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Faculty of Mechanical Engineering



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CONTENT
KEYNOTE LECTURES

Vojislav Novakovic INTEGRATED ENERGY DESIGN – MULTIDISCIPLINARY APPROACH TO DESIGN OF BUILDINGS	3
Sorin Ioan Deaconu DUAL STATOR WINDING CAGE INDUCTION GENERATOR FOR WIND OR HYDRO VARIABLE SPEED LOW POWER CONVERSION ENERGY SYSTEM	9
Atul Bhaskar, Enrique Cuan-Urquizo, Alessandra Bonfanti, Hayk Vasilyan, Tigran Saghatelyan, Loris Domenicale, S.J.A. Rizvi, Naresh Bhatnagar POROUS AND LATTICE MATERIALS: MECHANICS & MANUFACTURE	17

PRODUCTION AND COMPUTER-AIDED TECHNOLOGIES

Sasa Zivanovic, Nikola Slakovic, Dragan Milutinovic, Zoran Dimic CONFIGURING OF VIRTUAL 5-AXIS HYBRID KINEMATIC MILLING MACHINE	29
Marin Gostimirovic, Pavel Kovac, Milenko Sekulic, Mijodrag Milosevic, Dejan Lukic INVERSE THERMAL MODELING OF THE ELECTRICAL DISCHARGE MACHINING	37
Nikola Slakovic, Sasa Zivanovic, Dragan Milutinovic, Branko Kokotovic ROBOT MACHINING SIMULATION IN STEP-NC MACHINE ENVIRONMENT	43
Samir Butković, Emir Šarić, Muhamed Mehmedović MICROSTRUCTURAL CHANGES DURING HEAT TREATMENT OF SINTERED AUSTENITIC NICKEL-FREE STAINLESS STEEL	51
Dejan Lukić, Mijodrag Milošević, Mića Đurđev, Jovan Vukman, Aco Antić OPTIMIZATION OF OPERATION SEQUENCING USING PRECEDENCE CONSTRAINTS AND SIMULATION TECHNIQUE	57
Elvin Okugić, Milan Jurković THE ANALYSIS OF TECHNOLOGICAL PROCESS IN MANUFACTURING FACILITY “SANI GLOBAL” AND PROPOSED MEASURES TO IMPROVE THE PROCESS	65
Amir Ćorlaić, Anel Maslo, Mersida Manjgo, Senad Rahimić SIMULATION CASTING POINT IN THE PROCESS OF PLASTIC INJECTION UNDER	71
Srbislav Aleksandrovic, Slavisa Djacic, Milentije Stefanovic, Milan Djordjevic, Vukic Lazić, Dusan Arsic INFLUENCE OF PROCESS PARAMETERS ON THE FRICTION COEFFICIENT IN ONE AND MULTI PHASE STEEL STRIP DRAWING IRONING TEST	77
David Muženič, Gordana Globočki Lakić, Branislav Sredanović, Davorin Kramar, EMPIRICAL MODELLING OF LASER ASSISTED MILLING; OVERVIEW AND CASE STUDY	87

Content

Nenad Petrović, Nenad Marjanović, Nenad Kostić, Mirko Blagojević, Miloš Matejić SIZING OPTIMIZATION OF PARAMETRICALLY DESIGNED TRUSSES	93
Aleksandar Živković, Milan Zeljković, Miloš Knežev, Milivoje Mijušković ANALYSIS OF STATIC BEHAVIOUR OF THE BEARING ASSEMBLY FOR AGRICULTURAL MECHANIZATION	101
Mirna Nožić, Himzo Đukić, Darko Šunjić COMPARATION OF THEORETICAL, EXPERIMENTAL AND NUMERICAL METHODS FOR PROCESS ANALYSIS FOR DEEP DRAWING WITH REDUCTION OF WALL THICKNESS	109
Miodrag Manić, Miloš Ristić, Dragan Mišić, Miloš Kosanović CONCEPT OF THE SYSTEM FOR CUSTOMIZED IMPLANT MANUFACTURABILITY ANALYSIS	115
Milan Šljivić, Milija Krašnik, Jovica Ilić, Jelica Anić DEVELOPMENT OF SMALL BATCHES OF FUNCTIONAL PARTS USING INTEGRATION OF 3D PRINTING AND VACUUM CASTING TECHNOLOGY	121
Miloš Madić, Marko Kovačević, Miroslav Radovanović, SOME OPTIMIZATION ASPECTS IN TURNING PROCESSES	127
Branko Kokotovic, Sasa Zivanovic FUNCTIONS FOR PROCESSING OF WOKPIECE CAD MODEL FOR PREDICTION AND OPTIMIZATION OF MILLING PROCESS	133
Simo Jokanović FEATURE CENTRIC MANUFACTURING AUTOMATION – A CONCEPT	139
ENERGETICS AND THERMAL ENGINEERING	
Andreja Stefanović THE IMPACT OF PARTIAL REFURBISHMENT ON THE HEATING ENERGY CONSUMPTION OF A RESIDENTIAL BUILDING SECTOR	151
Igor Shesho, Done Tashevski, Filip Mojsovski METHODOLOGY FOR TECHNO-ECONOMIC OPTIMIZATION OF SOLAR ASSISTED HEATING SYSTEMS	157
Veselin Blagojević, Nebojša Lukić, Novak Nikolić, Aleksandar Nešović HEAT RECOVERY OF VENTILATION AIR IN EXISTING EDUCATIONAL BUILDING IN DOBOJ	171
Danijela Nikolić, Jasmina Skerlic, Vanja Šušteršič, Vanja Šušteršič, Aleksandar Mišković INFLUENCE OF HOT WATER TEMPERATURE IN DHW SYSTEM ON BUILDING EXERGY OPTIMIZATION	177

Sadoon Ayed, Predrag Živković, Mladen Tomić, Mirko Dobrnjac, Janja Branković, Gradimir Ilić EXPERIMENTAL STUDY RAYLEIGH–BÉNARD CONVECTION IN A RECTANGULAR MOTOR OIL TANK	185
Uroš Karadžić, Marko Jankovic, Filip Strunjaš INFLUENCE OF THE INITIAL CONDITIONS ON WATER HAMMER IN RESERVOIR-PIPELINE-VALVE SYSTEM	193
Veselin Blagojević, Vanja Šušteršič POSSIBILITY OF USE HEAT ENERGY FROM WASTE WATER SEWAGE SYSTEM FOR HEATING OF BUILDINGS	199
Kire Popovski, Aleksandar Trajkovski, Blagoj Ristovski, Igor Popovski COMPUTER PROGRAM FOR CALCULATING HEAT TRANSFER THROUGH TRANSPARENT WALLS IN GLASS HOUSE COATED WITH FOIL	205
Kire Popovski, Aleksandar Trajkovski, Blagoj Ristovski, Igor Popovski COMPUTER PROGRAM FOR CALCULATING DISTRIBUTION OF WATERFLOW IN HEAT EXCHANGERS WHICH ARE USED IN GRAPHIC INDUSTRY	211
Sasa Pavlovic, Evangelos Bellos, Velimir Stefanovic, Christos Tzivanidis EXPERIMENTAL AND NUMERICAL INVESTIGATION OF A SOLAR DISH COLLECTOR WITH SPIRAL ABSORBER	217
Danijela Kardaš, Petar Gvero, Siniša Rodić INSTITUTIONALIZATION OF ENERGY MANAGEMENT INFORMATION SYSTEM IN REPUBLIC OF SRPSKA	227
Šefko Šikalo, Aleksandra Kostić AN EQUATION FOR FITTING SPREADING DIAMETER OF A LIQUID DROPLET IMPACTING ON FLAT SURFACES	237
Marko Serafimov, Filip Mojsovski, Igor Šešo IMPACT OF INDOOR AIR QUALITY ON HEALTH EFFECTS	243
Zajim Aljicevic, Aleksandra Kostic, Nediz Dautbašić SELECTING LOCATION FOR INFRASTRUCTURAL INVESTMENT PROJECT IN RENEWABLE SOURCES OF ENERGY USING MATLAB AND FUZZY LOGIC	255
Miloš B. Radojević, Nebojša G. Manić, Vladimir V. Jovanović, Dragoslava D. Stojiljković, METHODOLOGY AND CHALLENGES OF CALIBRATING THE INSTRUMENT FOR SIMULTANEOUS THERMAL ANALYSIS	261
Živan Spasić, Miloš Jovanović, Jasmina Bogdanović Jovanović METHODS FOR PREDICTING THE PERFORMANCE OF CENTRIFUGAL PUMPS WHEN OPERATING IN THE TURBINE MODE	271
Izudin Delić, Amel Mešić CFD ANALYSIS OF FLUID STREAMING IN ROTARY DRYER	279
Ivana Terzić, Vanja Šušteršič, Katarina Đonovic COMPARATIVE ANALYSIS OF GEOTHERMAL HEAT PUMPS	285

