



UNIVERSITY OF EAST SARAJEVO
FACULTY OF MECHANICAL
ENGINEERING



4th INTERNATIONAL SCIENTIFIC CONFERENCE



COMETa2018

***„Conference on Mechanical Engineering
Technologies and Applications“***

PROCEEDINGS

27th-30th November
East Sarajevo-Jahorina, RS, B&H

COMET_a 2018

4th INTERNATIONAL SCIENTIFIC CONFERENCE

27th - 30th November 2018
Jahorina, Republic of Srpska, B&H



University of East Sarajevo
Faculty of Mechanical Engineering
Conference on Mechanical Engineering Technologies and Applications

Z B O R N I K R A D O V A

P R O C E E D I N G S

*Istočno Sarajevo – Jahorina, BiH, RS
27 - 30. Novembar 2018.*

*East Sarajevo – Jahorina, B&H, RS
27th – 30th November 2018.*

ZBORNIK RADOVA SA 4. MEĐUNARODNE
NAUČNE KONFERENCIJE
"Primijenjene tehnologije u mašinskom inženjerstvu"
COMETa2018, Istočno Sarajevo - Jahorina 2018.

PROCEEDINGS OF THE 4th INTERNATIONAL
SCIENTIFIC CONFERENCE
"Conference on Mechanical Engineering
Technologies and Applications"
COMETa2018, East Sarajevo - Jahorina 2018.

<i>Organizator:</i>	Univerzitet u Istočnom Sarajevu Mašinski fakultet Istočno Sarajevo
<i>Organization:</i>	University of East Sarajevo Faculty of Mechanical Engineering East Sarajevo
<i>Izdavač:</i>	Univerzitet u Istočnom Sarajevu Mašinski fakultet Istočno Sarajevo
<i>Publisher:</i>	University of East Sarajevo Faculty of Mechanical Engineering East Sarajevo
<i>Za izdavača:</i> <i>For publisher:</i>	Assistant professor Milija Krašnik PhD
<i>Urednici:</i> <i>Editors:</i>	Full professor Dušan Golubović PhD Assistant professor Aleksandar Košarac PhD Assistant professor Dejan Jeremić PhD
<i>Tehnička obrada i dizajn:</i> <i>Technical treatment and desing:</i>	Davor Milić, senior assistant Jelica Anić, senior assistant
<i>Izdanje:</i> <i>Printing:</i>	Prvo 1 st
<i>Register:</i> <i>Register:</i>	ISBN 978-99976-719-4-3 COBISS.RS-ID 7818520

REVIEWERS

PhD Antunović Ranko, FME UES (B&H)
PhD Banić Milan, FME Niš (Serbia)
PhD Blagojević Mirko, FE Kragujevac (Serbia)
PhD Dubonjić Ljubiša, FMCE Kraljevo (Serbia)
PhD Golubović Dušan, FME UES (B&H)
PhD Ivanović Lozica, FE Kragujevac (Serbia)
PhD Jovanović Jelena, FME Podgorica (MNE)
PhD Jovović Aleksandar, FME Belgrade (Serbia)
PhD Košarac Aleksandar, FME UES (B&H)
PhD Krašnik Milija, FME UES (B&H)
PhD Krstić Branimir, University of Defence, Military Academy (Serbia)
PhD Lozančić Silva, Faculty of Civil Engineering Osijek (Croatia)
PhD Lubura Slobodan, FEE UES (B&H)
PhD Marić Bogdan, FME UES (B&H)
PhD Marković Biljana, FME UES (B&H)
PhD Medaković Vlado, FME UES (B&H)
PhD Milovančević Miloš, FME Nis (Serbia)
PhD Milutinović Miroslav, FME UES (B&H)
PhD Milutinović Mladomir, FTS Novi Sad (Serbia)
PhD Moljević Slaviša, FME UES (B&H)
PhD Nestić Snežana, FE Kragujevac (Serbia)
PhD Orašanin Goran, FME UES (B&H)
PhD Pekez Jasmina, TF "Mihajlo Pupin" Zrenjanin (Serbia)
PhD Prodanović Saša, FME UES (B&H)
PhD Pršić Dragan, FMCE Kraljevo (Serbia)
PhD Rackov Milan, FTS Novi Sad (Serbia)
PhD Radić Nebojša, FME UES (B&H)
PhD Stanojević Miroslav, FME Belgrade (Serbia)
PhD Tabaković Slobodan, FTS Novi Sad (Serbia)
PhD Tanasić Nikola, FME Belgrade (Serbia)
PhD Tomić Mladen, FTS Novi Sad (Serbia)
PhD Tomović Radoslav, FME Podgorica (MNE)
PhD Vasković Srđan, FME UES (B&H)
PhD Vučina Adisa, FMCE Mostar (B&H)
PhD Vukelić Đorđe, FTS Novi Sad (Serbia)
PhD Zeljković Milan, FTS Novi Sad (Serbia)
PhD Žigić Miodrag, FTS Novi Sad (Serbia)
PhD Živanović Saša, FME Belgrade (Serbia)
PhD Živković Aleksandar, FTS Novi Sad (Serbia)

INTERNATIONAL SCIENTIFIC COMMITTEE

PhD Golubović Dušan, FME UES (B&H) – president

PhD Aleksandrov Sergej, Institute for Problems in Mechanics (Russia)
PhD Anđelić Nina, FME Belgrade (Serbia)
PhD Antunović Ranko, FME UES (B&H)
PhD Arsovski Slavko, FE Kragujevac (Serbia)
PhD Balasaheb M. Patre, SGGS Institute of Engineering and Technology (India)
PhD Bjelonja Izet, FME US (B&H)

PhD Blagojević Bratislav, FME Niš (Serbia)
 PhD Blagojević Mirko, FE Kragujevac (Serbia)
 PhD Bulatović Radislav, FME Podgorica (MNE)
 PhD Ciconkov Risto, Univerzitet St Kiril i Metodije (Republic of Macedonia)
 PhD Dobrnjac Mirko, FME Banja Luka (B&H)
 PhD Gašić Milomir, FMCE Kraljevo (Serbia)
 PhD I.Thirunavukkarasu, Manipal Institute of Technology (Indija)
 PhD Ivanović Lozica, FE Kragujevac (Serbia)
 PhD Jovović Aleksandar, FME Belgrade (Serbia)
 PhD Karabegović Isak, University of Bihac, Faculty of Technical Sciences (B&H)
 PhD Karapetrović Stanislav, University of Alberta (Canada)
 PhD Knežević Darko, FME Banja Luka (B&H)
 PhD Kovač Pavel, FTS Novi Sad (Serbia)
 PhD Krajcar Slavko, FER Zagreb (Croatia)
 PhD Krivokapić Zdravko, FME Podgorica (MNE)
 PhD Krstić Branimir, University of Defence, Military Academy (Serbia)
 PhD Kuzmanović Siniša, FTS Novi Sad (Serbia)
 PhD Lukić Ljubomir, FMCE Kraljevo (Serbia)
 PhD Lukić Nebojša, FE Kragujevac (Serbia)
 PhD Ljuboje Zoran, FEE UES (B&H)
 PhD Marić Bogdan, FME UES (B&H)
 PhD Marković Biljana, FME UES (B&H)
 PhD Miladinov Ljubomir, FME Belgrade (Serbia)
 PhD Milčić Dragan, FME Niš (Serbia)
 PhD Milovančević Milorad, FME Belgrade (Serbia)
 PhD Miltenović Vojislav, FME Niš (Serbia)
 PhD Milutinović Miroslav, FME UES (B&H)
 PhD Mitrović Radivoje, FME Belgrade (Serbia)
 PhD Moljević Slaviša, FME UES (B&H)
 PhD Nedić Novak, FMCE Kraljevo (Serbia)
 PhD Novak Peter, UNM FPUV (Slovenia)
 PhD Nyers Jozsef, Obuda University, Budapest (Hungary)
 PhD Ognjanović Milosav, FME Belgrade (Serbia)
 PhD Pavlović Nenad, FME Niš (Serbia)
 PhD Perić Sreten, University of Defence, Military Academy (Serbia)
 PhD Posavljak Strain, FME Banja Luka (B&H)
 PhD Putnik Goran, Univerzitet Minho (Portugal)
 PhD Radić Nebojša, FME UES (B&H)
 PhD Radovanović Radovan, Academy of Criminalistic and Police Studies (Serbia)
 PhD Rosić Božidar, FME Belgrade (Serbia)
 PhD Simić Stojan, FME UES (B&H)
 PhD Spasić Dragan, FTS Novi Sad (Serbia)
 PhD Stankovski Stevan, FTS Novi Sad (Serbia)
 PhD Stanojević Miroslav, FME Belgrade (Serbia)
 PhD Stefanović Velimir, FME Niš (Serbia)
 PhD Tanasić Zorana, FME Banja Luka (B&H)
 PhD Tanović Ljubodrag, FME Belgrade (Serbia)
 PhD Tica Milan, FME Banja Luka (B&H)
 PhD Tomić Mladen, FTS Novi Sad (Serbia)
 PhD Tomović Radoslav, FME Podgorica (MNE)
 PhD Vasković Srđan, FME UES (B&H)
 PhD Vilović Dragiša, FTS Novi Sad (Serbia)
 PhD Vučijak Branko, FME US (B&H)

