



University of Banja Luka
Faculty of Mechanical Engineering



DEMI 2021

**15th International Conference on
Accomplishments in Mechanical and
Industrial Engineering**

PROCEEDINGS



Banja Luka, 28 - 29 May 2021

University of Banja Luka
Faculty of Mechanical Engineering

**PROCEEDINGS
DEMI 2021**

Banja Luka, May 2021

**15th INTERNATIONAL CONFERENCE ON ACCOMPLISHMENTS IN
MECHANICAL AND INDUSTRIAL ENGINEERING**

DEMI 2021

Supported by:

MINISTRY OF SCIENTIFIC AND TECHNOLOGICAL DEVELOPMENT,
HIGHER EDUCATION AND INFORMATION SOCIETY OF THE REPUBLIC OF SRPSKA

Organizer and publisher:

FACULTY OF MECHANICAL ENGINEERING
UNIVERSITY OF BANJA LUKA

Co-organizer:

FACULTY OF MECHANICAL ENGINEERING,
UNIVERSITY OF NIŠ, SERBIA

FACULTY OF MECHANICAL ENGINEERING PODGORICA,
UNIVERSITY OF MONTENEGRO, MONTENEGRO

FACULTY OF ENGINEERING,
HUNEDOARA, ROMANIA

FACULTY OF ENGINEERING RESITA,
BABEŞ-BOLYAI UNIVERSITY, ROMANIA

For publisher:

Full. Prof. Aleksandar Milašinović, PhD

Editor in chief:

Assoc. Prof. Stevo Borojević, PhD

Executive editor:

Biljana Prochaska, MSc

ORGANIZING COMMITTEE

Chairman of the Organizing Committee: Assoc. Prof. Stevo Borojević, PhD, PhD, Faculty of
Mechanical Engineering, University of Banja Luka

Full. Prof. Darko Knežević, PhD

Full. Prof. Aleksandar Milašinović, PhD

Assoc. Prof. Zorana Tanasić, PhD

Full. Prof. Igor Vušanović, PhD (Podgorica),

Assoc. Prof. Dejan Mitrović, PhD (Niš),

Assoc. Prof. Sorin Ioan Deaconu PhD, (Hunedoara, Rumunija),

Lecturer Relu Costel Ciubotariu, PhD (Rešica, Rumunija),

Assist. Prof. Branislav Sredanović, PhD

Assist. Prof. Bojan Knežević, PhD

Assist. Prof. Milovan Kotur, PhD

Sen. Assist. Saša Laloš, MSc

Sen. Assist. Danijela Kardaš, MSc

Sen. Assist. Gordana Tošić, MSc

Assist. Saša Tešić, MSc

EFL Lecturer Sanja Maglov, MSc

Biljana Prochaska, MSc

Boro Marić, BSc

Nedeljka Sladojević Putnik, BSc

Milivoj Stipanović.

SCIENTIFIC COMMITTEE

Chairman of the Scientific Committee: Prof. Đorđe Čiča, PhD, Faculty of Mechanical Engineering, University of Banja Luka

Prof. Darko Knežević, PhD, Faculty of Mechanical Engineering, University of Banja Luka; Prof. Radivoje Mitrović, PhD, Faculty of Mechanical Engineering, University of Belgrade; Prof. Vlastimir Nikolić, PhD, Faculty of Mechanical Engineering, University of Niš; Prof. Nenad D. Pavlović, PhD, Faculty of Mechanical Engineering, University of Niš; Prof. Igor Vušanović, PhD, Faculty of Mechanical Engineering Podgorica, University of Montenegro; Prof. Gelu Ovidiu Tirian, PhD, University Politehnica Timisoara, Romania; Prof. Gilbert-Rainer GILLICH, PhD, Faculty of Engineering Resita, Babeş-Bolyai University; Prof. Dejan Lukić, PhD, Faculty of Technical Sciences, University of Novi Sad; Prof. Saša Živanović, PhD, Faculty of Mechanical Engineering, University of Belgrade; Prof. Mijodrag Milošević, PhD, Faculty of Technical Sciences, University of Novi Sad; Prof. Aleksandar Milašinović, PhD, Faculty of Mechanical Engineering, University of Banja Luka; Prof. Izet Bjelonja, PhD, Faculty of Mechanical Engineering, University of Sarajevo; Senior Researcher Aleksander Michailov, PhD, OAO NPO "Saturn", Russia; Prof. Dorian Nedelcu, PhD, Faculty of Engineering Resita, Babeş-Bolyai University; Assist. Prof. Alexander Remizov Evgenyevich, PhD, Rybinsk State Aviation Technical University, Russia; Prof. Milan Zeljković, PhD, Faculty of Technical Sciences, University of Novi Sad; Prof. Franci Pušavec, PhD, Faculty of Mechanical Engineering, University of Ljubljana; Prof. Miodrag Manić, PhD, Faculty of Mechanical Engineering, University of Niš; Prof. Mileta Janjić, PhD, Faculty of Mechanical Engineering Podgorica, University of Montenegro; Assist. Prof. Davorin Kramar, PhD, University of Ljubljana, Slovenia; Prof. Simo Jokanović, PhD, Faculty of Mechanical Engineering, University of Banja Luka; Prof. Gordana Globočki-Lakić, PhD, Faculty of Mechanical Engineering, University of Banja Luka; Prof. Ardelean Erika, PhD, University Politehnica Timisoara, Romania; Prof. Petar Gvero, PhD, Faculty of Mechanical Engineering, University of Banja Luka; Prof. Slobodan Lubura, PhD, Faculty of Electrical Engineering, University of East Sarajevo; Prof. Sanda Midžić – Kurtagić, PhD, Faculty of Mechanical Engineering, University of Sarajevo; Assist. Prof. Srđan Vasković, PhD, Faculty of Mechanical Engineering, University of East Sarajevo; Prof. Dragica Milenković, PhD, Faculty of Mechanical Engineering, University of Niš; Prof. Bratislav Blagojević, PhD, Faculty of Mechanical Engineering University of Niš; Prof. Milan Radovanović, PhD, Faculty of Mechanical Engineering, University of Belgrade; Prof. Dragoslava Stojiljković, PhD, Faculty of Mechanical Engineering, University of Belgrade; Prof. Nebojša Manić, PhD, Faculty of Mechanical Engineering, University of Belgrade; Prof. Dunja Martinović, PhD, Faculty of Mechanical Engineering, University of Sarajevo; Prof. Milan Lečić, PhD, Faculty of Mechanical Engineering, University of Belgrade; Prof. Neven Duić, PhD, Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb; Prof. Vojislav Novaković, PhD, NTNU, Norway;

