



University of Banja Luka
Faculty of Mechanical Engineering
Faculty of Electrical Engineering



DEMI 2015

**12. International Conference on Accomplishments in
Electrical and Mechanical Engineering
and Information Technology**

PROCEEDINGS

Banja Luka, 29th - 30th May 2015

University of Banja Luka
Faculty of Mechanical Engineering
Faculty Of Electrical Engineering

PROCEEDINGS

ZBORNIK RADOVA

Banja Luka, May 2015

**12TH INTERNATIONAL CONFERENCE ON ACCOMPLISHMENTS
IN ELECTRICAL AND MECHANICAL ENGINEERING AND
INFORMATION TECHNOLOGY**

Supported by:

MINISTRY OF SCIENCE AND TECHNOLOGY OF
THE REPUBLIC OF SRPSKA

Organizer and publisher:

FACULTY OF MECHANICAL ENGINEERING
UNIVERSITY OF BANJA LUKA

Co-organizer:

FACULTY OF ELECTRICAL ENGINEERING
UNIVERSITY OF BANJA LUKA

For publisher:

Prof. Darko Knežević, PhD

Editor in chief:

Prof. Vid Jovišević, PhD

Executive editor:

Biljana Prochaska, MSc

Editorial assistant:

Milivoj Stipanović

ORGANIZATIONAL COMMITTEE

Chairman:

Prof. Vid Jovišević, PhD, Faculty of Mechanical Engineering Banja Luka

Secretary:

Biljana Prochaska, MSc, Faculty of Mechanical Engineering Banja Luka

Members:

Prof. Zdravko Milovanović, PhD, Faculty of Mechanical Engineering Banja Luka

Prof. Darko Knežević, PhD, Faculty of Mechanical Engineering Banja Luka

Prof. Snežana Petković, PhD, Faculty of Mechanical Engineering Banja Luka

Prof. Petar Gvero, PhD, Faculty of Mechanical Engineering Banja Luka

Prof. Mladen Todić, PhD, Faculty of Mechanical Engineering Banja Luka

Assist. Prof. Zoran Đurić, PhD, Faculty of Electrical Engineering Banja Luka

Prof. Aleksandar Milašinović, PhD, Faculty of Mechanical Engineering Banja Luka

Prof. Mihajlo Stojičić, PhD, Faculty of Mechanical Engineering Banja Luka

Assist. Prof. Zorana Tanasić, PhD, Faculty of Mechanical Engineering Banja Luka

Assist. Prof. Strain Posavljak, PhD, Faculty of Mechanical Engineering Banja Luka

Assist. Prof. Đorđe Čiča, PhD, Faculty of Mechanical Engineering Banja Luka

Biljana Vranješ, MSc, Faculty of Mechanical Engineering Banja Luka

Branislav Sredanović, MSc, Faculty of Mechanical Engineering Banja Luka

Slaviša Todorović, Faculty of Mechanical Engineering Banja Luka

Goran Jotić, Faculty of Mechanical Engineering Banja Luka

Branislav Jovković, University of Banja Luka

Milivoj Stipanović, Faculty of Mechanical Engineering Banja Luka.

PROGRAM AND SCIENTIFIC COMMITTEE

Chairman:

Prof. Ostoja Miletić, PhD, Faculty of Mechanical Engineering Banja Luka, BiH.

Members:

Prof. Duško Lukač, PhD, University of Applied Science, Köln, /Germany/
Prof. Simo Jokanović, PhD, Faculty of Mechanical Engineering Banja Luka
Prof. Miloš Kojić, PhD, Harvard University, /USA/
Prof. Milorad Božić, PhD, Faculty of Electrical Engineering Banja Luka
Prof. Petar Marić, PhD, Faculty of Electrical Engineering Banja Luka
Prof. Bobrek Miroslav, PhD, Faculty of Mechanical Engineering Banja Luka
Prof. Ćosić Ilija, PhD, University of Novi Sad, /RS/
Prof. Hadžistević Miodrag, PhD, University of Novi Sad, /RS/
Prof. Soković Mirko, PhD, University of Ljubljana, /SL/
Prof. Milenko Stegić, PhD, University of Zagreb, /RH/
Prof. Ivan Filipović, PhD, University of Wien, /Austria/
Prof. Dušan Gruden, PhD, TU
Prof. Branko Blanuša, PhD, Faculty of Electrical Engineering Banja Luka
Prof. Čedomir Zeljković, PhD, Faculty of Electrical Engineering Banja Luka
Prof. Radivoje Pešić, PhD, University of Kragujevac, /RS/
Prof. Stevan Veinović, PhD, University of Kragujevac, /RS/
Prof. Solvang Björn, PhD, Narvik University, /Norway/
Prof. Ljubiša Papić, PhD, University of Kragujevac, /RS/
Prof. Petar Gvero, PhD, Faculty of Mechanical Engineering Banja Luka
Prof. Milan Radovanović, PhD, Society of Thermal Engineers, /RS/
Prof. Vladimir Savić, PhD, University of Novi Sad, /RS/
Prof. Zdravko Milovanović, PhD, Faculty of Mechanical Engineering Banja Luka
Prof. Janez Kopač, PhD, University of Ljubljana, /SL/
Prof. Milan Zeljković, PhD, University of Novi Sad, /RS/
Prof. Velimir Todić, PhD, University of Novi Sad, /RS/
Prof. Milentije Stefanović, PhD, University of Kragujevac, /RS/
Prof. Snežana Petković, PhD, Faculty of Mechanical Engineering Banja Luka
Assist. Prof. Strain Posavljak, PhD, Faculty of Mechanical Engineering Banja Luka
Prof. Miodrag Manić, PhD, University of Niš, /RS/
Prof. Emilia Assenova, PhD, Technical University of Sofia, /Bulgaria/
Prof. Bogdan Nedić, PhD, University of Kragujevac, /RS/
Prof. Marius Benea Calin, PhD, Faculty of Engineering Hunedoara, /Romania/
Prof. Konstantinos-Dionysios Bouzakis, PhD, AU Thessaloniki, /Greece/
Prof. Dragan Milutinović, PhD, University of Belgrade, /RS/
Prof. Vid Jovišević, PhD, Faculty of Mechanical Engineering Banja Luka
Prof. Ranko Zrilić, PhD, Faculty of Mechanical Engineering Banja Luka

Prof. Viktor Sajn, PhD, University of Ljubljana, /RS/
Prof. Darko Knežević, PhD, Faculty of Mechanical Engineering Banja Luka
Prof. Branislav Anđelković, PhD, University of Niš, /RS/
Prof. Mihajlo Stojčić, PhD, Faculty of Mechanical Engineering Banja Luka
Prof. Bojan Babić, PhD, University of Belgrade, /RS/
Prof. Milomir Gašić, PhD, Faculty of Mechanical and Civil Engineering,
Kraljevo, /RS/
Prof. Vidosav Majstorović, PhD, University of Belgrade, /RS/
Prof. Milorad Milovančević, PhD, University of Belgrade, /RS/
Prof. Ljubodrag Tanović, PhD, University of Belgrade, /RS/
Prof. Miroslav Trajanović, PhD, University of Niš, /RS/
Prof. Miodrag Bulatović, PhD, University of Podgorica, /CG/
Prof. Pavel Kovač, PhD, University of Novi Sad, /RS/
Dobrivoje Ninković, PhD, ABB Turbo-Systems AG, /Switzerland/
Prof. Zisis Samaras, PhD, AU Thessaloniki, /Greece/
Assist. Prof. Halil ÇALISKAN, PhD, Bartın University, Faculty of Engineering,/
TURKEY/
Prof. Dragoslava Stojiljković, PhD, University of Belgrade, /RS/
Prof. Olga Kordaš, PhD, KTH Stocholm, /Sweden/
Prof. Neven Duić, PhD, University of Zagreb, /Croatia/
Prof. Aurilla Aurelie Arntzen Bechina, PhD, /Norway/
Prof. Borut Kosec, PhD, University of Ljubljana, /SL/
Prof. Igor Budak, PhD, FTN, Novi Sad, /SR/

CONTENT
KEYNOTE LECTURES

Simo Jokanovic, Bjørn Solvang, Trygve Thomessen, Gabor Sziebig INTEGRATION OF DISTRIBUTED PRODUCTION RESOURCES BY MEANS OF RT- MIDDLEWARE AND VIRTUAL REALITY	3
Dušan Gruden ENVIRONMENTAL PROTECTION IN AUTOMOTIVE INDUSTRY	17
Radivoje Mitrovic, Milan Tica, Ivana Atanasovska, Predrag Popovic SCIENCE – GENERATOR OF INDUSTRIAL AND OVERALL DEVELOPMENT OF SERBIA AND REPUBLIC OF SRPSKA	41