PhD Vučina Adisa, FMEC Mostar (B&H)
PhD Željkoć Milan, FTS Novi Sad (Serbia)
PhD Živković Miroslav, FE Kragujevac (Serbia)

ORGANIZING COMMITTEE

PhD Krašnik Milija, FME UES – president

PhD Golubović Dušan, FME UES
PhD Košarac Aleksandar, FME UES
PhD Marković Biljana, FME UES
PhD Milutinović Miroslav, FME UES
PhD Orašanin Goran, FME UES
PhD Prodanović Saša, FME UES
PhD Radić Nebojša, FME UES
PhD Jeremić Dejan, FME UES - Technical Secretary
MSc Milić Davor, senior assistant, FME UES - Technical Secretary
MSc Anić Jelica, senior assistant, FME UES- Technical Secretary
Stanišić Vera – Secretary

GENERAL SPONSOR

Ministry of Science and Technology Republic of Srpska



SPONSORS



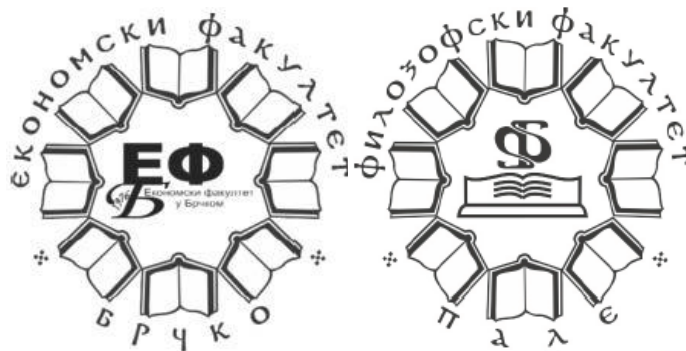
The conference has been supported by:



*International Federation for
the Promotion of Mechanism
and Machine Science*



*Association for Design,
Elements and Constructions*



KOLEKTOR

unis fabjan
FABRIKA GASNIH APARATA d.o.o. SARAJEVO

АН Инжењеринг



TERMoeLEKTRO
SINCE 1997

ECO TRADE



САРАЈЕВО-ГАС А.Д.





TEHNIČKI PREGLED VOZILA



Centrotrans®



SERVITEC BALKAN

ipCENTER
room for learning



Mješoviti holding „ERS“ - MP a.d. Trebinje

ZP „Elektrodistribucija“ a.d. Pale

PREFACE

Faculty of Mechanical Engineering East Sarajevo is organizing the 4th International Scientific Conference COMETa 2018 - "Conference on Mechanical Engineering Technologies and Applications". The aim of the conference is to contribute to the implementation of new technologies in production processes by achieving better cooperation between scientific research institutions and companies, and to enable practical application of research results presented in the proceedings.

The main objective of the conference is to bring together eminent domestic and international experts in the field of engineering and the application of new technologies and the development of mechanical systems, and to contribute increasing the competitiveness of the domestic economy through the exchange of experience and knowledge, public presentations of current research and new construction solutions.

The organization of previous conferences COMETa2012, COMETa2014 and COMETa2016, according to the assessments of participants, especially foreign colleagues, were successful.

The efforts were recognized by the Ministry of Science and Technology of the Republic of Srpska, since in May 2018 the COMETa conference was ranked among international scientific conferences of the first category.

The COMETa 2018 conference program consists of the following thematic areas:

- Manufacturing technologies and advanced materials,
- Applied mechanics and mechatronics,
- Machine design and product development,
- Energy and environmental protection,
- Maintenance and technical diagnostic,
- Quality, management and organization.

At this year's COMETa2018 conference, a record number of papers from the country and abroad have been submitted. In total 277 authors from 13 countries participates in the international conference COMETa2018, 112 papers were accepted, including 4 plenary papers. Within the COMETa2018 conference, it is planned to organize two working meetings that will focus on the current topics of the Conference.

With the desire to improve the organizational as well as the scientific effect of the Conferences, and appreciating the contributions made by the scientific community in this way, we want to emphasize that each of your suggestions is more than welcome and will be appreciated in connection with the above.

On behalf of the Organizing and Scientific Committee of the COMETa2018 conference, we would like to express our gratitude to all authors, reviewers, institutions, companies and individuals who contributed to the Conference.

Hoping that the results of our joint work will meet expectations, the organizer of the Conference, Faculty of Mechanical Engineering East Sarajevo, wants you active participation that will contribute to the development of modern ideas and solutions, in the spirit of technical and technological development of the modern world.

We wish you a pleasant stay in Jahorina. Welcome to the COMETa2018 conference.

East Sarajevo, November 21st, 2018.


President of the Scientific Committee

Full Professor Dušan Golubović, PhD



President of the Organizing Committee

Assistant Professor Milija Krašnik, PhD



CONTENT

PLENARY LECTURES

1. **Saša Živanović, Slobodan Tabaković, Milan Zeljković**
MACHINE TOOLS AND INDUSTRY 4.0 - TRENDS OF DEVELOPMENT 2
2. **Dragan T. Spasić**
A NEW APPROACH IN MODELING AND SIMULATION FOR ENGINEERING PROBLEMS 20
3. **Vojislav Miltenović, Biljana Marković**
THIRD MISSION OF UNIVERSITY - STATE, CHALLENGES, PERSPECTIVE 29
4. **Jozsef Nyers, Arpad Nyers**
LOCAL ENERGY OPTIMUM OF HOT WATER LOOP IN A HEAT PUMP HEATING SYSTEM 48

MANUFACTURING TECHNOLOGIES AND ADVANCED MATERIALS

Chairpersons: Dragiša Vilotić, Milan Zeljković, Saša Živanović, Mladomir Milutinović, Jasmina Pekez, Aleksandar Košarac

5. **Dragiša Vilotić, Milija Krašnik, Mladomir Milutinović, Dejan Movrin, Marko Vilotić, Jelica Anić, Mirko Ficko**
MATERIAL FORMABILITY AT BULK METAL FORMING, CRITERIA, METHOD OF DETERMINATION AND APPLICATION 58
6. **Dejan Lukić, Mijodrag Milošević, Aco Antić, Stevo Borojević, Mića Đurđev**
MANUFACTURING PROCESS PLANNING FOR FLEXIBLE MANUFACTURING SYSTEMS 68
7. **Aleksandar Košarac, Cvijetin Mladenović, Milan Zeljković, Lana Šikuljak**
EXPERIMENTAL METHOD FOR IDENTIFICATION THE STABILITY LOBE DIAGRA IN MILLING Č4732 STEEL 77
8. **Miloš Knežev, Aleksandar Živković, Milan Zeljković, Cvijetin Mladenović**
NUMERICAL AND EXPERIMENTAL MODAL ANALYSIS OF HIGH SPEED SPINDLE 83
9. **Obrad Spaić, Mirjana Jokanović, Aleksandra Koprivica, Miloš Lambeta, Veljko Vasiljević**
THE INFLUENCE OF THE REGIMES ON THE CUTTING TEMPERATURE 89