Prof. Milan Rackov, PhD, Faculty of Technical Sciences, University of Novi Sad; Prof. Mirko Blagojević, PhD, Faculty of Engineering Sciences, University of Kragujevac; Prof. Nataša Trišović, PhD, Faculty of Mechanical Engineering, University of Belgrade; Prof. Mladimir Milutinović, PhD, Faculty of Technical Science, University of Novi Sad; Prof. Dražan Kozak, PhD, University of Josip Juraj Strossmayer in Osijek, Croatia; Prof. Predrag Kozić, PhD, Faculty of Mechanical Engineering, University of Niš; Prof. Dragan Milčić, PhD Faculty of Mechanical Engineering; University of Niš; Prof. Radoslav Tomović, PhD; Faculty of Mechanical Engineering Podgorica; University of Montenegro; Prof. Janko Jovanović, PhD; Faculty of Mechanical Engineering Podgorica; University of Montenegro; Prof. Nebojša Radić, PhD; Faculty of Mechanical Engineering; University of East Sarajevo; Prof. Valentina Golubović – Bugarski, PhD; Faculty of Mechanical Engineering; University of Banja Luka; Prof. Strain Posavljak, PhD; Faculty of Mechanical Engineering; University of Banja Luka; Prof. Dong Leiting, PhD; Beijing University of Aeronautics & Astronautics; China; Prof. Atul Bhaskar, PhD; University of Southampton; United Kingdom; Assist. Prof. Milan Rakita, PhD; Perdue University; USA; Prof. Halil Caliskan, PhD; Bartin University; Turkey; Prof. Socalici Ana, PhD; University Politehnica Timisoara; Romania; Prof. Milan Tica, PhD; Faculty of Mechanical Engineering; University of Banja Luka; Prof. Milan Bajić, PhD; Faculty of Mechanical Engineering; University of Niš; Prof. Zoran Bučevac, PhD; Faculty of Mechanical Engineering; University of Belgrade; Prof. Radiša Jovanović, PhD; ; Faculty of Mechanical Engineering; University of Belgrade; Prof. Aleksandar Sedmak, PhD; Faculty of Mechanical Engineering; University of elgrade; Prof. Branko Blanuša, PhD; Faculty of Electrical Engineering; University of Banja Luka; Prof. Marina Mijanović Markuš, PhD; Faculty of Mechanical Engineering Podgorica; University of Montenegro; Prof. Miroslav Rogić, PhD; Faculty of Mechanical Engineering; University of Banja Luka; Prof. Dejan Mitrović, PhD; Faculty of Mechanical Engineering; University of Niš; Prof. Goran Janevski, PhD; Faculty of Mechanical Engineering; University of Niš; Prof. Uroš Karadžić, PhD Faculty of Mechanical Engineering Podgorica; University of Montenegro; Prof. Milan Petrović, PhD; Faculty of Mechanical Engineering; University of Belgrade; Prof. Predrag Cosić, PhD; University of Zagreb; Croatia; Prof. Deaconu Sorin, PhD; University Politehnica Timisoara; Romania; Prof. Bordeasu Ilare, PhD; University Politehnica Timisoara; Romania; Prof. Zdravko Milovanović, PhD; Faculty of Mechanical Engineering; University of Banja Luka; Prof. dr Vinko Babić, PhD; Faculty of Mechanical Engineering; University of Banja Luka; Prof. Jovanka Lukić, PhD; Faculty of Engineering Sciences; University of Kragujevac; Prof. Dragan Taranović, PhD; Faculty of Engineering Sciences; University of Kragujevac; Prof. Goran Petrović, PhD; Faculty of Mechanical Engineering; University of Niš; Prof. Radoje Vujadinović, PhD; Faculty of Engineering Sciences; University of Kragujevac; Prof. Snežana Petković, PhD; Faculty of Mechanical Engineering; University of Banja Luka; Prof. Miodrag Hadžistević, PhD; Faculty of Technical Sciences; University of Novi Sad; Prof. Milorad Pantelić, PhD; Technical Faculty Čačak; University of Kragujevac; Prof. Bratislav Blagojević, PhD; Faculty of Mechanical Engineering; University of Niš; Prof. Peđa Milosavljević, PhD; Faculty of Mechanical Engineering; University of Niš; Prof.

Jelena Jovanović, PhD; Faculty of Mechanical Engineering Podgorica; University of Montenegro; Prof. Mladen Todić, PhD;; Faculty of Mechanical EngineeringUniversity of Banja Luka; Prof. Milija Krajišnik, PhD; Faculty of Mechanical Engineering; University of East Sarajevo; Prof. Ilija Ćosić, Emeritus; Faculty of Technical Sciences; University of Novi Sad; Prof. Zorana Tanasić, PhD; Faculty of Mechanical Engineering; University of Banja Luka; Prof. Mirko Soković, PhD, University of Ljubljana, Slovenia; Prof. Miroslav Bobrek, PhD; Faculty of Mechanical Engineering; University of Banja Luka; Prof. Goran Janjić, PhD; Faculty of Mechanical Engineering; University of Banja Luka; Prof. Igor Budak, PhD; Faculty of Technical Sciences; University of Novi Sad; Prof. Tiomir Latinović, PhD; Faculty of Mechanical Engineering; University of Banja Luka; Prof. Sead Pašić, PhD; Faculty of Mechanical Engineering, "Džemal Bijedić"; University in Mostar; Prof. Borut Kosec, PhD; Faculty of Natural Sciences and Engineering; University of Ljubljana; Prof. Darko Bajić, PhD; Faculty of Mechanical Engineering Podgorica; University of Montenegro; Prof. Dragoslav Dobraš, PhD; Faculty of Mechanical Engineering; University of Banja Luka; Prof. Kiss Imre, PhD; University Politehnica Timisoara; Romania; Senior Scient.Eng. Milica Grahovac, PhD; Lawrence Berkeley National Laboratory USA; Prof. Doina Frunzaverde, PhD; Faculty of Engineering Resita; Babeş-Bolyai niversity; Prof. Calin Octavian Miclosina, PhD; Faculty of Engineering Resita; Babeş-Bolyai University; Prof. Gordana Stefanovic, PhD; Faculty of Mechanical Engineering; University of Niš.