Content

Jelena Petrović, Živojin Stamenković, Miloš Kocić, Milica Nikodijević, Jasmina Bogdanović-Jovanović MHD FLOW AND HEAT TRANSFER IN POROUS MEDIUM WITH INDUCED MAGNETIC FIELD EFFECTS	291
Ivana Kecman, Mirko Dobrnjac, Vladimir Stevanović, Milan Lečić TWO-PHASE FLOW ANALYSIS IN SPIRAL EVAPORATOR TUBE OF STEAM GENERATOR	297
Janja Branković, Predrag Živković, Dragana Dimitrijević, Jelena Janevski, Sanja Dobrnjac INFLUENCE OF A CONSTRUCTION SITE TO THE IMMEDIATE SURROUNDINGS AIR QUALITY	305
Dragana Dimitrijević, Predrag Živković, Janja Branković, Mirko Dobrnjac, Žana Stevanović AIR POLLUTION REMOVAL AND CONTROL BY GREEN LIVING ROOF SYSTEMS	313
Predrag Živković, Mirjana Laković, Dušan Petković, Dragana Dimitrijević, Milica Jović WIND ENERGY POTENTIALS OF THE NORTHERN BALKAN MOUNTAIN	321
Mladen A. Tomić, Biljana B. Milutinović, Predrag M. Živković, Petar S. Đekić, Mirjana S. Laković NUMERICAL ANALYSIS OF CONVECTIVE HEAT TRANSFER FROM A PERFORATED PLATE	327
Jasmina Bogdanović-Jovanović, Živojin Stamenković, Živan Spasić, Jelena Petrović, Miloš Kocić NUMERICAL INVESTIGATION OF CAVITATING FLOW IN VENTURI NOZZLE	333
Maja Mrkić Bosančić, Srđan Vasković, Petar Gvero DETERMINATION OF OPTIMAL ENERGY MIX SUPPLY FROM RENEWABLE ENERGY SOURCES BY USING MULTI-CRITERIA OPTIMIZATION	339
Miloš M. Kocić, Živojin M. Stamenković, Jelena D. Petrović, Jasmina B. Bogdanović-Jovanović, Milica D. Nikodijević MHD FLOW AND HEAT TRANSFER OF MICROPOLAR FLUID WITH INDUCED MAGNETIC FIELD EFFECTS	349
Jasmina Skerlic, Danijela Nikolić, Vanja Šušteršič, Jasna Radulovic, Aleksandar Mišković, Blaža Stojanović ANALYSIS AND EVALUATION OF SOLAR ENERGY SYSTEMS	355
Dragan Cvetković THE IMPACT OF INPUT TEMPERATURE AT PANEL HEATING SYSTEM TO HEAT THE SPORTS HALL	365
Esad Tombarević, Igor Vušanović NUMERICAL ANALYSIS OF UNSTEADY HEAT TRANSFER IN U-TUBE GEOTHERMAL HEAT EXCHANGER	375

Dušica Vuković, Vidosava Vilotijević, Uroš Karadžić HYDRAULIC TRANSIENTS CALCULATIONS ON KOMARNICA HPP	381
Marko Mančić, Dragoljub Živković, Dejan Mitrović, Milan Đorđević, Milena Jovanović OPTIMAL CONFIGURATION OF A POLYGENERATION SYSTEM FOR THE ENERGY DEMANDS OF A PUBLIC SWIMMING POOL BUILDING	387
Cvete Dimitrieska, Silvana Angelevska, Zore Angelevska, Sevde Stavreva HEATING WITH BIOMASS – BENEFITS OF THE INVESTMENTS	399
Mirjana Laković, Milica Jović, Predrag Živković, Dragana Dimitrijević ANALYSIS OF CARBON FOOTPRINT METHOD-AN REVIEW	405
Aleksandar Milašinović, Zdravko Milovanović, Željko Đurić EXPERIMENTAL INVESTIGATION OF HEAT FLUX AT THE PANEL HEATING SYSTEMS	409
Milica Jović, Mirjana Laković CARBON FOOTPRINT METHOD-A CASE STUDY FOR THERMAL POWER PLANTS IN REPUBLIC OF SERBIA	423
Darko Knežević, Saša Laloš EXPERIMENTAL DETERMINATION OF SMALL FLOW RATE WITHIN HYDRAULIC COMPONENTS	429
Jelena N. Janevski, Mladen M. Stojiljković, Branislav V. Stojanovic, Stefan D. Jovanović, ADVANTAGES OF DRYING OF VEGETABLES USING THE INTEGRATED HEAT PUMP TECHNOLOGY	435
Jelena N. Janevski, Branislav V. Stojanović, Predrag Živković, Dejan M. Mitrovic INVESTIGATION OF WOOD BIOMASS MARKET IN SOUTHEAST SERBIA	443

MECHANICS AND DESIGN

Aleksandar Radaković, Dragan Milosavljevic, Gordana Bogdanovic, Dragan Čukanović, Vladimir Geroski APPLYING THIRD ORDER SHEAR DEFORMATION THEORIES IN THE FREE VIBRATION ANALYSIS OF CROSS-PLY SYMMETRIC AND ANTISYMMETRIC LAMINATE PLATES	451
Mustafa Hadžalić, Josip Kačmarčik, Alma Žiga OPTIMIZATION OF MINE HOIST ROPE ATTACHMENT ASSEMBLY USING FEM ANALYSIS	457
Nenad Miloradović, Slobodan Garić, Rodoljub Vujanac MODELLING AND FINITE ELEMENT ANALYSIS OF ELEVATOR BUCKETS	463
Jelena Stefanović-Marinović, Sanjin Troha TWO-CARRIER TWO-SPEED PLANETARY GEAR TRAINS WITH BRAKES ON SINGLE SHAFTS	469