10. Miloš Pjević, Mihajlo Popović, Ljubodrag Tanović, Radovan Puzović, Goran Mladenović	
LAYERS OPTIMISATION OF THE PLA PARTS FORMED BY ADDITIVE TECHNOLOGIES	97
11. Borislav Savković, Pavel Kovač, Dušan Ješić, Dušan Golubović, Marin Gostimirović	
POWER CONSUMPTION MONITORING IN MILLING WITH CONSUMED ELECTRICITY	105
12. Bekir Novkinić, Aleksandar Košarac, Nebojša Radić, Milan Jurković	
LOCATING AND CLAMPING OF WORKPIECE BY ONE SURFACE	114
13. Uros Zuperl	
PLATFORM FOR SURFACE ROUGHNESS MONITORING VIA CUTTING TOOL LOAD CONTROL	125
14. Ibrahim Plančić, Edin Begović, Behar Alić	
STRENGTHENING MATERIALS IN THE FUNCTION OF DEFORMATION DEGREE DURING PROCESS COLD WIRE DRAWING	131
15. Stipo Buljan, Himzo Đukić, Darko Šunjić	
APPLICATION OF EXPLOSIVE ENERGY IN METAL FORMING TECHNOLOGIES	139
16. Dragoslav Dobraš, Milisav Marković, Saša Đurić	
INFLUENCE OF PARAMETERS OF PLASMA CUTTING TO CHANGING STRUCTURE FOR PREPARATION EDGE OF THE WELDING GROOVE	145
17. Darijo Božičković, Dragoslav Dobraš, Milisav Marković	
ANALYSIS OF THE APPLICATION OF THE MAG LOW SPATTER CONTROL FUNCTION	149
18. Jure Bernetič, Borut Kosec, Mirko Gojić, Milan Rimac, Zijah Burzić, Gorazd Kosec, Aleš Nagode	
ARMOUR STEEL PLATES OF NEW GENERATION	155
19. Belma Fakić	
CHANGES OF PHYSICO-METALIC PROPERTIES OF 16Mo3 and 13CrMo4-5 STEELS IN THE TIG WELDING PROCEDURE	162
20. Lamine Rebhi, Branimir Krstić, Boudiaf Achraf, Aderraouf Zemmour, Dragan Trifković	
STUDY OF THE INFLUENCE OF CYCLE FACTORS ON THE THERMAL FATIGUE BEHAVIOR OF ALUMINUM ALLOY 2017A	170
21. Vladimir Milovanović, Aleksandar Dišić, Vukašin Slavković, Miroslav Živković	
DETERMINATION OF TENSILE STRAIN-HARDENING EXPONENT AND STRENGTH COEFFICIENT FOR HIGH STRENGTH STEEL AT ELEVATED TEMPERATURE	181
22. Aida Imamović, Marina Jovanović, Mustafa Hadžalić, Mirsada Oruč	
THE PERSPECTIVES OF THE USE OF BLASTFURNACE SLAG AS THE REPLACEMENT OF THE NATURAL MINERAL AGREGATES IN TECHNOLOGY OF PRODUCING THE STONE WOOL	187
23. Svetomir Simonović	
ON NANOMECHANICAL PROPERTIES IDENTIFICATION BY OPTICAL TWEEZERS	195

24. Dragan Lazarević, Bogdan Nedić, Živče Šarkoćević, Ivica Čamagić, Jasmina Dedić	
THE DEVELOPMENT OF OPTICAL SYSTEMS FOR ON-MACHINE INSPECTION OF PARTS MADE WITH MACHINING PROCESS	203
25. Isak Karabegović	
FLEXIBILITY OF PRODUCTION PROCESSES IN THE AUTOMOTIVE INDUSTRY BY APPLICATION OF COLLABORATIVE ROBOTS	211
26. Uros Zuperl	
AN APPLICATION OF FOUR ROBOTS AND AN INTELLIGENT CONVEYER SYSTEM FOR AUTOMATED FIXTURING IN MACHINING	217
27. Ivan Palinkaš, Jasmina Pekez, Eleonora Desnica, Ljiljana Radovanović	
APPLICATION OF MODERN TECHNOLOGY FOR INCREASING EXPERTISE OF EMPLOYEES IN MECHANICAL INDUSTRY	221

APPLIED MECHANICS AND MECHATRONICS

Chairpersons: Novak Nedić, Stevan Stankovski, Nebojša Radić

28. Nebojša Radić, Dejan Jeremić	
INVESTIGATION OF VIBRATION RESPONSE OF ORTHOTROPIC DOUBLE-NANOPLATE SYSTEM SUBJECTED TO INITIAL IN-PLANE PRELOAD	230
29. Ranko Antunović, Goran Šiniković, Nikola Vučetić, Amir Halep	243
DIAGNOSTICS AND FAILURE OF PLAIN BEARINGS	
30. Snežana Vulović, Miroslav Živković, Rodoljub Vujanac, Jelena Živković	
SOLUTION OF CONTACT PROBLEMS USING THE FINITE ELEMENT METHOD	253
31. Radoslav Tomović, Vuk Vujošević, Marko Mumović, Aleksandar Tomović	
KINEMATIC MODEL OF ROBOT BASED ON JANSEN MECHANISM	261
32. Spasoje Trifković, Miroslav Milutinović, Saša Golijanin	
CALCULATION OF THREE SECTION PUBLIC LIGHTING POLES	269
33. Nikola Vučetić, Gordana Jovičić, Vladimir Milovanović, Branimir Krstić, Dragan Rakić, Radoslav Tomović, Ranko Antunović	
RESEARCH WITH THE AIM OF METHODOLOGY FOR THE INTEGRITY ASSESSMENT OF AIRCRAFT PISTON ENGINE CYLINDER ASSEMBLY DEVELOPMENT	277
34. Biljana Mijatović, Dejan Jeremić, Nebojša Radić	
ANALYSIS OF VIBRATION BEHAVIOUR OF SINGLE-LAYERED GRAPHENE NANOPlates USING NONLOCAL STRAIN GRADIENT THEORY	286
35. Boris Crnokić, Miroslav Grubišić	
DEVELOPMENT OF A GRAPHICAL USER INTERFACE FOR MOBILE ROBOT MOTION CONTROL	296
36. Vojislav Filipović, Vladimir Djordjević	
PREMISES PARAMETER ESTIMATION OF TS MODELS FOR RATIONAL NONLINEAR SYSTEMS WITH DISTURBANCE	304
37. Saša Lj. Prodanović, Novak N. Nedić, Ljubiša M. Dubonjić	
ON THE DIVERSITIES OF MULTIVARIABLE CONTROL SYSTEMS	312

38. **Jelena Erić Obućina, Stevan Stankovski, Gordana Ostojić, Stanimir Čajetinac, Slobodan Aleksandrov**
U/f CONTROL FOR VARIABLE SPEED THREE - PHASE AC MOTOR IN HYDRAULIC SYSTEM 320
39. **Silva Lozančić, Davorin Penava, Mirjana Bošnjak Klečina, Aleksandar Jurić**
A CASE STUDY ON INFLUENCE OF TRAFFIC-INDUCED VIBRATIONS ON BUILDINGS AND RESIDENTS 326

DEVELOPMENT OF PRODUCTS AND MECHANICAL SYSTEMS
Chairpersons: Biljana Marković, Lozica Ivanović, Milan Tica, Siniša Kuzmanović, Mirko Blagojević, Tale Geramitcioski