CONTENT

KEYNOTE LECTURE	1
1. PROGRAMMING OF MACHINE TOOLS AND ROBOTS FOR MACHINING USING STEP-NC IN THE ERA OF INDUSTRY 4.0 Saša Živanović, Nikola Slavković	3
2. RECENT TRENDS IN ENERGY EFFICIENT AC MOTOR DRIVES Darko Marčetić	27
3. COMPARATIVE STUDIES ON THE MICROSTRUCTURE AND CORROSION BEHAVIOUR OF FORGED AND SLM PROCESSED 316L STAINLESS STEEL D. Woelk, N. Kazamer, G. Margineana	36
	<hr/>
PRODUCTION AND COMPUTER-AIDED TECHNOLOGIES	43
1. IRONING PROCESS IN CONDITIONS OF CONSTANT AND VARIABLE LATERAL FORCE S. Djacic, S. Aleksandrovic, D. Arsic, M. Delic, V. Lazic	45
2. POROSITY DISTRIBUTION IN METAL INJECTION MOLDED PARTS Samir Butković, Emir Šarić, Muhamed Mehmedović	51
3. 3D PRINTING: TECHNOLOGY, MATERIALS, AND APPLICATIONS IN THE MANUFACTURING INDUSTRY S. Đurović, D. Lazarević, Ž. Šarkoćević, M. Blagojević, J. Stanojković	55
4. EFFECTS OF SHAPE OPTIMIZATION ON THE 10 BAR TRUSS EXAMPLE N. Petrovic, N. Kostic, N. Marjanovic	61
5. EXPERIMENTAL RESEARCH OF SURFACE ROUGHNESS IN POWDER MIXED ELECTRIC DISCHARGE MACHINING D. Rodic, M. Gostimirovic, M. Sekulic, B. Savkovic, N. Kulundzic, A. Aleksic	65
6. ANALYSIS OF CUTTING FORCES IN HYBRID TURNING AIDED BY GAS COMBUSTION HEATING OF WORKPIECE B. Sredanović, Đ. Čiča, S. Borojević, S. Tešić, D. Kramar	71
7. ADVANCED METAL FORMING TOOLS AS A MAIN LINK OF DIGITAL MANUFACTURING Ilić Jovica, Milutinović Mladomir, Kraišnik Milija, Marković Milisav	77

8.	IMPROVEMENT OF BRAKE TRIANGLE THROUGH APPLICATION OF REVERSE ENGINEERING AND RAPID PROTOTYPING P. Đekić, B. Milutinović, M. Ristić, M. Pavlović, M. Nikolić	81
9.	ENERGY CONSUMPTION MODEL OF THE FACE MILLING S. Tesic, Dj. Cica, M. Zeljkovic, S. Borojevic, B. Sredanovic , G. Jotic	89
10	MODERN APPROACH IN PROCESS PLANNING AND OPTIMIZATION OF THE PRODUCT MANUFACTURING D. Lukić, M. Milošević, R. Čep, I. Kuric, M. Kljunović, M. Zagoričnik	94
11	EFFECT OF VARIOUS FLUID FLOW ON TEMPERATURE OF AN ANGULAR CONTACT BALL BEARINGS IN MOTORIZED SPINDLE M. Knežev, M. Zeljković, C. Mladenović, H. Smajić, A. Stekolschik, A. Živković	102
12	KNEE PROSTHESIS BIOMATERIAL SELECTION BY USING MCDM SOLVER D. Petković, M. Madić, G. Radenković	107
13	AN OPEN ARCHITECTURE CONTROL SYSTEM FOR MULTI-AXIS WOOD CNC MACHINING CENTER S. Živanović, Z. Dimić, A. Rakić, M. Knežević, S. Mitrović	113

	ENERGETICS AND THERMAL ENGINEERING	121
1.	MONITORING OF THERMAL STRESSES OF HOT WATER BOILER TUBE PLATE IN REGIME OF STARTING UP Dragoljub Živković, Milena Rajić, Milan Banić, Marko Mančić	123
2.	PERSPECTIVES OF HYDROPOWER POTENTIALS IN REPUBLIKA SRPSKA O. Kašiković, D. Golubović, D. Milić	133
3.	COMPUTATIONAL INVESTIGATION OF HOT AIR GENERATION SYSTEM USING PELLETS FOR DRIVING AN ABSORPTION PROCESS M. Ilić, V. Stefanović, S. Pavlović, M. Grozdanović, G. Ilić	141
4.	REVIEW OF SOLAR DISH STIRLING ENGINES FOR MICRO-COGENERATION M. Grozdanović, V. Stefanović, S. Pavlović, M. Laković-Paunović, M. Ilić, N. Tomić	147
5.	INFLUENCE OF BUILDING ENVELOPE ON BUILDING ENERGY CONSUMPTION J. Skerlić, D. Nikolić, J. Radulović, A. Radojević, M. Djordjević, A. Mišković	153

