



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, Ph, 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 Engineering University 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



Experimental determination of thermal stresses disk brakes in depending from the braking pressure and vehicle speed

N. Stojanović^a, I. Grujić^a, J. Glišović^a

^aUniversity of Kragujevac, Faculty of Engineering, Department for Motor Vehicles and Motors, 6 Sestre Janjić STR., 34000 Kragujevac, Serbia

Abstract *The goal is that during the process of braking stopping distance as short as possible, which is one of the important parameters of braking. During the braking process itself, a certain heat is generated on the brake disc and brake pads, which depends on the speed of movement that the vehicle had at the time of the brakes, as well as from the realized pressure in the brake installation. The purpose of this work is to find optimal braking parameters, in order to generate as less heat as possible on the disc brakes. The paper presents experimental research on a test rig BRAKE DYNO 2020, for a simulated vehicle speed of 100 km/h when the braking pressure of 2.8 MPa and 5 MPa. It is concluded that higher temperatures occur in the case when the braking pressure is 2.8 MPa, because it takes more time to stop. The results of this research can be applied in practice, in defining braking pressure.*

Keywords *braking parameters, heat, experimental research, BRAKE DYNO 2020*

1. INTRODUCTION

During the exploitation from vehicle is expecting to achieve the fastest possible desired speed, as well as to slow down or to stop for shortest possible time, all depending from road conditions. Because of this reason, the system that is the most exposed to the stresses, is the braking system. The braking system should do three basic tasks and that:

- Emergency braking – characteristic for critical situations;
- Easy long-term braking – vehicle

movement on long downhill, and

- Easy short-term braking – characteristic for city situations.

During the braking process, the entire kinetic energy transforms into the heat energy, on disc brakes. The heat energy generates in the contact between the braking disc and braking pads, as the consequence of the friction appearing. The tendency is, that the friction coefficient during the braking process be as great is possible, in order to provide as shortest possible stopping distance. However, the undesirable consequence of friction is the heat generation in the braking system.

With the temperature increment, the friction coefficient value falls [1]. However, this happens, when the temperature value on the contact surfaces passes value of 250 °C. In the case, when the temperature on the contact

Corresponding author

M.Sc., Ivan Grujić
ivan.grujic@kg.ac.rs

University of Kragujevac, Faculty of Engineering,
Department for Motor Vehicles and Motors
6 Sestre Janjić STR.
Kragujevac, Serbia

surface of the braking disc is 150 °C, the friction coefficient is biggest [2]. Important parameters from which depends, the amount of heat that generates on the contact surfaces are coefficient of heat transfer, heat flux, specific heat and heat dissipation into the environment [3].

Braking pads, during the braking process acting on the braking disc with determined force. Due this, it comes to the deformations of elements, which are in contact, which further causes the appearance of wear on the same elements. On the wear size, as well as on the size of contact temperatures are influencing loads that appear in observed moment [4], where are separating three different wear types and that:

- Slight wear;
- Moderate wear, and
- Hard wear

In more researches, the same conclusions have been obtained, that is that the temperature that was generated on the contact surfaces is not uniform [5, 6]. Because of this it comes to greater wear of contact elements. When the sliding speed is high, the temperatures that are generating on the contact surfaces are very high, which can cause the disturbances in the material [7]. The shape of hot surfaces that appearing during the braking process (Figure 1), can be separated on five types [8]:

1. Asperity – the heating appears on discrete points on the contact surface of the braking disc, are short-term character.
2. Gradients on hot bands – its appearing one long contact track, with interruptions.
3. Hot bands – are consequence of reduced contact between the braking disc and braking pads, can be present more bands.
4. Macroscopic hot spots – are representing hot spots that are deployed on the contact surface of the braking disc. Due such generated temperature on the braking disc, it can come to the braking disc twisting.
5. Regional hot spots – on the contact surfaces are appearing lower temperatures that are characteristic for nonhomogeneous cooling

By observing all five heating types, Figure 1, the greatest damages of the braking disc are appearing in the cases 2., 3. and 4. types of heating.

The aim of the paper is the investigation of the influence of the braking pressure on the size of the generated temperature on the braking disc

and braking pads, all with reason to find optimal braking parameters.

