average size of the rotor diameter is 129 m. Turbine are zoned out of four times the rotor diameter. In the event that you double the rotor diameter you get a cleared region which is four times as well as the four times power output from the rotor.

The rotor diameter data is collected from site [20]. In the collected data there were 21 readings of rotor diameter out of which 3,3 samples are used for testing and validation respectively and 15 are used for training purpose. To train the neural network only 10 sec has been taken. After this we can determine the neural net calculated data.

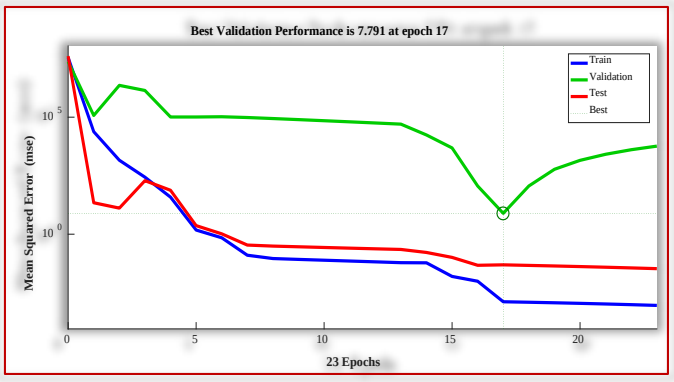


Figure 2- Rotor Diameter Performance graph

Fig-2 shows a plot of the training errors (Blue line), validation errors (Green line), and test errors (Red line) and the Best is denoted by dotted line with the circle in the graph. 23 epoch means it took 23 cycles to give the best result. The best performance is obtained with 15 number of hidden layer having Mean Square Error (MSE) and number of epoch of 7.791 and 17 respectively. The ANN trained structure has error of 0.01677.If the training plot (blue line) reached to zero than it depicts that the error is zero.

B.WIND SPEED

Wind speed to a great extent decides the measure of power produce by a turbine. Higher wind speeds cultivate more power because durable wind permits the blade to turn quicker. Turbines are designed in such a fashion so that it works inside a particular dimension of wind speed. The limit of range are known as cut in speed and cut out speed. The cut in speed is where the wind turbine can create control. Between the cut in speed and the evaluated speed where the most extreme output is arrived at the power yield will increment cubically. Cut out speed is where the turbine must be closed down to stay away from harm to the equipment. The wind speed of 2 m/s is required for small wind turbine and at speed of 25 m/s the turbine stops or braked must be applied. The anemometer is one of the tools used to measure wind speed. The wind speed data is collected from the site [21]. In the collected data there were also 21 readings of wind speed out of which 3,3 samples are used for testing and validation respectively and 15 are used for training purpose. To train the neural network only 0 sec has been taken and hence neural net calculated data is determined.

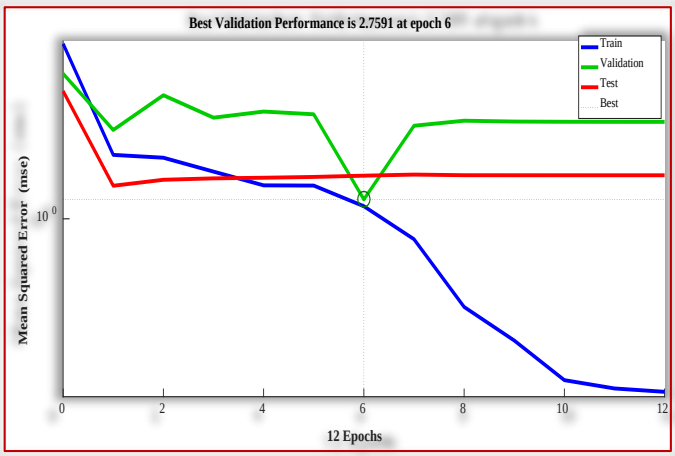


Figure 3- Wind Speed Performance graph

In wind speed performance graph 12epoch means it took 12 cycles to give the best result. The best performance is obtained with 10 number of hidden layer having MSE and number of epoch of 2.7591 and 6 respectively. The ANN trained structure has error of 0.001375. If the training plot (blue line) reached to zero than it depicts that the error is zero.

C.BLADE PITCH ANGLE

Blade pitch refers to spinning the angle of attack of the blade of the propeller. Wind turbine utilizes this to alter the revolution speed and the created power. While working a wind turbine control framework modify the sharp blade pitch to keep the rotor speed inside working cut-off points as the wind speed changes. Blade pitch control is favoured over rotor brake as brake is dependent upon failure or over-burden by the wind power on the turbine.

Pitch control does not need to be active. Passive wind turbine depends on the way that approach speeds up. This is a piece of the explanations behind twisted blades-the twist allow to take into consideration a steady slow down as each part of the blade has an alternate approach and will stop at an alternate time. The data of blade pitch angle is collected from the reference paper [7] In the collected data there were 17 readings of rotor diameter out of which 3, 3 samples are used for testing and validation respectively and 11 are used for training purpose. To train the neural network only 0 sec has been taken. With this we can determine the neural net calculated data.

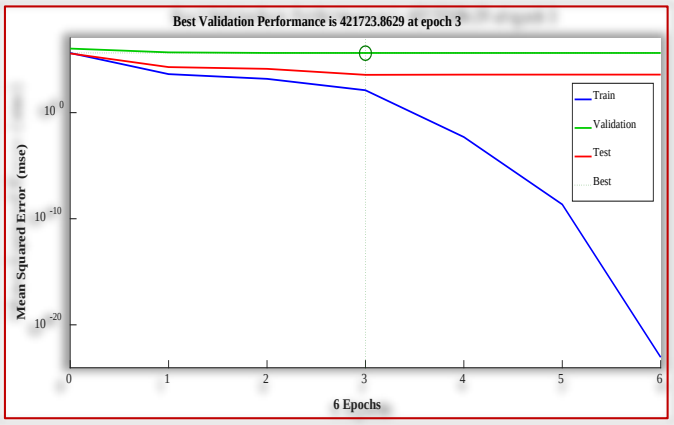


Figure 4-Pitch Angle Performance graph

In blade pitch performance graphs 6 epoch means it took 6 cycles to give the best result. The best performance is obtained with 18 number of hidden layer having MSE and number of epoch of 42123.8629 and 3 respectively. The ANN trained structure has error of 0.2752. If the training plot (blue line) reached to zero than it depicts that the error is zero.

RESULTS

The collected data from different papers and sites are trained and neural net data is calculated from simulink diagram. The plot has been drawn between collected data and neural net data of all the parameters. The x axis represents the parameters and the y axis represents the power output.

The blue line denotes the collected output from the different sites and the pink dots depicts the output which we have obtained after training the artificial neural network.

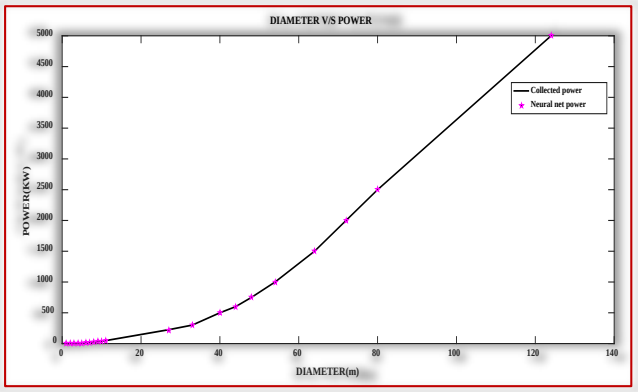


Figure 5-Plot between diameter and power

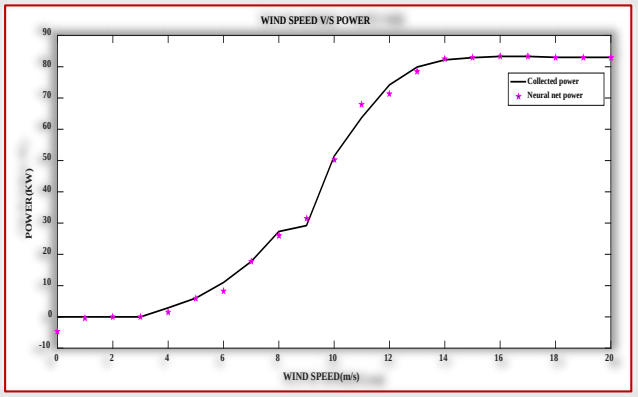


Figure 6-Plot between wind speed and power

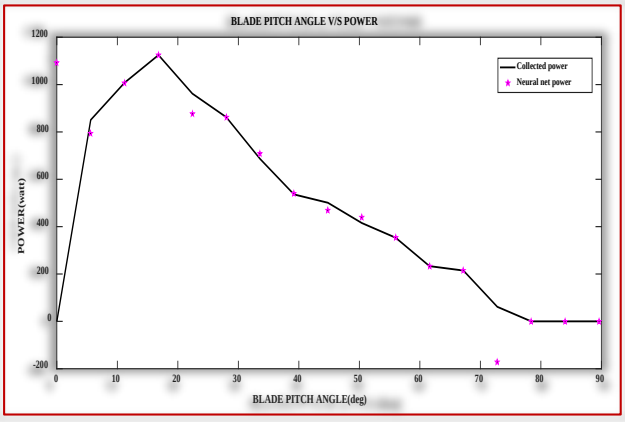


Figure7-Plot between blade pitch angle and power

CONCLUSIONS

In this paper we have collected the data and trained it using neural network. After training a data we are able to establish a nonlinear relationship between input and output. The established relationship is a model based relationship and not a mathematical relationship. Collection of data also plays a very important role as by collecting the more number of data we can minimize the difference between the collected data and the neural net data. In the above figs the graph is plotted to compare collected data and the neural net data. After comparison it is found that the collected data and the neural net trained data are almost same. Hence we can conclude that neural net trained data give more accurate result. The future scope of this project is in different field. They are as follows-

Forecasting and predictions Neural systems are end up being increasingly proficient for momentary wind speed forecast, and the cross breed ANN based strategy gives better outcomes to transient expectations than other convectional techniques.

Fault detection and diagnosis: The main ANN based techniques to detect faults and perform diagnostics of wind turbine. Most of the ANN based methods are created to detect breaks down in gearbox and bearings. The fault detection does not desire a fast computation process and, therefore, the main factor is the accuracy of the method. Control optimization: The most influential and recent ANN based methods for controllers. The controllers require low computational costs because immediate responses to sudden changes of the system condition are needed. For this purpose, neuro-fuzzy inference systems and radial basis function neural networks are the most employed methods.

References

[1] Lee K. Y, Heo J. S, Hoffman J. A, Kim S, Jung W, "Neural Network-Based Modeling for A Large-Scale Power Plant," IEEE Power Engineering Society General Meeting, Tampa, pp. 1-8, 2007.

[2] Mohatram Mohammad, Tewari Peeyush, Shahjahan "Applications of Artificial Neural Networks in Electric Power Industry: A Review" International Journal of Electrical Engineering, Volume 4, Number 2, pp.161-171, 2011.

[3] Mishra A. K, Ramesh L, "Application of neural networks in wind power (generation) prediction" International Conference on Sustainable Power Generation and Supply, Nanjing, pp. 1-5,2009.

[4] Shivnandam S.N, Deepa S. N "Introduction to neural networks using MATLAB 6.0" Tata McGraw-Hill Education, 656 pages ,2006

[5] Pliego Alberto, Pedro Fausto, Marquez Garcia, Jesus Maria Pinar Perez, Ruiz-Hernandez Diego, "A survey of Artificial Neural Network in Wind Energy system" article in applied energy Volume 228, pp 1822-1836,oct,2018

[6] Amrutha J. and Remya Ajai A.S., "Performance analysis of Backpropagation Algorithm of Artificial Neural Networks in Verilog," 3rd IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT), Bangalore, India, pp. 1547-1550,2018.

[7] Musyafa Ali, Noriyati ronny Dwi, "Implementation of pitch angle wind turbine position for maximum power" vol.3, No 1, pp.510-518, July 2012

[8] Răzuşi P. C, Eremia M, "Prediction of wind power by artificial intelligence techniques"16th International Conference on Intelligent System Applications to Power Systems, Hersonissos, pp. 1-6,2011.

[9] Ahmed W. U., Zahed M. J. H., Rahman M. A, Mamun M, "Numerical study of two and three bladed Savonius wind turbine," 2nd International Conference on

Green Energy and Technology, Dhaka, 2014, pp. 36-40,.2014.
[10] Chainok B., Tunyasrirut S, Wangnipparnto S , Permpoonsinsup W, "Artificial neural network model for wind energy on urban building in Bangkok," International Electrical Engineering Congress, Pattaya, pp. 1-4, 2017.
[11] Ali S. A, Nawaz M. F, Bilal M, Ahmad F, Hayat U. Y, "Modeling of wind power plant using MATLAB, "Power Generation System and Renewable Energy Technologies (PGSRET), Islamabad, pp. 1-5,2015.
[12] Kumar Jitendra, Dexit rajarshi, Soota Tarun "Modeling of thermal power plant using neural network and regression technique" Journal of scientific research and advance.2.pp 166-174,2015.
[13] Mishra M, Srivastava M, "A view of Artificial Neural Network," 2014 International Conference on Advances in Engineering & Technology Research (ICAETR - 2014), Unnao, 2014, pp. 1-3, 2014
[14] Alshehri J, Alzahrani A, Khalid M, "Wind Energy Conversion Systems and Artificial Neural Networks: Role and Applications," IEEE Innovative Smart Grid Technologies - Asia (ISGT Asia), Chengdu, China, pp. 1777-1782, 2019.
[15] Bilal B, "Wind turbine power output prediction model design based on artificial neural networks and climatic spatiotemporal data," IEEE International Conference on Industrial Technology (ICIT), Lyon, pp. 1085-1092, 2018.
[16] Nithya M, Nagarajan S, Navaseelan P, "Fault detection of wind turbine system using neural networks," 2017 IEEE Technological Innovations in ICT for Agriculture and Rural Development (TIAR), Chennai, 2017, pp. 103-108, 2017.
[17] Luna J, Gros S, Geisler J, Falkenberg O, Noga R, Schild A, "Super-short Term Wind Speed Prediction based on Artificial Neural Networks for Wind Turbine Control Applications," IECON, 44th Annual Conference of the IEEE Industrial Electronics Society, Washington, DC, pp. 1952-1957, 2018.
[18] https;//ourworldindata.org/energy-production-and-changing-energy-sources.
[19] https://www.environmentalscience.org/renewable-energy.
[20] Windy Miller. Site location Wind conditions Meteorological data.
[21] https://windenergysolutions.nl/turbines/windturbine-wes-80/
[22] https://www.mathworks.com/help/deeplearning/ref/nnstart.html.