6.	EXPERIMENTAL INVESTIGATION OF HYDROGEN ENGINE WORKING CYCLE WITH A LEAN MIXTURE I. Grujić, N. Stojanović, A. Davinić, R. Pešić	159
7.	INTEGRATION OF LARGE-SCALE HEAT PUMPS IN THE DISTRICT HEATING SYSTEM OF SKOPJE Igor Shesho, Done Tashevski, Risto Filkoski, Monika Uler-Zefikj	163
8.	POSSIBILITY FOR ENERGY SAVING IN SERBIAN BUILDING WITH PHOTOVOLTAIC-THERMAL COLLECTORS D. Nikolić, J. Skerlić, J. Radulović, V. Šušteršič, A. Radojević, I. Terzić	173
9.	EXPERIMENTAL INVESTIGATIONS OF FSI MECHANISMS IN PIPELINE SYSTEMS R. Brđanin, U. Karadžić, A. Bergant, J. Ilić	180
10.	THE USE OF PASSIVE TECHNIQUES TO IMPROVE HEAT TRANSFER IN PELLET STOVE M. Jovčevski, M. Laković, F. Stojkovski, M. Jovčevski, M. Mančić, S. Pavlović	185
11.	THE IMPACT OF THERMAL POWER PLANTS ON RIVER THERMAL POLLUTION -A CASE STUDY M. Laković, M. Jovčevski, F. Stojkovski, V. Stefanović, M. Mančić, M. Rajić	192
12.	NUMERICAL INVESTIGATION OF CENTRIFUGAL PUMP WITH CYLINDRICAL BLADES AND DIFFERENT BLADE WRAP ANGLE J. Bogdanović, Jovanović, Ž. Stamenković, M. Kocić, J. Petrović	199
13.	DESIGN OF THE AIR CONDITIONING SYSTEM IN THE DATA CENTER S. Stavreva, M. Serafimov, C. Dimitrieska, K. Popovski	205
14.	THE USE FLAT PLATE COLLECTORS IN A PUMPED THERMAL ENERGY STORAGE LATENT SYSTEM S. Pavlović, E. Bellos, V. Stefanović, M. Ilić, M. Grozdanović, C. Tzivanidis	210
15.	ENERGY MANAGEMENT TO LOW-CARBON CITIES: THE EXAMPLE OF THE CITY OF KRAGUJEVAC A. Radojević, D. Nikolić, J. Skerlić, J. Radulović	216
16.	ANALYSIS OF SEASONAL DEVIATIONS INFLUENCE ON AIR-COOLED CONDENSER PERFORMANCES J. Škundrić, P. Živković, D. Mitrović, M. Vukić, D. Đurica, B. Bačić	222

17. DOMESTIC WASTEWATER TREATMENT IN THE RURAL AREAS OF THE REPUBLIC OF SERBIA N. Aleksić, V. Šušteršič, J. Nikolić, N. Rakić, D. Gordić	229
18. OPTIMIZATION OF THE COOLING SYSTEM OF THE REFRIGERATED DISPLAY CASE IN THE SUPERMARKET Ivan Rajič, Diana Bogdan, Petar Gvero	237
19. INFLUENCES ON URBAN AIR QUALITY IN THE CITY OF NIŠ P. Živković, M. Tomić, J. Janevski, M. Vukić, B. Radovanović	242
<hr/>	
MECHANICS AND DESIGN	251
1. COMPARATIVE FREE VIBRATION ANALYSIS OF FG PLATE AND FG PLATE RESTING ON AN ELASTIC FOUNDATION D. Čukanović, D. Milosavljević, G. Bogdanović, A. Radaković, N. Velimirović	253
2. PROPAGATION OF ELASTIC WAVES IN ISOTROPIC AND ANISOTROPIC MEDIA A. Radaković, D. Milosavljević, G. Bogdanović, D. Čukanović, N. Velimirović	258
3. SOLVING NONLINEAR PROBLEMS IN MECHANICS USING SIMULATION I. Terzic, M. Todorovic, S. Aleksandrov, G. Miodragovic	265
4. GEARS REPLACEMENT OF MINUTEMAN COVER DRIVE PLANETARY GEAR TRAIN J. Stefanović-Marinović, S. Troha, Ž. Vrcan, K. Marković, A. Šoljić	271
5. ESTIMATION OF THE REMAINING LIFE OF THE HIGH PRESSURE PIPELINE IN THE THERMAL POWER PLANT K. Maksimović, S. Posavljak, M. Maksimović, I. Vasović Maksimović	276
6. INFLUENCE OF CYCLOID DISK PROFILE CORRECTION ON CONTACT FORCE T. Mačkić, N. Marjanović, G. Jotić, M. Tica, Ž. Đurić	282
7. UPRIGHT AND FRAME PROTECTIVE COMPONENTS OF PALLET RACKING R. Vujanac, N. Miloradovic, L. Petrovic, P. Zivkovic	286
8. STRUCTURAL FEM ANALYSIS OF AN AIRCRAFT PISTON ENGINE CYLINDER ASSEMBLY AT ELEVATED TEMPERATURE N. Vučetić, R. Antunović, B. Krstić, D. Jeremić	291
9. FATIGUE ENDURANCE ANALYSIS OF A SURFACE STRESS RAISER Slobodanka Boljanović, Strain Posavljak, Stevan Maksimović	299

MECHATRONICS	305
1. UPGRADING OF THE HYDRAULIC SYSTEM BY INSTALLING A FREQUENCY CONVERTER J. Eric Obucina, S. Stankovski, G. Ostojic, S. Aleksandrov	307
2. A NEW CONCEPT OF ROBOTIC PLANT PROTECTION IN GREENHOUSES B. Z. Knezevic, A. Gojkovic, Z. Gajic, S. Mitric	313
AUTOMOTIVE AND TRANSPORTATION ENGINEERING	321
1. EXPERIMENTAL DETERMINATION OF THERMAL STRESSES DISK BRAKES IN DEPENDING FROM THE BRAKING PRESSURE AND VEHICLE SPEED N. Stojanović, I. Grujić, J. Glišović	323
2. POSSIBILITY OF IMPLEMENTING THE LEAN SIX SIGMA CONCEPT ON LOGISTICS PROCESSES N. Simić, A. Stanković, I. Mačužić, G. Petrović	330
3. AN OVERVIEW OF NON-EXHAUST BRAKE EMISSION MEASURING METHODS S. Vasiljević, J. Glišović, N. Stojanović, I. Grujić	339
4. APPLICATION OF HYBRID COMPOSITES BASED ON ZA27 ALLOY IN AUTOMOTIVE INDUSTRY D. Miloradović, N. Miloradović, J. Glišović, B. Stojanović, R. Vujanac	349
MATERIALS SCIENCE	355
1. OPTIMIZATION OF HYBRID ZA-27 NANOCOMPOSITES USING ANOVA AND ANN ANALYSIS S. Gajević, S. Miladinović, O. Güler, H. Çuvalcı, N. Miloradović, B. Stojanović	357
2. THERMAL PROPERTIES OF ARMOUR STEEL PROTAC 600 M. Lešnjak, B. Kosec, B. Karpe, G. Janjić, M. Gojić, J. Bernetič, G. Kosec	363
3. THE MATERIAL SELECTION OF THE HEATING PLATES USED IN THE VULCANIZATION PROCESS OBTAINED USING DIFFERENT MCDM METHODS J. Mihajlović, G. Petrović, D. Ćirić, M. Madić	367