40. **Lozica Ivanović, Miloš Matejić**
FEM ANALYSIS OF GEROTOR MACHINES IMPELLER WITH PLANETARY MOTION 335
41. **Goran Pavlović, Mile Savković, Goran Marković, Nebojša Zdravković**
MASS-OPTIMIZED DESIGN OF THE MAIN GIRDER WITH BOX-SECTION OF THE DOUBLE-GIRDER BRIDGE CRANE WITH THE RAIL PLACED IN THE MIDDLE OF THE TOP FLANGE 343
42. **Milan Tica, Nikola Radulović, Tihomir Mačkić**
PRODUCT DESIGN CASE STUDY: CONCEPTUAL SOLUTION OF HAND DRILL/ANGLE GRINDER TABLE STAND 351
43. **Radivoje Mitrović, Marko Tasić, Žarko Mišković, Milan Tasić, Zoran Stamenić**
GENERATION OF DYNAMIC RADIAL LOAD COMPONENTS IN TESTING OF TRANSPORT ROLLERS 359
44. **Slavica Miladinović, Sandra Veličković, Blaža Stojanović, Stefan Milojević**
OPTIMIZATION OF RAVIGNEAUX PLANETARY GEAR SET 366
45. **Nebojša Rašović, Adisa Vučina, Remzo Dedić**
LIFTING TABLE DESIGN IN A LEARNING FACTORY AT UNIVERSITY OF MOSTAR 374
46. **Predrag V. Živković**
ASSESSMENT OF THE SERVICE LIFE TO DESTRUCTION OF THE GEARS PLANETARY GEAR UNITS 380
47. **Predrag V. Živković**
COMPUTATIONAL MODAL ANALYSIS OF PLANETARY GEAR UNITS 388
48. **Pugin Konstantin Georgievich**
IMPROVEMENT OF THE SYSTEM OF SAFETY OF TECHNOLOGICAL MACHINES WORKING ON THE POLYGONS OF THE DISPOSAL OF MUNICIPAL WASTE 396
49. **Lyalin E. A., Trutnev M. A.**
DISCRETE METHOD OF DOSING FREE-FLOWING CONCENTRATED FEED WITH SPIRAL-SCREWED FEEDER 401
50. **Ivan Pantić, Miloš Matejić, Mirko Blagojević**
SINGLE-STAGE CYCLOID REDUCER DYNAMIC ANALYSES USING PLM SOFTWARE 406
51. **Mirjana Bojanić Šejat, Aleksandar Živković, Ivan Knežević, Milan Rackov, Milan Zeljković**
INFLUENCE THE AMOUNT OF LUBRICATION ON DYNAMIC BEHAVIOR OF THE BALL BEARING 414

52. Rade Vasiljević	COMPARATIVE MODAL ANALYSIS OF THE SPATIAL BEAM FRAMES OF A TYPE "H" AND "X"	420
53. Milica Borisavljević, Zorica Djordjević, Sonja Kostić, Dragomir Miljanić	MODELING AND STRUCTURAL ANALYSIS OF CYLINDRICAL COIL SPRING	428
54. Milan Blagojević, Miroslav Živković, Saša Jovanović, Đorđe Marković, Sava Sretenović	CALIBRATION CERTIFICATION OF ATTRIBUTE CHECK FIXTURES FOR TUBE MANUFACTURING USING STRUCTURED LIGHT 3D SCANNERS	434
55. Biljana Marković, Marijana Krajišnik, Aleksija Đurić	DEVELOPMENT OF A RIGID CONSTRUCTION PRINCIPLE, PRACTICE EXAMPLE	442
56. Milan Rackov, Ivan Knežević, Siniša Kuzmanović, Maja Čavić, Marko Penčić	ANALYSIS OF HOUSING MODELS OF MODERN TWO-STAGE UNIVERSAL GEAR REDUCERS	450
57. Dejan Momčilović, Ivana Atanasovska, Radivoje Mitrović	DESIGN OF THE TRANSITION ZONE OF TURBINE SHAFT TO FLANGE BY BIOMIMETICS PRINCIPLES	458
58. Nenad Petrović, Nenad Kostić, Nenad Marjanović	A COMPARISON OF TRUSS STRUCTURAL OPTIMIZATION TYPES WITH AND WITHOUT BUCKLING DYNAMIC CONSTRAINTS	464
59. Saša Vasiljević, Dragan Rajković, Sonja Kostić, Jasna Glišović	MEASUREMENT THE INFLUENCE OF AIR PRESSURE ON THE EXAMPLE OF KARTING VEHICLES USING CAE TECHNOLOGY	472
60. Marko Rastija, Krešimir Vučković, Stjepan Risović	PARAMETRIC MODELLING OF SPUR GEAR WITH INVOLUTE TEETH	478
61. Tale Geramitcioski, Ljupco Trajcevski, Stefan Talevski	DESIGN OF THE MACHINE FOR PIPE SHAPING WITH BENDING	486

ENERGY AND ENVIRONMENTAL PROTECTION

Chairpersons: Dušan Golubović, Mirko Dobrnjac, Blaža Stojanović

62. Danijela Nikolić, Jasmina Skerlić, Blaža Stojanović, Radoslav Tomović, Dragan Cvetković, Saša Jovanović	ENERGY CONSUMPTION AND ECONOMIC ANALYSIS OF DIFFERENT HEATING SYSTEMS IN SERBIAN BUILDING	495
63. Gordana Tica, Danijela Kardaš, Petar Gvero	POSSIBILITY OF USE OF GEOTHERMAL ENERGY IN BOSNIA AND HERZEGOVINA	503
64. Valentino Stojkovski, Zvonimir Kostikj, Filip Stojkovski	UPGRADING A MEASURING PIPE LINE IN HEATING POWER PLANT BY CFD TECHNOLOGY	510
65. Nemanja Koruga, Mirko Dobrnjac	SOLAR SYSTEM IN COMBINATION WITH A PYROLYSIS BOILER IN THE SYSTEM OF HEAT SUPPLY OF THE BUILDING	518

66. Mirko Dobrnjac, Radoslav Grujić, Dragana Dragojević, Miloš Marković	
HEAT AND MATERIAL BALANCE OF DRYING PROCESS IN THE TUNNEL DRYER	525
67. Srđan Vasković , Zoran Radović , Krsto Batinić , Velid Halilović , Petar Gvero , Anto Gajić Maja Mrkić Bosančić	
SENSITIVITY ANALYSIS OF WOOD PELLETS SUPPLY CHAIN FOR REAL CONDITIONS CORRESPONDING TO BOSNIA AND HERZEGOVINA	534
68. Lozica Ivanović, Andreja Ilić, Aleksandar Aleksić, Miroslav Vulić	
IMPROVING THE QUALITY OF INNOVATIVE PROCESSES IN THE CONSTRUCTION OF ELV RECYCLING EQUIPMENT	544
69. Velid Halilović, Srđan Vasković, Jusuf Musić, Jelena Knežević, Besim Balić, Jasmin Softić	
INSTALLATIONS FOR THE PRODUCTION SECONDARY ENERGY SOURCES FROM WOOD WASTE – CAPACITIES AND POSSIBILITIES ON THE AREA OF ZE-DO CANTON	552
70. Natalia Nikitskaya	
THE POSSIBILITY OF USING LIQUID WASTE BIOGAS PLANT AS FERTILIZER FOR CORN	565
71. Dragutin Funda, Ema Vlahek, Goran Funda	
ENERGY EFFICIENCY AND INTERNATIONAL STANDARDS	570
72. Dragan Vujović , Pavle Popović, Dragan Protić	
ECONOMIC JUSTIFICATION OF THE USE OF SOLAR ENERGY IN THE ZLATIBOR REGION	578
73. Novak Nikolić, Nebojša Lukić, Miloš Proković, Aleksandar Nešović	
THE USE OF PV/T SOLAR COLLECTORS FOR DOMESTIC HOT WATER PREPARATION WITHIN A RESIDENTIAL HOUSE IN THE CITY OF KRAGUJEVAC (SERBIA)	586
74. Aleksandar Nešović, Nebojša Lukić, Novak Nikolić, Marko Radaković	
THE INFLUENCE OF THERMAL PARAMETERS OF DIFFERENT TYPES OF SOIL ON THE CONSUMPTION OF FINAL ENERGY FOR HEATING THE LOW-ENERGY RESIDENTIAL BUILDING AND THE INVESTMENT COST OF PLACING GEOTHERMAL VERTICAL PROBES	594
75. Saša Jovanović, Slobodan Savić, Zorica Đorđević, Danijela Nikolić, Goran Bošković	
DEFINING AN OPTIMAL CITY AND REGIONAL MUNICIPAL SOLID WASTE MANAGEMENT SYSTEM BY USING MULTI - CRITERIA DECISION MAKING METHOD	601
76. Svetlana Stevović, Slađana Mirjanić, Dušan Golubović	
INNOVATIVE BIONIC SYSTEMS IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT AND ENVIRONMENTAL QUALITY	611
77. Tanja Glogovac, Mirjana Jokanović, Nikolina Miletić	
QUALITY IMPROVEMENT OF WASTE WATER BY ADSORPTION OF LEAN AND ZINC ON METAKAOLINE	621
78. Anto Gajić, Slavica Šijaković	
MODELING TEST OF CAPLAN TURBINE	628