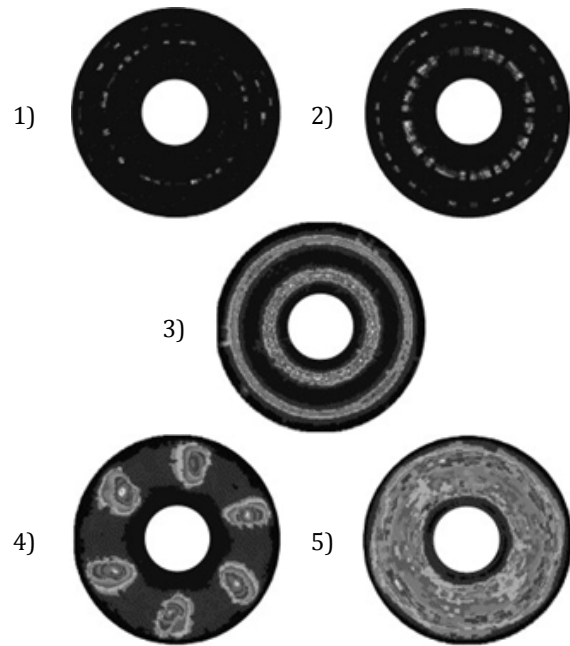


Fig. 1. Types of braking disc surface heating: 1) asperity, 2) gradients on hot bands, 3) hot bands, 4) macroscopic hot spots, and 5) regional hot spots [8]

2. THE TEST RIG WITH APPLIED DEVICES/SENSORS FOR MEASUREMENT

The experimental investigation for this paper was performed on the test rig BRAKE DYNO 2020, on the Faculty of Engineering University of Kragujevac. The scheme of the test rig for investigation of the disc brake thermal stresses can be seen on the Figure 2.

The test rig control is performing by application of the PC (11), from which command signals are sent through A/D converter 6353, to the actuators. By command signals is performing the activation of the electric motor (29) start. Also the same electric motor is controlled by AC drive (13), which also receives command signal from the PC. At the end, the signal for the activation and deactivation of the electromagnetic clutch (2), also is also sent form the PC. The activation of the brake caliper (27), is performing by braking cylinder (12), which activates by application of the pneumatic installation (9), Figure 3. The air supply for pneumatic installation is from compressor (10), which can provide maximal pressure 10 bar. The electromagnetic clutch is on one side in

rigid connection with electric motor and on other side, with the flywheel mass shaft (5). The flywheel mass is on the both side with two bearings placed on the carrying construction (22) of the test rig. While the position of the electric motor is defined by vertical adjusters (23) in order to achieve axis adjustment

between the shaft of the electric motor, and shaft of the flywheel mass. On the other side of the flywheel mass shaft is mounted braking disc (6). Where the braking calliper is in rigid connection with the calliper carrying plate (28), which is with other side relying on a force sensor (19).