4.	HIGH STRENGTH LOW-ALLOY STEELS IMPACT TOUGHNESS ASSESSMENT AT DIFFERENT TEST TEMPERATURES S. Bulatović, V. Aleksić, Lj. Milović, B. Zečević	375
5.	CAVITATION EROSION BEHAVIOR OF ALUMINIUM BASED ALLOYS M. Ćosić, S. Boljanović, M. Dojčinović	379
6.	INFLUENCE OF THE POLYMER MATRIX TYPE ON CAVITATION RESISTANCE OF COMPOSITES M. Dojčinović, M. Pavlović, S. Jezdimirović, B. Purić, A. Cvetković	383
<hr/>		
	QUALITY AND ECOLOGY	387
1.	ENERGY MANAGEMENT SYSTEM APPLICATION IN HEALTHCARE Milena Rajić, Rado Maksimović, Peđa Milosavljević, Dragan Pavlović	389
2.	DUST PARTICLES EMISSIONS AT STEEL CUTTING AND WELDING PROCESSES L. Cigić, B. Kosec, M. Ilić Mićunović, D. Klobčar, Z. Tanasić, B. Karpe, A. Nagode	399
3.	ANALYSIS OF ENERGY SAVING OPPORTUNITIES IN THE BUILDING, TRANSPORT AND PUBLIC LIGHTING SECTORS IN LOCAL COMMUNITIES H. Muratović, S. Midžić Kurtagić, S. Arnaut, F. Ćorović, E. Manić	405
4.	STRATEGIC ANALYSIS OF THE POSSIBILITY OF STARTING THE PRODUCTION OF FAST - GROWING PAULOWNIA TREE G. Janjić, M. Radaković, Z. Tanasić, B. Kosec, D. Kardaš Ančić	415
5.	BUSINESS PROCESS IMPROVEMENT IN THE AUTOMOTIVE INDUSTRY - QUALITY METHODS AND TOOLS Z. Tanasić, A. Jokić, G. Janjić, M. Bobrek, B. Kosec	423
6.	COMPARATIVE STUDY OF DIFFERENT OPTICAL COORDINATE MEASUREMENT SYSTEMS G. Jotić, B. Štrbac, S. Tešić, M. Hadžistević	431
7.	KNOWLEDGE MANAGEMENT AS A TOOL FOR MANAGEMENT QUALITY IMPROVEMENT M. Bobrek, Z. Tanasic, G. Janjic, K. Macanović	436
8.	CONTAMINANTS IN USED ENGINE OIL AND THEIR IMPACT ON THE ENVIRONMENT AND HUMAN HEALTH S. Rațiu, A. Josan, V.G. Cioată, I. Kiss	440

MAINTENANCE OF ENGINEERING SYSTEMS AND OCCUPATIONAL SAFETY ENGINEERING	445
1. THE INFLUENCE OF THE APPLICATION OF TECHNICAL DIAGNOSTIC ON THE EFFICIENCY OF THE INDUSTRIAL SYSTEM D. Branković, Z. Milovanović	447
2. OCCUPATIONAL INJURY ANALYSIS ACCORDING TO THE INJURED PART OF THE BODY IN THE FUNCTION OF RISK MANAGEMENT Msc Mile Vajkić, PhD Biljana Vranješ, PhD Evica Stojiljković	451
3. EXPOSURE OF PRODUCTION WORKERS TO STRESS K. Mijanović, M. Jukić, J. Mijanović-Jukić, J. Kopač	458
4. ANALYSIS OF THE CAUSES OF OCCUPATIONAL INJURIES IN A PRODUCTION SYSTEM – A CASE STUDY A. Helvida, L. Haznadarević, B. Vranješ, D. Adamović, E. Stojiljković	464



Banja Luka
28–29 May 2021.

DEMI 2021

15th International Conference on Accomplishments in Mechanical and Industrial Engineering

www.demi.mf.unibl.org



Application of hybrid composites based on ZA27 alloy in automotive industry

D. Miloradović^a, N. Miloradović^a, J. Glišović^a, B. Stojanović^a, R. Vujanac^a

^aUniversity of Kragujevac, Faculty of Engineering, Sestre Janjić 6, 34000 Kragujevac, Serbia

Abstract The field of application of ZA27 alloy is very wide due to favourable combination of physical, mechanical and tribological properties. In automotive industry, it is used for the production of engine cylinders and pistons, engine blocks, plain bearings, pumps, brakes, etc. Composites based on ZA27 alloy were developed with the aim of obtaining materials with better mechanical and tribological characteristics compared to the original matrix alloy. In this paper, special attention is given to metal matrix composites developed from ZA27 alloy with a high content of aluminium. Based on experimental research, the paper presents the tribological characteristics of hybrid composites based of ZA27 alloy and reinforced with silicon carbide and graphite particles. Experimental tribological tests were performed on a tribometer under different test conditions, by varying normal loads and sliding speeds. The obtained composites retain good mechanical properties at elevated temperatures and have better tribological properties compared to the base alloy. Application of the tested composites in the automotive industry is justified by their lower weight and high wear resistance. It directly affects the reduction of vehicle weight and gives positive economic and environmental effects.

Keywords ZA27, hybrid composites, automotive industry

1. INTRODUCTION

The automotive industry is one of the largest consumers of various kinds of raw materials. The process of material selection during product development in this industry presents a hard endeavour of balancing between demands of corporation, market and society. Modern needs for lightweight, compact and impact-resistant vehicle designs are the key factors inducing the use of alternative materials to metals in automotive applications.

Composite materials have been utilized in vehicle designs since 1945 (Stout Scarab vehicle's body structure with glass fibre reinforced plastic). Today, automotive producers are introducing new composite parts in their vehicles in order to meet the stringent emission norms, increase the fuel efficiency by reducing vehicle weight and increase the overall efficiency of vehicle manufacturing. Composites are commonly used to replace steel and other heavy materials because of their better structural and mechanical properties compared to other materials such as steel and aluminium. Use of automotive composites in Europe has increased dramatically in recent years due to the presence of the key automotive manufacturers in Germany, UK, Poland, France, and Spain. It is anticipated that Europe

Corresponding author

Ph.D. Danijela Miloradović, assoc. prof.
neja@kg.ac.rs

University of Kragujevac, Faculty of engineering
Sestre Janjić 6
Kragujevac, Serbia

automotive composites market share will grow at a compound annual growth rate (CAGR) of 6.6% from 2019 to 2026, Fig. 1 [1].