Content

Ognjen Ognjanović, Stevan Maksimović, Nenad Vidanović, Gordana Kastratović, Katarina Maksimović STRUCTURAL ANALYSES OF BALISTIC MISSILE FIN CONFIGURATION DURING SUPERSONIC FLIGHT CONDITIONS	477
Mersida Manjgo, Tomaž Vuherer, Meri Burzić, Eldar Pirić DETERMINATION OF MECHANICAL PROPERTIES OF COMPOSITE MATERIALS - THE RUBBER CONVEYOR BELT WITH CARTRIDGES MADE OF POLYESTER AND POLYAMIDE	483
Djordjevic Zorica, Jovanovic Sasa, Stanojevic Milan, Blagojević Mirko, Veličković Sandra OPTIMIZATION OF FIBER ORIENTATION ANGLE OF A HYBRID Al /COMPOSITE CARDAN SHAFT	489
Marko Penčić, Maja Čavić, Milan Rackov, Branislav Borovac ASSISTIVE HUMANOID ROBOT MARKO: DEVELOPMENT OF THE WAIST MECHANISM	495
Stevan Maksimović, Ivana Vasović, Mirko Maksimović, Mirjana Đurić COMPUTATIONS AND EXPERIMENTAL STRENGTH ANALYSIS OF HELICOPTER TAIL ROTOR BLADES MADE FROM COMPOSITE MATERIALS	501
Delić Marko, Djordjevic Zorica, Matejic Miloš, Jovanovic Sasa CALCULATION OF STRESS STATE OF GEAR MADE OF COMPOSITE MATERIALS	509
Isak Karabegović THE ROLE OF INDUSTRIAL AND SERVICE ROBOTS IN THE 4th INDUSTRIAL REVOLUTION – “INDUSTRY 4.0”	515
Nebojša Radić, Dejan Jeremić ANALYTICAL SOLUTION FOR THERMAL VIBRATIONS OF SINGLELAYERED GRAPHENE SHEETS WITH VARIOUS BOUNDARY CONDITIONS	525
Milan Rackov, Siniša Kuzmanović, Maja Čavić, Marko Penčić, Ivan Knežević INFLUENCE OF OPERATING AND AMBIENT TEMPERATURE ON LOAD CAPACITY OF UNIVERSAL WORM GEAR REDUCER	533
Sanel Gredelj, Milan Jurković CORRELATION DIMENSION OF NONLINEAR TIME-SERIES AND EXPERIMENTAL ANALYSIS	539
Saša Milanović, Miloš Jovanović, Vladislav Blagojević SOLID PHASE VELOCITY DISTRIBUTION OF TWO-PHASE TURBULENT FLOW AT PREUMATIC TRANSPORT IN STRAIGHT CHANNELS OF QUADRATIC CROSS	545
Dragan Čukanović, Aleksandar Radaković, Gordana Bogdanović, Dragan Milosavljević, Vladimir Geroski CRITICAL BUCKLING TEMPERATURE OF CERAMIC-METAL FUNCTIONALLY GRADED PLATE	551

Gordana Bogdanović, Vladimir Geroski, Aleksandar Radaković, Dragan Čukanović, Dragan Milosavljević FAILURE STRESS ANALYSIS OF FIBER REINFORCED COMPOSITE LAMINATES	555
Slobodanka Boljanović, Stevan Maksimović, Strain Posavljak CRACK PROPAGATION ANALYSIS OF CYCLICALLY LOADED STRUCTURAL COMPONENTS	561
Katarina Maksimović, Dragi Stamenković, Slobodanka Boljanović, Mirko Maksimović, Ivana Vasović MODELING FRACTURE MECHANICS PARAMETERS OF CRACKED STRUCTURAL ELEMENTS UNDER THERMOMECHANICAL LOADS	567
Boban Andjelković, Dragan Milčić, Biljana Djordjević, Miodrag Milčić, Nataša Zdravković, MEASURING SYSTEM FOR DETERMINING SN CURVE BASED ON THE ARDUINO PLATFORM	577
Miodrag Milčić, Dragan Milčić, Boban Anđelković, Nataša Jovanović DESIGNING OF FIXATOR FOR VIBRATION TESTING OF WELDED JOINTS SPECIMENS	583
Dečan Ivanović GENERALIZED SIMILARITY INCOMPRESSIBLE BOUNDARY LAYER EQUATION WITH VELOCITY AND SHEAR STRESS DISTRIBUTIONS FOR UNSTEADY FLOW AROUND CIRCULAR CYLINDER	589
Saša Randelović, Marina Trajković THE BENDING TECHNOLOGY DESIGN AT HIGHER PRECISION	597
Aleksija Đurić, Biljana Marković CALCULATION OF LBKz FACTOR FOR CARBON FIBER REINFORCED POLYMER UNDER COMPRESSION AND THEIR COMPARISON WITH OTHER LIGHTWEIGHT MATERIALS	603
Đorđe Miltenović, Milan Tica, Aleksandar Miltenović, Milan Banić ANALYSIS OF LOAD CARRYING CAPACITY OF WORM GEARS FROM THE ASPECT OF ENGINEERING PRACTICE	611
Amir Al Sammarraie, Dragan Milčić, Miodrag Milčić, Miodrag Milčić TRIBOLOGICAL BEHAVIOUR OF TIN-BASED MATERIALS –TEGOTENAX V840 IN OIL LUBRICATED CONDITIONS	619
Miroslav Milutinović, Spasoje Trifković DETERMINATION OF STRESS AND TORSION ANGLE OF THE CARDAN SHAFT FOR KNOWN LOAD	625
 MECHATRONICS	
Emina Petrović, Miloš Simonović, Nevena Tomić, Vlastimir Nikolić, Ivan Ćirić NEURAL NETWORK BASED SYSTEM FOR HUMAN ACTION RECOGNITION	635

Biljana Djordjevic, Boban Andjelkovic, Natasa Zdravkovic COEFFICIENT CONTRAST ASSESMENT OF THE HOMOMORPHIC FILTERING BASED ON IMAGE HISTOGRAM	641
Miloš Simonović, Emina Petrović, Vlastimir Nikolić, Ivan Ćirić, Aleksandar Miltenović ADVANCED OPTIMIZATION TECHNIQUES FOR MARSHALLING YARD MANAGEMENT PROBLEM	647
Milan Pavlović, Vlastimir Nikolić, Ivan Ćirić, Milica Ćirić APPLICATION OF THERMAL IMAGING SYSTEMS FOR OBJECT DETECTION	653
Radoslav Tomović NEW APPROACH IN THE RESEARCH OF DYNAMIC BEHAVIOR OF ROLLING ELEMENT BEARING	663
Tihomir Latinovic, Mladen Todoc, Cristian Barz, Pop Vadean Adina, Pop Paul Petrica DATA RECORDING SYSTEMS WITH TELOC - 1500 FOR UPGRADING SAFETY SYSTEMS ON LOCOMOTIVE SERIES 441-521	669
Jelena Eric Obucina, Stevan Stankovski, Vladimir Savic, Gordana Ostojic, Stanimir Cajetinac ENERGY SAVINGS USING FREQUENCY REGULATION IN THE HYDRAULIC SYSTEM WITH A PUMP OF CONSTANT DISPLACEMENT AUTOMOTIVE AND TRAFFIC ENGINEERING	679