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

[1.]Dragoş–Florin MARCU, [2.]Mihai BUZATU, [3.]Gheorghe IACOB, [4.]Florentina NICULESCU

TECHNOLOGICAL PROCESS FOR SEPARATION AND RECOVERY OF METALLIC MATERIAL FROM USED HOUSEHOLD BATTERIES

[1–4.]University Politehnica of Bucharest, 313 Spl. Independenţei, Bucharest, ROMANIA

Abstract: The intense development of the recovery of non–ferrous metals from secondary resources in the second half of the twentieth century raised the issue of using new technologies, "environmentally friendly", for processing this type of raw materials, by removing as much as possible noxious processes. Used batteries are also part of this category, and currently only 3–4% of total world battery production is processed in order to recover metals. Developing countries recycle an almost insignificant percentage, and underdeveloped countries are not involved at all, batteries being disposed of with household waste. This paper presents experimental processes regarding the recovery of non–ferrous metals contained in used household batteries (alkaline and zinc–carbon) using simple but efficient processes. Following the research, a technological flow was established, being performed analyses to determine the chemical composition (XRFS) and the morphological aspect (SEM) of the obtained powdery material. The possibilities of capitalization of the materials resulting from the battery disassembly processes are also established.
Keywords: circular recycling, eco–friendly technology, non–ferrous metals, used batteries

INTRODUCTION

A huge amount of metals (Ni, Zn, Li, Co, Mn, Fe, Cr, Al, Cu and others in low concentrations) is embedded in batteries and accumulators widely used as a source of energy for any items, from remote controls and children's toys to electronics and medical devices [1]. As their number and degree of use increases then the amount of batteries required for their operation becomes higher leading to many questions about how to extract and reprocessing these secondary raw materials in an efficient and economical manner [2]. Battery recycling helps save resources by recovering valuable metals such as nickel and cobalt. In addition, the use of recycled metals from batteries requires lower energy consumption (the use of recycled nickel requires 75% less primary energy than its extraction and refining in its natural state) [3, 4, 5, 6, and 7].

There are two main types of batteries: primary batteries (disposable batteries – saline, alkaline and lithium batteries) and secondary batteries (rechargeable batteries – NiCd, NiMH and Li–ion). Globally, only 8% of "batteries" are actually rechargeable batteries (batteries), 90% are single–use household batteries, and 2% are small, button–like batteries [8].

According to recycling companies, the recycling process will only be a profitable business when a steady stream of sorted batteries is established. The process becomes profitable when the batteries contain large amounts of recoverable metal (in the case of NiMH batteries), and not when low–metal batteries are used for recycling (in the case of Li–ion batteries) [8, 9].

Of all the municipal waste generated, used batteries are the most harmful to human health and the environment. Cadmium–containing batteries still have a high market share in most countries so their storage together with household waste leads to serious long–term environmental problems, but in Europe they have been banned from sale and replaced with other types of batteries (such as NiMH, NiOOH, $LiMnO_2$, $LiSOCl_2$, $LiFeS_2$, Li–ion types, alkaline/carbon–zinc) [10]. NiMH batteries contain nickel and electrolyte, which are considered semi–toxic substances, and proper storage and recycling is recommended [11]. Lithium–containing batteries when exposed to moisture give a violent reaction, so batteries must be disposed of properly. Before recycling, lithium batteries must first be completely discharged [3, 12]. One method of processing lithium batteries is to cryogenize them with liquid nitrogen and then crushing and grinding them. In order for the lithium not to become reactive, it is dissolved in a special solution [13]. Cobalt is separated in the same way.

The process of recycling batteries begins with sorting them according to their composition (zinc–carbon, alkaline, Li–Ion, pill type, lead–acid, etc.) and charge level. Sorting is a time consuming process. For each type, a process of shredding, separation and reprocessing follows. Pyrometallurgical or hydrometallurgical processes are most often used in the technological flow. At the end of the processes, metals such as Ni, Zn, Li, Co, Mn, Fe, Cr, Al, Cu and others are extracted [5, 6, 7, 14].

Mechanical treatment of batteries consists in their crushing and milling, magnetic separation, separation by sieving and qualitative separation of particles. The common goal of all processes is to separate the component metals of the batteries in order to obtain the highest possible purity so that they can be reused in different industries. Ferrous and non–ferrous fractions re–enter the economic circuit in the steel and zinc industry, and paper and plastic are used as

alternative fuel in the cement industry [15]. From one ton of alkaline batteries, 330 kg of zinc and zinc compounds and 240 kg of iron and nickel–based alloy can be recovered. These metals can be reused immediately for the manufacture of everyday and industrial objects [16].

In pyrometallurgical battery recycling processes, 6 to 10 times more energy is consumed to extract constituent metals. In order to reduce costs, some companies in the field of battery recycling do not separate the metals independently but melt them and then deliver the products obtained to the manufacturers of ferroalloys and stainless steels. Thus, these energy–intensive and sometimes polluting processes must be replaced by hydrometallurgical processes, using efficient and non–polluting solutions and especially those that can be easily recovered and reused [6] and by completing it with an electrochemical process (electrolytic deposition and refining of metals) we have the possibility to obtain metals with high purity. By using appropriate parameters (current density, intensity, electrolyte concentration and temperature) can reduce energy consumption.

Today, in the European Union, it is estimated that it is necessary to treat 250–425 tons of waste batteries and accumulators per year per million inhabitants, i.e. an average of 410 g / inhabitant / year. Most developed countries face an increasing problem, namely the recycling of used batteries through processes that must meet several key elements: ease of application, environmentally friendly and last but not least economically feasible. Any method of treating waste batteries and accumulators is technically and economically feasible only if the resulting products can be recycled as primary products, which return to the original manufacturing process. The value of these recycled products is directly related to their degree of purity [17].

There is still a big gap between the percentage of waste defined by law that needs to be collected and recycled and that which is actually recycled. Currently only 3–4% of total world battery production is processed in order to recover metals. Australia has a high degree of recycling with 80% of total used batteries, then the USA with 60% and EU with 48%. Developing countries recycle an almost insignificant percentage, and underdeveloped countries are not involved at all, batteries being disposed of with household waste [2, 14, 17].

A recent European Commission study found that more than half of the batteries used in the EU are not collected or recycled. The study concludes that the level of battery waste collection in the EU is insufficient; thus a large amount of batteries end up in municipal waste [4]. Romania still does not meet the collection targets for battery waste. Insufficient quantities of such waste, poorly developed technologies and a fluctuating market for recycled materials make these types of waste unattractive to local processors. Preserving the value of existing materials in waste, especially in waste batteries, and reintroducing them into the economic circuit, through extraction and reuse can be part of the idea of circular economy.

EXPERIMENTS

The non–rechargeable batteries (primary batteries) used in the experimental process, shown in figure 1, were of the types based on their chemistry – alkaline ($Zn/Alkaline/MnO_2$) and zinc–carbon – and were processed according to the technological flow shown in Figure 2.

Figure 1. Types of batteries by shape and size used in the experiment: AA, AAA, C, D and 9V

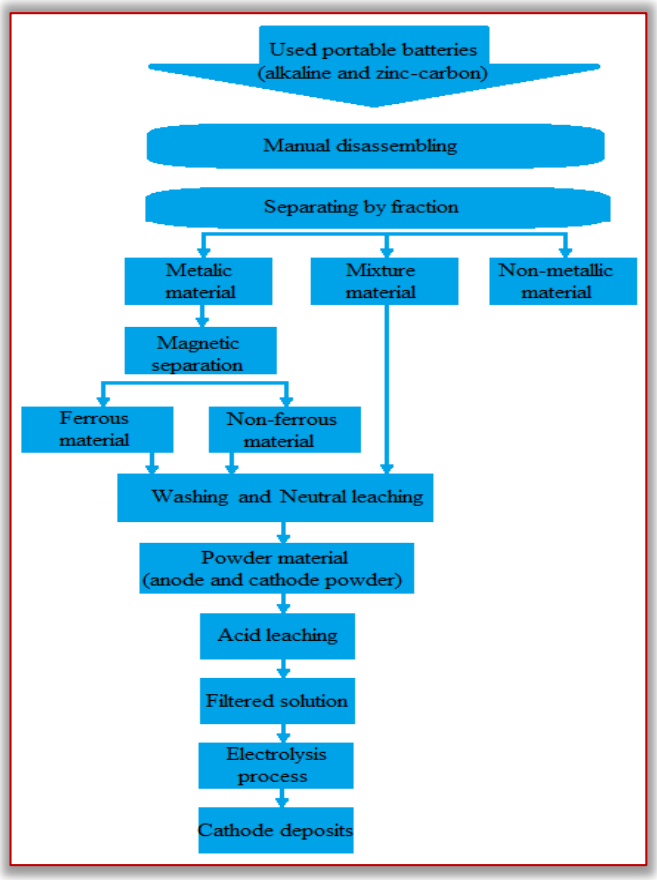


Figure 2. Technological scheme of the process

The used batteries (alkaline and zinc–carbon) were manually dismantled by cutting, the component materials being separated into different fractions and the mixture of the cathodic and the anodic materials was extracted. The obtained material was dried in a drying stove at a temperature of 110^{0}C for one hour, to remove moisture and perform chemical analyses to determine the constituent elements by means of X–Ray Fluorescence Spectrometer (WDXRF S8 Tiger Bruker).

Sorting materials into categories was done manually and by magnetic separation, due to the small amount of material used in experiments (the batteries weighed 382g). These were divided as follows:

- non–ferrous metal fraction (bronze or brass connectors, Zn cases);
- ferrous metal fraction (steel components – exterior case, pin connectors, negative and positive pole);
- mixture material fraction (anode and cathode powder);
- non–metallic fraction (graphite connectors, plastic polymers – insulators, separators, paper).

In a zinc–carbon dry cell, the zinc is oxidized by the chloride (Cl^-), according to the following half–reactions:

Anode:

$$Zn + 2\ Cl^- \rightarrow ZnCl_2 + 2\ e^- \quad (1)$$

Cathode:

$$2MnO_2 + 2\ NH_4Cl + H_2O + 2\ e^- \rightarrow Mn_2O_3 + 2\ NH_4OH + 2\ Cl^- \quad (2)$$

The overall reaction:

$$Zn + 2\ MnO_2 + 2\ NH_4Cl + H_2O \rightarrow ZnCl_2 + Mn_2O_3 + 2\ NH_4OH \quad (3)$$

If ZnCl is substituted for NH_4Cl as the electrolyte, the anode reaction remains the same (Eq. 1) and the cathode reaction becomes:

$$2MnO_2 + ZnCl_2 + H_2O + 2\ e^- \rightarrow Mn_2O_3 + Zn(OH)_2 + 2\ Cl^- \quad (4)$$

Result the overall reaction:

$$Zn + 2MnO_2 + H_2O \rightarrow Mn_2O_3 + Zn(OH)_2 \quad (5)$$

In an alkaline battery, Zn represent the negative electrode and MnO_2 the positive electrode. During the discharge reactions only the Zn and MnO_2 are consumed, the alkaline electrolyte of potassium hydroxide remains because is not part of the reaction. The half–reactions are:

Anode:

$$Zn_{(s)} + 2OH^-_{(aq)} \rightarrow ZnO_{(s)} + H_2O_{(l)} + 2e^- \quad (6)$$

Cathode:

$$2MnO_{2(s)} + H_2O_{(l)} + 2e^- \rightarrow Mn_2O_{3(s)} + 2OH^-_{(aq)} \quad (7)$$

The overall reaction:

$$Zn_{(s)} + 2MnO_{2(s)} \rightleftharpoons ZnO_{(s)} + Mn_2O_{3(s)} \quad (8)$$

The separated non–ferrous and ferrous fractions will be washed with water to remove the active mass, electrolyte and other components adhering to these components of the batteries, and the resulting wash water will be used in the chemical treatment step.

Neutral leaching was performed at a temperature of 60^{0}C for about one hour, during which time the pH of the solution was constantly measured using the HI–83141 pH Meter (Hanna Instruments) with Electrode and Temperature Probe. After a contact time of one hour the pH of the solution was 9.9, so most of the KOH was dissolved in water.

In this paper we focused on the physical–mechanical processes of processing used batteries and obtaining different types of metallic or non–metallic materials. Following, we will focus on the selective recovery of various metals through electrochemical processes, which are much more complex and require extensive research.

RESULTS AND DISCUSSION

The portable batteries are very diverse in terms of chemical composition. Depending on the size and shape we can sort them into categories and depending on the chemical composition we can determine which metals can be recovered from each category, which categories can be treated together and which separately. Household batteries – alkaline MnO_2, and saline Zn–C represent 83% of the total portable batteries collected these containing the same metals Mn and Zn, so they can be processed together, recovering and reuse the materials, instead of being incinerated in municipal waste incinerators or landfilled.

After dismantling the batteries and sorting the materials obtained into fractions, they were weighed resulting in the quantities of materials shown in Table 1.

The mixture material (Figure 3) was weighed before and after drying in the oven to determine the moisture content of the batteries. The loss of material was also established (by the difference between the total quantity and the sum of all the quantities obtained).

Figure 3. Mixture material (anode and cathode powder)

Table 1. Material compositions of the dismantled batteries

Fractions	Composition	(g)	(%)
Non–ferrous metal	Zinc	59.35	15.54
	Bronze	8.77	2.30
Ferrous metal	Steel	21.66	5.67
Mixture material	anode powder	26.29	6.88
	cathode powder	183.51	48.04
Non–metallic	graphite connectors	24.68	6.46
	plastic polymers	7.20	1.88
	paper	28.47	7.45
Moisture		20.85	5.46
Losses		1.218	0.32
Total		382	100

Ferrous metal fraction can be used in the production of ferroalloys or even in the elaboration of steel for new batteries and other industrial applications. The zinc shell, brass rods and so on, which represent the non–ferrous fraction are recovered by various recyclers for the production of the same elements or other applications and the non–metallic fraction compose of carbon rods, pulp and / or cardboard, paper and plastic can be used for the production of different types of fuel.

The material mixture fraction is used in chemical treatment processes through hydro and electrometallurgical routes for recovering electrolyte Zn and MnO_2, which can return in the battery manufacturing processes.

Regarding the recovery of other metals from the mixed fraction, the processes become more complex. So far no optimal strategy has been established and their recovery is selective and largely depends on the process used. We can only increase extraction yields or reduce pollution by using environmentally friendly and accessible substances so that these processes become economical and can be applied on a larger scale.

In the experiment, the resulting mixture powder obtained after dismantling the used batteries was subjected to the chemical composition analysis by three successive XRF analyses (X–Ray Fluorescence) (CC1, CC2 and CC3) and the average of the values (ACC) was calculated and rendered in table 2.