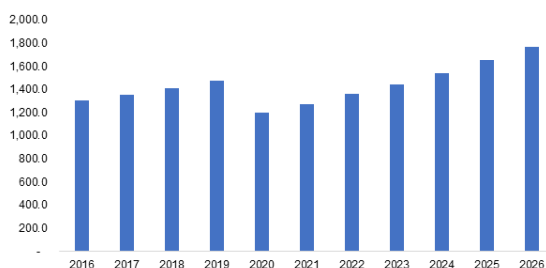


Fig. 1. Europe automotive composite market size, 2016 – 2026 (USD Million) [1]

Composite materials were majorly used for the exteriors of the vehicle (door frames, fenders, bumpers), but their application area has widened. Today, they are used in interiors, chassis, powertrain, under the hood parts and structural parts of the vehicle, Fig. 2, and provide distinct structural and weight advantages. In 2019, the biggest share in global automotive composite market (38.6%) belonged to exterior vehicle components, followed by interior components such as central console, carpets, steering wheels, cockpit modules, door panels, headliners and automotive seats [2].

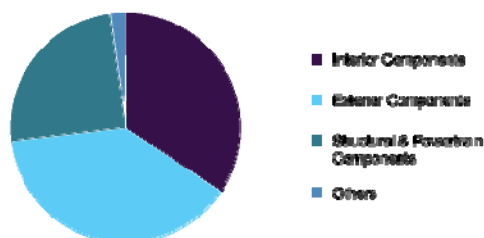


Fig. 2. Global automotive composite market share, by application, 2019 (%) [2]

Major types of composite materials which are used in automotive industry are: polymer matrix composites (PMC), metal matrix composites (MMC), ceramic matrix composite (CMC) and others (hybrid composites). In 2019, the biggest share of the automotive composite market (75.3%) had belonged to polymer matrix composites, followed by metal matrix composites and ceramic matrix composites. On the other hand, hybrid composites have gained

preference in the recent years due to their lower cost in regard to single fibre composites.

Due to their low cost and easy fabrication method, polymer composites are most frequently used in inner door panels, roof modules, flaps, lids and dashboards. They are also known for improving the crash performance of vehicles.

Ground transportation (automotive and locomotive) segment dominates the metal matrix composites market, Fig. 3, with more than 50% share. Metal matrix composites for automotive applications are based on aluminium and its alloys. They are generally used for engine components (pistons, connecting rods, cylinder blocks, and valve train parts), brake components, fins, drive shafts and bearings.

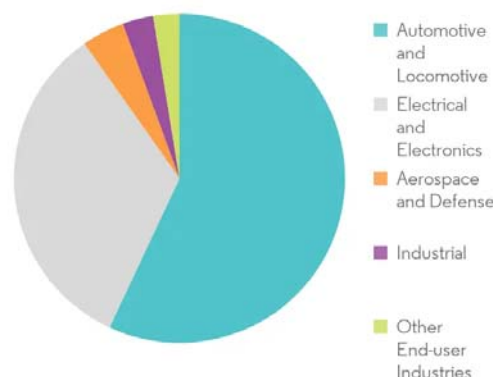


Fig. 3. Metal matrix composites market, Revenue (%), by end-user industry, global, 2020 [3]

Ceramic matrix composites have the high cost of production, but they are known for high strength, excellent corrosion and wear resistance and superior chemical and thermal resistance. Thus, their key applications in automotive industry are in brake disks, brake system components and clutches.

The largest end-use segment of hybrid composite materials market, the automotive and transportation segment, Fig. 4, is anticipated to register a CAGR of 13.9% from 2020 to 2027 [4]. Compared to automotive product made from traditional materials, hybrid composites offer higher strength, lower density, and higher impact resistance. Applications of hybrid composite materials in automotive industry include: seat backs, side and back door panels, boot liner, hat rack, spare tire lining,

windshield dashboard, business table, pillar cover panel, etc.

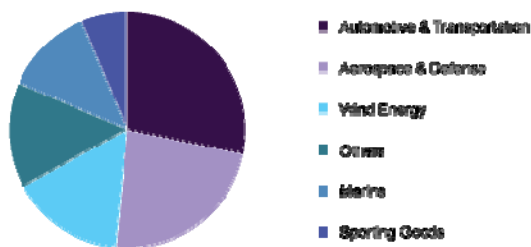


Fig. 4. Global hybrid composites market share, by end-use, 2019 [4]

2. APPLICATION OF ZA27 ALLOY AND COMPOSITES BASED ON ZA27 ALLOY

Zinc-aluminium alloys (ZA alloys) have higher concentrations of aluminium than traditional zinc alloys and have unparalleled bearing properties. Due to good mechanical characteristics (strength, hardness, toughness), ZA alloys are easy to machine and are especially suitable for the production of various types of bearings in the machine industry.

ZA27 alloy has the highest aluminium content of 27%. The basic alloying elements in ZA27 alloy are aluminium, copper and magnesium. The presence of aluminium has a favourable effect on strength and increases the fluidity of the alloy. The addition of small amounts of magnesium has a positive effect on corrosion resistance and on increasing the strength of ZA27 alloy. The presence of copper has a favourable effect on the hardness of the alloy and its tensile strength and creep resistance. ZA27 alloy is characterized by higher hardness and higher modulus of elasticity than aluminium alloy, which together with high strength provides high resistance of ZA27 alloy to abrasion and wear [5].

ZA27 alloy is also characterized by good technological properties, such as excellent castability, easy machining, good damping characteristics, the possibility of applying various surface protection procedures on castings, etc. It is very easy to machine, with minimal tool wear, resulting in items with clean and smooth surfaces.

Due to the favourable combination of physical, mechanical and technological properties, the field of application of ZA27 alloy is very wide.

ZA27 alloy has the lowest density of all ZA alloys, so its application can achieve a significant reduction in the total weight of structures (up to 60% if it replaces bronze products). In the automotive industry, grey cast iron components are increasingly being replaced by ZA27 alloy components, with a weight reduction of over 40%.