AUTOMOTIVE AND TRAFFIC ENGINEERING

Slavica Mačužić, Jovanka Lukić TRENDS IN THE DEVELOPMENT OF BRAKE SYSTEMS OF THE AGRICULTURAL TRACTORS AND TRAILERS	689
Danijela Miloradović, Gordana Bogdanović, Lozica Ivanović, Vladimir Geroski, Marija Rafailović COMPARISON OF NUMERICAL INTEGRATION METHODS I N THE LINEAR DYNAMIC ANALYSIS	697
Slobodan Mišanović, Dragan Taranovic, Radivoje Pešić, Jovanka Lukić EXPLOITATION SPECIFICITIES OF E-BUSES IN WINTER CONDITIONS FROM THE ASPECT OF ENERGY EFFICIENCY	703
Almir Blažević, Mirsad Trobradovic, Ivan Filipović ANALYSIS OF EFFECT OF FLYWHEEL ON CRANKSHAFT SPEED NONUNIFORMITY IN ENGINE OPERATING RANGE	711
Jasna Glišović, Jovanka Lukić, Blaža Stojanović, Nadica Stojanović AIRBORNE WEAR PARTICLES FROM AUTOMOTIVE BRAKE SYSTEMS IN URBAN AND RURAL AREAS	717
Saša Milojević, Radivoje Pešić, Dragan Taranović DETERMINATION OF LOSSES RELATED TO FRICTION WITHIN THE RECIPROCATING COMPRESSORS – INFLUENCES OF TRIBOLOGICAL OPTIMIZATION OF PISTON AND CYLINDER	723

Ivan Grujić, Jovanka Lukić, Aleksandar Davinić, Nadica Stojanović IDENTIFICATION OF COMBUSTION NOISE	729
Zoran Majkić RESEARCH INFLUENCE OF ROAD-OFF ROAD ROUGHNESS ON TERRAIN MOTOR VEHICLES	733
QUALITY AND ECOLOGY	
Amna Bajtarević, Samir Lemeš, Fuad Hadžikadunić MEASUREMENT OF ROLLER BEARING GEOMETRY DEVIATIONS USING COORDINATE MEASURING MACHINE	751
Ranka Radić, Petar Gvero AIR QUALITY IN RURAL RESIDENTIAL AREA	757
Goran Janjić, Zorana Tanasić, Gorazd Kosec, Borut Kosec, Mirko Soković AN INTEGRATED APPROACH TO THE IMPLEMENTATION OF AN ENVIRONMENTAL MANAGEMENT SYSTEM AND LIFE CYCLE ASSESSMENT METHOD IN COMPANY	765
Radovan Martić, Zorana Tanasić, Goran Janjić IMPLEMENTATION OF LEAN CONCEPT IN SMEs	773
Peđa Milosavljević, Milena Rajić, Dragan Pavlović, Srđan Mladenović, Marija Mitrović, THE APPLICATION OF QUALITY AND MANAGEMENT TOOLS IN THE AUTOMOTIVE INDUSTRY	779
Svetlana Lazarević Petrović, Mioljub Lazarević, Tamara Petković BOLOGNA PROCESS IN SERBIA – TEN YEARS AFTER	785
Miloš Sorak, Miroslav Dragić, Zorana Tanasić DEVELOPMENT OF MODEL FOR THE DESIGN AND IMPLEMENTATION OF QUALITY MANAGEMENT SYSTEM ACCORDING TO ISO STANDARD 9001:2015	791
Mirko Soković, Goran Janjić, Igor Budak, Zorana Tanasić, Boris Agarski, Milana Ilić, Gorazd Kosec, Davorin Kramar, Borut Kosec ENVIRONMENTAL LABELLING WITH TYPE I ECO LABELS	797
Vijoleta Vrhovac, Stevan Milisavljević, Nela Cvetković, Nemanja Sremčev THE QUALITY OF THE EDUCATION SYSTEM	803
Nela Cvetković, Slobodan Morača, Vijoleta Vrhovac, Stevan Milisavljević MEASURING THE QUALITY AND PROGRESS OF SOFTWARE PROJECTS WITH PROJECT METRICS	811
Miroslav Bobrek, Milan Ivanović KNOWLEDGE AUDIT AS A QUALITY TOOL	815

**MAINTENANCE OF ENGINEERING SYSTEMS AND OCCUPATIONAL SAFETY
ENGINEERING**

Boris Agarski, Igor Budak, Goran Simunovic, Borut Kosec, Miodrag Hadzistevic, Djordje Vukelic DEVELOPMENT OF INNOVATIVE METHODOLOGY FOR ECODESIGN OF PRODUCTS AND PROCESSES FOR THE REGION OF VOJVODINA	821
Biljana Vranješ, Zorana Tanasić THE APPLICATION OF THE ISHIKAWA METHOD FOR DETERMINING THE CAUSE OF ACCIDENTS AT WORK	827
Biljana Milutinović, Petar Djekić, Milan Pavlović, Mladen Tomić ARTIFICIAL NEURAL NETWORK FOR PREDICTION OF THE BEGINNING OF DELAMINATION AT RUBBER CONVEYOR BELTS	835
Mladen Todic, Latinovi Tihomir, Djudurevic Biljana, Majstorovic Aleksandar SECURITY APPLICATIONS OF INSULATION MASK	841
Velibor Karanović, Mitar Jocanović, Nebojša Nikolić, Mike Lubich, Marko Orošnjak LUBRICATING OILS FOR AUTOMOTIVE NATURAL GAS ENGINES	847
Mitar Jocanović, Velibor Karanović, Darko Knežević, Marko Orošnjak, Saša Laloš SIGNIFICANCE OF HYDRAULIC SYSTEM WORKING FLUID MAINTENANCE WITH INTEGRATED LOGIC AND BUILT-IN COMPONENTS	855
Aleksandar Majstorović, Mladen Todić THE HEAT DISTRIBUTION AT COMPRESSION FILLING OF BOTTLES AND EXPANSION OF MEDICAL AIR	863
Stevan Jovičić, Zoran Ilić, Ljubiša Tomić, Aleksandar Mićović CONSTRUCTION OF ACCOMMODATION FACILITIES FOR BASIC MAINTENANCE AND TESTING OF AIRCRAFT IN SERBIAN ARMY	869
Ile Mircheski, Tashko Rizov NONDESTRUCTIVE DISASSEMBLY PROCESS OF TECHNICAL DEVICE SUPPORTED WITH AUGMENTED REALITY AND RFID TECHNOLOGY	877
Petar Pejic, Dejan Mitrovic, Sonja Krasic SPATIAL ORIENTATION USING VIRTUAL REALITY, CASE OF FACULTY OF MECHANICAL ENGINEERING, NIŠ	887

MATERIALS SCIENCE

Blaž Karpe, Marko Krivec, Aleš Nagode, Daniela Korolija Cerkvenjakov, Mirko Gojić, Igor Budak, Milan Bizjak, Borut Kosec RESTORATION AND CONSERVATION OF SIGNIFICANT RIFLE FROM I. WORLD WAR	895
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Natalia I. Cherkashina COMPOSITE FOR RADIATION PROTECTION	901
Miruna Magaon, Ana Socalici, Sorina Serban RESEARCH ON THE INFLUENCE OF THE VACUUMING PARAMETER ON THE GAS CONTENT IN STEELS	905
Dragoslav Dobraš, Nenad Bukejlović, Milisav Marković ANALYSIS OF QUALITY OF WELDED JOINT ACHIEVED WITH FLUX CORED WIRE IN PG WELDING POSITION	911
Dragoslav Dobraš, Milisav Marković CONDITIONS FOR THE SELECTION OF WELDERS	917
Petar Djekić, Biljana Milutinović, Mladen Tomić APPLICATION OF POLYURETHANE WASTE IN VIRGIN RUBBER BLENDS	923
Stojana Vesković Bukudur, Aleš Nagode, Blaž Karpe, Janez Kovač, Stjepan Kožuh, Milan Bizjak PACK ALUMINIZATION PROCESS OF HEAT RESISTANT FeCrAl AND NiCr ALLOYS	929
Nadežda Šubara, Srđan Stojičić MODERN METHODS OF EXAMINATION THE RAILWAY AXLES ON FATIGUE	937
Milan Radošević, Sebastijan Baloš, Dragan Ružić METALLOGRAPHIC TESTS AND STRENGTH OF THE MATERIAL OF CHAINS SNOW	943
Ivana Ivanić, Stjepan Kožuh, Andrej Vračan, Borut Kosec, Mirko Gojić SEM ANALYSIS OF FRACTURE SURFACE OF THE CuAlNi SHAPE MEMORY ALLOY AFTER HEAT TREATMENT	949