The obtained material will be used in experiments of solubilisation and electrolytic extraction of metals, which can be reused for battery production or in other fields.

The mixture material, separated from the batteries, was subjected to the process of washing with water to remove easily soluble components and will be used in the chemical treatment step together with the resulted material after cleaning with water the non–ferrous and ferrous fractions. The powder separated by washing the non–ferrous and ferrous fractions and filtration (Figure 4) will enter the hydrometallurgical circuit, in which the metals are selectively dissolved in aqueous sulphuric acid solution followed by a purification and cementation process, and the obtained solutions will be subjected to electrolysis processes for the selective recovery of metals.

Table 2. Chemical compositions of the powder obtained after dismantling the used batteries

No. crt.	Symbol	CC1	CC2	CC3	ACC
1	Zn	18.320	19.740	22.067	20.042
2	Mn	34.070	33.870	39.560	35.833
3	K	6.470	7.090	4.890	6.150
4	Fe	0.410	0.550	0.510	0.490
5	Pb	0.004	0.007	0.007	0.006
6	Hg	0.008	0.008	0.006	0.008
7	Cr	0.110	0.150	0.180	0.147
8	Cd	0.006	0.007	0.005	0.006
9	Na	0.150	0.180	0.120	0.150
10	Al	0.520	0.790	0.630	0.647
11	Cl	2.890	3.020	3.220	3.043
12	Ti	0.360	0.280	0.240	0.293
13	Si	0.610	0.560	0.480	0.550
14	Ni	0.019	0.018	0.013	0.017
15	Ca	0.120	0.304	0.140	0.188
16	Si	0.180	0.290	0.250	0.240
17	Cu	0.410	0.640	0.590	0.547
18	Others	35.343	32.496	27.091	31.643
Total		100	100	100	100

Figure 5. The powder separated after washing and filtration process

The water wash step (neutral leaching) was used to reduce the amount of unwanted ions in the solution and to remove potassium in order to improve the subsequent electrolysis process of the solution, by reducing the interference due to the alkali metals which have the effect of reducing the process yield. Further removal of potassium from the material mixture may also contribute to the reduction of sulphuric acid consumption in the leaching steps.

An SEM analysis of the obtained mixture material was also performed; the morphological aspect is presented in Figure 6. These particles are in fact aggregates of submicron particles.

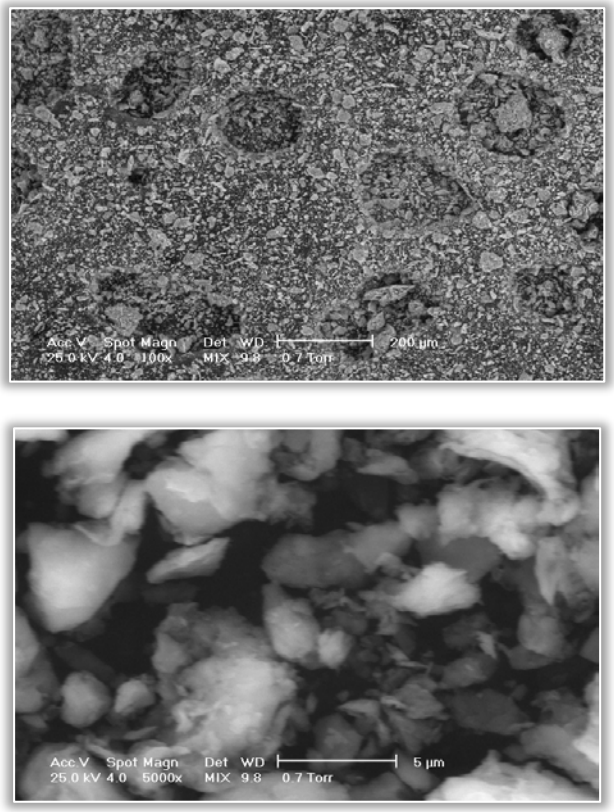
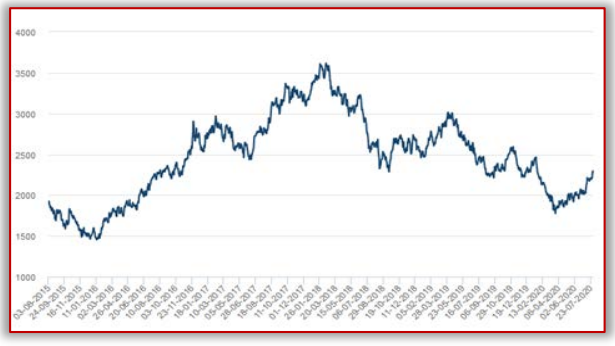


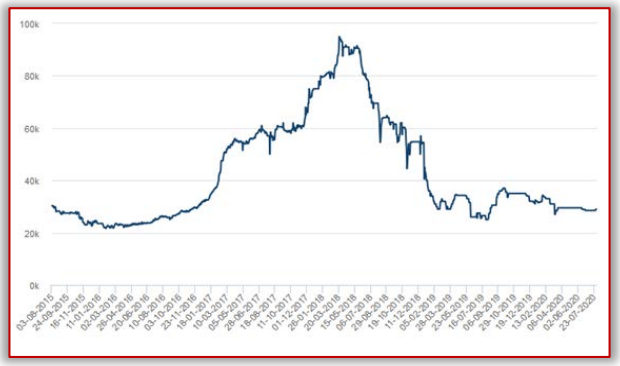
Figure 6. SEM images of alkaline and zinc–carbon battery black mass (a) ×100, (b) ×5000

Sustainable development must focus on the implementation of economic activities that are consistent with issues related to society and the environment and this goal is the only valid option to develop activities with a positive long–term impact on human quality of life.

Nickel

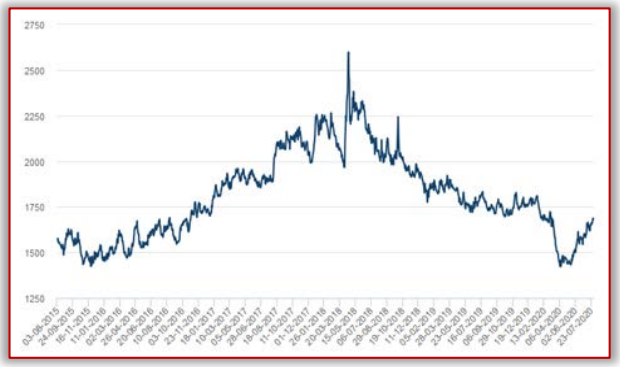


Zinc



Cobalt

Iron



Aluminium

Copper

Figure 7. Price evolution (Dollars / metric ton) in the last 5 years
Source: London Metal Exchange

As can be seen, for the metals listed on the London Metal Exchange, prices are on an upward trend. Under these conditions, their recovery represents a double benefit, both economic and environmental.

CONCLUSIONS

In this paper we focused on the physical–mechanical processes of processing used batteries – alkaline MnO_2, and saline Zn–C, which represent over 80% of the total portable batteries collected worldwide. Thus, their useful metal content is huge and their recovery and recycling is a beneficial opportunity for both the environment and the economy.

After dismantling the batteries and sorting the materials we obtain four different fractions: non–ferrous metals, ferrous metal, and a mixture material with metal content and non–metallic materials establishing the weight of each fraction (this may vary from case to case).

The resulting mixture powder obtained after dismantling the used batteries was subjected to the chemical composition analysis by three successive XRF analyses and the average of the values was calculated. The obtained mixture material together with the powder separated by washing the non–ferrous and ferrous fractions and filtration will enter to a hydro–electrometallurgical circuit for the selective recovery of metals.

Acknowledgments:

The work has been funded by the Operational Programme Human Capital of the Ministry of European Funds through the Financial Agreement 51668/09.07.2019, SMIS code 124705.

References

[1] Eurostat, Waste statistics – recycling of batteries and accumulators, https://ec.europa.eu/eurostat/statistics–explained/index.php/Main_Page

[2] EPBA, Study on the Collection of Waste Portable Batteries in Europe – data 2018 (short update), https://www.epbaeurope.net/

[3] E. Mossali, N. Picone, L. Gentilini, O. Rodrìguez, J.M. Pérez, M. Colledani, Lithium–ion batteries towards circular economy: A literature review of opportunities and issues of recycling treatments, Journal of Environmental Management, Volume 264, 2020, 110500

[4] EU Comission, Batteries: Commission requires collection and recycling of all batteries, IP/03/1596, Brussels, 2003 http://ec.europa.eu/environment/waste/batteries_index.htm

[5] H. Li, J. Dai, A. Wang, S. Zhao, H. Ye, J. Zhang, Recycling and Treatment of Waste Batteries, IOP Conf. Series: Materials Science and Engineering 612 (2019) 052020.

[6] M. Buzatu, S. Săceanu, V.G. Ghica, G. Iacob, T. Buzatu, Simultaneous recovery of Zn and MnO2 from used batteries, as raw materials, by electrolysis, Waste Management, vol. 33, nr. 8, 2013/2014, pg. 1764–1769.

[7] V.E.O. Santos, V.G. Celante, M.F.F. Lelis, M.B.J.G. Freitas, Chemical and electrochemical recycling of the nickel, cobalt, zinc and manganese from the positives electrodes of spent Ni–MH batteries from mobile phones, Journal of Power Sources 218, 2012, pp. 435–444.

[8] ABRI, Analysis of battery consumption, recycling and disposal in Australia, Warnken ISE, 2010

[9] Battery University™, BU–705a: Battery Recycling as a Business

[10] N. Ferronato, V. Torretta, Waste Mismanagement in Developing Countries: A Review of Global Issues. Int. J. Environ. Res. Public Health, 2019, 16, 1060.

[11] V. Agarwal, M.K. Khalid, A. Porvali, B.P.Wilson, M. Lundström, Recycling of spent NiMH batteries: Integration of battery leach solution into primary Ni production using solvent extraction, Sustainable Materials and Technologies 22 (2019) e00121.

[12] L. Kavanagh, J. Keohane, G. Garcia Cabellos, A. Lloyd, Cleary, J. Global Lithium Sources—Industrial Use and Future in the Electric Vehicle Industry: A Review. Resources, 2018, 7, 57.

[13] L. Talens Peiró, G. Villalba Méndez, R.U. Ayres, Lithium: Sources, Production, Uses, and Recovery Outlook. JOM 65, 986–996 (2013).

[14] E. Sayilgan, T. Kukrer, G. Civelekoglu, F. Ferella, A. Akcil, F. Veglio, M. Kitis, A review of technologies for the recovery of metals from spent alkaline and zinc–carbon batteries, Hydrometallurgy 97 (2009) 158–166.

[15] X. Zhang, L. Li, E. Fan, Q. Xue, Y. Bian, F. Wu, R. Chen, Toward sustainable and systematic recycling of spent rechargeable batteries, Chem. Soc. Rev., 2018, 47(18), 7239–7302.

[16] SNRB, How to recycle, 2018, https://www.snrb.org/en/

[17] EU Comission, Directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators and repealing Directive 91/157/EEC, Brussels, 2019, https://ec.europa.eu/commission/sites/beta–political/files/swd–report–batteries–accumulators–april2019_en.pdf

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

Andrei Mihai BACIU, Imre KISS

USE OF POLYMER FIBERS INTO REINFORCED CONCRETE SOLUTIONS

[1,2.]University Politehnica Timisoara, Faculty of Engineering Hunedoara, Department of Engineering & Management, 5 Revolutiei, 331128 – Hunedoara, ROMANIA

Abstract: Generally speaking, the fibre–reinforced concrete applications are based on the principle of improving the properties and mechanical characteristics of the concrete, most of them being based on the idea of improving the strength properties. Fibres are typically added at the batching stage and are uniformly distributed throughout the concrete giving full reinforcement to the full depth of concrete. Are produced a range of fibre reinforced concrete mixes that include the polymer fibers (polypropylene and polypropylene fibres), macro–synthetic and steel fibres. These fibres are used to enhance the concretes performance both in the fresh and hardened state. Polymer fibers, such polyethylene or polypropylene fibres, are primarily used to reduce the potential for plastic shrinkage and increasing fire resistance. They are not designed to replace structural reinforcement.
Keywords: fibre–reinforced concrete, polymer fibres, fibres relates particularities

BACKGROUND OF THE KNOWLEDGE

Many constructions require precise techniques and technologies that can utilize a number of new materials [1–5]. In this context, the use of simple concrete and reinforced concrete is somewhat restricted by specific phenomena such as: cracking, fire resistance, shrinkage, shock resistance, wear resistance, durability, etc. For this reason, various studies have been carried out and in–depth research, which has resulted in an improvement in the performance of the concrete can be obtained by adding in their mass of reinforcements dispersed in the form of fibres from different materials [1–22]. The dispersed reinforced concrete results in the inclusion of a variable amount of discontinuous fibres in the concrete mass [1–10]. These fibres can be of different types and sizes and have different properties.

Ordinary concrete is an artificial conglomerate, the preparation of which is used inorganic hydraulic binders, heavy compact aggregates (gravel or broken stone), water and, in some cases, additives (plasticizing additives, accelerators or retarders). In its simplest form, concrete is a mixture of cement paste and aggregates (different type of sands and rocks). The paste, composed of cement and water, coats the surface of the fine (sand) and coarse aggregates (rocks) and binds them together into a rock–like mass known as concrete [1–5].

A properly proportioned concrete mixture will possess the desired workability for the fresh concrete and the required durability and strength for the hardened concrete [1–5]. Typically, a mixture is by volume about 10 to 15% cement, 60 to 75% aggregates and 15 to 20% water. Entrained air bubbles in many concrete mixtures may also take up another 5 to 8% [3–5,16–18].

By mixing the binder with water, the cement paste (the active part) is formed, which, after physical–chemical processes of hydrolysis and hydration, hardens over time, transforming into a hard body that binds the aggregate particles together, conferring thus the monolithic character of the cement mixture [1–5]. The cement paste, called the matrix, represents the continuous phase, and the aggregates form the dispersed phase [1–5,21–22].

Figure 1. Solid factions of the concrete recipe

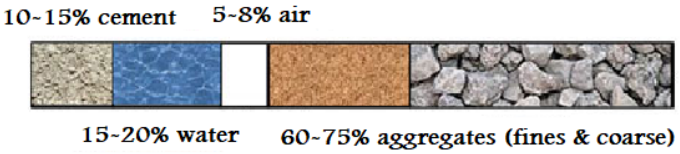


Figure 2. Typically concrete mixture

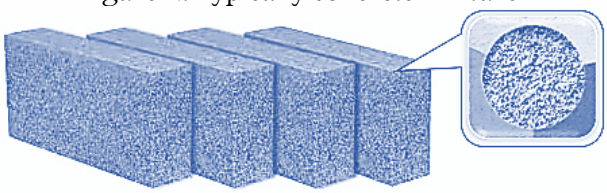


Figure 3. The concrete structure

Generally speaking, the fibre–reinforced concrete applications are based on the principle of improving the properties and mechanical characteristics of the concrete, most of them being based on the idea of improving the strength properties [1–11]. However, the role of fibre reinforcement of simple or classical reinforced concrete should not be reduced not only to this principle of improving the resistance but especially to the control of the cracking process and thereby to improving the resistance, the energy absorption properties and the impact resistance, shock, temperature variations, and fire resistance.

