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Faculty of Mechanical Engineering



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CONTENT
KEYNOTE LECTURES

Vencislav Grabulov

LOADING RATE EFFECT ON FRACTURE RESISTANCE OF ARMOUR STEELS WELDMENTS 3

Slavko Krajcar

THE FUTURE OF POWER SYSTEM 11

PRODUCTION AND COMPUTER-AIDED TECHNOLOGIES

Zivanovic Sasa, Dimic Zoran, Vorkapic Nikola, Mitrovic Stefan

CONFIGURING OF 3 AXIS MINI CNC MACHINE TOOL WITH CONTROL SYSTEM
BASED ON LINUXCNC 15

Hasan Smajic, Faruk Bađci

MODELLING AND DESIGN OF DISTRIBUTED CONTROL SYSTEM BASED ON
INDUSTRIAL SOFTWARE AGENT 29

Milija Kraišnik, Jovica Ilić, Goran Jotić, Tihomir Mačkić, Jelica Anić

COMPARING THE ACCURACY OF MASTER MODEL AND THEIR REPLICAS
PRODUCED BY RAPID TOOLING USING VACUUM CASTING 37

Aleksandar Živković, Miloš Knežev, Milan Zeljković, Milivoje Mijušković

STATIC ANALYSIS OF FOUR-POINT CONTACT BALL BEARINGS FOR AGRICULTURAL
MECHANIZATION 43Andjelko Aleksic, Milenko Sekulic, Borislav Savkovic, Marin Gostimirovic,
Ilija Kamenko, Pavel Kovac

OPTIMIZATION OF CUTTING PARAMETERS BY NATURE-INSPIRED ALGORITHMS 51

Slobodan Tabaković, Milan Zeljković

PREDICTION OF POSITIONING ACCURACY PARAMETERS 57

Dušan Petković, Miloš Madić, Goran Radenković, Predrag Živković

AN EXAMPLE OF MCDM SOLVER APPLICATION FOR MATERIAL SELECTION PROBLEMS 65

Adnan Mustafić, Mirza Krajnović, Džemal Kovačević, Edis Nasić, Jasmin Halilović

SELECTION OF OPTIMAL PROCESSING CONDITION DURING HELICAL
COMPRESSION SPRING PRODUCTION USING THE GREY BASED TAGUCHI METHOD 71

Ostoja Miletić, Mladen Todić

THE EFFECT OF CONTACT SURFACES ON ENERGY PARAMETERS OF PROCESS
PROFILING 81

Mladen Todic, Ostoja Miletic, Sead Pašalić

ZONE OF THE STRESS AND OF THE STRAINS WHEN BENDING LAMINARY COMPOSITES 89

Dejan Lukić, Mijodrag Milošević, Mića Đurđev, Jovan Vukman, Ivan Kuric, Aco Antić