MAINTENANCE AND TECHNICAL DIAGNOSTICS

Chairpersons: Bogdan Marić, Ljiljana Radovanović, Ljupco Trajchevski

- | | |
|---|-----|
| 79. Ljiljana Radovanović, Jasmina Pekez, Eleonora Desnica, Ivan Palinkas, Dragoljub Ilić | |
| APPLICATION OF NON-DESTRUCTIVE METHODS IN THE | 635 |
| DIAGNOSTICS OF THE TURBINE SHAFT IN THE HYDROELECTRIC | |
| POWER PLANT | |
| 80. Miloš Milovančević, Natalija Tomić, Ana Kitić | |
| OPTIMIZED TURBO MACHINES CONDITION MONITORING MODEL | 643 |
| 81. Miloš Milovančević, Natalija Tomić, Ana Kitić | |
| FUZZY LOGIC IN MACHINE CONDITION MONITORING | 652 |
| 82. Rade Vasiljević, Dragan Pantelić | |
| REVIEW OF PERFORMED RECONSTRUCTIONS OF MECHANICAL | 663 |
| SYSTEMS | |
| 83. Miroslav Grubišić, Boris Crnokić | |
| CONNECTION MODEL OF THE ELECTRONIC CONTROL UNIT IN A | 671 |
| VEHICLE USING DATA BUSES | |
| 84. Ljupco Trajcevski, Tale Geramitchioski | |
| QUANTIFICATION OF THE DAMAGE TO THE GEAR TOOTH | 677 |
| 85. Olivera Janković, Đorđe Babić | |
| MAINTENANCE IN AIRCRAFT INDUSTRY AND DATA DRIVEN | 688 |
| MODELS | |
| 86. Goran Radoičić, Miomir Jovanović, Miodrag Arsić, Vojislav Tomić | |
| EXPERIMENTAL RESEARCH OF LIFTING MACHINES FOR | 696 |
| VERTICAL MINING TRANSPORT | |

QUALITY, MANAGEMENT AND ORGANIZATION

Chairpersons: Branko Vučijak, Galia Marinova, Slaviša Moljević, Mirsada Oruč, Zorana Tanasić, Vassil Guliashki

- | | |
|--|-----|
| 87. Robin Støckert, Vojislav Novaković, Aleksandar Košarac | |
| DESIGNING A LEARNING SPACE FOR MECHANICAL | 707 |
| ENGINEERING EDUCATION | |
| 88. Branko Vučijak, Tim Scholze | |
| KEY ENTREPRENEURIAL COMPETENCIES WITHIN THE CONTEXT | 717 |
| OF MECHANICAL ENGINEERS EDUCATION IN BIH | |
| 89. Slaviša Moljević, Ranka Gojković, Snežana Nestić, Goran Orašanin, Dino Tihčić | |
| PROCESS OF IMPROVING THE ENTREPRENEURIAL | 723 |
| COMPETENCIES | |
| 90. Vlado Medaković, Bogdan Marić | |
| ORGANIZATIONAL CULTURE AND SUCCESS OF MANAGEMENT | 729 |
| 91. Zorana Tanasić, Goran Janjić, Biljana Vranješ, Miroslav Dragić, Borut Kosec | |
| FMEA FOR ISO 9001 – RISK MANAGEMENT | 733 |
| 92. Zdravko Krivokapić, Slaviša Moljević, Budimirka Marinović, Jelena Lojović | |
| APPLICATION OF FMEA METHODS AS A UNIVERSAL METHOD | 739 |
| FOR ESTIMATE ELECTRICITY LOSS IN DISTRIBUTION COMPANIES | |

93. Jelena Jovanović, Zdravko Krivokapić, Aleksandar Vujović	
APPROACH OF THE ENTREPRENEURSHIP DEVELOPMENT AT THE UNIVERSITY OF MONTENEGRO	747
94. Bogdan Marić, Željko Batinić, Vlado Medaković	
5S AS A TOOL OF LEAN CONCEPT IN THE MACHINE PROCESSING OF PLATE MATERIALS	754
95. Darko Petković, Ibrahim Plančić, Merima Ramić	
THE LOGISTIC FUNCTIONS IMPROVEMENT OF THE TOOLROOM AND EFFECTIVE CHANGE SHEET FORMING TOOLS	762
96. Branko Popović	
INCREASING QUALITY WITH CHANGES AND TOOL REPLACEMENT	770
97. Tatjana Savić-Šikoparija, Ljubica Duđak, Tamara Kliček	
THE DIFFERENCES IN ATTITUDES REGARDING CORPORATE RESPONSIBILITY OF THE COMPANY TOWARDS THE WIDER SOCIAL COMMUNITY IN RELATION TO THE TYPE OF THE EMPLOYEES EDUCATION	779
98. Misada Oruč, Raza Sunulahpašić, Branka Muminović, Aida Imamović	
NEW EDITION STANDARD FOR COMPETENCE LABORATORY FOR EXAMINATION AND CALIBRATION	787
99. Nina Đurica, Dragan Soleša, Jovana Radulović, Maja Đurica	
STRATEGIC MANAGEMENT AND MOBILE TECHNOLOGY IMPLEMENTATION IN HIGHER EDUCATION	794
100. Vassil Guliashki, Gašper Mušič, Galia Marinova	
A HEURISTIC "MINIMAL DEVIATION" ALGORITHM FOR SOLVING FLEXIBLE JOB SHOP SCHEDULING PROBLEMS	799
101. Lana Šikuljak, Ranka Gojković, Slaviša Moljević	
STATISTICAL PROCESS CONTROL – CASE STUDY	807
102. Mirjana Jokanović, Aleksandra Koprivica, Petar Ivanković	
THE MOTIVATION IN PRIVATE AND PUBLIC SECTOR	815
103. Alexey Fominykh, Eldar Kurbanov, Marina Kurdiumova	
UNUSUAL APPLICATIONS, INTANGIBLE OUTCOMES: THE ERASMUS+ REBUS PROJECT AT VOLGA TECH	823
104. Dmitry Kaznacheev, Boris Kruk, Ekaterina Meteleva, Sophia Plakidina	
EXPERIENCE IN FORMING ENTREPRENEURIAL COMPETENCES OF STUDENTS AT THE SIBERIAN STATE UNIVERSITY OF TELECOMMUNICATIONS AND INFORMATION SCIENCES WITHIN THE FRAMEWORK OF THE EUROPEAN ERASMUS+ PROJECT «REBUS»	830
105. Predrag Petrović	
IS THE TRANSITION THEIR MANAGERS IN SERBIA AT THE BEGINNING OF XXI CENTURY JUSTIFY HOPES POPULATION	836
106. Vlastimir Pantić, Ljubomir Lukić	
CROWDFUNDING PLATFORMS AS OPPORTUNITY FOR FINANCING OF INNOVATION DEVELOPMENT	843
107. Uran Rraci, Armend Berisha	
ASSESSING THE NEED FOR VALIDATION TOOLS IN THE ICT SECTOR IN KOSOVO	847