Fibres are typically added at the batching stage and are uniformly distributed throughout the concrete giving full reinforcement to the full depth of concrete

[1–5]. Are produced a range of fibre reinforced concrete mixes that include the polymer fibers (polypropylene and polypropylene fibres), macro–synthetic and steel fibres [4–17]. These fibres are used to enhance the concretes performance both in the fresh and hardened state [1–5].

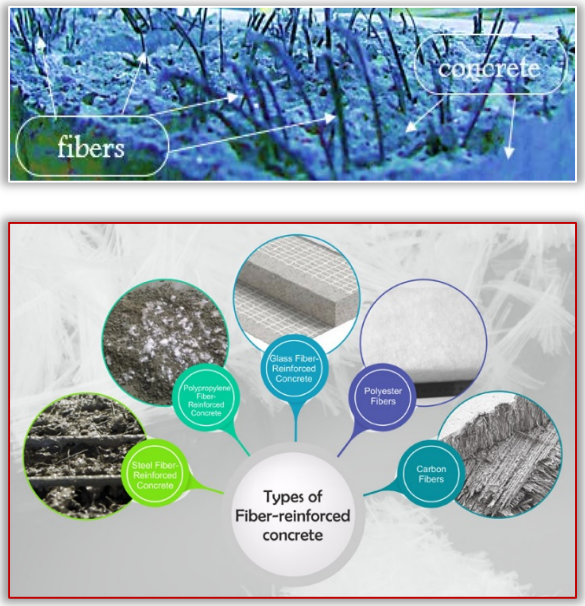


Figure 4. Fiber–reinforced concrete

Polymer fibers, such polyethylene or polypropylene fibres, are primarily used to reduce the potential for plastic shrinkage and increasing fire resistance. They are not designed to replace structural reinforcement [17–21].

FIBRES RELATED PARTICULARITIES

Fiber–reinforced concrete contain fibrous material which increases its structural integrity. It contains short discrete fibers that are uniformly distributed or randomly oriented. Fibers include steel fibers, glass fibers, synthetic fibers and natural fibers – each of which lend varying properties to the concrete. In addition, the character of fiber–reinforced concrete changes with varying concretes, fiber materials, geometries, distribution, orientation, and densities. Research into new fiber–reinforced concretes continues today [1–22].

Adding the fibrous material to concrete will increase the strength [1–22]. The basic idea is that fibers in the mix create a multi–directional, interstitial "mesh" within the concrete matrix that, when is used correctly, will make concrete stronger. But, in fact, the subject is more complex. The types and size of fibers, their distribution and orientation are a hugely complex topic. The main aspects can be summarised as follows:

— **minimum fibre length**

Based on experimental studies, it has been shown that the length of polymer fibres used for dispersed reinforcement must meet certain conditions.

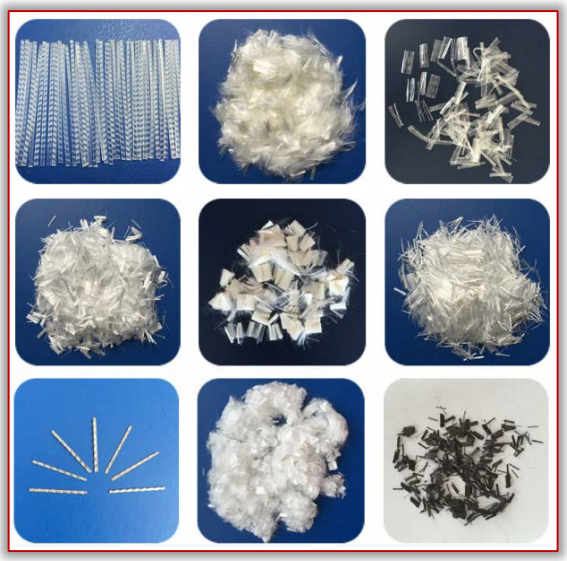


Figure 6. Various length of polymer fibres

For the determination of the minimum fibre length, it is assumed that it is oriented in the direction of the tensile stresses required by the matrix, taking into account the mechanism of transmitting the unitary efforts from the matrix to the fibres. The critical length depends on the diameter of the fibre and the unitary effort in the fibre, so the type of fibre and the average unitary effort of adhesion.

— **the ratio or geometric aspect of the fibres**

Fibers used for concrete reinforcement come in a variety of sizes and are made from an ever–increasing range of materials, including micro fibers and far larger macro fibers.

The geometric ratio or geometric aspect of the fibres is a feature that represents the ratio of the length and diameter of the circular cross–section fibres. The literature shows that there is a critical geometrical relationship, to which the fibres can be regarded as operating with maximum efficiency. There is some data that indicates that regardless of the geometric ratio (l/df) the fibre length must exceed the maximum size of the aggregates in the matrix.

Figure 7. The geometry of fibres

— **the adhesion of the fibre surface to the matrix**

In any composite system, the physical and chemical properties of the constituents and the interaction between them determine the behaviour of the material. In cement–based systems, the contact area between the fibres and the matrix is often diffuse and, instead of the distinct boundaries between the two, there is a continuous transition from one phase to the

next. Often, the strength and durability of the contact area indicate a combination of physical and chemical characteristics that are due to the formation of surface reaction products. Obviously, the properties of the composite are greatly influenced by the adhesion to this surface and that, often, the contact area is the weakest link of the systems. Uniform strength of concrete slab is guaranteed by fibre maximum adhesion to concrete structure and their even distribution.

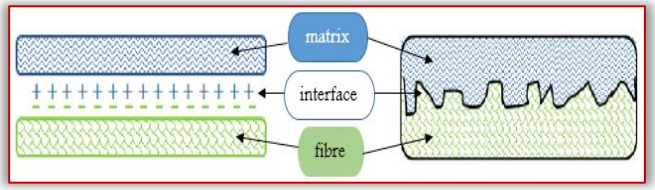


Figure 8. The fibre surface, the matrix and the interface

— fibre distribution and orientation

The orientation of a fibre to the plane of the crack strongly influences its ability to transmit the load through the crack. A fibre that has an orientation parallel to the crack has no favourable effect, while a fibre perpendicular to the crack has a maximum effect. The efficiency of the fibres in a matrix depends on the number of fibres that intersect a surface unit and on the tear resistance of the fibres, which is dependent on factors such as geometric ratio (l/d), surface shape and texture.

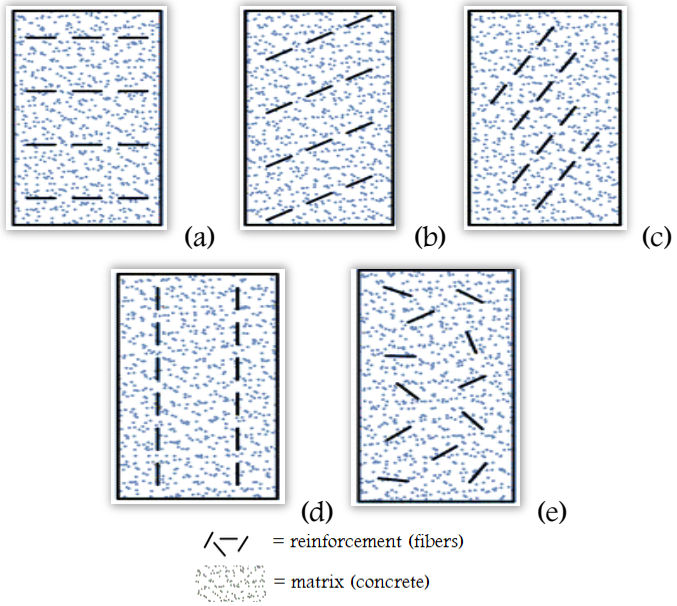


Figure 9. Fibre distribution and orientation in a cement matrix. (a)–(d) layered fibers with determined orientation (0º, 30º, 60º, 90º) (e)–randomly distributed fibers

— fibre content

In order to improve the properties of ordinary concrete, a minimum quantity of fibres of 1 kg/m3 is required, corresponding to about 0.04% by weight of the mixture and 0.1% of the total volume of the mixture.

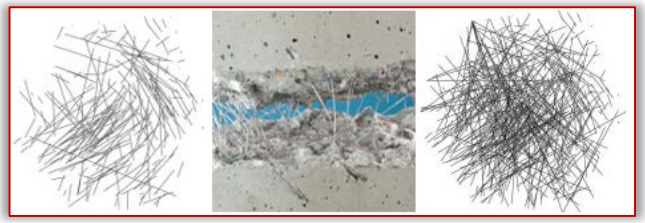


Figure 10. The fibre content

The efficiency of fibre addition increases with increasing content. Also, the fibre content influences the compactness of the dispersed reinforced concrete. Multiple dosage options let use polymer fibre for anti–cracking–during–shrink–process purpose only, as well as for structural reinforcement.

— texture, shape and nature of fibre surface

Any solution to increase the shear strength of the bond between the fibre surface and the matrix increases the value of the fibre resistance and improves its efficiency. Such solutions include processes for the production of fibres with deformed surfaces or asperities, deformed ends or various profiles along them.

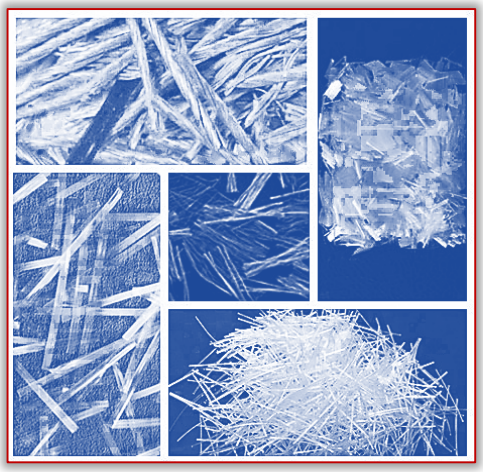


Figure 11. The shape and nature of fibre

BASIC COMPONENTS RELATED PARTICULARITIES

It is important to understand all components of concrete. But the concrete mix designs consider they purpose, rather than just the strength and cost. The mixing parameters of concrete that most influence drying shrinkage are the amount of reinforcement provided but also the size, shape, and surface area–to–volume ratio of the concrete basic components.

— aggregates (rock and sand)

Apart from the above mentioned factors, the size, shape and volume of the fraction of the aggregates also exert a certain influence on the properties of the concrete with dispersed reinforcement. They plays a significant role, acting as structural filler in the concrete. Aggregates are extremely important to understand in terms of how their properties affect the properties of fresh and hardened concrete. Aggregates in any particular mix of concrete are selected for their durability, strength and workability. Therefore, they

properties have a significant influence on the workability, shrinkage, strength and durability of the concrete.

Natural aggregates are available in the crushed or uncrushed state such as sand and gravel or stones. Round shaped aggregates, irregular or partly round shaped aggregates, angular and flaky shaped aggregates are the shape wise classification of aggregates. Fine aggregates and coarse aggregates are the size wise classifications of aggregates. Fine aggregates are usually sand or crushed stone and its compositions are variable depending on the source. It is defined by size, being finer than gravel and coarser than silt.

Figure 12. Fine and coarse aggregates

Figure 13. Fine and coarse sand

When choosing aggregates into the concrete mixture, one must also consider their shape. Rough-textured and sharp aggregates will require more cement paste than round aggregates. The importance of using the right type and quality of aggregates cannot be overemphasized. The fine and coarse aggregates generally occupy 60% to 75% of the concrete volume (70% to 85% by mass) and strongly influence the concrete's freshly mixed and hardened properties, mixture proportions, and economy. The larger the size of the aggregates, the larger the problems of ensuring the adhesion between the fibres and the concrete. Sand cannot be an overlooked component of concrete. Although the stone will supply the strength, sand also has an important purpose – workability. Based on the experimental results, it can be stated that at a known volume of fine and coarse aggregates there is a critical fibre content, over which the compactness decreases.

— **cement**

Cement comprises from 10 to 15% of the concrete mix, by volume. Cement is very important, having an ability to hold the concrete structure together. It provides good strength and also helps concrete to harden early and to resist moisture. Influence the behaviour of concrete with dispersed reinforcement is proportional to the amount added. Thus, a larger amount of cement ensures better adhesion between fibres and matrices, which results in better material behaviour in terms of cracks occurrence, effect on external actions and deformations. Cement is necessary, but the strength can still be retained when using well-graded aggregates that cost significantly less.

— **aggregate–cement ratio and water–cement ratio**

The effect of coarse aggregate on drying shrinkage is double. First, the use of a high coarse aggregate content will minimize the total water and cement paste contents of the concrete mixture and, therefore, will minimize the drying shrinkage. Therefore, the effects of aggregate–cement ratio and water–cement ratio on drying shrinkage are important. In fact, at a given water–cement ratio, drying shrinkage is reduced as the aggregate–cement ratio is increased. Second, drying shrinkage of the cement paste is reduced by coarse aggregate because of its restraining influence. The coarse aggregate is dependent on the type and size of aggregate and its stiffness and the total amount of the aggregate used for concrete. Hard, rigid aggregates should therefore be used to produce concrete with low drying shrinkage.

Aggregates are very important for strength, thermal and elastic properties of concrete, their dimensional stability and volume stability. Including aggregate in the concrete mixture can control the shrinkage level and prevent cracking. Cement is more likely to be affected by shrinkage.

ECOLOGICAL CONTEXT

In the new context of ecological and sustainable development, the reduction of the quantities of waste is considered an important criterion and therefore the introduction in the current practice of some ecological materials is necessary. The use of waste products in concrete not only makes it economical, but also helps in reducing disposal problems. Reuse of plastic wastes is considered the best environmental alternative for solving the problem of disposal. One such waste is plastic, which could be used in various applications.

Taking into account the requirements related to environmental protection, and the construction sector (including concrete and reinforced concrete) must become more environmentally friendly, to minimize pollution. The development of new construction materials using recycled plastics is important to both the construction sector and the recycling industries. Therefore, reuse of recycled plastic materials in concrete mix as an environmental friendly

construction material has drawn attention in recent times.