APPLICATION OF THE MULTI-CRITERIA DECISION MAKING IN THE PRODUCT
DEVELOPMENT PROCESS 97

Dragan Lazarević, Bogdan Nedić, Živče Šarkoćević, Ivica Čamagić, Jasmina Dedić

METHODS OF INTEGRATING MODERN MEASURING DEVICES ON MACHINING SYSTEMS 105

Mladomir Milutinović, Tomaž Pepelnjak, Dejan Movrin, Plavka Skakun, Marko Vilotić, Saša Ranđelović EFFECTS OF MATERIAL PROPERTIES AND BLANK HOLDER PRESSURE ON FORMING LOAD IN DEEP DRAWING OF BOX LIKE COMPONENTS	113
Srbislav Aleksandrovic, Djordje Milosavljevic ACCURACY OF PURE COPPER FLOW CURVES DETERMINATION IN COMPRESSION TESTS	119
Saša Ranđelović, Mladomir Milutinović, Dejan Tanikić, Vladislav Blagojević THE TECHNOLOGY OF TUBE HYDROFORMING AND PARAMETERS PROCESS	125
Cica Djordje, Tesic Sasa, Sredanovic Branislav, Borojevic Stevo INVESTIGATION OF THE EFFECTS OF THE CUTTER PATH STRATEGIES ON MACHINING TIME AND SURFACE ROUGHNESS IN THREE-AXIS SCULPTURED SURFACE MACHINING	131
Zdravko Bijelić, Jelena Petrović, Biljana Milanović RESEARCH OF THE POSSIBILITY AND LIMITATION OF THE REVITALIZATION OF THE PRODUCTION OF WEAPONS AND MILITARY EQUIPMENT IN THE REPUBLIC OF SRPSKA	139
Hasan Smajic, Jean Bosco, Fraz Ahmad SIMULATION TOOLS FOR VIRTUAL PLC-TESTING IN EXTRUSION PROCESS	145
Clemens Faller, Tobias Theis, Max Born, Ferdinand Heinemann, Stefan Bäunker, Philipp Stenkamp CONTROL-SYSTEM-ALGORITHM IMPLEMENTED WITH NODE-RED AND OPC-UA	153
ENERGETICS AND THERMAL ENGINEERING	
Nebojša Manić, Bojan Janković, Dragoslava Stojiljkovića, Vladimir Jovanovića, Miloš Radojević, Blanca Castells Somoza EVALUATION OF SPONTANEOUS IGNITION POTENTIAL FOR SOLID BIOMASS THROUGH THERMAL ANALYSIS	163
Igor Shesho, Martina Blazheska, Nebojša Vasikj, Done Tashevski, Filip Mojosovski PERFORMANCE EVALUATION OF MICRO ORC SYSTEMS FOR POWER GENERATION IN NEARLY ZERO ENERGY BUILDINGS (NZEB)	173
Miodrag Arsić, Srđan Bošnjak, Vencislav Grabulov, Dušan Arsić, Zoran Savić PREDICTION OF SERVICE LIFE OF COMPONENTS AND STRUCTURES OF HYDRO POWER PLANTS DURING THE DESIGN, PROTOTYPING AND SERVICE PERIOD	183
Sanda Midžić Kurtagić, Samra Arnaut, Šejla Mahmutović ANALYSIS OF POSSIBILITIES FOR EXPANDING DISTRICT HEATING SYSTEM TO INDIVIDUAL HOUSES IN CANTON SARAJEVO	189
Radislav Brđanin, Jovan Ilić, Uroš Karadžić, Anton Bergant EXPERIMENTAL WATER HAMMER SETUP AT UNIVERSITY OF MONTENEGRO – DESCRIPTION AND POSSIBILITIES	195
Kire Popovski, Sevde Stavreva, Ivo Kuzmanov, Igor Popovski MATHEMATICAL MODEL FOR COMPUTER SIMULATION FOR SELECTION OF THE ORDER FOR THE LAYERS FROM THE WALL OF INDUSTRIAL COOLERS	201

Aleksandar Nešović, Vanja Šušteršič, Nebojša Lukić, Novak Nikolić, Ivana Terzić OPTIMIZATION OF THE FREE FACADE OF THE EARTH-SHELTERED HOUSES IN ORDER TO MINIMIZE THE FINAL ENERGY CONSUMPTION DURING THE HEATING SEASON	209
Jovan Ilić, Ivan Božić, Uroš Karadžić, Radislav Brđanin COMPARATIVE ANALYSIS OF THE HYDROPOWER PLANT TRANSIENT PROCESSES FOR VARIOUS SURGE TANK TYPES AND IMPROVED GUIDE VANES CLOSING LAW	215
Ivana Terzic, Danijela Nikolic, Vanja Sustersic, Jasmina Skerlic, Vladimir Vukasinovic PHOTOVOLTAIC THERMAL SYSTEMS – DESIGN AND BUILDING APPLICATION	223
Jasmina Bogdanović-Jovanović, Živojin Stamenković, Živan Spasić, Miloš Kocić, Jelena Petrović CALCULATION OF MERIDIAN STREAMLINES FOR AVERAGED FLOW PARAMETERS IN LOW PRESSURE AXIAL FANS	229
Vladimir Mijakovski, Filip Mojsovski, Monika Lutovska ANALYSIS OF VALUES FROM THE CLIMATIC CURVE AND HEAT LOAD ON THE WATER LOSSES IN TPP 'BITOLA'	235
Natalija Aleksić, Vanja Šušteršič, Dušan Gordić, Danijela Nikolić, Nikola Rakić REDUCTION OF WATER CONSUMPTION IN WASTE WATER TREATMENT SYSTEMS IN THE AUTOMOTIVE INDUSTRY	241
Filip Mojsovski, Vladimir Mijakovski THERMAL CAPABILITY OF HYPERBOLIC COOLING TOWER	247
Sanda Midžić Kurtagić, Šejla Mahmutović, Melina Džajić Valjevac ENERGY RECOVERY POTENTIAL OF WASTE FROM CANTON SARAJEVO	255
Viktor Iliev, Marija Lazarevikj, Zoran Markov ANALYSIS OF THE PRESSURE DISTRIBUTION AROUND NACA 0015 AIRFOIL IN OPEN WIND TUNNEL	261
Velimir Stefanović, Bojan Drobnjaković, Sasa Pavlović TECHNICAL PERFORMANCE OF A DEEP BOREHOLES HEAT EXCHANGERS	267
Svetlana Dumonjić-Milovanović, Petar Gvero DYNAMIC THERMAL CHARACTERISTICS OF COMPOSITE BUILDING ELEMENTS AND THEIR IMPACT ON THE DECREASE OF INTERNAL TEMPERATURE IN CONDITIONS OF THE HEATING INTERRUPTION	273
Danijela Kardaš, Petar Gvero, Mirko Komatina, Gordana Tica COMPARATIVE ANALYSIS OF WASTEWATER AND SOLAR ENERGY AS RENEWABLE ENERGY SOURCES	279
Dragana D. Temeljovski, Milena B. Blagojević, Bratislav D. Blagojević, Marko G. Ignjatović RESIDENTIAL BUILDINGS REFURBISHMENT TOWARD NZEB IN SERBIA	287
Vidosava Vilotijević, Uroš Karadžić, Ivan Božić, Jovan Ilić DESIGN DISCHARGE DETERMINATION FOR SHPPs WITH CAPACITY BELOW 1 MW	297
Sanda Midžić Kurtagić, Petar Gvero, Milovan Kotur, Fejsal Ćorović TOWARDS ENERGY EFFICIENCY IN BUILDINGS –A STRATEGIC APPROACH TO BUILDING RENOVATION IN BOSNIA AND HERZEGOVINA	303