PRODUCTION AND COMPUTER-AIDED TECHNOLOGIES

Dušan Petković, Miloš Madić, Goran Radenković, Predrag Živković, Mladen Tomić HEAT EXCHANGERS MATERIALS SELECTION BY USING MCDM APPROACH	55
Elvis Hozdić EUROPEAN TECHNOLOGY PLATFORM FOR FACTORIES OF THE FUTURE	61
Marina Dojčinović, Milena Ćosić INFLUENCE OF ALLOYING ELEMENTS ON CAVITATION RESISTANCE OF QUENCHED AND TEMPERED CARBON STEEL	73
Milena Ćosić, Marina Dojčinović, MICROSTRUCTURE OF AISi18CuMg ALLOY PRODUCED BY RHEOCASTING PROCESS	79
Miloš Madić, Miroslav Radovanović, Srđan Mladenović, Dušan Petković, Predrag Janković AN EXPERIMENTAL INVESTIGATION OF KERF WIDTH IN CO ₂ LASER CUTTING OF ALUMINUM ALLOY	85
Todic Mladen, Miletic Ostoja ZONE OF DEFORMATION AT MULTI-LAYER MATERIALS	91
Predrag Živković, PARAMETRIC MODELING OF GEOMETRY SHAPES OF GEAR TEETH BY USING CAD SOFTWARE	97
Dragana Temeljkovski, Stojanče Nusev, Climent Ohridski, Dragan Temeljkovski STONE IN THE WORLD OF ARCHITECTURE AND DESIGN – REENGINEERING STONE PROCESSING	105
Milentije Stefanović, Dragan Adamović, Zvonko Gulišija, Srbislav Aleksandrović, Vesna Mandić, Milan Milovanović LIMITATIONS OF PHYSICAL TRIBO-MODELING IN METAL FORMING PROCESSES	111

Content

Petar S. Đekić, Goran Radenković, Biljana Milutinović IMPROVEMENT OF THE PROPERTIES OF GROUND TIRE RUBBER BY MECHANOCHEMICAL MODIFICATION AND APPLICATION IN SRB/NR BLENDS	119
Vujadin Aleksić, Bojana Aleksić, Dejan Momčilović, Ljubica Milović, Aleksandar Sedmak NON-DESTRUCTIVE TESTING OF PRESSURE VESSELS – APPLICATION OF SolidWorks	125
Dejan Lukić, Velimir Todić, Mijodrag Milošević, Goran Jovičić, Jovan Vukman, Mića Đurđev COST ESTIMATION AS ASPECT OF DESIGN FOR MANUFACTURING-DfM	131
Goran Jovičić, Mijodrag Milošević, Dejan Lukić, Jovan Vukman, Mića Đurđev APPLICATION OF MULTI-AGENT SYSTEMS WITHIN THE CONCEPT OF DISTRIBUTED INTELLIGENT PRODUCTION	139
Aleksandar Vujović, Zdravko Krivokapić, Jelena Jovanović, Gordan Kijanović POSSIBILITY OF APPLICATION OF THE INTELLIGENT AGENT-BASED SYSTEM IN THE WOOD INDUSTRY	147
Milan Šljivić, Nenad Grujović, Ana Pavlović, Cristiano Fragassa, Jovica Ilić, Mirko Topić DEVELOPING PROFILES FROM WOOD-PLASTIC COMPOSITES	159
Said Pašalić, Milan Jurković, Mladen Todić MOVEMENT AND MOVING SPEED EDGE OF THE CORNICE CIRCLES BLANK OF THE WORKPIECE IN DEEP DRAWING	169
Miloš Madić, Miroslav Radovanović, Dušan Petković, Predrag Janković, Miloš Milošević PREDICTION OF SURFACE ROUGHNESS USING REGRESSION AND ANN MODELS IN CO ₂ LASER CUTTING OF MILD STEEL	175
Dragoslav Dobraš, Nenad Bukejlović HARDOX 450 – ATTACHMENT ASSESSMENT OF WELDABILITY	181
Dragoslav Dobraš, Ismar Hajro SPECIFICS OF THE TRAINING AND CERTIFICATION OF WELDERS FOR ALUMINOTHERMIC WELDING PROCESS	187
Velibor Karanović, Mitar Jocanović, Saša Laloš, Bojan Knežević OIL CLEANLINESS CLASS INFLUENCE ON WEAR INTENSITY OF PISTON/CYLINDER CONTACT PAIR INSIDE OF HYDRAULIC DISTRIBUTIONAL VALVE	193
Tomaz Irgolic, Franc Cus, Janez Kopač CUTTING FORCE PREDICTION BY MILLING GRADED MATERIAL	199
Ranko Radonjic, Mathias Liewald, Fei Han INFLUENCE OF BLANK HOLDER STIFFNESS ON PART SURFACE QUALITY IN DEEP DRAWING PROCESS	205
Bekir Novkinić, Vladimir Kočović, Marija Jeremić, Dragomir Miljuš PROBLEMS OF CLAMPING FIXTURES COMPLIANCE DURING THE MACHINING	