CONCLUSIONS & FINAL REMARKS

There are multiple reasons for adding polymer fibers in concrete. Choosing the right polymer fiber mostly depends on the type of application. Among the advantages of using polymer fibres into the concretes are the following, being perfectly aware that we can even include all:

- One of the main benefits of polymer fibers are the homogenous distribution in the concrete. Other benefits include the better cohesion of the fresh concrete;
- Thanks to extreme durability of polymers the fibre retain their full characteristics during entire concrete. The use of polymer fibres in the concrete composition increases its tensile and compressive strength. Also, the reinforced concrete dispersed with polymer fibres has an increased shock resistance;
- The polymer reinforcement fibres being neutral to corrosive chemical components, the surface of reinforced concrete dispersed with these fibres is much more resistant to the action of corrosive substances, to the action of weathering (especially frost), and to the action of degreasing materials (especially salt). Therefore, resistance to oxidization and corrosion (from chlorides, sulphates and salts) make them candidates for aggressive environments in marine industry. Also, polymer fibers are great for not chemically stable applications in the chemical industry;
- The use of polymer fibres contributes to the elimination of the degradation caused by the corrosion of the reinforcements and in this way to the prolongation of the life of the constructions;
- The addition of polymer fibres remove cracks due to stresses and contractions. Therefore, other benefits include the control and reduce crack sizes due to early-age shrinkage;
- The addition of polymer fibres increase toughness and abrasion resistance, and also increases the resistance of the concrete to wear by rubbing, thus reducing the costs of making quality industrial floors;
- The addition of polymer fibres require a lower processing costs, compared to steel reinforcements. The advantages of using reinforced concrete with polymer fibres are evident in the small prefabricated building materials, where the costs of reinforcement with bars are high;
- The use of dispersed polymer fibres determine a reduced weight of prefabricated reinforced concrete, and therefore, traditional mesh and steel fiber reinforcement may be avoided. The addition of polymer fibres replace or partially replace traditional reinforcing steel;
- The addition of polymer fibres save time in the construction process and reduce costs.

The development of the construction sector, in particular the investments in infrastructure, remain the key factors of the economic growth. This implies a strong increase in the consumption of building materials in times of economic boom, and against the background of the significant increase in demand, the needs of raw materials also increase. Concrete is one of the main materials used in construction, therefore, the consumption of concrete is determined by the state of the construction industry. Being easy to use, dosed industrial or into a simply concrete mixer, the polymer fibers save time compared to traditional mesh application.

References

[1] BEAUDOIN, J.J., Handbook of fiber–reinforced concrete. Principles, properties, developments and applications, 1990
[2] JOHNSTON, C.D., Fiber–reinforced cements and concretes. CRC Press, 2014
[3] UDDIN, N. (ed.), Developments in fiber–reinforced polymer (FRP) composites for civil engineering, Elsevier, 2013
[4] KISS, I., BACIU, A.M., BORDEASU, I., MICU, L.M., Compressive strength of stripes and flakes of recycled polyethylene terephthalate (PET) added concrete. Materiale Plastice, 57(1), 2020, pp. 244–252
[5] BACIU, A.M., KISS, I., BORDEASU, I., MICU, L.M., Compressive strength of woven and strand of recycled polyethylene terephthalate (PET) reinforced concrete, Materiale Plastice, 57(1), 2020, pp. 263–271
[6] GRACE, N.F., SAYED, G.A., SOLIMAN, A.K., SALEH, K.R., Strengthening reinforced concrete beams using fiber reinforced polymer (FRP) laminates, ACI Structural Journal–American Concrete Institute, 96(5), 1999, pp. 865–874
[7] MELO, G.S., Strengthening reinforced concrete beams using fiber–reinforced polymer (FRP) laminates. Discussion. ACI Structural Journal, 97(5), 2000
[8] CHAALLAL, O., NOLLET, M.–J., PERRATON, D., Strengthening of reinforced concrete beams with externally bonded fiber–reinforced–plastic plates: Design guidelines for shear and flexure, Canadian Journal of Civil Engineering, 25(4), 1998, pp. 692–704
[9] LAWLER, J.S., ZAMPINI, D., SHAH, S.P. Microfiber and macrofiber hybrid fiber–reinforced concrete, Journal of Materials in Civil Engineering, 17(5), 2005, pp. 595–604
[10] HERMAN, E, Is fiber–reinforced concrete the material of the future?, Aqua Magazine, 2016, https://aquamagazine.com/
[11] SONG, P.S., HWANG, S., SHEU, B.C., Strength properties of nylon–and polypropylene–fiber–reinforced concretes, Cement and Concrete Research, 35(8), 2005, pp. 1546–1550

[12] SHARMA, R., PAL BANSAL, P., Use of different forms of waste plastic in concrete – A review, Journal of Cleaner Production, 112(1), 2016, pp. 473–482
[13] ZOLLO, R.F., Fiber–reinforced concrete: An overview after 30 years of development, Cement and Concrete Composites, 19(2), 1997, pp. 107–122
[14] YAO, W., LI, J., WU, K., Mechanical properties of hybrid fiber–reinforced concrete at low fiber volume fraction, Cement and Concrete Research, 33(1), 2003, pp. 27–30
[15] HSIE, M., TU, C., SONG, P.S., Mechanical properties of polypropylene hybrid fiber–reinforced concrete, Materials Science and Engineering: A, 494(1–2), 2008, pp. 153–157
[16] THORNEYCROFT, J., ORR, J., SAVOIKAR, P., BALL, R.J., Performance of structural concrete with recycled plastic waste as a partial replacement for sand, Construction and Building Materials, 161, 2018, pp. 63–69
[17] OCHI, T., OKUBO, S., FUKUI, K., Development of recycled PET fiber and its application as concrete–reinforcing fiber, Cement and Concrete Composites, 29(6), 2007, pp. 448–455
[18] GRZYBOWSKI, M., SHAH, S.P., Shrinkage cracking of fiber reinforced concrete, Materials Journal, 87(2), 1990, pp. 138–148
[19] MOBASHER, B., STANG, H., SHAH, S.P., Microcracking in fiber reinforced concrete, Cement and Concrete Research, 20(5), 1990, pp. 665–676
[20] GOANTA, V., HADAR, A., LEITOIU, B., Experimental procedure designed to determine the elastic characteristics of fiber–reinforced polymeric composite materials, Materiale Plastice, 47(4), 2010, pp. 450–456
[21] BAYASI, Z., ZENG, J., Properties of polypropylene fiber reinforced concrete, Materials Journal, 90(6), 1993, pp. 605–610
[22] SOROUSHIAN, P., LEE, C.–D., Distribution and orientation of fibers in steel fiber reinforced concrete, Materials Journal, 87(5), 1990, pp. 433–439

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

[1.]Dragos DUMITRU, [2.]Adriana MUSCALU, [3.]Cristian-Marian SORICĂ, [4.]Mihai MARIAN

RESEARCH ON THE OPTIMIZATION OF TECHNOLOGIES APPLIED IN THE CONSTRUCTION OF AGRICULTURAL MACHINES

[1-4.]INMA Bucharest, ROMANIA

Abstract: In this paper we present the static and modal analysis of the main shaft, the static analysis of the hydraulic universal and of the clamping system. Also, the 3D model of the turning center and of the main kinematic chain was realized, the operation of an automatic system for fixing the parts, the construction of a hydraulic universal in detail and the static analysis by means of the finite element method.
Keywords: numerical control, machining center, turning, static analysis with finite element

INTRODUCTION

Lately, the objective need to produce as quickly as possible, with the highest productivity, has led to an amazing evolution of the current conception of agricultural machinery, which depends largely on the technological specificity of the various parts that are mechanically processed, as well as the volume of their production. Especially for the unique parts or for those that are produced in small series specific to these types of equipment, the last 15-20 years have marked the replacement of the classic universal machine tools with numerically controlled machine tools. These allow for high processing precision, which remain constant over long periods of time, without the intervention of the human operator to make some corrections.

According to several specialized works C. Mohora, Cr. Pupază, Cr., Zapciu, M., Popoviciu, G., Rusu-Casandra, A., (1997) machining centers are numerically controlled machine tools capable of processing revolution parts by combining the main rotational movement of the semifabricated with the movement advance of the cutting tool. The numerical control is a set of instructions in the form of letters, numbers and symbols that control the same kinematic chains and based on which the machine tool performs various processing operations. Dr. Eng. Vlad Diciuc (2015)

The machining operation that underlies such a center is turning. This represents the cutting process, with the most frequent use, being the basic method for obtaining revolution bodies, with profiles of the shape: curvilinear, cylindrical and conical. In the construction of agricultural machines, the parts containing such surfaces have a significant weight, which justifies the intense use of this type of processing. In general, the types of parts that can be processed on these centers are: hub type, disc type or shaft type.

MATERIAL AND METHOD

In this paper, the ANSYS program was used for a better post-processing of the results. ANSYS is a finite element analysis program widely used in research and industry with the aim of simulating the response of a physically required mechanical, thermal or electromagnetic system. Each launch of the program starts with specifying the problem. The final solution is obtained by launching the program, specifying the element type of the constants, specifying the material properties, discretizing the model, specifying the boundary conditions, post-processing the results and validating the results.

A modal analysis of the main shaft of the machining center was carried out to determine its own frequencies and modes, in order to simulate the requests to which it is subjected during operation.

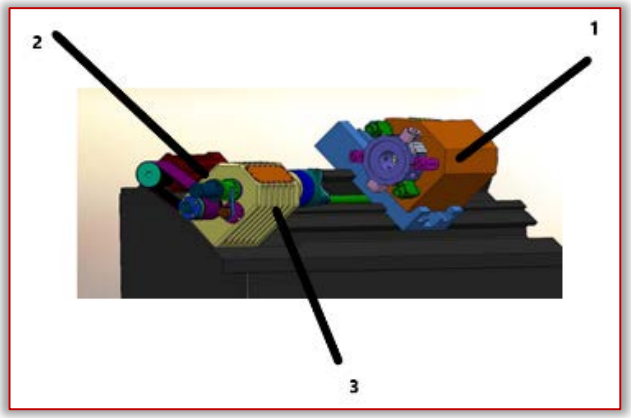


Figure 1. Turning center
Legend: 1- Main kinematic chain, 2-Advance kinematic chain, 3-Gearbox

The Turning Center (Figure 1) consists of: the *main kinematic chain*, the *kinematic feed chain* and the *gearbox*, placed on a work stand. The main kinematic chain consists of the 18.5 kW *power electric motor*, the *Poly-V belt wheels* and the *Poly-V belt*, the *gearbox* that is in the housing and the *universal* that is actuated for fixing the parts by means of the bays by a linear hydraulic motor. The kinematic chain of advance has in its composition the revolver head.

The main drive is carried out with an 18.5 kW AC Siemens 200 AC motor with a maximum speed of 8000rot / min. The main shaft is mounted on 3 axial

radial ball bearings (front) and 2 axial radial ball bearings (rear). The lubrication is done with oil under pressure. The movement from the main drive is received by means of a belt wheel (Poli V), using a solution that does not require the main shaft to bend.
The working support is provided with a longitudinal and a transverse sled for the movement on the Z (longitudinal) and X (transverse) axes, which represents the advances. Advance operation is done with two DC motors type SMUC-C 1A-102, by means of ball screws, with pre-tensioned nuts for eliminating the games. Each motor is controlled by a converter. The feed engines have a minimum speed of 0.2 rpm and for fast feeds (5000mm / min on the X axis and 1000 mm / min on the Z axis), and a maximum speed of 1000 rpm on the X axis and 2000 rpm. min on the Z axis.
The feed speeds are controlled through a closed loop system, via an analog transducer type RD. The advance systems are equipped with electromagnetic brakes that provide braking when the power is interrupted. For the limitation of the movements on axes, blocks with micro-switches are used for each axis.

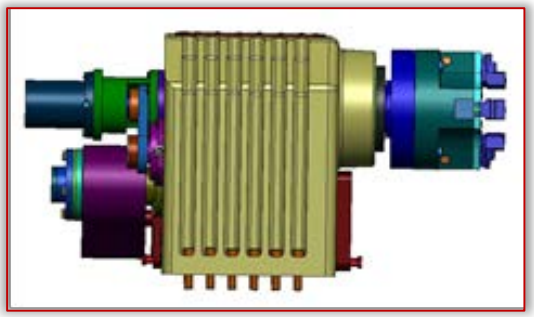


Figure 2. The gearbox

The gearbox (Figure 2) consists of the input shaft, main shaft, thread transducer, housing.
The input shaft is grooved and ends with a Poly V belt wheel, the movement transmitted from the electric motor via the belt wheels and the Poly V belt first reaches the input shaft which is well extended to the end where the wheel is located. Poly V belt, to withstand twisting, and high speeds. The strap wheel is placed on a body that has 2 radial ball bearings and a spacer between the two bearings, and a safety ring. Thus, the input shaft does not take all the forces, because the belt wheel is placed on this well-widened body, and the input shaft enters the body and is less demanded.
On this shaft there is still a group of radial ball bearings and the balador group, it has the role of changing the rpm, being only 2 rpm.
In the figure 3 you can see how the system for tightening the trays on the universal works. The universal consists of a universal body, the actuating bushing, the tray holder, the lever, the bolt, the guide tray and the tray.

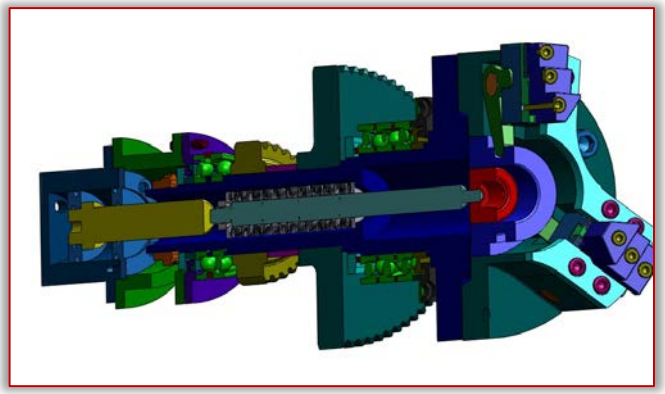


Figure 3. The system for tightening the bins

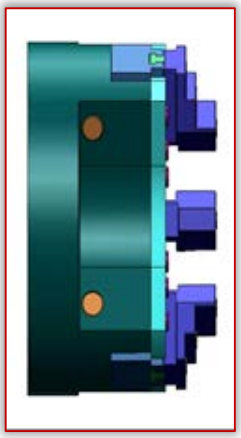


Figure 4. Universal

Thus, the rods are held in position to tighten the piece with a rod that has a cage at the end and is screwed into the universal drive bush, on this rod there is a package of 40 talar springs that rest on one shoulder from the inside of the main shaft and is tightened with a nut. This spring pack is meant to keep the pods in this position.
If we want to release the part, then the linear hydraulic motor, which is made of piston, rod comes into operation. The pressure is formed inside the MHL with the help of a hydraulic system. Thus, the pressure pushes the piston, the rod changes its position and pushes the rod on which the talar springs are, the rod has a cage that is screwed into the actuator bush, and on this bush there are 3 levers fixed by it, and of the tray support. Through the movement of the MHL rod, the rod will also move where the talar springs will compress, so with the help of the levers, the rods are detached from the piece, which can be taken. After removing the part, the pressure in the MHL returns to normal and thus the MHL rod stops pushing the rod from the shaft, the springs return to normal, and thus the rods return to their original position. This cycle will resume whenever it is necessary to process a piece or to remove the part from the universal (Figure 4).