Content

Predrag Živković, Mladen Tomić, Dragana Dimitrijević Jovanović, Dušan Petković, Jelena Janevski, Mirko Dobrnjac EXPERIMENTAL STUDY RAYLEIGH-BÉNARD CONVECTION IN A RECTANGULAR ALCOHOL TANK	309
Marko Đekić, Esad Tombarević, Igor Vušanović LONG TERM PERFORMANCE OF BUILDING WITH VERTICAL GROUND COUPLED HEAT PUMP SYSTEM	317
Marko Ilić, Velimir Stefanović, Gradimir Ilić PRELIMINARY COMPUTATIONAL ANALYSIS OF A BIOMASS DRIVEN STOVE FOR ABSORPTION HEAT PUMP	323
Branislav Stojanović, Jelena Janevski, Milica Ljubenović, Marko Ignjatović, Dejan Mitrović SPACE HEATING ENERGY SAVINGS IN RESIDENTIAL BUILDINGS WITH VARIABLE OCCUPANCY	329
Veljko Begović, Živan Spasić, Saša Milanović ANALYSIS AND DETERMINATION OF THE PERFORMANCE OF CENTRIFUGAL PUMP USING NUMERICAL SIMULATIONS	335
Živan Spasić, Miloš Jovanović, Jasmina Bogdanović-Jovanović, Veljko Begović, Miloš Kocić EFFECTS OF THE IMPELLER REDUCTION ON A CENTRIFUGAL PUMP PERFORMANCE	341
Damijan Cerinski, Jakov Baleta, Martina Lovrenić-Jugović UTILIZING A NEURAL NETWORK MODELLING APPROACH IN THE FIXED BED BIOMASS GASIFIER	347
Katarina Jovanović, Jovan Milić, Mirjana Laković FURNITURE PRODUCTION AND WASTE BIOMASS – POSSIBILITIES FOR THE USE OF WASTE BIOMASS	353
MECHANICS AND DESIGN	
Milicevic Jovana, Djordjevic Zorica, Kostic Sonja, Jovanovic Sasa MODELING AND STRUCTURAL ANALYSIS OF SCOOTER'S PARTS MADE OF COMPOSITE MATERIALS	361
Srđan Bulatović, Živče Šarkoćević, Mladen Mladenović MECHANICAL PROPERTIES OF WELDED PIPES PRODUCED BY HIGH FREQUENCY WELDING OF THE STEEL API J55	367
Nedeljko Vukojević, Josip Kačmarčik, Alma Žiga, Nedeljko Babić, Nemanja Tanasijević DESIGN OF STIFFENERS FOR INDUSTRIAL PIPING UNDER EXTERNAL PRESSURE USING FEM	373
Nadica Stojanovic, Oday I. Abdullah, Ivan Grujic, Jasna Glisovic, Sasa Vasiljevic STUDY THE EFFECT OF VANES SHAPE ON THE CONVECTIVE COOLING OF THE VENTILATED BRAKE DISC	379
Tihomir Mačkić, Goran Jotić, Milan Tica, Jovica Ilić MECHANICAL PROPERTIES OF MODIFIED FLIPWING HYDROKINETIC TURBINES	385