STUDENT SESSION

Chairpersons: Davor Milić, Aleksija Đurić, Nikola Vučetić

- | | |
|--|-----|
| 108. Dušan Josipović, Nikola Kurdulija | |
| SIMULATION OF THE CAD / CAM PROGRAMMING PROCESS
SYSTEM FOR CATIA GENERAL PURPOSE | 854 |
| 109. Njegoslav Đokić | |
| INFLUENCE FRICTION COEFFICIENT OF THE BRAKING SYSTEM
AT FREIGHT MOTOR VEHICLES AND PREVENTIVE TECHNICAL
INSPECTION OF DISC BRAKE | 860 |
| 110. Nemanja Milidragović | |
| DETECTION OF LEAKAGE OF WATER IN THE WATER NETWORK
USING ACOUSTIC DEVICES | 868 |
| 111. Aleksandar Miljković, Milan Blagojević | |
| NUMERICAL SIMULATION OF EXPERIMENTAL EXAMINATION OF
IMPACT ATTENUATOR | 876 |
| 112. Aleksandar Reljić | |
| SYNHRONIZATION OF MITSUBISHI ROBOT AND CNC MACHINING
CENTER EMCO CONCEPT MILL 105 | 883 |

INDEX OF AUTORS

891

PRESENTATIONS OF COMPANIES

900



THE USE OF PV/T SOLAR COLLECTORS FOR DOMESTIC HOT WATER PREPARATION WITHIN A RESIDENTIAL HOUSE IN THE CITY OF KRAGUJEVAC (SERBIA)

Novak Nikolić¹, Nebojša Lukić², Miloš Proković³, Aleksandar Nešović⁴

Abstract: In this paper the possibility of using PV/T solar collectors for DHW preparation within a residential house in the city of Kragujevac (Serbia) was investigated. Based on the consumption profile of domestic hot water of a single family the PV/T solar system is sized to meet the demand for electricity consumed for the DHW heating during the summer season (15th of April-15th of October). The thermal behavior of the PV/T system was simulated only for the summer season, since the working medium is water. The electrical behavior of the analyzed PV/T solar system was simulated for the entire year. All simulations were performed in the EnergyPlus simulation soft-ware. Four scenarios of payback period of using PV/T solar system were investigated. All of them are defined according to the price of electricity that is saved and/or sold to the utility company: the average electricity selling price for residential houses (5.089 c€/kWh) and the electricity selling price for privileged electricity producers (20.66 c€/kWh). The first two scenarios are related to the system without solar batteries and the other two to the system with solar batteries. The most favorable scenario is scenario for which the total produced electricity is sold to the utility company for the selling price for privileged electricity producers. The payback period for this scenario is 13.7 years.

Key words: PV/T solar collector, domestic hot water, simulation, EnergyPlus.

1 INTRODUCTION

The increasing need for renewable energy sources, specifically solar energy, requires more complex research to be conducted to improve the efficiency of systems that transform solar energy. The most common solar systems are flat-plate (water) solar collectors. The men-tioned collectors transform solar energy into heat energy through

¹ Ph. D., Novak Nikolić, University of Kragujevac, Faculty of Engineering, Department for Energy and Process Engineering, Sestre Janjić 6, 34000 Kragujevac, Serbia, novak.nikolic@kg.ac.rs (CA).

² Ph. D., Nebojša Lukuć, University of Kragujevac, Faculty of Engineering, Department for Energy and Process Engineering, Sestre Janjić 6, 34000 Kragujevac, Serbia, lukic@kg.ac.rs.

³ B. S. M. E., Miloš Proković, University of Kragujevac, Faculty of Engineering, Department for Energy and Process Engineering, Sestre Janjić 6, 34000 Kragujevac, Serbia, prokovicmilos@aol.com.

⁴ B. S. M. E., Aleksandar Nešović, University of Kragujevac, Faculty of Engineering, Department for Energy and Process Engineering, Sestre Janjić 6, 34000 Kragujevac, Serbia, aca.nesovic@gmail.com.

an absorber plate with high thermal conductivity (copper, aluminum) placed in an insulated box with a flat glass cover. The main carrier of heat energy is a working fluid (water or antifreeze liquid) that passes through the absorber or absorber tubes integrated or attached to the same. Conventional flat-plate solar collectors receive a relatively low solar flux and have an average efficiency, especially at lower level of solar radiation. Many investigations have been carried out to improve a performance of flat-plate solar collectors by concentrating solar radiation using reflective surface [1, 2]. Also, one of the ways to increase the overall solar energy conversion efficiency is usage of a hybrid solar collectors (PV/T solar collectors). A PV/T solar collectors generate both electricity and thermal energy from a single aperture area. Many research has been conducted to model and improve the design of hybrid solar collectors [3-7]. Most residential water heating systems are equipped with conventional gas or electric heaters that generate heat by consuming fossil fuels or electricity. These systems are undesirable in terms of energy utilization efficiency because the overall conversion efficiency into thermal energy is relatively low [8]. In relation to this, the goal of this paper is related to the investigation of the possibility of using hybrid water solar collectors for domestic hot water preparation within a single family residential house.

2 MODEL DESCRIPTION

2.1 Description of the analyzed residential building

Isometric view of the analyzed residential building is shown in Fig. 1. The total heated floor area of the building is 118.1 m².

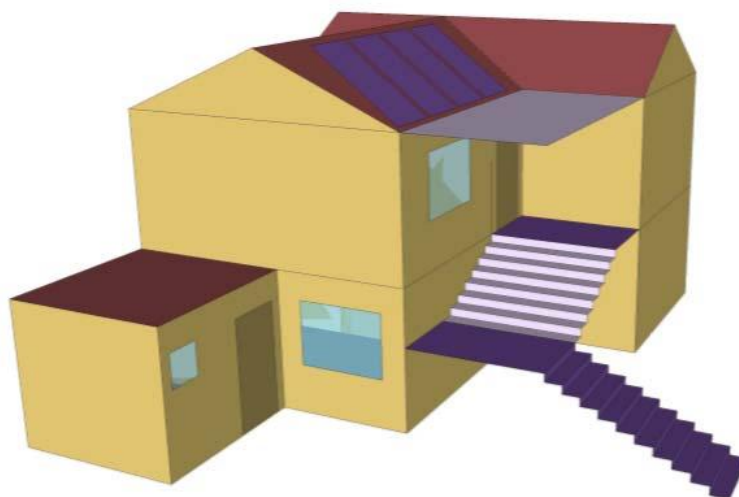


Figure 1. *Isometric view of the analyzed residential building*

The building has a total of 10 heated zones (rooms) distributed on 2 levels. It is assumed that the building located in the city of Kragujevac (Serbia) is not surrounded with any object. Total number of people that accommodates this building is four.

2.2 Description of the analyzed system for heating of domestic hot water

In this paper the possibility of using hybrid solar collectors for heating of domestic hot water was analyzed. Consumption profile of domestic hot water within the analyzed

house is given in Table 1.

Table 1. *Domestic hot water consumption*

Bathroom and kitchen	Time period [h]	Water consumption [l]
Washing, dish washing (40°C)	06:00-06:03	12
Washing, dish washing (40°C)	07:00-07:03	12
Meal preparation (40°C)	08:00-08:05	7
Meal preparation (40°C)	11:00-11:05	5
Dish washing (40°C)	16:00-16:05	30
Showering (40°C)	19:00-19:06	50
Showering (40°C)	19:30-19:36	50
Showering (40°C)	19:54-20:00	50
Face washing, brushing teeth (40°C)	22:00-22:06	6
Laundry (50°C)	21:00-23:27	49

The main components of the system for domestic hot water heating (Fig. 2) are: hybrid solar collectors (1), heat storage tank (3) and water heater (7). There are two water circulation loops. The first loop includes the solar collectors and heat storage tank, while the second circulation loop connects the storage tank, water heater and water consumers. The hot water from the heat storage tank circulates into the water electric heater which, if necessary, heats the water to the desired temperature.