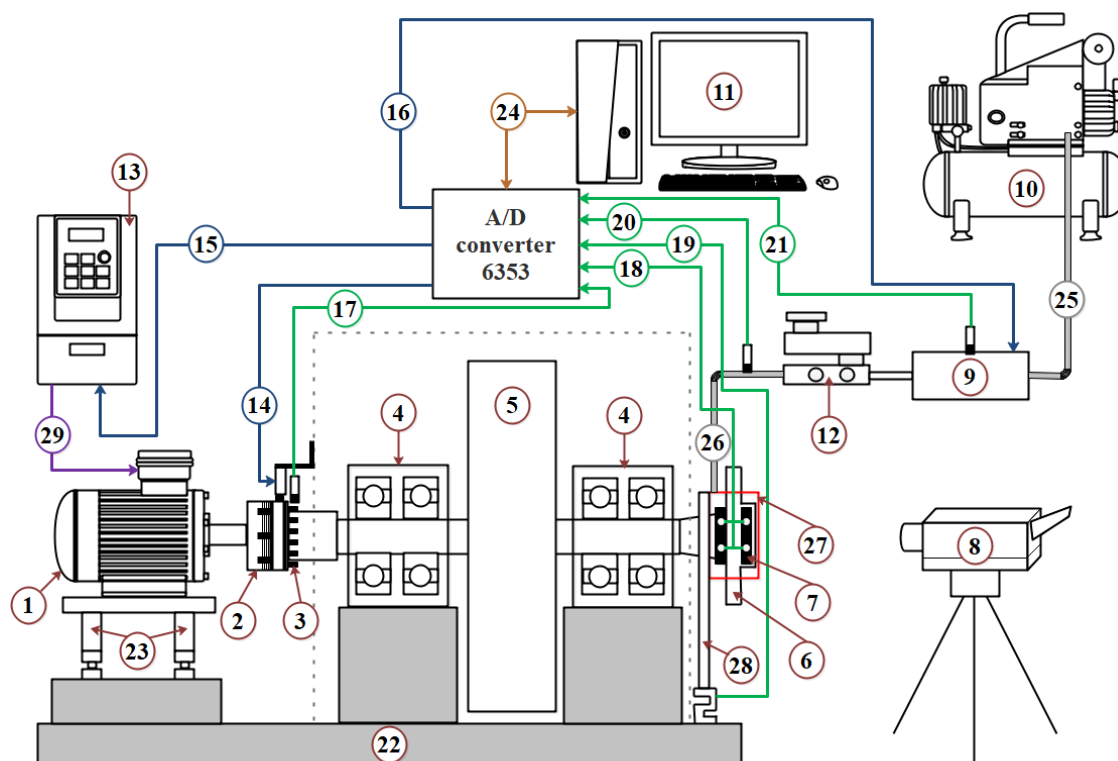


Fig. 2. The scheme of the test rig

Also, by A/D converter 6353 are collecting the measured signals from mounted sensors, which are mounted on the test rig. On the test rig, during the experimental work, are measured next parameters:

- The angular speed of the flywheel mass/braking disc (14).
- The pressure in the pneumatic installation (Figure 2 – position 21, Figure 3 – position 7).
- The pressure in the braking installation (20).
- Braking torque (19).
- Temperature in the braking pads (18).

While the temperature on the contact surfaces of the braking disc is measured by application of thermal imager TESTO 868 (8). Inside each

braking pad are located two temperature probes at 2 mm depth, from the contact surface. One is located on the entering side of the braking pad and the other on the exiting side of the braking pad

Pneumatic installation (Figure 3) consists from air conditioning group (1 and 2), 5/2 electromagnetic valve (3), with which is performing activation of the pneumatic cylinder (8). The air pressure is controlling by pressure regulator (4), while by flow control valves (5 and 6) are controlled activation and deactivation speed of the pneumatic installation.

The test rig for the investigation of the disc brake thermal stresses BRAKE DYNO 2020, is shown on the Figures 4 and 5. The Figure 4 represent the 3D model of the test rig that was

created in the CATIA software package, while Figure 5 illustrates the realized test rig.

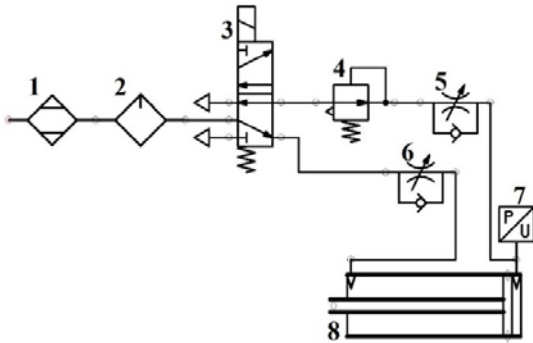


Fig. 3. The pneumatic installation for the braking system activation

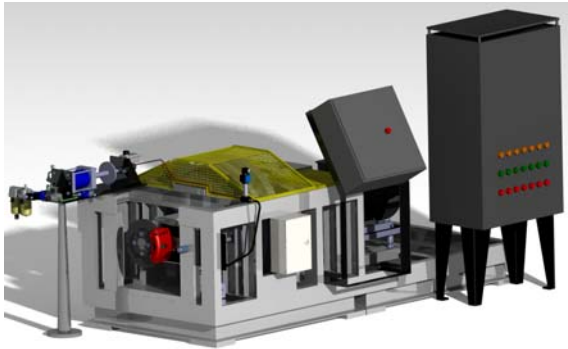


Fig. 4. 3D model of test rig BRAKE DYNO 2020



Fig. 5. The appearance of test rig BRAKE DYNO 2020

3. TESTING PROCEDURE

How the aim is to determine how the size of the braking pressure influences on the value of the generated temperature on the disc brake, is was defined testing procedure, Figure 6. First step is to define the testing conditions such are value of the braking pressure, the vehicle quarter mass

(the test rig simulates one quarter of the vehicle) and desired vehicle speed. After that are defining values which are observing during the investigation process – output parameters. The output parameters are the temperatures on braking pads and on the braking disc, deceleration, friction coefficient, the pressure changes during the stopping period and braking torque.