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THE IMPACT OF INPUT TEMPERATURE AT PANEL HEATING SYSTEM TO HEAT THE SPORTS HALL

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Summary: *Low temperature heating panel systems offer distinctive advantages in terms of thermal comfort and energy consumption, allowing work with low energy sources. The low temperature panel systems, by their nature work at a low temperature sources. However, this method of application panel system is not suitable for work in large spaces such as the sports hall. The aim of this study was to investigate the effect of inlet temperature of the panel systems in order to facilitate their application in sport halls. Simulation models are developed in the EnergyPlus software package developed by Lawrence Berkeley Laboratory in the United States.*

Key words: *energy, radiant panel heating, temperature, Energy Plus*

1. INTRODUCTION

Low temperature heating panel systems have been increasingly used in Europe today for purpose of heating and cooling of residential buildings and houses. According to some studies, spread of these systems go over 50% [1,2]. It is possible to save even 30% of energy when using this system [3, 4]. On the other hand, application of low temperature heating panel systems is questioned in case of big spaces and volumes.

Radiation systems are very complex because they involve different heat transfer mechanisms, transfer through wall, convection between space and air in these interiors, radiation between panels and surrounding areas and transfer between floor and ground.

Many studies are dedicated to lab research of panel systems in terms of heat transfer and development of new ways to manage them [5-10]. When looked through the prism of modeling, there are few analytical studies about thermal characteristics of panel systems. In the first model, Kollmar and Lises [11] show that heat is mainly lost on the upper side of panel. Leal and Miler [12] have been using analytical numeric methods to determine temperature in installation used to heat pedestrian roads. Zhang and Pate developed two dimensional method of finite elements for ceiling heating, that was used for modeling of NTS heating [13,14]. Kilkis [15] developed stationary composite model for modeling of radiation systems for heating and cooling. After that, Kilkis and Sapci [16] together with Kilkis and Coley [17] used this model to develop software for design of floor heating and cooling systems.

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Maloney [18] developed model of radiation heating panels for BLAST program. Strand and Pederson [19, 20] used conduction transfer method to develop radiation model for heating and cooling within the EnergyPlus software. Miriel [21] used TRNSYS software for modeling of ceiling panels for heating and cooling.

Aim of this paper is to explore the possibility to apply panel heating systems to big spaces and volumes. Because of balanced acting, the system with wall panels is connected to natural gas boiler. Inlet temperatures were changed from 40°C to 90°C.

2. DESCRIPTION OF THE BUILDING

Analyzed building shown on figure 3 is a standard sports hall. Building consists of main room and annex space that is used for fitting room, showers space and toilets. Surface area of sports hall is around 1130 m². Walls of the hall consist of hollow bricks of 190mm, Styrofoam insulation layer of 50mm and lime mortar of 20mm. Coefficient of heat passage is 0.57 W/(m²K). Windows are two layered with coefficient of heat passage of 2.72 W/(m²K).

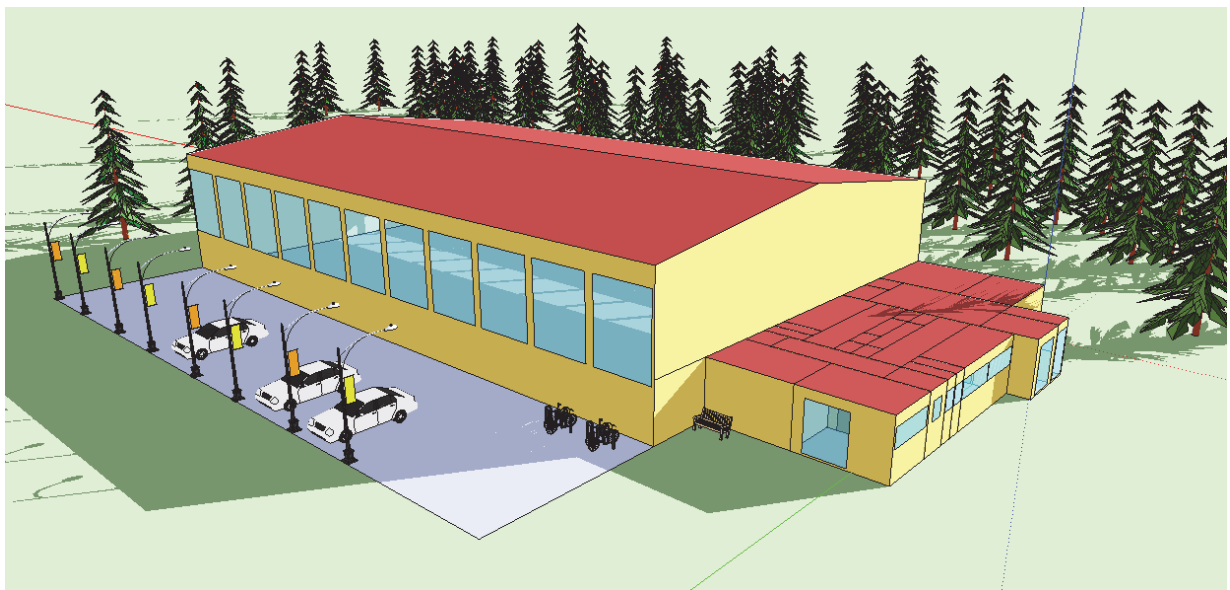


Figure 3. *Analyzed sports hall*

3. LOCATION AND CLIMATE CONDITIONS OF THE BUILDING

Analyzed building is located in Kragujevac, Serbia. Altitude above sea level of Kragujevac city is 209m. The sports hall is located on 44°1N and 20°55E. Climate is moderately continental with different seasons such as summer, autumn, winter and spring. Weather file generated inside Metenorm software was used for EnergyPlus calculations [23]. Heating season in the city of Kragujevac lasts from 15th October to 15th April [24].

Table 1 Climate parameters for Kragujevac, Serbia [25]

Month	Average temperature °C		Average falls (mm)	Number of rain days
	Daily minimum	Daily maximum		
Jan	-3.8	3.8	4.1	11.6
Feb	-1.7	6.7	3.87	10.4
Mar	1.4	11.8	4.44	10.6
Apr	5.5	17.3	4.94	12.2
May	10.1	22.0	7.38	13.1
Jun	13.0	25.0	8.47	12.9
Jul	14.2	25.0	6.8	9.3
Aug	13.7	27.2	5.33	9.3
Sep	10.7	23.9	4.48	8.1
Oct	6.3	18.2	3.82	8.6
Nov	2.4	11.5	4.82	10.3
Dec	-1.6	5.6	4.76	12.3

4. MATHEMATICAL MODEL

4.1. PANEL SYSTEMS DESCRIPTION

In case of panel heating, panels are integrated within construction elements - walls. These elements are heated to the temperature higher than the temperature of the surrounding air, so that they transfer heat by convection and radiation.