Vlada Gašić, Aleksandra Arsić, Milorad Pantelić, Dejan Kočović CONSIDERATION OF STRUCTURAL ELEMENTS CHARACTERISTICS ON THE STRESSES AT THE I-BEAM END-PLATE MOMENT CONNECTION	391
Aleksandar Radaković, Dragan Milosavljević, Gordana Bogdanović, Milivoje Milanović, Dragan Čukanović APPLICATION OF ANALYTICAL METHODS IN BENDING ANALYSIS OF CROSS PLY SYMMETRIC LAMINATES	397
Stevan Maksimović, Katarina Maksimović, Ivana Vasović, Mirko Maksimović, Dragi Stamenković STRENGTH ANALYSIS OF HELICOPTER MAIN ROTOR BLADE MADE FROM COMPOSITE MATERIALS	403
Nenad Miloradovic, Rodoljub Vujanac DESIGN OF TOWER CRANE BASED ON CONSTRUCTION SITE LAYOUT PLANNING	409
Nenad Petrović, Nenad Kostić, Nenad Marjanović, Mirko Blagojević, Miloš Matejić INFLUENCE OF BUCKLING CONSTRAINTS ON TRUSS STRUCTURAL OPTIMIZATION	415
Slobodanka Boljanović, Stevan Maksimović, Strain Posavljak ANALYSIS OF TWO SYMMETRIC CRACKS AT A HOLE UNDER CYCLIC LOADING	423
Dragan Čukanović, Gordana Bogdanović, Aleksandar Radaković, Milivoje Milanović DYNAMIC ANALYSIS OF FUNCTIONALLY GRADED PLATE USING HIGHER ORDER SHEAR DEFORMATION THEORY	429
Ivan Grujic, Nadica Stojanovic, Oday I. Abdullah, Radivoje Pesic, Jovan Doric, Sasa Vasiljevic VERIFICATION OF NUMERICAL ANALYSIS FOR THE WORKING CYCLE OF AN IC ENGINE BASED ON THE EXPERIMENTAL DATA	433
MECHATRONICS	
Pavle Stepanić, Živko Murar, Aleksa Krošnjar RETROFITTING A CONVENTIONAL HORIZONTAL MILLING MACHINE TO CNC MACHINE TOOL	441
Vladislav Blagojević, Saša Ranđelović, Predrag Janković TYPES OF ENERGY EFFICIENT CONTROL OF PNEUMATIC ACTUATOR SYSTEM	447
AUTOMOTIVE AND TRANSPORTATION ENGINEERING	
Jovanka Lukić, Slavica Mačužić SEATED HUMAN BODY RESPONSES TO DUAL-AXIS VIBRATION	455
Radoje Vujadinovic, Sreten Simovic, Milanko Damjanovic OVERVIEW OF INCENTIVES AND POLICIES FOR ELECTRIC VEHICLES IN THE EUROPEAN COUNTRIES	461
Slobodan Mišanović, Dragan Taranović, Jovica Vasiljević, Nenad Novaković TECHNICAL AND ECONOMIC ASPECTS OF THE TEST DRIVE IVECO CNG BUS IN BELGRADE, COMPARED TO DIESEL BUS AND E-BUS	471

Zlatko V. Sovreski, Zoran Joševski, Elizabeta Hristovska, Vangelica Jovanovska, Feta Sinani APPLICATION OF PASSIVE SAFETY SYSTEMS IN PASSENGER MOTOR VEHICLES – CASE STUDY R.N MACEDONIA	479
Saša Milojević, Radivoje Pešić, Dragan Taranović, Aleksandar Davinić POWER MEASUREMENT OF MECHANICAL LOSSES IN EXPERIMENTAL RECIPROCATING AIR COMPRESSOR IMPACT OF PISTON GROUP	485
Milanko Damjanović, Sreten Simović, Radoje Vujadinović IMPACT OF CURRENT CHANGES OF TORQUE AND EXTERNAL RESISTANCES ON VALUE OF A CARDAN SHAFT LOAD IN MOTOR VEHICLES	491
Aleksandar Stanković, Danijel Marković, Goran Petrović, Žarko Čojbašić A SIMULATED ANNEALING AND PARTICLE SWARM OPTIMIZATION FOR THE VEHICLE ROUTING PROBLEM AND COMMUNAL WASTE COLLECTION IN URBAN AREAS	497
Tijana Ivanisevic, Jasna Glisovic, Dragan Taranovic, Sreten Simovic AN ANALYSIS OF BRAKING COEFFICIENT AND DIFFERENCE IN BRAKING FORCE OF DIFFERENT CATEGORIES OF VEHICLES INVOLVED IN TRAFFIC ACCIDENTS	507
Vojislav Krstić, Božidar Krstić HAZARDS IN THE OPERATION OF INTERVENTION UNITS IN CASE OF TRAFFIC ACCIDENTS (EXTERNAL SITUATIONS) WITH HAZARDOUS MATERIALS	515
Vojislav Krstić, Božidar Krstić PLACE AND ROLE OF INTERVENTIONAL TEAMS IN TRAFFIC INCREASES (IN EXTERNAL SITUATIONS) IN TRANSPORT OF DANGEROUS MATERIALS	527
QUALITY AND ECOLOGY	
Milan Ivanović, Miroslav Bobrek FROM QUALITY MANAGEMENT TO CORPORATE MANAGEMENT QUALITY	537
Branko Štrbac, Miodrag Hadžistević, Biserka Runje, Amalija Horvatić Novak, Ivan Matin, Goran Jotić THE ANALYSIS OF THE ACCURACY AND EVALUATION MEASUREMENT UNCERTAINTY OF CMM USING BALL BAR	545
Goran Janjić, Vladan Račić, Zorana Tanasić, Danijela Kardaš, Dušica Pešević THE SIMULATION OF ENERGY PROCESSES IN PUBLIC TRANSPORTATION AND ITS IMPACT ON THE ENVIRONMENT	553
Stefan Đurić, Bogdan Nedić, Slobodan Malbašić, Jelena Baralić APPLICATION OF NEW TECHNOLOGIES FOR DEMILITARIZATION ORDNANCE IN ORDER TO PROTECT ENVIRONMENT	561
Miroslav Bobrek, Zorana Tanasić, Goran Janjić SYSTEMS ENGINEERING METHODOLOGIES FOR STUDY PROGRAM DEVELOPMENT	567
Milica Ivanović, Gordana Stefanović, Biljana Milutinović, Sandra Stanković, Ana Momčilović COMPOSTING AS A WAY OF UTILIZATION OF AGRICULTURAL ORGANIC WASTE	573