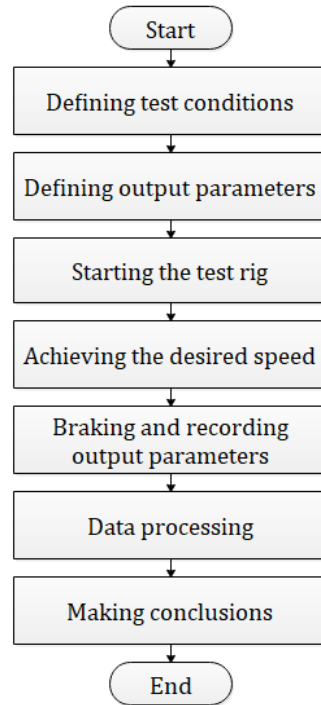


Fig. 6. Testing procedure

Next step after defining input and output parameters is the test rig starting, and after achieving the desired speed, the simulated vehicle is stopping and during the braking process are recorded the input and output parameters. After that, the measured data is processing and showing by charts, from where are coming conclusions, about thermal stresses that occurred during the braking process. While the temperature obtained by application of the thermal imager, are showing in the shape of thermal images.

4. RESULTS AND DISCUSSION

In this chapter are shown the obtained results by experimental work, according to the defined testing procedure on the test rig BRAKE DYNO 2020.

In the moment of achieving the maximal speed, the brake activates and it starts the stopping process of the simulated vehicle. According to the defined braking conditions, at the moment when starts the braking process, the electromagnetic clutch deactivates and

separates the electric motor from the flywheel mass. The maximal braking pressure in both cases was achieved after 1 s, Figures 7 and 8, and it stays almost constant during entire braking process.

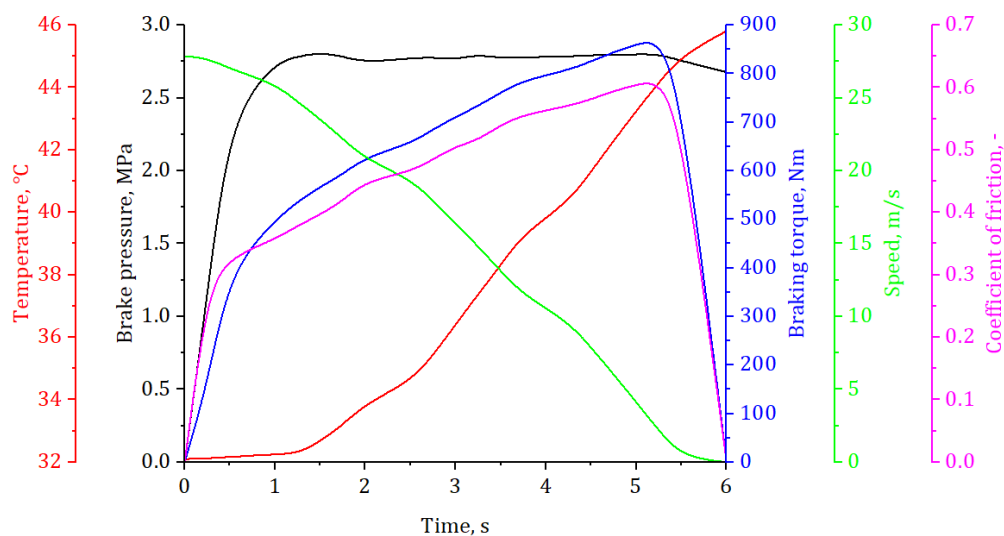


Fig. 7. Changes of braking pressure, temperature, braking torque, speed and friction coefficient in the function of time, when the maximum pressure in braking installation is 2.8 MPa