RESULTS

Static analysis provides information on the deformations of the structure as well as the voltage state.

The analysis aimed to study the behavior of the hydraulic universal during rotation with a maximum speed of 4000 rpm and an angular speed of 420 rad/s (mechanical or hydraulic pull force is 1500 N).
During the rotation of the universal the rods tend to weaken the part and may cause accidents, therefore the hydraulic universal is analyzed so that the displacements are not too high because the piece can be detached from the rods at a maximum speed.
In (Figure 5) the maximum voltage of 981 MPa appears in the coupling between the tray and the tray support, in conclusion they must be made from a high-quality steel σa> 1000 MPa.

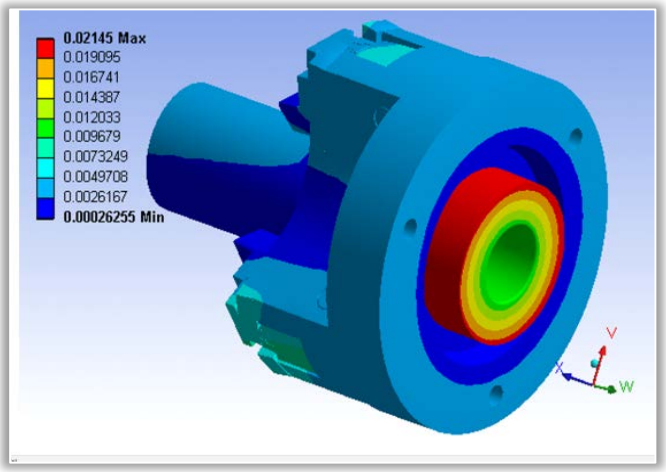


Figure 5. Maximum voltage

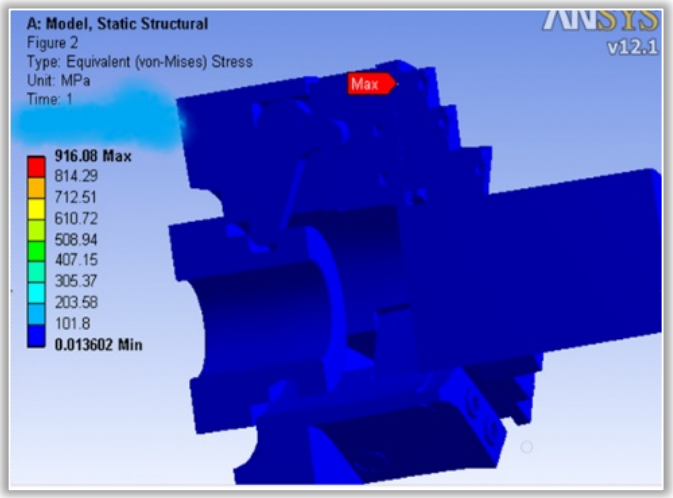
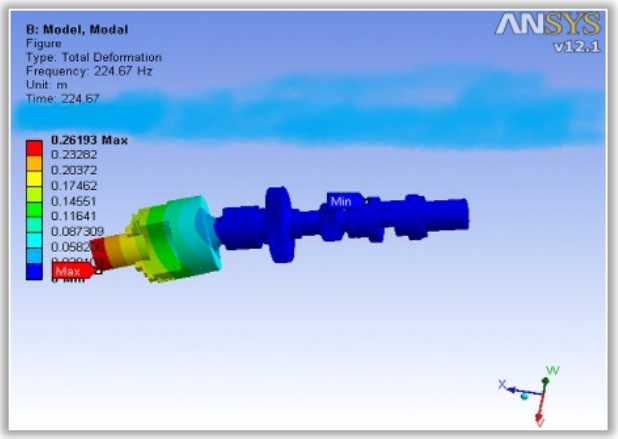
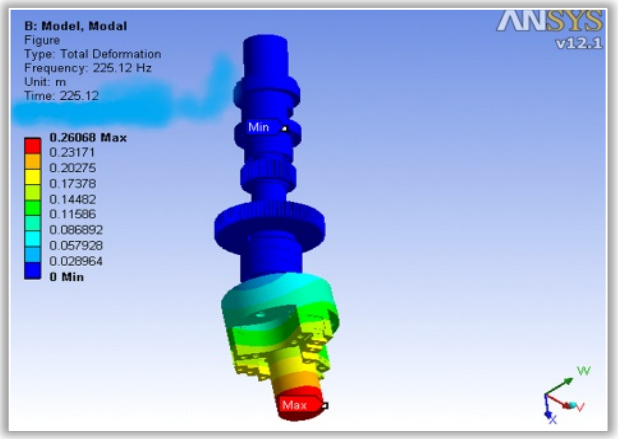


Figure 6. Von Mises

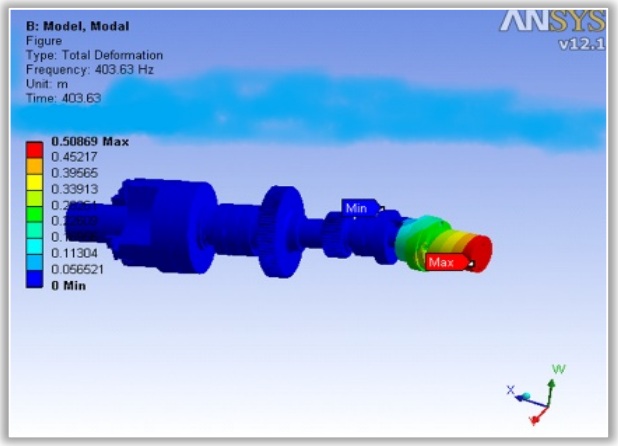
It is observed in (Figure 6) that the maximum displacements of the structure are 21 microns and do not negatively influence the universal displacement and in terms of stresses their maximum value calculated according to the Von Mises criterion (resulting from the stresses).
The maximum voltage of 981 MPa appears in the connection between the tank and the support of the tank in conclusion they must be made of a high-quality steel σa> 1000 MPa.
The modal analysis of the main shaft and the part fixing system was performed to highlight the dynamic behavior, especially by determining the frequencies and modes.
With this analysis, the frequency at which the machine tool resonates is determined. At resonance, deformations with a large amplitude appear, which have a direct influence on the machining accuracy of machine tools and negatively influence the strength of their structure.
The first own modes are the most dangerous being characterized by large amplitudes, so it is recommended that the own frequency be greater than the working frequency (> 66 Hz).



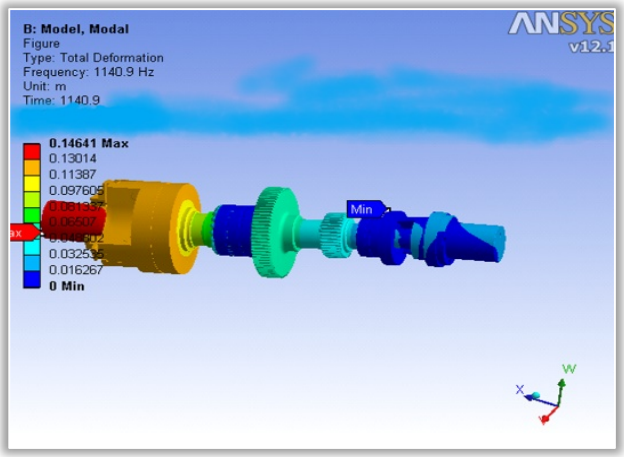
Mode 1 - Vertical bending mode = 224 Hz



Mode 2 – Horizontal bending mode = 225 Hz



Mode 3 – Horizontal bending mode = 403 Hz



Mode 4 – Axial deformation mode – 1141 Hz

CONCLUSIONS

Both CNC processing and 3D simulation allow manufacturers to move from design to manufacturing quickly. Simply put the design on a CAD file (computer-aided design) and upload it to the machine. Thus, conventional cutting processes can be analyzed and optimized using the Finite Element Method (MEF).

The simulations represent a solution for shortening the process duration, reducing costs and ensuring ecological conditions in the production systems.

Acknowledgement

This work was supported by a grant of the Romanian Research and Innovation Ministry, through Programme 1 – Development of the national research-development system, sub-programme 1.2 – Institutional performance – Projects for financing excellence in RDI, contract no. 16PFE."

Note:

This paper is based on the paper presented at ISB–INMA TEH' 2019 International Symposium (Agricultural and Mechanical Engineering), organized by Politehnica University of Bucharest – Faculty of Biotechnical Systems Engineering (ISB), National Institute of Research–Development for Machines and Installations Designed to Agriculture and Food Industry (INMA Bucharest), Romanian Agricultural Mechanical Engineers Society (SIMAR), National Research & Development Institute for Food Bioresources (IBA Bucharest), National Institute for Research and Development in Environmental Protection (INCDPM), Research-Development Institute for Plant Protection (ICDPP), Research and Development Institute for Processing and Marketing of the Horticultural Products (HORTING), Hydraulics and Pneumatics Research Institute (INOE 2000 IHP) and "Food for Life Technological Platform", in Bucharest, ROMANIA, between 31 October – 1 November, 2019.

References

[1] Prodan, D., Marinescu, S., (2005), Refabricarea şi modernizarea maşinilor-unelte. Sisteme hidraulice. Editura Tehnică, Bucureşti

[2] Dogariu, C., (2007/2008), Proiectare asistată de calculator. Note de curs. UPB;

[3] Botez.E., (1966), Bazele generării suprafeţelor pe maşini-unelte. Editura Tehnică, Bucureşti

[4] Ispas, C., Mohora, Cr., Pupăză, Cr., Zapciu, M., Popoviciu, G., Rusu-Casandra, A., (1997), Maşini-unelte. Elemente de structură. Editura Tehnică, Bucureşti;

[5] Moraru, V., Catrina, D., Minciu, C., (1980), Centre de prelucrare. Editura Tehnică, Bucureşti

[6] Minciu C., Străjescu E., Tănase I., Gladcov P., Dogariu C., Nicula S., Constantin G., (1995), Scule aşchietoare. Îndrumar de proiectare. Vol. 1. Editura Tehnică, Bucureşti

[7] Dr. Ing. Vlad Diciuc, (2015) Allmetech Sollutions www.allmetech.com

[8] Jonathan Wilkins, (2019) EU Automatation www.automatation.com

[9] Qin JianHua; Li Wen; Deng ChenYun (2018), International Agricultural Engineering Journal_2018 Vol.27 No.2 pp.121-127 ref.16

[10] Myke Linch, (2019) The Basics of Computer of Numerical control www.cncci.com

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

[1.]Sunny THUKRAL, [2.]Jatinder SINGH BAL

DESIGN OF AN INTELLIGENT FUZZY LOGIC PREDICTIVE SYSTEM FOR CELIAC DISEASE ASSESSMENT

[1.]Sant Baba Bhag Singh University, Jalandhar, INDIA

Abstract: Disease prediction can be attainable through fuzzy logic using relevant member functions with Mamdani model. Fuzzy logic has prophesied several diseases based on the symptoms in the form of existing predictions systems in almost every sphere of medicine. Celiac disease is a sort of auto-immune dysfunction which attacks small intestine after any celiac patient devours gluten in the nutrition. The disease can be diagnosed simply with clinical examinations like tTG-IgA, Biopsy, Genetic Testing etc. To conquer the sensitive process for the evidence of disease, the fuzzy logic celiac system has been proposed based on the symptoms. The proposed system implemented in PyCharm software accompanying with SPSS tool for the interpretation of the data. The system comprised of all the common symptoms transpired in celiac patients by using factor analysis procedure in SPSS. The most obvious symptoms grasped to be fuzzy inputs supplied to the system and offer de-fuzzification singleton value as celiac disease prognostication. The proposed system will be profitable for the surgeons to catch the celiac disease in a more reliable way outwardly any clinical testing strategy, which delivers cost and significant life.
Keywords: Body Mass Index, Celiac Disease, Fuzzy Logic, PyCharm

INTRODUCTION

The conception of fuzzy logic was coined by Lotfi Zadeh [1] in 1965, to tackle the problem of inconsistency. Through fuzzy logic, varying types of models can be adapted to deal with linear and non-linear real-life scenarios. Mamdani and Sugeno patterns respond according to the desired outcome of the system with footing on the specification of the problem [2-3]. Fuzzy logic has been utilised in the context of medicine to discover numerous diseases by formulating fuzzy rules applying member functions. So, Celiac disease fuzzy system can be thoughtful using fuzzy logic Mamdani method [4-5]. Celiac is a variety of chronic disease which afflicts intestine following the consumption of wheat by any celiac patient [6]. The genetic factor also worked a significant role because of halotype instant in celiac patients [7]. These halotypes when associating with gluten drives to various symptoms like vomiting, diarrhea, weight loss, skin rashes, dental problems, a stomach infection, abdominal pain etc. The symptoms varied with different patients with their intensity depend upon the gluten ppm taken by the celiac patient. The distinct diagnosis methods are possible to detect celiac disease in the frame of tTG-IgA, Biopsy or genetic procedure [8]. These clinical aspects require high cost and painful format for any celiac patient for its appropriate detection. So, it leads to thinking about celiac disease prediction with the fuzzy logic strategy by a useful combination of symptoms as similar retrieved from celiac patients. The essential benefit of this system will be for any physician to foretell celiac disease based on the symptoms with no need for any type of clinical testing for the analysis [4-5].

Section II of the paper designs the literature study based on diverse studies on multiple diseases using fuzzy logic methodology without any type of clinical tests. Section III illustrates the design model of fuzzy logic to predict celiac disease. Section IV concentrates on the implementation in Python using fuzzy input-output parameters with membership functions. Section V outlines on results achieved with a fuzzy logic system with appropriate discussions. Additionally, the conclusion of the fuzzy system related with all the benefits of the fuzzy system along with future paradigm.