Nikola Petrović, Bojan Krstić, Jelena Petrović EVALUATION OF FREIGHT TRANSPORT MODES BASED ON EXTERNAL COSTS	579
Jasna Glišović, Radivoje Pešić, Saša Vasiljević, Nadica Stojanović, Ivan Grujić ROAD VEHICLE AS A SOURCE OF NON-EXHAUST PARTICULATE MATTER	585
Biljana Milutinović, Petar S. Djekić CONTRIBUTION OF LEAN PRODUCTION TO ENVIRONMENTAL PROTECTION IMPROVEMENT	591
Zorana Tanasić, Saša Petrović, Goran Janjić, Borut Kosec APPLICATION OF LEAN CONCEPT IN THE ELAS METALEXPRT COMPANY	597
Gordana Stefanović, Biljana Milutinović, Ana Momčilović, Milica Ivanović ESTIMATION OF ROW MATERIAL POTENTIAL IN LANDFILL MINING	603
Pedja Milosavljević, Dragoljub Živković, Marina Spasov, Milena Rajić, Dragan Pavlović LEAN GREEN MANAGEMENT APPLICATION IN A RECYCLING COMPANY	609
Goran Jotić, Saša Tešić, Čiča Đorđe, Simo Jokanović QUALITY INSPECTION OF FREE-FORM SURFACE PARTS	623
MAINTENANCE OF ENGINEERING SYSTEMS AND OCCUPATIONAL SAFETY ENGINEERING	
Biljana Vranješ, Mile Vajkić, Branko Lazić, Mladen Todić INJURIES TREND AS AN INDICATOR OF OCCUPATIONAL SAFETY AND HEALTH	631
Nikola Trbojević, Ivana Ribarić, Biljana Vranješ REDUCTION OF HAZARD LEVELS ON CNC MACHINES	641
Mitar T. Jocanović, Velibor V. Karanović, Marko D. Orošnjak, Dejan O. Lukić, Miodrag Hadžistević PROTECT WORKERS IN THE WORKING ENVIRONMENT OF THE SAW BLADE	651
Dejan Brankovic, Zdravko N. Milovanovic MAINTENANCE INFORMATION SYSTEMS IN INDUSTRIAL PRACTICE	657
Aleksandar Majstorović, Mladen Todić DISTRIBUTION OF TENSION IN BOTTLES OF BREATHING APPARATUS DURING NORMAL AND FAST EXPANSION OF COMPRESSED MEDICAL AIR	663
MATERIALS SCIENCE	
Blaž Karpe, Mateja Vodlan, Igor Kopač, Igor Budak, Milana Ilić Mićunović, Alenka Pavlič, Tatjana Puškar, Aleš Nagode, Zorana Tanasić, Milan Bizjak, Borut Kosec MEASUREMENT OF THERMAL PROPERTIES OF TITANIUM ALLOYS USED IN DENTAL MEDICINE	673
Milena Ćosić, Slobodanka Boljanović CHARACTERIZATION OF THE STRUCTURAL CHANGES OF Al ₁₈ SiCuMg ALLOY DURING THE RHEOCASTING PROCESS	679
Marko Pavlović, Marina Dojčinović, Radica Prokić-Cvetković, Ljubiša Andrić APPLICATION OF GLASS-CERAMICS BASED ON BASALT FOR THE PRODUCTION OF PARTS OF EQUIPMENT IN METALLURGY	687
	xvii

Content

Belma Fakić, Diana Ćubela, Adisa Burić, Edib Horoz REGRESSION ANALYSIS OF TENSILE STRENGTH TESTING RESULTS AT STEEL 17-7PH WITH MODIFIED CHEMICAL COMPOSITION	691
Petar S. Djekic, Biljana Milutinovic STUDY OF APPLICATION OF WASTE GLASS POWDER IN VIRGIN RUBBER BLENDS	699



PHOTOVOLTAIC THERMAL SYSTEMS – DESIGN AND BUILDING APPLICATION

Ivana Terzic¹, Danijela Nikolic², Vanja Sustersic³, Jasmina Skerlic⁴,
Vladimir Vukasinovic⁵

Summary: *Within the solar energy technologies, the hybrid photovoltaic-thermal (PV-t) systems provide an appropriate option for the production of thermal and electrical energy, as the absorbed solar radiation is converted into the thermal energy and electricity.*

The aim of this paper is to review, present and evaluate the suitability of using hybrid PV-t solar systems for the supply of electricity and thermal energy in households (space heating is not considered). Special emphasis is placed on the design of the PV-t system as well as on their division. Great attention has been paid to PV-t systems based on water.