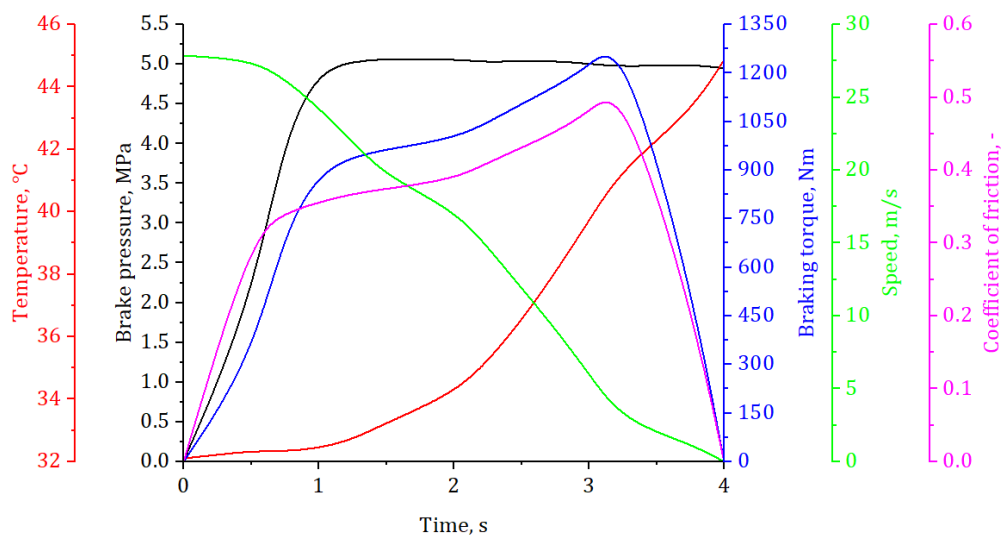


Fig. 8. Changes of braking pressure, temperature, braking torque, speed and friction coefficient in the function of time, when the maximum pressure in braking installation is 5 MPa

Maximal values of braking torque and friction coefficient are appearing when the speed of the simulated vehicle falls under 3 m/s. The temperature that was observed, is the temperature on the external braking pad, on the side that first enters in contact with the braking disc, from reason, because on it are appearing

highest values. In the first period, while vehicle speed don't falls under 20 m/s, the temperature changes are insignificant, more accurately its grown for 1.5 °. After the speed falls under the 20 m/s, the temperature change is significantly greater. In the case when is defined 5 MPa braking pressure, the temperature it's grown

for 9.7 \square . While in the case when the braking pressure is 2.8 MPa, it has grown for 11.22 \square . The reason for higher temperature in the case when the maximal braking pressure is 2.8 MPa, is because the braking time is longer, Figures 7 and 8.

The thermographic representation of the braking disc and braking pads is shown on Figures 9 and 10. Different from braking pads, greater temperatures are appearing on the braking disc. Which is very good, because only the braking disc can dissipate heat into the environment, because during the braking process, the greatest part of the braking disc rotates free in space, where on it acts only the air. How the testing was performed in stationary conditions, without air that flows around disc, the heat dissipates only because the temperature difference of the braking disc and air. Higher values of temperature on the braking disc are consequence of higher pressure in the braking installation, which is proven and in earlier researches [9, 10].

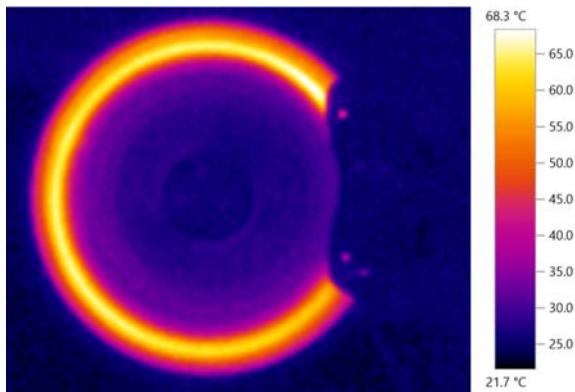


Fig. 9. The thermographic representation of the braking disc for braking pressure 2.8 MPa

the braking disc for braking pressure 5 MPa
During the braking process, when the braking pressure is 2.8 MPa, on the braking disc can be noticed hot band on the entire contact surface of the braking disc. This is not good from the aspect of the greatest damages appearing of the braking disc, which further have shorter life as the consequence [8].

However in the case when the braking pressure is 5 MPa, on the contact surface of the braking disc, can be noticed two hot bands. Which also is not good from the aspect of greatest damages appearing of the braking disc.