Castings made of ZA27 alloy are used in automobile engines and drive mechanisms, for the manufacture of machine tools, presses, pumps, household appliances, agricultural machinery, in the chemical, textile and construction industries, on railways, in refineries, in electric power plants, thermal power plants and foundries. Due to its good electrical and thermal conductivity, it is used in various cooling systems.

Many cast aluminium alloys are being replaced by ZA27 alloy which, in addition to high strength, also has high resistance to wear and atmospheric corrosion. This enabled the commercial application of this alloy as a significant tribo-material, primarily for the manufacture of plain bearings and sleeves.

ZA27 alloy is non-magnetic, which makes it suitable for use in electronic devices. Due to good vibration absorption, it is widely used for the manufacture of various housings.

ZA27 alloy is also acceptable from the ecological point of view, because, according to EU legislation, it is not classified as a hazardous material, which is important for its application in automotive industry.

Relatively low melting temperature of ZA27 alloys requires less energy for melting and casting, so the production costs are lower. However, the mechanical properties of the alloy deteriorate at elevated temperatures, i.e. its hardness and strength decrease. One way to reduce the deterioration of the mechanical properties of ZA27 alloy at elevated temperatures is to make composites based on this alloy.

A composite material is a compound of two or more materials with different characteristics, which has different properties with respect to the constituent components. The production of composite materials has been in continuous expansion since the 1970s. It is expected that this production will reach its maximum in the middle of the 21st century. Composites are used in the aerospace, automotive and electronic industries, medicine and construction [6].

Graphite is nontoxic and acts as a lubricant, so it is used to make composites with a ZA27 base, from which bearings, pistons of automobile and other engines and cylinder liners are produced, Fig. 5.



Fig. 5. Connecting rod and engine piston

Cheap and reliable housings of mechanisms for moving seats in vehicles, are shown in Fig. 6.

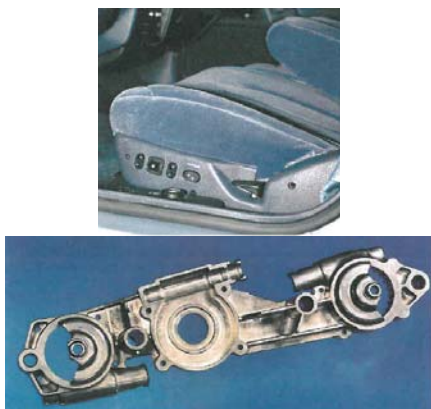


Fig. 6. Mechanism for moving the vehicle seats

The ZA27 alloy is also used for manufacture of plain bearings, gears, plain slats, worm wheels and similar parts, for which good tribological properties are required. The structural and mechanical characteristics of ZA27 alloy, which are extremely important for its application, can be influenced by heat treatment. Thus, the heat-treated ZA27 alloy can be used to make elements such as worm gears, gears, etc, Fig. 7.



Fig. 7. Manufacture of gears

High wear resistance is a consequence of the high hardness of ZA27 alloy and its natural lubricity. Thanks to this, ZA27 alloy plain bearings are increasingly used as a direct replacement for bronze bearings, especially when it comes to larger bearings, Fig. 8.



Fig. 8. Bearings for working machines

The best bearing characteristics of ZA27 alloy are found when used in conditions of high loads and low sliding speeds, with lubrication. The bearings also have improved wear characteristics, because deformation of the graphite particles results in the formation of a continuous graphite film, which provides self-lubrication of the component, allowing for improved component longevity.

3. PROPERTIES OF HYBRID COMPOSITES BASED ON ZA27 ALLOY OBTAINED BY EXPERIMENT

Due to its wide temperature range of solidification, ZA27 alloy is very suitable as a metal base for obtaining composites by the compocasting procedure.

The composting procedure is one of the most promising procedures for obtaining composites. This procedure is increasingly used in the commercial production of composite materials, given the savings in energy and material, as well as the relatively low temperature at which the process takes place [7].

The paper presents the results of testing the tribological behaviour of ZA27 alloy as well as the composite reinforced with SiC particles (ZA27+5%SiC) and the hybrid composite reinforced with SiC and Gr particles

(ZA27+5%SiC+3%Gr). Both composites are based on the ZA27 alloy.

Tribological tests were performed using a block-on-disc tribometer.

The dependences of the wear scar width on the sliding speed and the normal load for ZA27 alloy and the two observed composite materials are shown in Figs. 9 to 11, respectively.

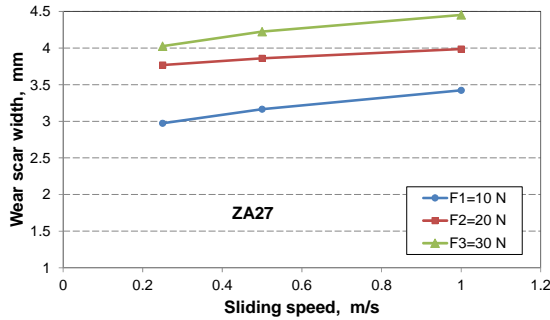


Fig. 9. Dependence of wear scar width on sliding speed for ZA27 alloy

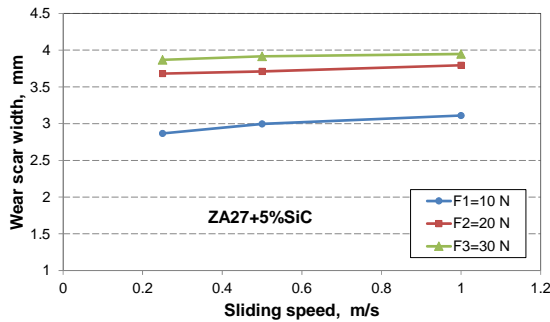


Fig. 10. Dependence of wear scar width on sliding speed for ZA27+5%SiC composite

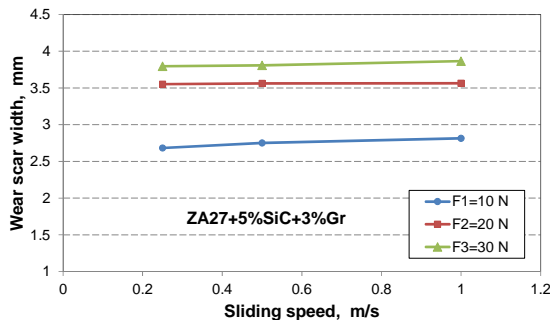


Fig. 11. Dependence of wear scar width on sliding speed for ZA27+5%SiC+3%Gr hybrid composite

The values of the wear scar widths given in the figures represent the mean values after three

tests were performed under the same operating conditions (dry sliding, normal loads of 10 N, 20 N and 30 N, sliding speeds of 0.25 m/s, 0.5 m/s and 1 m/s). It can be observed that the wear scar width increases with the increase in sliding speed and applied normal loads. This applies to all tested materials. Hybrid composite ZA27+5%SiC+3%Gr has the smallest values of wear scar widths, which means that it has the best tribological characteristics for all testing conditions.