The review examined various articles with the proposed design of PV-t collectors and absorbers. The paper is presented the possibilities of using solar PV-t system in the buildings.

Key words: *photovoltaic thermal (PV-t) collector, thermal energy, electricity, efficiency, building*

1. INTRODUCTION

It is known that the use of solar energy requires converting it into different types of energy (electricity, heat). The conversion of solar energy into heat and electricity provides the opportunity to use more than 90% of the energy used in the power supply.

Solar energy can be classified into two areas of study: solar thermal systems, where solar radiation is converted into heat, and photovoltaic (PV) systems, where solar energy is converted into electricity.

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PV-t is a hybrid technology that combine PV and solar thermal components into a single module to enhance the solar conversion efficiency of the module and make economic use of the space. During the seventies of the last century, a first step was made to merge solar thermal and photovoltaic systems into one model, known as Photovoltaic Thermal Solar System (PV-t) or Hybrid Solar Systems. The general concept of the PV-t was originally developed by Kern and Russell in 1978 [1].

A PV-t module is basically constructed as a combined functions of a flat-plate solar (thermal) collector and photovoltaic panel and it simultaneously generate electricity and heat, and therefore takes advantages of both PV and solar thermal technologies. The dual functions of the PV-t result in a higher overall solar conversion rate than that of solely PV or solar collector, and thus enable a more effective use of solar energy [1].

In this paper, an overview of the possibility of using the PV-t system in the building industry was carried out.

2. PHOTOVOLTAIC THERMAL (PV-t) SOLAR SYSTEMS

The energy conversion in PV-t systems (electrical and thermal energy) is achieved when the PV panel (which converts solar radiation into electricity) functions as an absorber of the thermal collector [2]. When temperature increases, electrical efficiency decreases. However, in these systems, this is regulated by the removal of excess heat through solar cells, which establishes cooling in PV cells, and consequently increases the efficiency of the system [3]. Figure 1 shows the PV-t scheme for the production of electricity and heat. The electricity flows into an inverter for use in the building or export to the grid according to a standard PV configuration. The temperature is regulated through a control sensor and the coolant is transferred using a pump to a heat exchanger which heats water in a storage tank for use in DHW and heating systems.

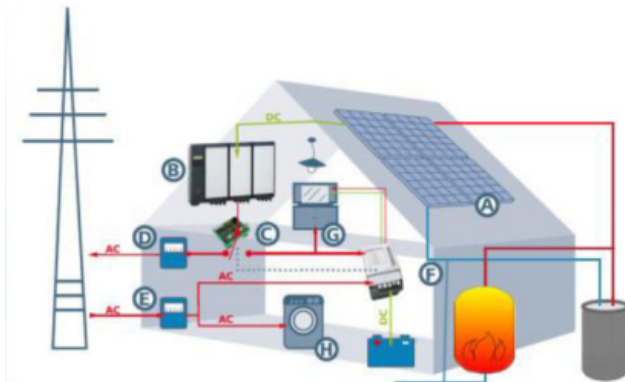


Fig. 1 PV-t scheme for the production of electricity and heat energy [2]

Figure 2 shows the cross-section of an glazed PV-t collector, with solar thermal and photovoltaic component. This type of hybrid solar system is used typical and it is covered with transparent glass. A typical PV-t module is a inserted structure consisting of several layers.

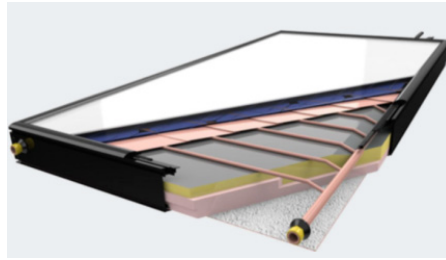


Fig. 2 Photovoltaic thermal cross-section [2]

Figure 3 shows the basic structure of the hybrid PV-t collector. The PV-t system consists mainly of: a transparent cover (glass), an air gap, a mono-crystalline (c-Si) PV module, an EVA encapsulating film, an absorber–exchanger which transforms the solar radiation to heat and transfers it to the collector fluid, and a layer of insulation material at the bottom [4].

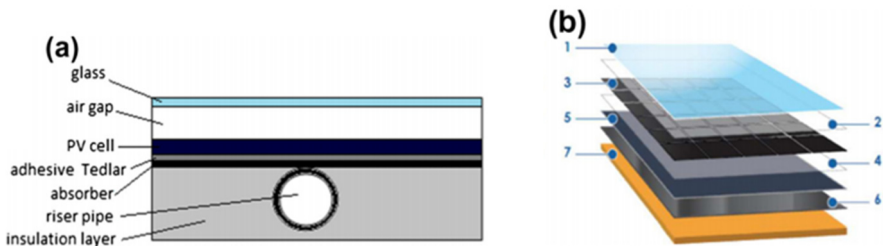


Fig. 3 Construction of a PV-t: a) PV-t collector cross-section, b) PV-t layers [4]

PV-t systems, based on the working fluid, can be categorized into:

- Water-based PV-t systems and
- Air-based PV-t systems.