LITERATURE REVIEW

Literature clarified that celiac disease diagnosis with computer terminologies is not up to the mark. But on the other aspect, fuzzy logic is consistently propagating helpful outcomes in the field of medicine as described in Table 1. In 2018, Heart disease diagnosis was achieved using fuzzy logic by Iancu [9] with just accomplished 44 distinct rules to develop software which showed much better results for heart disease prediction. Manikandan et al. [10] in 2017, focused on Lung diseases using the fuzzy logic scheme. The system was analyzed on 271 persons, clarified 95% accuracy of the fuzzy system by capturing data in the form of a questionnaire using SPSS software. Parwe [11] in 2016, worked on Dental disease using fuzzy logic in Indonesia with sparse common dental parameters. The system was validated using 100 dental patients with an outcome of 82% accuracy of the fuzzy system. Hashmi [12] in 2015 implemented liver disease with fuzzy logic with diagnosis procedure reciprocates with CBC tests and fuzzy inputs with similar input-output parameters. The sensitivity and specificity of the proposed system were essential to implement the fuzzy system in real-

time diagnosis. In 2014, Rana [13] developed a combination of an intelligent fuzzy system which deals with Cardiac, Brain Tumor and Thyroid with fuzzy logic using the Mamdani model. The predication of the proposed system was exclusively based on symptoms supplied by personalities while getting disease data.

Table1: Literature Review on Diseases

Diseases/ Author	Methodology	Outcome
Heart Disease by Iancu (2018) [9]	Fuzzy Logic	Heart disease prediction system with minimal rules using the Mamdani model
Lung Diseases by Manikandan et al. (2017) [10]	Fuzzy Logic	Implemented on 271 patients, Accuracy achieved 95%
Dental Disease by Parwe (2016) [11]	Fuzzy Logic	Applied in Indonesia with 82% accuracy on 100 dental patients
Liver Disease by Hashmi (2015) [12]	Fuzzy Logic	Differentiates with the clinical testing approach and implemented with similar input-output parameters
Brain tumor, Cardiac and Thyroid disease by Rana (2014) [13]	Fuzzy Logic	Embedded fuzzy system diagnosis based on symptoms given by individuals
Cholera Disease by Uduak (2013) [14]	Fuzzy Logic	Accuracy up to the mark with an error rate of 0.15 using Mamdani Fuzzy Model
Asthma Disease by Zarandi (2010) [15]	Fuzzy Logic	Implemented with fuzzy rule-based approach concludes with the asthmatic and non-asthmatic outcome
Breast Cancer by Kovalerchuk et al. (1997) [16]	Fuzzy Logic	Achieved robustness outcome to detect breast cancer using image processing with fuzzy logic

Uduak [14] in 2013 proclaimed cholera fuzzy logic system for disease judgment. The accuracy of the system is preferred with an insignificant error rate. The Mamdani model was implemented using a fuzzy if-then rule-based structure with the centre of gravity as de-fuzzification technique. In 2010, Zarandi [15] accomplished the fuzzy system on Asthmatic disease by distinguishing with non-asthma patients. The inputs for the fuzzy rules were obtained through historical information from the patients, and clinical aspects are taken from the diagnosis test reports of asthmatic patients. Kovalerchuk et al. [16] in 1997 formulated breast cancer detection fuzzy system by using the image processing technique. The extraction of cancer was analyzed by using lobulated mass images taken from breast cancer patients. The system produced accuracy with minimum error rate for disease diagnosis.

So, these are the valuable contributions furnished by numerous researchers to deal with the prediction of diseases using fuzzy logic as given in Table 1. In a similar manner, it conveys an intention to predict celiac disease applying fuzzy logic with the proposed system.

DESIGN OF FUZZY LOGIC SYSTEM

The design of a fuzzy logic system to predict celiac disease necessitates appropriate member functions for the fuzzy values [17-19]. For hiring any membership function demands fuzzy inputs which should be as related to the celiac disease symptoms. The common symptoms gathered from the questionnaire manner among infrequent individuals to carry out the most common symptoms among all utilising SPSS software. To do this, 6 most common symptoms fitted to the fuzzy system to get the probabilistic value which acts as consequent of celiac disease. Triangular membership function was practised to formulate fuzzy inference system as in Figure 1. Every fuzzy value prevails in between 0 to 1 which expresses the maximum values of the fuzzy variable. The values and range of every symptom transformed into fuzzification procedure using multiple fuzzy inputs.

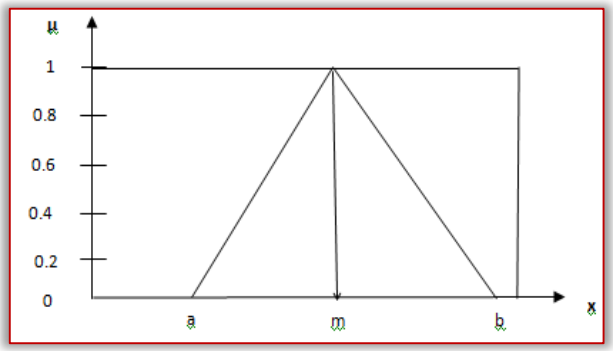


Figure 1: Triangular Fuzzification Structure

$$\mu_{mild}(x) = \begin{cases} 0 & x<0,\ x>4 \\ (4-x)/4 & 0 \le x \le 4 \end{cases}$$ where a=0, b=4 and m=0

$$\mu_{mod}(x) = \begin{cases} 0 & x<1,\ x>9 \\ (x-1)/4 & 1 \le x \le 5 \\ (9-x)/4 & 5 \le x \le 9 \end{cases}$$ where a=1, b=9 and m=5

$$\mu_{sev}(x) = \begin{cases} 0 & x<6,\ x>10 \\ (x-6)/4 & 6 \le x \le 10 \end{cases}$$ where a=6, b=10 and m=10

Figure 2: Triangular Fuzzification Values of Symptom

There are some other membership functions available to design the fuzzy logic but triangular function comprised of three possible values with two ends of extreme nature. Below is the given form of triangular membership function with abdominal pain as input

parameter having fuzzy values as Mild, Moderate and Severe in Figure 2. The stipulation of fuzzy values lies with a range as 0-10 with the mild range as 0-4, Moderate range as 1-9 and severe range as 6-10 depicted in the figure. There is an opportunity of intersection points develop because of ambiguous range values due to transition.

The fuzzy graph of abdominal pain is represented in figure 3 with all attainable outcomes as mild, moderate and severe [20-21]. The similar type of inputs in the form of symptoms with fuzzification can be accomplished similarly with similar membership function but different fuzzy values for each symptom according to its range.

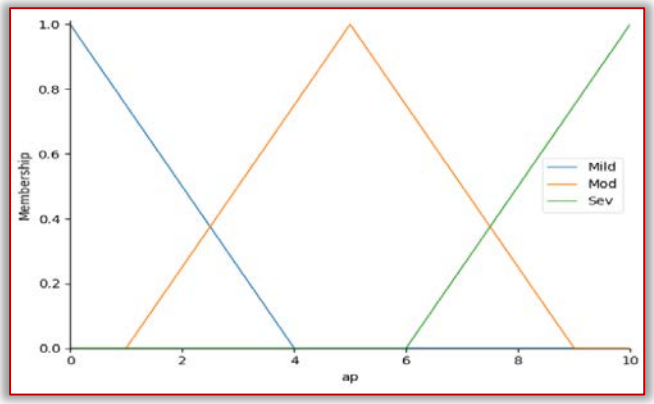


Figure 3: Abdominal Fuzzy Graph

The output membership function also executed using triangular membership values but further composed of 11 sub fuzzy values due to achieve optimum accuracy. The values varied according to its range with sub-division of its range that lies from 0-100 for disease prediction as manifested in figure 4.

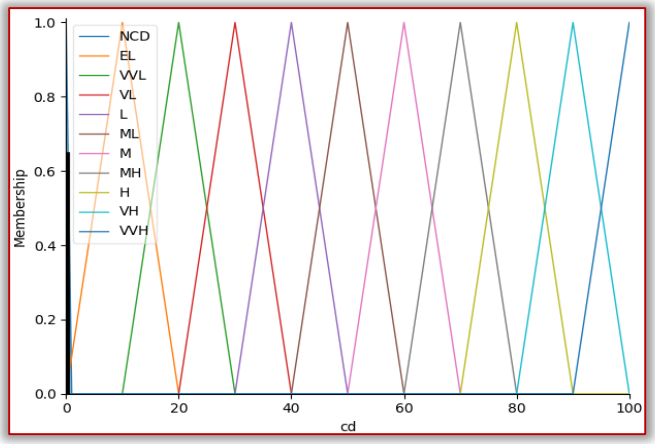


Figure 4: Celiac Fuzzy Outcome Graph

After receiving the input and output membership function, there is a requirement to develop fuzzy rules using if-then values. Fuzzy rules consist of multiple fuzzy operators to be required for the final formation of the fuzzy database. The purpose of the inference engine is to compare each and every symptom value to the fuzzy probabilistic system to get the de-fuzzification value [22-25].

IMPLEMENTATION OF FUZZY LOGIC SYSTEM

The proposed system completed in Python using sub-software as PyCharm for its evaluation. The system needs several sub-modules as matplotlib for fuzzy graph, numpy for fuzzy variables declaration and skfuzzy for the computation in the form of fuzzification and de-fuzzification. The values of fuzzy variables inputted in the form of numerical to concise the fuzzification using numpy variables. The figure 5 quoted here to implement one of the scenarios in which individual input the values of various symptoms as abdominal pain with 9.0, anemia factor with 8.0, diarrhea value with 10.0, vomiting input as 9.0, critical parameter weight loss as 10.0 and Body mass index as 22.143. All these inputs when tendered to a fuzzy system deliver a consequence in the form of de-fuzzification value as celiac disease prediction output.

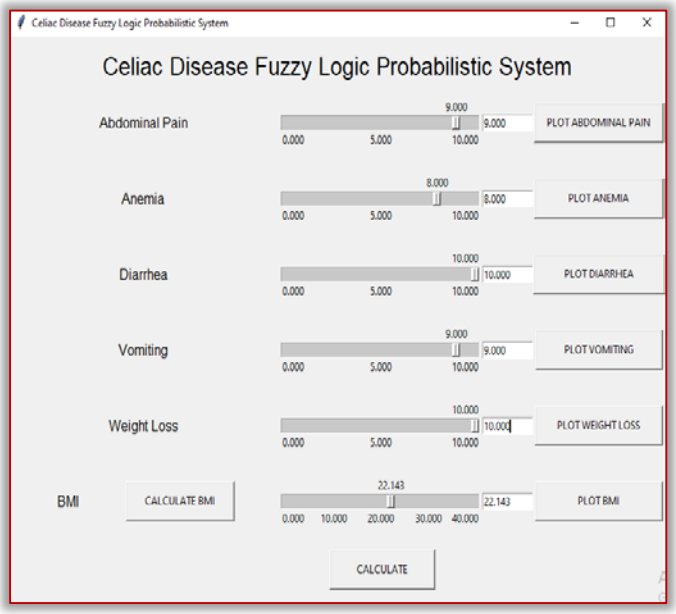


Figure 5: Scenario of a Fuzzy System

The sub-module of evaluating BMI is also determined independently using the height and weight of an individual. On the basis of supposed input, the fuzzy system will take evaluation time to compare every single input with all rules wrapped in the form of a fuzzy database. The process of de-fuzzification renders the outcome by evaluation using the centre of gravity or area of the maximum technique [26-28].

RESULTS

The system generated an output of 96.11%, which dispenses a strong chance of celiac disease with respect to a given input in the inputted scenario in figure 6. The system also blueprints recommendation should be taken to the assigned individual to perform tTG testing for the final confirmation of the disease. If the value appears out to be less than 40% then there will be no requirement to conduct any type of clinical testing.

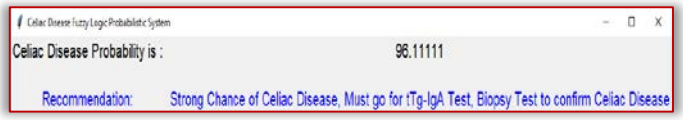


Figure 6: Outcome of Fuzzy Input Scenario

The graphical layout exposed in Figure 7 from the matplotlib indicates all rules matched from the de-fuzzification lies in between 90-100, which is an alarming situation for the submitted individual value. The evaluation method of de-fuzzification is based on the fuzzy inputs in comparison with fuzzy rules in the database [29-30]. Different operators like 'AND' and 'OR' for the conjunction of several consecutive inputs

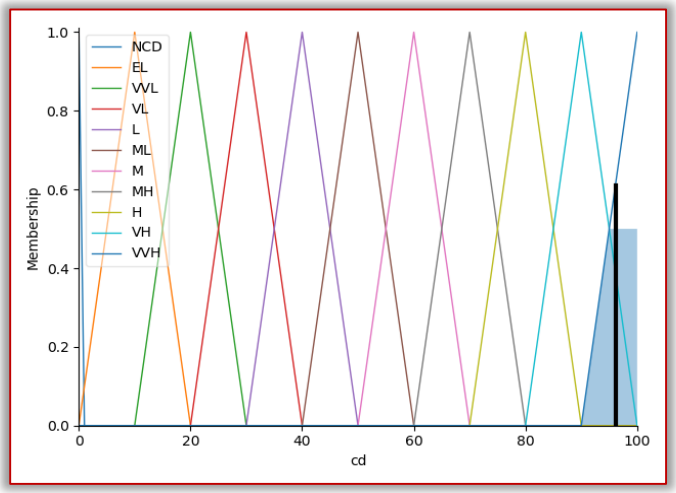


Figure: Fuzzy Outcome Graph

So, the proposed system is advantageous for evaluating celiac disease prediction outcome with certain inputs given by any individual. The time taken by the system is trivial in comparison with clinical testing time which resolves painful testing procedure.

CONCLUSION AND FUTURE SCOPE

The fuzzy system offers results with optimal accuracy and insignificant error rate. The implementation of the proposed system is as related to the given guidelines of ESPHAGN. The system delivers an output in the form of celiac disease foresight based on the symptoms. The system will be propitious for experts to foretell celiac disease and take urgent decision to tackle the disease by recommendation in the form of a gluten-free diet to save small intestine. With the aid of a fuzzy system, any person does not require a clinical test in the first endeavour which conserves painful procedure for the recognition of the disease. For the future perspective, a related type of systems can be formulated to divine unknown diseases with the cooperation of symptomatic study and presents recommendations to tackle diseases in a better way.