Wall panels are applied increasingly because limits in floor and ceiling temperatures. They are installed on cold outside walls thus stopping heat transfer through them. Differently from the ceiling panels, floor panels provide the most of heat by radiation, therefore being better for functioning on higher temperatures of fluids, which outcomes with higher heat flux.

The way heat pipes are positioned increases complexity to determine heat transfer. Usually two types of heat pipe layouts are used; spiral and serpentine (Figures 1 and 2). In case of the serpentine, heat flux moves across the surface of the pipe, while in case of spiral layout, it is radial.

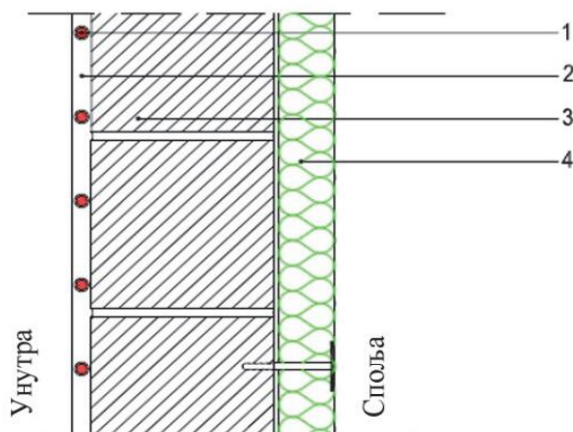


Figure 1 Wall panel

1 – heating pipe, 2 – mortar, 3 – hollow brick, 4 – Styrofoam

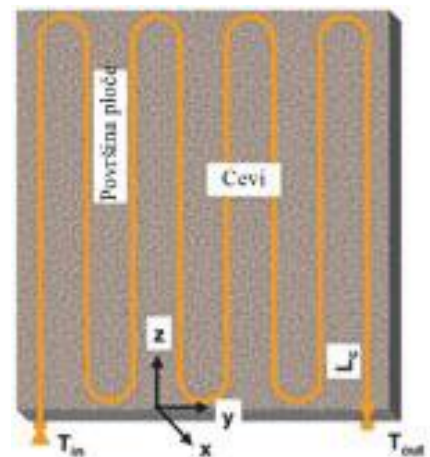


Figure 2 Wall panel

4.2. AMOUNT OF SPENT ENERGY OF THE HEATING SYSTEM

Amount of spent primary energy per heating period of the analyzed building was calculated by using the following formula:

$$E_{sys} = E_{ng} + E_{el} \cdot R \quad (1)$$

E_{ng} is natural gas consumption per heating period, E_{el} is power consumption per heating period to empower heating system and R coefficient of primary energy transformation. This coefficient is defined as relationship between total input energy from different energy sources (hydro energy, coal, oil and natural gas) and final production of electric energy. This value for produced electric energy for Serbia is $R = 3.61$ [26].

5. RESULTS AND DISCUSSION

This research inquiry simulates heating panel system connected to gas boiler with an aim to heat sports hall. Wall heating was chosen for this purpose. It was placed on the outside surface which contains thermo insulation. Non-condensation boiler was used to generate heat based on natural gas with continuous flow circulation pump.

Low temperature panel systems are not convenient to be used in big inside spaces. Because of that, impact of input temperature on panels was considered, with an aim to adjust certain temperature inside the heated space. Panel inlet temperatures are changed from 40 to 90°C. Wall panels that work with input temperatures until 50°C can be considered low temperature panels, while wall panels with inlet temperatures of 60 and more degrees can be considered high temperature panels.

5.1. RESULTS

Results of the simulation for every of the analyzed cases were first shown through energy consumption of fluids.

Energy consumption that involves consumption of natural gas and electric energy to keep the pump working was shown on figure 4. First case resembles wall panel with inlet temperature of 40°C and, as such, it represents classical low temperature wall panel. Its consumption of final energy is around 244.8 kWh/m²a. Heating system consumption with inlet temperature of 50°C is 7.6% higher and it is around 263.4 kWh/m²a. Heating system consumption with inlet temperature of 60°C is around 9.7% higher than in the case when inlet temperature is 40°C and it is around 268.5 kWh/m²a.

Heating system with inlet temperature of 70°C consumes more than 11% than if the inlet temperature is 40°C and it is around 271.6 kWh/m²a. If the panel inlet temperature is 80°C then the consumption is around 12.6% higher than the case when inlet temperature is 40°C which in that case is 275.7 kWh/m²a. Consumption of the heating system in case of inlet temperature of 90°C is around 14.1% higher than the case in which the inlet temperature is 40°C and it accounts to around 279.2 kWh/m²a.

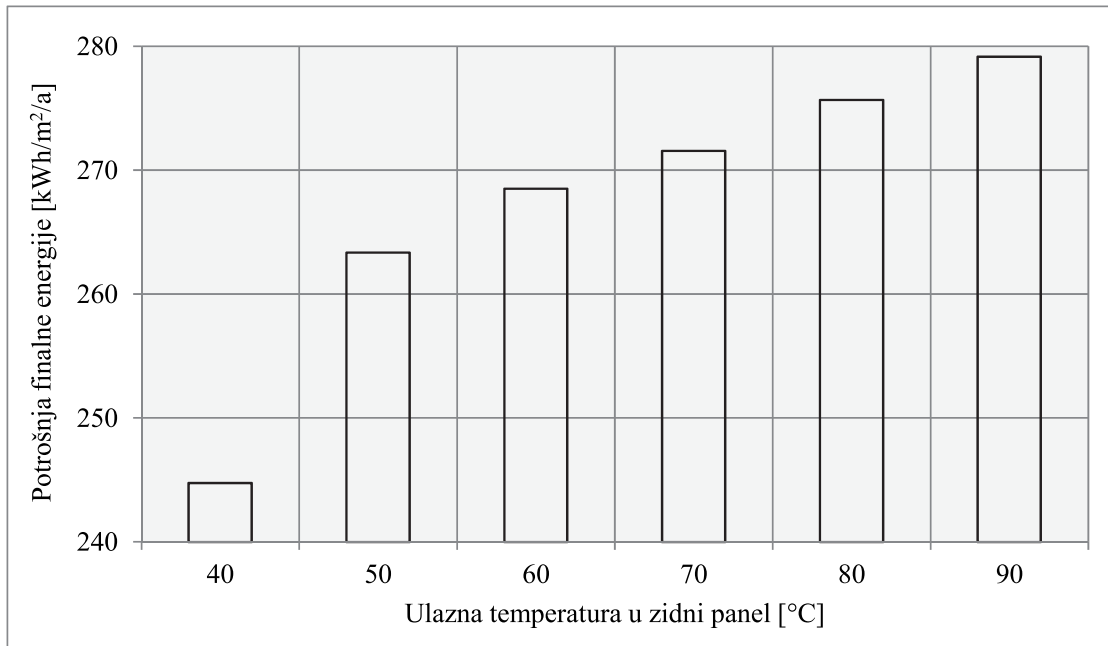


Figure 4. Final energy consumption for heating with different inlet temperatures to wall panel

Mean air temperature, Mean radiant temperature, Operative temperature in heated spaces and Design temperature are shown on figure 5. Operative temperature was regulated with thermostat and its value was 18°C. It can be noticed that goal value is reached only for panels working with inlet temperature of 60°C and higher. On the other hand, mean air temperature was too low for cases in which inlet temperatures are 40°C or 50°C. Mean radiant temperature was below given values only in case when inlet temperature was 40°C.