2.1 WATER TYPE SOLAR PV-t SYSTEM

For these types of systems, the heat transfer fluid is water. Appropriate channels take the collected amount of heat from the absorber. The constructive solution of the channel performance in the absorber affects the efficiency of the system, so that they can be connected either in series or in parallel, while the circulation of heat transfer fluids can be achieved either by the pump system or by the difference in the specific gravity of the heat transfer fluid (gravity system). Figure 4 presents the flow-through channels of the PV-t collector on the water basis, and Figure 4 is a schematic representation of the PV-t system for the production of the electricity and thermal energy (heat).

The PV-t-water model is more efficient due to its better thermophysical characteristics compared to the air model, and further research in this paper is based on water PV-t systems [5].

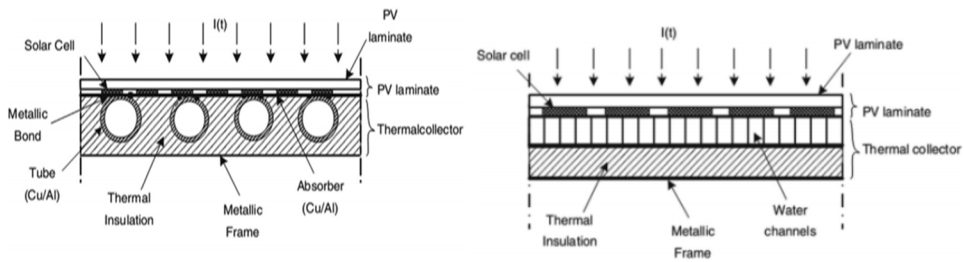


Fig. 4 A typical water PV-t collector [6]

2.2 APPLICATION OF PV-t SYSTEMS IN BUILDINGS

PV-t systems can greatly contribute to the reduction of fossil fuel energy consumption especially in buildings, where the available surfaces are often limited, on the other hand, with a great need for electrical and thermal energy.

Figure 5 presents the possibilities of applying the PV-t system in the building, where the roof modules of the PV-t system are applied. A significant improvement in electrical and thermal effects is achieved by Zhao [7] using innovative PV-t system designs as the roof module. It is an electrical generator of the roof element and a heat pump heat exchanger which can achieve a significant increase in electrical and thermal efficiency. In the figure 5.a. is presented the intention for construction of a building energy system based on advanced new type of heat pump, while using a unique PV-t solar collector provides both - electricity and heat. This is the EU's largest research and innovation program and a receipt for maintaining high quality.

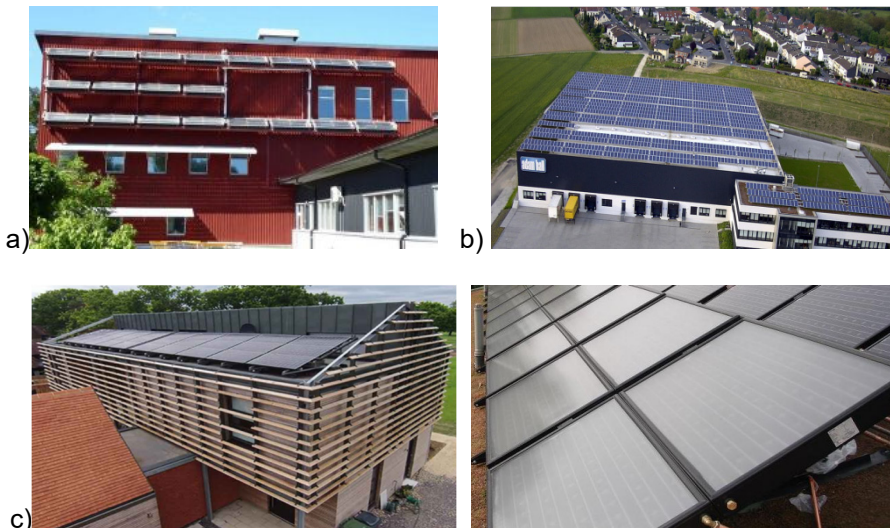


Fig. 5 Examples of the application of the PV-t system in the buildings: a) An installation of 20 PV-t collectors from Solarus at Gävle University (HiG) [8]; b) Large commercial flat-roof system; c) Solar PV-t Project (Hawkes Architecture) with roof-mounted 6kW PVT system [9]

This project (Fig. 5 c), designed by Hawkes Architecture, uses a roof-mounted 6kW PVT system to harness solar energy as electricity and heat [9].