References

[1] Zadeh, L.A. (1965). Fuzzy Sets. Elsevier, Information and Control 1965, 8(3), 338-353
[2] Sadegh-Zadeh, K. (2000). Fuzzy Health, Illness, and Disease. Journal of Medicine and Philosophy, 25, 605–638.
[3] Mamdani, E.H., Assilian, S. (1975). An experiment in linguistic synthesis with a fuzzy logic controller. International Journal of Man-Machine Studies, 7(1), 1-13.
[4] Thukral, S., Rana, V. (2019). Versatility of Fuzzy Logic in chronic diseases: A review. Medical Hypotheses, Elsevier, 122, 150-156
[5] Thukral, S., Bal, J.S. (2019). Medical Applications on Fuzzy Logic Inference System: A review. Int J. Advanced Networking and Applications, 10(4), 3944-3950
[6] Gee, S.J. (1888). On the coeliac affection. St. Bartholomew's Hosp Rep., 24, 17-20.
[7] Dowd, B., Walker-Smith, J. (1974). Samuel Gee, Aretaeus, and the coeliac affection.Br Med J, 2(5909), 45-47.
[8] Husby, S., Koletzko, S., Korponay-Szabo, I. R., Mearin, M. L., Phillips, A., Shamir, R., Nutrition. (2012). European Society for Pediatric Gastroenterology, Hepatology, and Nutrition guidelines for the diagnosis of coeliac disease. J Pediatr Gastroenterol Nutr, 54(1), 136-160
[9] Iancu, I. (2018). Heart disease diagnosis based on mediative fuzzy logic. Artificial Intelligence in Medicine, 89, 51–60
[10] Manikandan, T., Bharathi, N., Satish, M., &Asokan, V. (2017). Hybrid neuro fuzzy system for prediction of lung diseases based on the observed symptom values. Journal of Chemical and Pharmaceutical Sciences, 28(2):69-76.
[11] Parewe, A.M., Mahmudy, W.F., Ramdhani, F., Anggodo, Y. (2016). Dental disease detection using hybrid fuzzy logic and evolution strategies.Journal of Telecommunications, Electronic and Computer Engineering 2016, 10(10
[12] Hashmi, A., Khan, M.S. (2015). Diagnosis blood test for liver disease using fuzzy logic. International Journal of Sciences: Basic and Applied Research, 20(1), 151-183.
[13] Rana, M., Sedamkar, R.R. (2013). Design of expert system for medical diagnosis using fuzzy logic. International Journal of Scientific and Engineering Research, 4(6):2914-2921.
[14] Uduak, A., Mfon, M. (2013). Proposed fuzzy framework for cholera diagnosis and monitoring. International Journal of Computer Applications, 82(17), 1-10
[15] Zarandi, M.H., Zolnoori, M., Moin, M., Heidarnejad H. (2010). A fuzzy rule based expert system for diagnosing asthma. Trans-action E: Industrial Engineering, 17(2), 129-142
[16] Kovalerchuk, B., Triantaphyllou, E., Ruiz, J. F., Clayton, J. (1997). Fuzzy logic in computer-aided breast cancer diagnosis: Analysis of lobulation. Artificial Intelligence in Medicine, 11(1), 75–85
[17] Marsh, M. N. (1992). Gluten, major histocompatibility complex, and the small intestine. A molecular and immunobiologic approach to the spectrum of gluten sensitivity ('celiac sprue').Gastroenterology, 102(1), 330-354.

[18] Bascunan, K. A., Vespa, M. C., Araya, M. (2017). Celiac disease: understanding the gluten-free diet. Eur J Nutr, 56(2), 449-459
[19] Murry, J.A., Watson, T., Clearnnan, B., Mitros, F. (2004). Effect of a gluten-free diet on gastrointestinal symptoms in celiac disease. Am J ClinNutr., 79(4), 669-673
[20] *** Revised criteria for diagnosis of coeliac disease. Report of Working Group of European Society of Paediatric Gastroenterology and Nutrition. (1990). Arch Dis Child, 65(8), 909-911.
[21] Falodia, S., Vyas, A., Joshi, A. (2019). Oral Manifestations of celiac disease in north western part of India: A case-control study. *International Journal of Scientific Research, 8*(4), 54-56.
[22] Gulseren, Y.D., Adiloglu, A.K., Yucel, M., Dag, Z., Caydere, M. (2019). Comparison of non-invasive tests with invasive tests in the diagnosis of celiac disease.J Clin Lab Anal. 2019; 33:e22722
[23] Senapati, S., Sood, A., Midha, V., Sood, N., Sharma, S., Kumar, L., Thelma, B. K. (2016). Shared and unique common genetic determinants between pediatric and adult celiac disease. BMC Medical Genomics, 9(1),44
[24] Koh, J. E. W., Hagiwara, Y., Oh, S. L., Tan, J. H., Ciaccio, E. J., Green, P. H., Rajendra Acharya, U. (2019). Automated diagnosis of celiac disease using DWT and nonlinear features with video capsule endoscopy images. Future Generation Computer Systems, 90, 86–93
[25] Kayali, I. (2018). Expert system for diagnosis of chest diseases using neural networks. Artificial Intelligence, arXiv:1802.06866v1
[26] Jesus, M.H., Manuel, Z.R., Faiyaz, D., Rosario, B.F., Carlos, L.R., Alfonso, R.D. (2018). Modeling independence and security in Alzheimer's patients using fuzzy logic. Intelligent Data Sensing and Processing for Health and Well-being Applications
[27] Satarkar, S.L., Ali, M.S. (2017). Fuzzy expert system for the diagnosis of common liver disease. International Engineering Journal for Research and Development, 1(1)
[28] Manikandan, T., Bharathi, N., Satish, M., Asokan, V. (2017). Hybrid neuro fuzzy system for prediction of lung diseases based on the observed symptom values. Journal of Chemical and Pharmaceutical Sciences, 28(2):69-76.
[29] Makharia, G. K., Verma, A. K., Amarchand, R., Bhatnagar, S., Das, P., Goswami, A., Anand, K. (2011). Prevalence of celiac disease in the northern part of India: a community based study. J Gastroenterol Hepatol, 26(5), 894-900
[30] Aronsson, C. A., Lee, H. S., Liu, E., Uusitalo, U., Hummel, S., Yang, J., Teddy Study, G. (2015). Age at gluten introduction and risk of celiac disease. Pediatrics, 135(2), 239-245
[31] Phuong, N. H., Kreinovich, V. (2001). Fuzzy logic and its applications in medicine.Int J Med Inform, 62(2-3), 165-173.

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

Fascicule 4
[October – December]
tome XIII
[2020]

ACTA Technica CORVINIENSIS
BULLETIN OF ENGINEERING

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

http://acta.fih.upt.ro

MANUSCRIPT PREPARATION – GENERAL GUIDELINES

Manuscripts submitted for consideration to ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering must conform to the following requirements that will facilitate preparation of the article for publication. These instructions are written in a form that satisfies all of the formatting requirements for the author manuscript. Please use them as a template in preparing your manuscript. Authors must take special care to follow these instructions concerning margins.

INVITATION

We are looking forward to a fruitful collaboration and we welcome you to publish in our ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering. You are invited to contribute review or research papers as well as opinion in the fields of science and technology including engineering. We accept contributions (full papers) in the fields of applied sciences and technology including all branches of engineering and management. ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering publishes invited review papers covering the full spectrum of engineering and management. The reviews, both experimental and theoretical, provide general background information as well as a critical assessment on topics in a state of flux. We are primarily interested in those contributions which bring new insights, and papers will be selected on the basis of the importance of the new knowledge they provide.

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

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

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

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

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

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

BASIC MANUSCRIPT REQUIREMENTS

The basic instructions and manuscript requirements are simple:

- Manuscript shall be formatted for an A4 size page.
- The all margins of page (top, bottom, left, and right) shall be 20 mm.
- The text shall have both the left and right margins justified.
- Single-spaced text, tables, and references, written with 11 or 12-point Georgia or Times New Roman typeface.
- No Line numbering on any pages and no page numbers.
- Manuscript length must not exceed 15 pages (including text and references).
- Number of the figures and tables combined must not exceed 20.
- Manuscripts that exceed these guidelines will be subject to reductions in length.

The original of the technical paper will be sent through e-mail as attached document (*.doc, Windows 95 or higher). Manuscripts should be submitted to e-mail: redactie@fih.upt.ro, with mention "for ACTA TECHNICA CORVINIENSIS".

STRUCTURE

The manuscript should be organized in the following order: Title of the paper, Authors' names and affiliation, Abstract, Key Words, Introduction, Body of the paper (in sequential headings), Discussion & Results, Conclusion or Concluding Remarks, Acknowledgements (where applicable), References, and Appendices (where applicable).

THE TITLE

The title is centered on the page and is CAPITALIZED AND SET IN BOLDFACE (font size 14 pt). It should adequately describe the content of the paper. An abbreviated title of less than 60 characters (including spaces) should also be suggested. Maximum length of title: 20 words.

AUTHOR'S NAME AND AFFILIATION

The author's name(s) follows the title and is also centered on the page (font size 11 pt). A blank line is required between the title and the author's name(s). Last names should be spelled out in full and succeeded by author's initials. The author's affiliation (in font size 11 pt) is provided below. Phone and fax numbers do not appear.

ABSTRACT

State the paper's purpose, methods or procedures presentation, new results, and conclusions are presented. A nonmathematical abstract, not exceeding 200 words, is required for all papers. It should be an abbreviated, accurate presentation of the contents of the paper. It should contain sufficient information to enable readers to decide whether they should obtain and read the entire paper. Do not cite references in the abstract.

KEY WORDS

The author should provide a list of three to five key words that clearly describe the subject matter of the paper.

TEXT LAYOUT

The manuscript must be typed single spacing. Use extra line spacing between equations, illustrations, figures and tables. The body of the text should be prepared using Georgia or Times New Roman. The font size used for preparation of the manuscript must be 11 or 12 points. The first paragraph following a heading should not be indented. The following paragraphs must be indented 10 mm. Note that there is no line spacing between paragraphs unless a subheading is used. Symbols for physical quantities in the text should be written in italics. Conclude the text with a summary or conclusion section. Spell out all initials, acronyms, or abbreviations (not units of measure) at first use. Put the initials or abbreviation in parentheses after the spelled-out version. The manuscript must be writing in the third person ("the author concludes... ").

FIGURES AND TABLES

Figures (diagrams and photographs) should be numbered consecutively using Arabic numbers. They should be placed in the text soon after the point where they are referenced. Figures should be centered in a column and should have a figure caption placed underneath. Captions should be centered in the column, in the format "Figure 1" and are in upper and lower case letters.

When referring to a figure in the body of the text, the abbreviation "Figure" is used Illustrations must be submitted in digital format, with a good resolution. Table captions appear centered above the table in upper and lower case letters.

When referring to a table in the text, "Table" with the proper number is used. Captions should be centered in the column, in the format "Table 1" and are in upper and lower case letters. Tables are numbered consecutively and independently of any figures. All figures and tables must be incorporated into the text.

EQUATIONS & MATHEMATICAL EXPRESSIONS

Place equations on separate lines, centered, and numbered in parentheses at the right margin. Equation numbers should appear in parentheses and be numbered consecutively. All equation numbers must appear on the right-hand side of the equation and should be referred to within the text.

CONCLUSIONS

A conclusion section must be included and should indicate clearly the advantages, limitations and possible applications of the paper. Discuss about future work.

Acknowledgements

An acknowledgement section may be presented after the conclusion, if desired. Individuals or units other than authors who were of direct help in the work could be acknowledged by a brief statement following the text. The acknowledgment should give essential credits, but its length should be kept to a minimum; word count should be <100 words.

References

References should be listed together at the end of the paper in alphabetical order by author's surname. List of references indent 10 mm from the second line of each references. Personal communications and unpublished data are not acceptable references.

- *Journal Papers:* Surname 1, Initials; Surname 2, Initials and Surname 3, Initials: Title, Journal Name, volume (number), pages, year.
- *Books:* Surname 1, Initials and Surname 2, Initials: Title, Edition (if existent), Place of publication, Publisher, year.
- *Proceedings Papers:* Surname 1, Initials; Surname 2, Initials and Surname 3, Initials: Paper title, Proceedings title, pages, year.

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809

INDEXES & DATABASES

We are very pleased to inform that our international scientific journal **ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering** completed its 12 years of publication successfully **[2008–2019, Tome I–XII]**.
In a very short period the **ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering** has acquired global presence and scholars from all over the world have taken it with great enthusiasm.
We are extremely grateful and heartily acknowledge the kind of support and encouragement from all contributors and all collaborators!

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering is accredited and ranked in the **"B+" CATEGORY Journal** by **CNCSIS – The National University Research Council's Classification of Romanian Journals, position no. 940** (http://cncsis.gov.ro/).
ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering is a part of the **ROAD, the Directory of Open Access scholarly Resources** (http://road.issn.org/).

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering is also indexed in the digital libraries of the following world's universities and research centers:

WorldCat – the world's largest library catalog
https://www.worldcat.org/
National Lybrary of Australia
http://trove.nla.gov.au/
University Library of Regensburg – GIGA German Institute of Global and Area Studies
http://opac.giga-hamburg.de/ezb/
Simon Fraser University – Electronic Journals Library
http://cufts2.lib.sfu.ca/
University of Wisconsin – Madison Libraries
http://library.wisc.edu/
University of Toronto Libraries
http://search.library.utoronto.ca/
The University of Queensland
https://www.library.uq.edu.au/
The New York Public Library
http://nypl.bibliocommons.com/
State Library of New South Wales
http://library.sl.nsw.gov.au/
University of Alberta Libraries – University of Alberta
http://www.library.ualberta.ca/
The University of Hong Kong Libraries
http://sunzi.lib.hku.hk/
The University Library – The University of California
http://harvest.lib.ucdavis.edu/

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering is indexed, abstracted and covered in the world–known bibliographical databases and directories including:

INDEX COPERNICUS – JOURNAL MASTER LIST
http://journals.indexcopernicus.com/
GENAMICSJOURNALSEEK Database
http://journalseek.net/
DOAJ – Directory of Open Access Journals
http://www.doaj.org/
EVISA Database
http://www.speciation.net/
CHEMICAL ABSTRACTS SERVICE (CAS)
http://www.cas.org/
EBSCO Publishing
http://www.ebscohost.com/
GOOGLE SCHOLAR
http://scholar.google.com
SCIRUS – Elsevier
http://www.scirus.com/
ULRICHSweb – Global serials directory
http://ulrichsweb.serialssolutions.com
getCITED
http://www.getcited.org
BASE – Bielefeld Academic Search Engine
http://www.base-search.net
Electronic Journals Library
http://rzblx1.uni-regensburg.de
Open J–Gate
http://www.openj-gate.com
ProQUEST Research Library
http://www.proquest.com
Directory of Research Journals Indexing
http://www.drji.org/
Directory Indexing of International Research Journals
http://www.citefactor.org/

ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
ISSN: 2067-3809