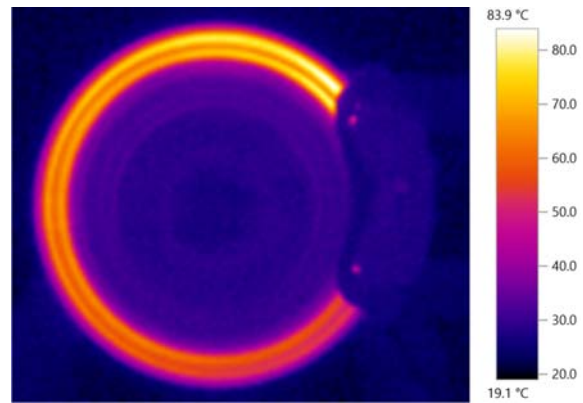


Fig. 10. The thermographic representation of

On the braking disc can be noticed that the contact surface heats more than hub, which further can cause appearance of the uneven temperature expansion, which further can led to the appearance of deformations, and at the end to breaking.

5. CONCLUSION

The stopping process is followed with appearance of temperatures generation on the braking disc and braking pads. Which further as consequence have appearance of deformations and damages. The braking pressure is very important parameter how from the aspect of traffic participants safety, where the tendency is that the stopping distance be as less as possible in the case of some critical situation, so and from the aspect of disc brake stresses. How the final temperature that was generated on braking pads is different only for 1.52 \square , the pressure in the braking installation can be 5 MPa.

Future research should include analysis of braking disc and braking pads made from alternative materials, and to investigate their influence how in normal conditions of exploitation, so in the extreme exploitation conditions.

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.

REFERENCES

- [1] Breuer, B., Karlheinz, H. B. (2012). *Bremsenhandbuch – Grundlagen, Komponenten, Systeme, Fahrdynamik, Springer Fachmedien Wiesbaden.*
- [2] Ahmed, I., Leung, P., Datta, P. (2000). Experimental Investigations of Disc Brake Friction. *SAE Technical Paper*, 2000-01-2778, DOI: [10.4271/2000-01-2778](https://doi.org/10.4271/2000-01-2778).
- [3] Ostermeyer G.P., Graf M. (2013). Influence of wear on thermoelastic instabilities in automotive brakes. *Wear*, vol. 308, iss. 1-2, p. 113–120. DOI: [10.1016/j.wear.2013.09.009](https://doi.org/10.1016/j.wear.2013.09.009)
- [4] Riahi, A.R., Alpas, A.T. (2003). Wear map for grey cast iron. *Wear*, vol. 255, iss. 1-6, p. 401–409. DOI: [10.1016/S0043-1648\(03\)00100-5](https://doi.org/10.1016/S0043-1648(03)00100-5)
- [5] Barber, J.R. (1967). The influence of thermal expansion on the friction and wear process. *Wear*, vol. 10, iss. 2, p. 155-159. DOI: [10.1016/0043-1648\(67\)90087-7](https://doi.org/10.1016/0043-1648(67)90087-7)
- [6] Hartsock, D.L., Dinwiddie, R.B., Fash, J.W., Dalka, T., Smith, G.H., Yi Y.B. (2000). Development of a high speed system for temperature mapping of a rotating target. *Proc. SPIE 4020*, p. 2-9. DOI: [10.1117/12.381533](https://doi.org/10.1117/12.381533)
- [7] Anderson, A.E., Knapp R.A. (1990). Hot spotting in automotive friction systems. *Wear*, vol. 135, iss. 2, p. 319-337. DOI: [10.1016/0043-1648\(90\)90034-8](https://doi.org/10.1016/0043-1648(90)90034-8)
- [8] Panier, S., Dufrenoy, P., Brunel, J.F., Weichert, D. (2004). Progressive waviness distortion: a new approach of hot spotting in disc brakes. *Journal of Thermal Stresses*, vol. 28, iss. 1, p. 47-62, DOI: [10.1080/01495730490498638](https://doi.org/10.1080/01495730490498638)
- [9] Stojanović, N.R., Glišović, J.D., Abdullah, O.I., Grujić, I.Lj., Vasiljević, S.Ž. (2020). Pressure influence on heating of ventilating disc brakes for passenger cars. *Thermal Science*, vol. 24, no. 1A, p. 203-214. Doi [10.2298/TSCI190608314S](https://doi.org/10.2298/TSCI190608314S)
- [10] Stojanović, N., Abdullah, O.I., Schlattmann, J., Grujić, I., Glišović, J., (2020). Investigation of the penetration and temperature of the friction pair under different working conditions. *Tribology in Industry*, vol. 42, no. 2, p. 288-298. DOI: [10.24874/ti.849.02.20.05](https://doi.org/10.24874/ti.849.02.20.05)



ISBN 978-99938-39-92-7