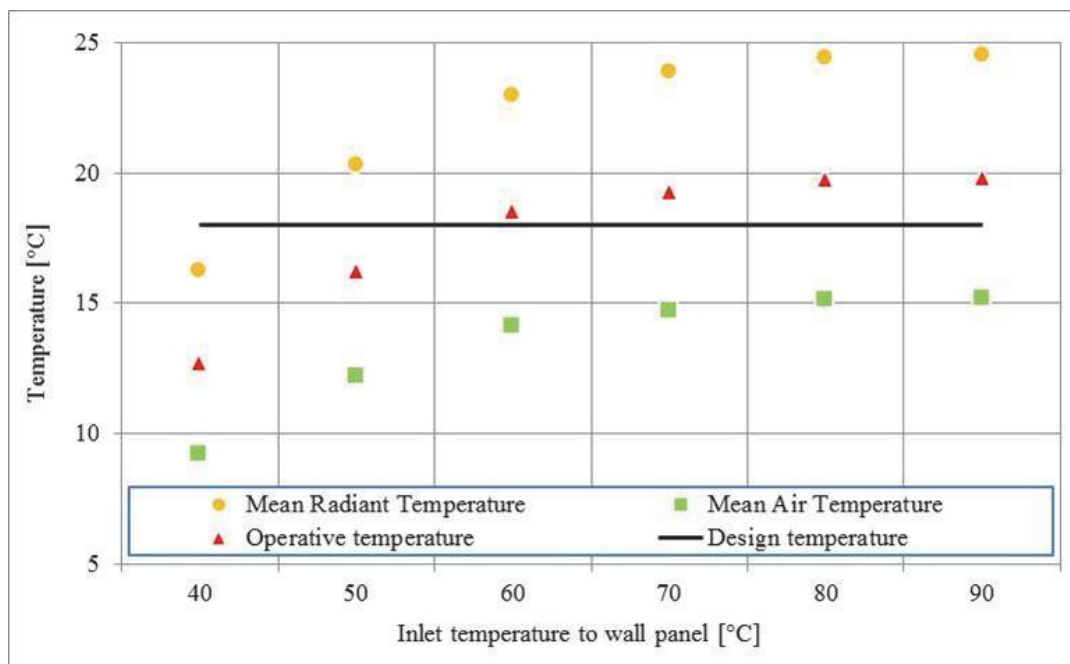


Figure 5 Temperature inside sports hall with different inlet temperatures to wall panel

Mean radiant temperature with different inlet temperatures was shown on figure 6. Heating system was not working in period from 24 to 09h. In this case, temperature had a tendency to drop, depending from the accumulative features of the sports hall and amount of radiated heat during the previous day. Time needed to achieve aimed temperature differs because of different inlet temperatures. For example, in order to achieve 18.3°C, with inlet temperature of 40°, there was 2h late, while for inlet temperatures from 50 to 90°C aimed temperature was achieved very quickly.

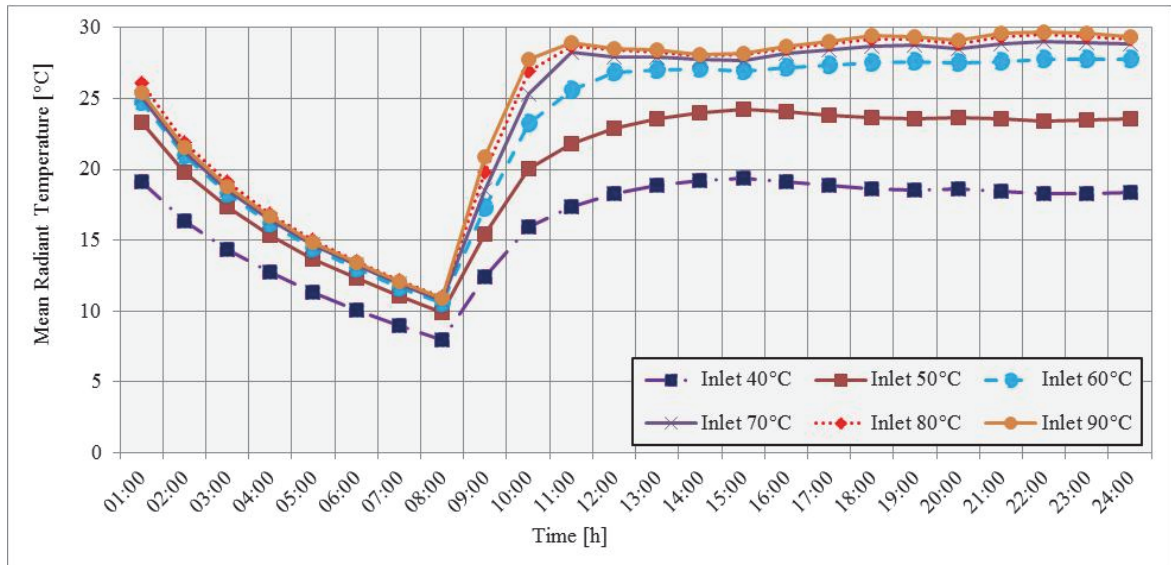


Figure 6 Dependence of mean radiant temperature from the inlet temperature to the wall panel

Mean air temperatures for different values of inlet temperatures to the wall panel are shown on figure 7. There was no heating from 24 to 09h as indicated from the graph. In this period, temperature was dropping as dependent from accumulative feature of the space and amount of radiated heat during the previous day. Time needed to achieve aimed temperature differs depending from the inlet temperature to the wall panel. For example, aimed temperature could not be achieved if inlet temperature is from 40°C to 50°C. For inlet temperatures of 60, 70, 80 and 90°C there is a delay of 4h, 3h, 2h, 2h and 2h, respectively.

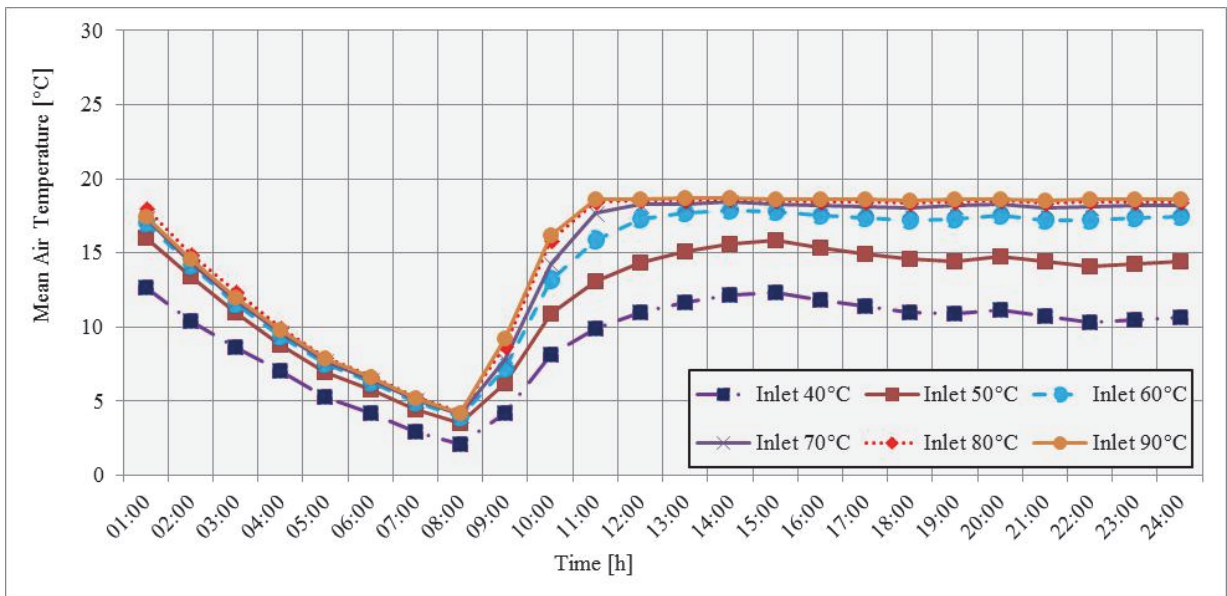


Figure 7 Dependence of mean air temperature from inlet temperature to panel

Values of operative temperature depending from different inlet temperatures to the wall panel are shown on figure 8. As written before, there was no heating in the period from 24 to 09h. Temperature has a tendency to drop in this period depending from accumulative feature of the space and radiated heat during the previous day. Time needed to achieve aimed temperature differs from the inlet temperature to the wall panel. Aimed temperature has not been achieved for inlet temperature of 40°. Aimed temperature was achieved for inlet temperatures of 50, 60, 70, 80 and 90°C with delay of 2h, 1h, 1h, 1h, 1h and 1h, respectively.