The PV-t demonstration plant (fig. 6 a) was set up in the neighbourhood of Oberfeld, a sustainable and car-free housing area in the town of Ostermundigen, near the Swiss city of Bern. A reference PV system had been installed on the roof next to the PV-t one and had also been connected to an independent inverter. During the first year in operation, both PV installations produced the same number of kilowatt-hours, which means that there was no cooling effect from the thermal absorber in the back of the PV-t element. The PV-t system generated 163.3 kWh/m² and the reference system provided 162.4 kWh/m², resulting in a module efficiency of 13 % [10].

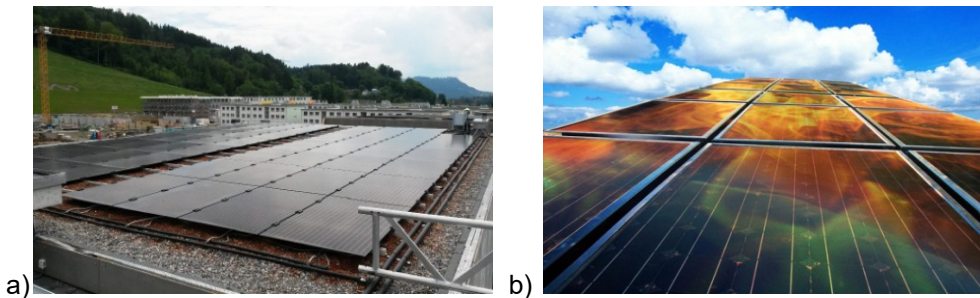


Fig. 6 PV-t System: a) Swiss multi-family housing area; b) Solimpeks PV-t system

Solar panel manufacturer Solimpeks (fig. 6 b) is offering a hybrid solar panel that is capable of providing both electricity and water heating from the same panel. The panels are ideal for applications where there is limited roof space available, but both solar electricity and solar hot water are desired. Even better, the combination of the two functions actually improves the efficiency of the electrical generation of the photovoltaics [11].

3. CONCLUSION

The application of the PV-t system in the building allows the simultaneously production of electric and thermal energy by exploiting solar radiation.

The potential of solar radiation in the Republic of Serbia is around 0.64 million toe per year. With the assumption of a plan, about 10 600 000 m² of area could be used for the potential production of these two types of energy. That means that each household has PV-t system with area of 4 m², which is sufficient for partially energy needs of every individual residential building.

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REFERENCES

- [1] Xingxing Zhang et al (2011). Review of R&D progress and practical application of the solar photovoltaic/thermal (PV/T) technologies. *Renewable and Sustainable Energy Reviews* 16, 599-617.
- [2] Mosterio-Romero, M. U.-W. (2014). Relative importance of electricity sources and construction practices in residential buildings: A Swiss US comparison of energy related life-cycle impacts. *Energy and Buildings* 68, 620-631.
- [3] Karman Moradi, M. A.-X. (2013). A review of PV/T technologies: Effects of control parameters. *International Journal of Heat and Mass Transfer*, Volume 64, 483-500.
- [4] MaríaHerrando, Christos N. Markides, Klaus Hellgardt, (2014) „A UK-based assessment of hybrid PV and solar-thermal systems for domestic heating and power: System performance“, *Applied Energy* 122, pg 288-309.
- [5] Hedayatzadeh, M. Y. (2013). Thermal and electrical assessment of an integrated solar photovoltaic thermal (PV/T) water collector equipped with a compound parabolic concentrator (CPC). *International Journal of Green Energy* 10, no 5, 494-522.
- [6] Zondag H.A., (2008) *Realized PV/T installations – experiences and monitoring results*, Energy research Centre of The Netherlands (ECN).
- [7] Zhao XD, Zhang XX, Riffat SB, Su YX. Theoretical study of the performance of a novel PV/e roof module for heat pump operation. *Energy Conversion and Management* 2011; 52:603–614.
- [8] Gävle University is part of a very large EU environmental project for increasing renewables in buildings, [https://solarus.com/gavle-university-is-part-of-a-very-large-eu-environmental-project-for-increasing-renewables-in-buildings/\(01.04.2019.\)](https://solarus.com/gavle-university-is-part-of-a-very-large-eu-environmental-project-for-increasing-renewables-in-buildings/(01.04.2019.))
- [9] Solar PVT Panels Guide, Homebuilding and renovating, England. [https://www.homebuilding.co.uk/solar-pvt-guide/\(01.04.2019.\)](https://www.homebuilding.co.uk/solar-pvt-guide/(01.04.2019.)).
- [10] Global Solar Thermal Energy Council, [https://www.solarthermalworld.org/content/switzerland-pvt-system-output-reaches-330-kwhthm2-top-163-kwhelm2,\(01.04.2019.\)](https://www.solarthermalworld.org/content/switzerland-pvt-system-output-reaches-330-kwhthm2-top-163-kwhelm2,(01.04.2019.)).
- [11] Photovoltaic Solar Hot Water Panels Reap Multiple Benefits, [https://inhabitat.com/photovoltaic-solar-hot-water-panels-reap-multiple-benefits/\(01.04.2019.\)](https://inhabitat.com/photovoltaic-solar-hot-water-panels-reap-multiple-benefits/(01.04.2019.)).



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