Wear rates for all materials were obtained by calculation based on the known geometry of the contact pair and on the volumes of the worn material. Analytical and graphical dependences between the wear rate and the adopted parameters are presented in Figs. 12 to 14 [8].

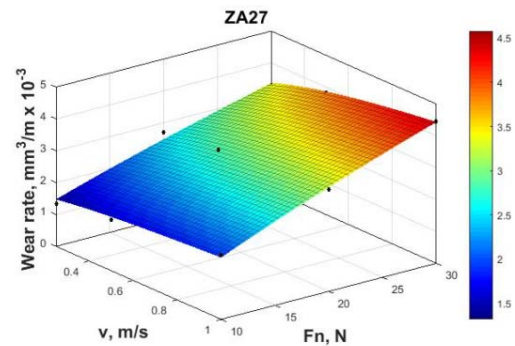


Fig. 12. The wear rate surface for ZA27 alloy

The wear rates of the tested composites are smaller than the wear rates of the ZA27 alloy for all the applied sliding speeds and normal loads.

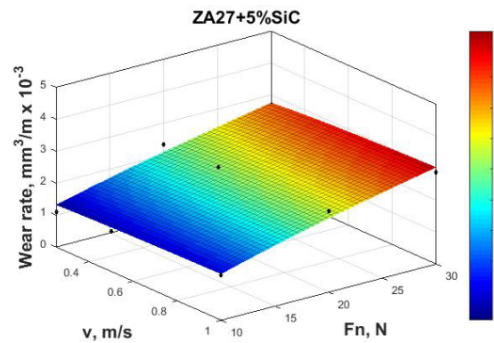


Fig. 13. The wear rate surface for ZA27+5%SiC composite

Values of the wear rates of all tested materials increase with the increase of the normal load

and also increase with the increase in the sliding speed.

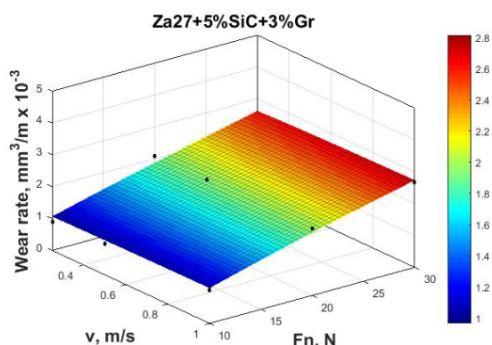


Fig. 14. The wear rate surface for ZA27+5SiC+3Gr hybrid composite

4. CONCLUSIONS

Modern automotive producers must face the challenges imposed by strict emission regulations and better fuel economy demands. Part of the solution to these problems is found in application of composite materials in vehicle design. Their properties like high-strength, wear-resistance and self-lubrication can be customized in order to obtain significant weight reductions and improved fuel efficiency of the vehicles.

Hybrid composites based on ZA27 alloy, which contain SiC particles and graphite, are materials with significant tribological potential for application in the automotive industry. Experimental research have shown that these composites are characterized with high hardness, high wear resistance and good overall tribological properties. Projections from market reports forecast the increase in use of this lightweight and high-strength alternative for traditional fiberglass and metal applications in the automotive industry.

Acknowledgement

Research presented in this paper was supported by the Ministry of education, science and technological development of the Republic of Serbia (grant TR35041).

REFERENCES

- [1] Graphical Research Report ID: GR1504. Europe Automotive Composites Market Share 2020-2026 – Covering trends. From: <https://www.graphicalresearch.com/industry-insights/1504/europe-automotive-composites-market>, accessed on: February 20, 2021.
- [2] Grand View Research Inc. Global Automotive Composite Market Size Report, 2020-2027. From: <https://www.grandviewresearch.com/industry-analysis/automotive-composites-market>, accessed on: February 20, 2021.
- [3] Mordor Intelligence. Metal Matrix Composites Market - Growth, Trends, COVID-19 Impact, and Forecasts (2021 - 2026). From: <https://www.mordorintelligence.com/industry-reports/metal-matrix-composites-market>, accessed on: February 20, 2021.
- [4] Grand View Research Inc. Hybrid composite market size - Industry report, 2020-2027. From: <https://www.grandviewresearch.com/industry-analysis/hybrid-composites-market>, accessed on: February 20, 2021.
- [5] Gangwar, S., Payak, V., Pathak, V.K., Jamwal, A., Gupta, P. (2020). Characterization of mechanical and tribological properties of graphite and alumina reinforced zinc alloy (ZA-27) hybrid metal matrix composites. *Journal of Composite Materials*, vol. 54, no. 30, p. 4889-4901. DOI: 10.1177/0021998320938442
- [6] Owoeye, S.S., Folorunso, D.O., Oji, B., Borisade, S.G. (2019). Zinc-aluminum (ZA-27)-based metal matrix composites: a review article of synthesis, reinforcement, microstructural, mechanical, and corrosion characteristics. *Int J Adv Manuf Technol*, vol. 100, p. 373-380. DOI:10.1007/s00170-018-2760-9
- [7] Miloradović, N., Stojanović, B., Nikolić, R., Gubeljak, N. (2018). Analysis of wear properties of Zn-based composites using the Taguchi method. *Materials Testing*, vol. 60, no.3, p. 265-272. DOI 10.3139/120.111142
- [8] Miloradović, N., Vujanac, R., Mitrović, S., Miloradović D. (2019). Dry Sliding Wear Performance of ZA27/SiC/Graphite Composites. *Metals - Special Issue: "Advances in Design by Metallic Materials: Synthesis, Characterization, Simulation and Applications"*, vol. 9, no. 7, p. 717. DOI: 10.3390/met9070717



ISBN 978-99938-39-92-7