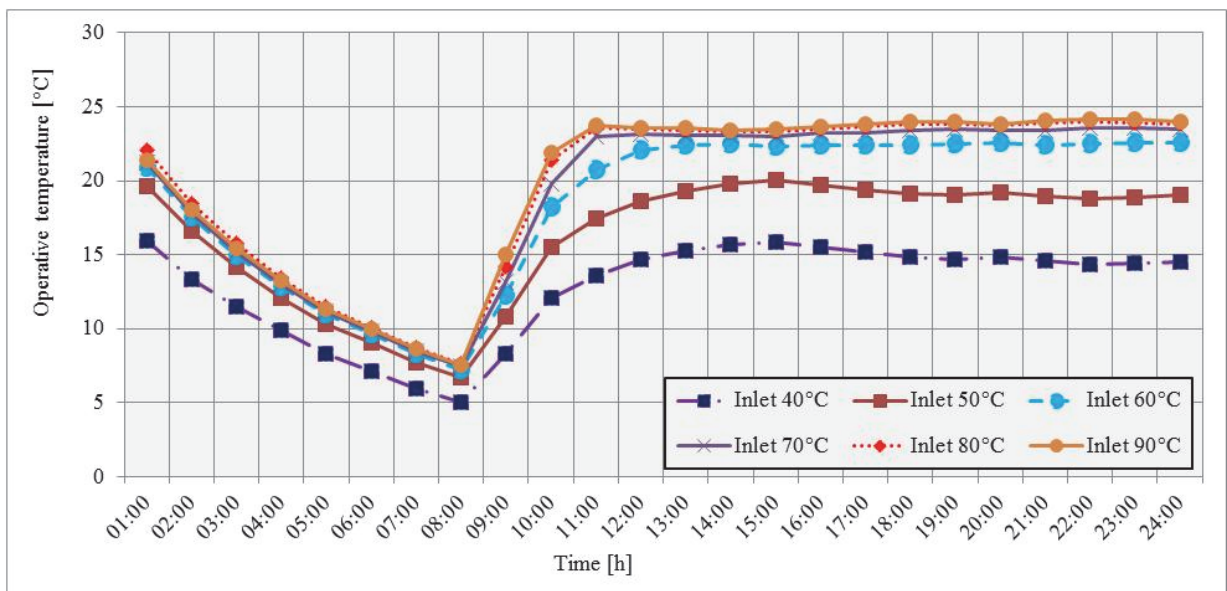


Figure 8 Dependence of operative temperature from inlet temperature to the wall panel

Figure 9 shows dependence of outlet temperature from the panel in relation to given values of inlet temperature to wall panel. It is possible to conclude that more values of inlet temperature have greater variation and less stable workflow. Thus, temperature difference is greatest if inlet temperature is 90°C and it goes to 37°C, while the lowest inlet temperature is from 40°C to 5°C

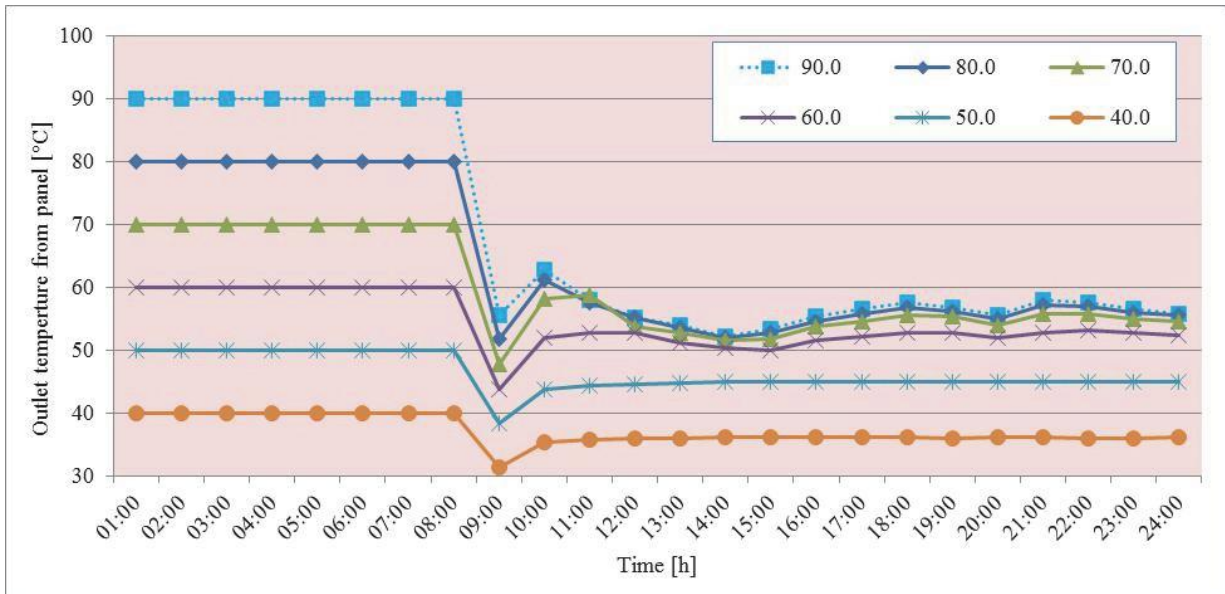


Figure 9 Dependence of outlet temperature from outlet temperature from the wall panel

6. CONCLUSION

This research inquiry analyzes impact of inlet temperatures for the heating systems, with wall panels to the energy consumption and temperature inside heated space. As source of heat, classical non-condensation boiler was used, based on natural gas, connected to circulation pump, with constant flow. Analyzed sports hall is located in Kragujevac city area. Its architecture represents typical way of construction for this kind of buildings in Serbia.

Heating system with inlet temperature of 40°C has lower consumption of energy, while system with inlet temperature of 90°C has highest consumption of energy. Panel systems of heating with inlet temperature cannot achieve aimed values and thus its use is unacceptable for this sports hall. Its use may be acceptable if different architectural concept is in question, with fewer transparent surfaces and better heat insulation. Heating system with inlet temperature of 50°C is not satisfactory in terms of aimed temperatures, but it is near that point. Heating system with inlet temperature of 60°C is the first system that achieves aimed values of temperature. Its energy consumption is around 9.7% higher than if the inlet temperature 60°C.

Also, higher inlet temperature outcomes with greater temperature difference and thus greater exergy unbalance. Low inlet temperatures are of no use for this kind of building because of huge volume of space to heat and bad heat insulation. Its eventual application can be achieved by changing the architecture of the building.

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