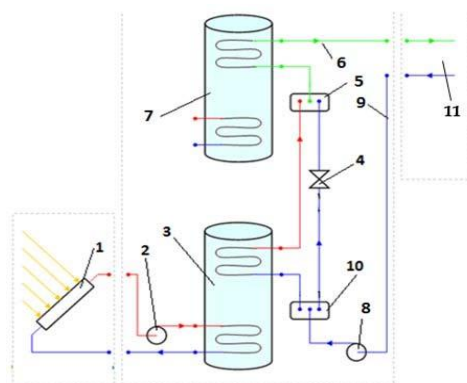


Figure 2. *Scheme of the system for domestic hot water heating: 1-hybrid solar collectors, 2-pump, 3-heat storage tank, 4-regulating valve, 5-mixer, 6-water consumer inlet, 7-water heater, 8-pump, 9-water consumer outlet, 10-splitter, 11-water consumers*

Table 2. *The sizing parameters of the water electric heater*

Parameter	Unit	Value
Maximum flow rate of the DHW during one hour	[l/s]	0.04166
Minimum allowed temperature for water in water heater	[°C]	10
Mean water temperature at the points of consumption	[°C]	45
Heat loss coefficient of the water heater	-	1.1
Thermal efficiency of the electric heater	-	0.9
Number of hours for water heating	[h]	1
Number of hours for water heater operation	[h]	1
Maximum temperature for water in water heater	[°C]	60
Factor due to unused space under the heating surface of the water heater	-	1.1
Heat capacity of the water heater (electric heater)	[W]	4000
Volume of the water heater tank	[l]	80

The heat capacity and volume of the water electric heater are determined according to the procedure described in [9]. The adopted values of the parameters needed for sizing of the water heater are given in Table 2.

The thermal and electrical power of the analyzed hybrid solar collector is determined according to the following equations:

$$Q_{TH} = A_S \cdot f_A \cdot G_T \cdot \eta_{TH} \quad (1)$$

$$P_E = A_S \cdot f_A \cdot G_T \cdot \eta_{EL} \cdot \eta_{INVERT} \quad (2)$$

It was assumed that the electric efficiency of the hybrid solar collector ($\eta_{EL} = 0.15$) is fixed throughout the year as well as the thermal efficiency ($\eta_{TH} = 0.3$). For the volume of the heat storage tank the value of 250 l was adopted. The water flow rate through the solar collector amounts 0.015 kg/sm². The PV/T solar collectors are sized to meet the demand for electricity consumed for the DHW preparation during the summer season (15th of April-15th of October). During the winter season the PV/T solar collectors produce only electric energy since the working medium within the solar collector is water. This was the limitation of the simulation software. The total surface area of the PV/T solar collectors is 6.32 m². The collector tilt angle is 37.5° and the orientation is 180°. This is the yearly optimal collector position for the city of Kragujevac, Serbia. The technical characteristics for the investigated PV/T solar collectors are summarized in Table 3 [10].

Table 3. *The technical characteristics of the single PV/T solar collector module [10]*

Electrical characteristics	
Number of cells per module	60
Cell type (dimensions)	Monocrystalline (156 mm x 156 mm)
Nominal power	250 W _p
Module efficiency	15.4%
Rated voltage	30.7 V
Rated current	8.15 A
Open circuit voltage	38.5 V
Short circuit current	8.55 A
Maximum system voltage	1000 V DC
NOCT	49°C
Thermal characteristics	
Gross area	1.66 m ²
Aperture area	1.58 m ²
Maximum temperature	74.7°C
Maximum operating pressure	1.2 bar
Average thermal efficiency	30%

2.3 EnergyPlus software

In order to simulate the thermal and electrical behavior of the investigated system for domestic hot water heating, software EnergyPlus (version 8.4.0) was used. This program is very useful tool for modeling of energy and environmental behavior of buildings and HVAC systems [11]. The EnergyPlus software takes into account all factors that influence thermal loads in the building, such as electricity devices, lighting, people occupancy, solar radiation, wind, infiltration, and shading [12]. The simulations

were conducted for real weather data for the city of Kragujevac (latitude of 44.02°N, longitude of 20.92°E, the average height of the above sea level of 209 m).

2.4 Simulation scenarios

The main goal of this investigation is analysis of application of the PV/T solar collectors for DHW preparation within a single family residential house in the city of Kragujevac. This analysis is related to the payback period of using PV/T solar collectors. The payback period is determined by the value of the investment and operating costs of the DHW heating system and by energy (money) savings achieved by using the same system. Four scenarios were investigated (Table 4). All of them are defined according to the price of electricity that is saved and/or sold to the state company for electricity generation and distribution. The first two scenarios are related to the system without solar batteries and the other two to the system with solar batteries.

Table 4. *Investigated scenarios for payback period of using PV/T solar system*

Scenario	PV/T solar system	Electricity selling price [c€/kWh]
1	PV/T solar system without batteries	5.089 (average electricity selling price for residential houses)
2	PV/T solar system without batteries	20.66 (electricity selling price for privileged electricity producers)
3	PV/T solar system with batteries	5.089 (average electricity selling price for residential houses)
4	PV/T solar system with batteries	20.66 (electricity selling price for privileged electricity producers)

3 RESULTS AND DISCUSSION

The electrical behavior of the analyzed PV/T solar system was simulated for the entire year, while the thermal behavior was simulated only for the summer season (15th of April-15th of October), since the working medium is water. The values of the produced electric energy of the hybrid solar collectors, consumed electric energy of the water heater with and without PV/T solar system are shown in Fig. 3.

As it was mentioned, the hybrid solar collectors are sized to meet the demand for electricity consumed for the DHW heating during the summer season. For this period the amount of produced electricity is higher than the consumed electricity of the DHW system that includes PV/T solar collectors. The highest and lowest value for the produced electricity is recorded in July and December, respectively. For these months the intensity of solar radiation on a tilted solar collector surfaces was the highest and lowest. The electricity consumption of the water heater without PV/T system is more than three times higher than the electricity consumption of the water heater with PV/T system. For both systems, the monthly electricity consumption is approximately the same. This is explained by the fact that it was assumed that the consumption profile of domestic hot water is the same for every day during the simulated period.

In order to determine the payback period of the investigated system for DHW preparation it is necessary to know the value of investment costs. The investment costs for every component of the PV/T system are given in Table 5. In Table 6 the comparison of four analyzed scenarios of payback period is shown.

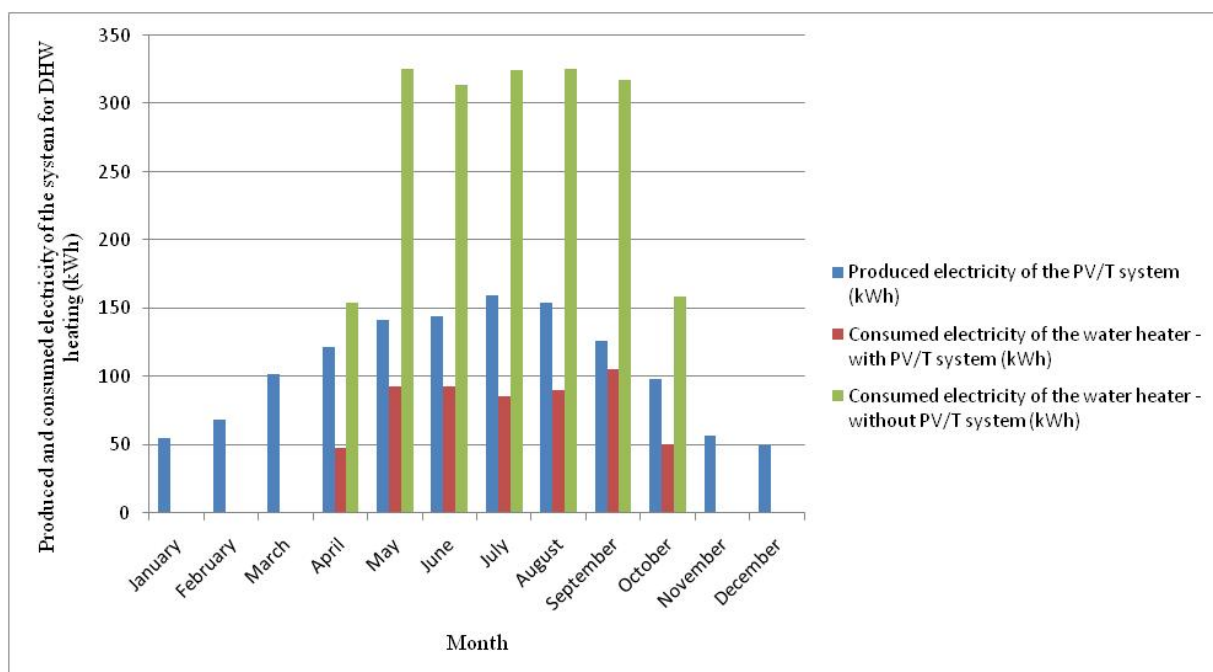


Figure 3. Monthly values of the produced electricity of the PV/T system and consumed electricity of the water heater with and without PV/T system

Table 5. Investment costs for analyzed system for DHW heating

Component	Investment costs [€]
Inverter	100 [13]
Heat storage tank	657 [14]
PV/T solar collectors	2440 [10]
Voltage controller	190 [13]
Pumps	321 [15]
Solar batteries	1360 [13]
Installation	850 [13]
Total costs for system without batteries	4558
Total costs for system with batteries	5918

Table 6. Payback period of analyzed system for DHW heating for four investigated scenarios

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Total investment costs (€)	4558	4558	5918	5918
Electricity savings (kWh)	1356.14	1356.14	1921.15	1921.15
Electricity savings (€)	69.02	69.02	97.78	97.78
Produced electricity (kWh)	1277.25	1277.25	712.24	712.24
Produced electricity (€)	65	263.88	36.25	147.15
Money savings (€)	134.02	332.9	134.03	244.93
Payback period (years)	34	13.7	44.2	24.16

It should be noted that for the first two scenarios there are costs of consumed electricity. For the scenario 1 and 2 all produced electricity is sold to the state company for electricity generation and distribution. On the other side, for the other two cases due

to solar batteries there are no costs of consumed electricity. In other words, for the scenario 3 and 4 part of the produced electricity is used for DHW heating while the excess electricity is sold to the utility company.

According to the economic analysis it can be concluded that the most favorable scenario is scenario 2, for which the total electricity produced by the PV/T solar collectors is sold to the utility company for the selling price for privileged electricity producers. The payback period for this scenario is 13.7 years. For the city of Kragujevac (Serbia), the electricity selling price for privileged electricity producers is approximately four times higher than the average electricity selling price for residential houses. The payback period for the scenario when total produced electricity is sold for the average electricity selling price for residential houses (scenario 1) amounts 34 years. If the system for DHW heating included batteries for electricity storage the payback period would amount 44.2 years for the scenario 3 and 24.2 years for the scenario 4. The values for the payback period would be certainly lower in the case of higher electricity consumption (more expensive tariff rates), higher electricity selling price, lower investment costs as well as higher values of the thermal and electrical efficiency of a PV/T solar collectors.

4 CONCLUSIONS

In this paper the possibility of using PV/T solar collectors for heating of domestic hot water within a residential house in the city of Kragujevac (Serbia) was investigated. Based on the consumption profile of domestic hot water of a single family the PV/T solar system is sized to meet the demand for electricity consumed for the DHW heating during the summer season (15th of April-15th of October). The thermal behavior of the PV/T system was simulated only for the summer season, since the working medium is water. The electrical behavior of the analyzed PV/T solar system was simulated for the entire year. All simulations were performed in the EnergyPlus simulation software. Four scenarios of payback period of using PV/T solar system were investigated. All of them are defined according to the price of electricity that is saved and/or sold to the utility company. The first two scenarios are related to the system without solar batteries and the other two to the system with solar batteries. The most favorable scenario is scenario for which the total produced electricity is sold to the utility company for the selling price for privileged electricity producers (20.66 c€/kWh). The payback period for this scenario is 13.7 years. The most unfavorable scenario (44.2 years) is the scenario 3. This scenario relates to the PV/T system that consists of solar batteries and for which the excess produced electricity is sold for the average electricity selling price for residential houses (5.089 c€/kWh). The higher values of the electricity selling price, lower values of the investment costs and higher values of the thermal and electrical efficiency of a PV/T solar collectors. would certainly reduce the value of the payback period.

ACKNOWLEDGMENTS

This investigation is a part of the project TR 33015 of the Technological Development of the Republic of Serbia and project III 42006 of Integral and Interdisciplinary investigations of the Republic of Serbia. We would like to thank the Ministry of Education, Science and Technological Development of the Republic of Serbia for their financial support during this investigation.

NOMENCLATURE (10 PT BOLD, UPPERCASE, Spacing Before 18 pt, After 6 pt)

Q_{TH} thermal power of the hybrid solar collector, W
 A_s gross area of the hybrid solar collector, m²

- f_A fraction of the surface with active PV/T solar collector
 G_T intensity of the instantaneous solar radiation on a tilted solar collector surface, W/m^2
 η_{TH} thermal efficiency of the hybrid solar collector;
 η_{EL} electrical efficiency of the hybrid solar collector;
 η_{INVERT} conversion efficiency from direct to alternating current ($\eta_{invert} = 1$).

REFERENCES

- [1] Nikolić, N., Lukić, N. (2013). A mathematical model for determining the optimal reflector position of a double exposure flat-plate solar collector, *Renewable Energy*, 51, 292-301.
- [2] Nikolić, N., Lukić, N. (2015). Theoretical and experimental investigation of the thermal performance of a double exposure flat-plate solar collector, *Solar Energy*, 119, 100-113.
- [3] Sotehi, O., Chaker, A., Maalouf, C. (2016). Hybrid PV/T water solar collector for net zero energy building and fresh water production: A theoretical approach, *Desalination*, 385, 1-11.
- [4] Dubey, S., Tiwari, G.N. (2008). Thermal modeling of a combined system of photovoltaic thermal (PV/T) solar water heater, *Solar Energy*, 82, 602-612.
- [5] Rosell, J.I., Vallverdú, X., Lechón, M.A., Ibáñez, M. (2005). Design and simulation of a low concentrating photovoltaic/thermal system, *Energy Conversion and Management*, 46, 3034–3046.
- [6] Koronaki, I.P., Nitsas, M.T. (2018). Experimental and theoretical performance investigation of asymmetric photovoltaic/thermal hybrid solar collectors connected in series, *Renewable Energy*, 118, 654-672.
- [7] Mellor, A., Alonso Alvarez, D., Guarracino, I., Ramos, A., Riverola Lacasta, A., Ferre Llin, L., Murrell, A.J., Paul, D.J., Chemisana, D., Markides, C.N., Ekins-Daukes, N.J. (2018). Roadmap for the next-generation of hybrid photovoltaic-thermal solar energy collectors, *Solar Energy*, 174, 386-398.
- [8] Kim, T., Choi, B.-I., Han, Y.-S., Do, K.H. (2018). A comparative investigation of solar-assisted heat pumps with solar thermal collectors for a hot water supply system, *Energy Conversion and Management*, 172, 472-484.
- [9] Recknagel, H., Sprenger, E., Schramek, E.-R., Taschenbuch für Heizung und Klimatechnik, R. Oldenbourg Verlag GmbH, München, 2001.
- [10] www.dualsun.fr, accessed 11.10.2017.
- [11] Lukić, N., Nikolić, N., Timotijević, S., Tasić, S. (2017), Influence of an unheated apartment on the heating consumption of residential building considering current regulations - Case of Serbia, *Energy and Buildings*, 155, 16-24.
- [12] Crawley, D.B., Lawrie, L.K., Winkelmann, F.C., Buhl, W.F., Huang, Y.J., Pedersen, C.O., Strand, R.K., Liesen, R.J., Fisher, D.E., Witte, M.J., et al. (2001). Energyplus: creating a new-generation building energy simulation program, *Energy and Buildings*, 33, 319 - 331.
- [13] <http://www.solarni.rs>, accessed 01.11.2017.
- [14] <https://www.suncica.rs/solarni-kolektori-oprema/prohromski-solarni-bojler-250-l-elit-inox.html>, accessed 01.11.2017.
- [15] <http://www.etazgrejanje.com/katalog/solarna-pumpna-grupa-269-caleffi/>, accessed 01.11.2017.