OF THE WORKPIECE ON THE MULTI-AXIAL MILLING MACHINE TOOL	213
Aleksandar Košarac, Milan Zeljković, Cvijetin Mladenović, Aleksandar Živković	
MODAL ANALYSIS OF A HORIZONTAL MACHINING CENTER	221
Aleksandar Živkovic, Milan Zeljkovic, Cvijetin Mladjenovic	
MATHEMATICAL MODEL FOR STIFFNESS DETERMINATION OF BALL BEARINGS WITH ANGULAR CONTACT	233
Bogdan Nedić, Marko Janković, Milan Erić, Gordana G. Lakić, Branislav Sredanović	
SPECIFICS OF THE DESIGN FOR CNC PLASMA CUTTING	241
Živko Babić, Rodoljub Lekanić	
THE IMPACT OF TOOL DESIGN ON PHARMACEUTICAL BLISTER PACKAGING	249
Saša Živanović, Branko Kokotović	
CONFIGURING A VIRTUAL DESKTOP 5-AXIS MACHINE TOOL FOR MACHINE SIMULATION	255
Mario Močić, Sanja Dobrnjac	
DEDUSTING OF DUST POLYURETHANE IN THE PROCESS OF PRODUCTION ORTHOPEDIC AIDS	263
Ostoja Miletic, Mladen Todoc	
STRESS-STRAIN STATE IN PROFILING ANISOTROPIC STRIPS	269
Nenad Grujović, Miroslav Živković, Fatima Živić, Andreja Radovanović, Miloš Mladenović, Milan Šljivić	
COST OPTIMIZATION OF ADDITIVE MANUFACTURING IN WOOD INDUSTRY	275
Nenad Miloradović, Slobodan Mitrović, Blaža Stojanović	
WEAR OF ZA27/10SIC/1GR HYBRID COMPOSITE	287
Branislav Sredanović, Gordana Globočki - Lakić, Davorin Kramar, Janez Kopač	
MODELLING OF TOOL WEAR IN TURNING OF BEARING STEEL USING CARBIDE TOOL AND HPJAM TECHNIQUE	293
Zvnoko Gulišija, Marija Mihailović, Aleksandra Patarić	
THE STRUCTURE-PROPERTIES CORRELATION OF NICKEL BASED SUPERALLOYS IN DESIGNING THE TECHNOLOGY FOR TURBINEBLADES PROCESSING	299
Zvonko Gulišija, Aleksandra Patarić, Marija Mihailović, Milentije Stefanović	
DESIGNING THE HIGH QUALITY AL-ALLOYS OBTAINED WITH ELECTROMAGNETIC FIELD FOR HOT FORGING PROCESS	305
Jure Bernetič, Gorazd Kosec, Matjaž Marčetič, Borut Kosec, Aleš Nagode, Mirko Gojić, Zijah Burzić	
ARMOURED STEEL PLATE OF NEW GENERATION	309

ENERGETICS AND THERMAL ENGINEERING

Cvete Dimitrieska, Igor Andreevski, Sanja P. Vasilevska, Sevde Stavreva	
NUMERICAL SOLUTION OF MATHEMATICAL MODEL FOR FLUID FLOW AND	

HEAT TRANSFER PROCESSES IN PLATE EXCHANGER BASE ON STREAMLINE – VORTEX METHOD	317
Dragan Cvetković, Milorad Bojić, Dragan Taranović, Jasmina Skerlić EXPERIMENTAL INVESTIGATION OF HEAT FLUX AT THE PANEL HEATING SYSTEMS	323
Dragana Dimitrijević, Mladen Tomić, Predrag Živković, Mladen Stojiljković, Mirko Dobrnjac THERMAL CHARACTERISTICS AND POTENTIAL FOR RETROFIT BY USING GREEN VEGETATED ROOFS	329
Filip Mojsovski ENTERING AIR STATE INFLUENCE ON THERMAL PERFORMANCE OF HYPERBOLIC COOLING TOWER	335
Miloš Simonović, Vlastimir Nikolić, Ivan Ćirić, Emina Petrović RECURRENT NEURAL NETWORK SHORT-TERM PREDICTION OF DISTRICT HEATING SYSTEM IN TRANSIENT REGIMES	341
Mladen Tomić, Predrag Živković, Mića Vukić, Mirko Dobrnjac, Dragana Dimitrijević A NUMERICAL STUDY OF PERFORATED PLATE LOCAL HEAT TRANSFER COEFFICIENT	347
Mladen Tomić, Mića Vukić, Predrag Živković, Žana Stevanović, Ivan Ćirić EXPERIMENTAL INVESTIGATION OF THERMAL AND FLUID FLOW PROCESSES IN A PERFORATED PLATE HEAT EXCHANGER	353
Predrag Živković HEAT BALANCE OF LOSSES IN PLANETARY GEAR DRIVES	359
Saša Pavlović, Velimir Stefanović, Marko Mančić, Zivan Spasic DEVELOPMENT OF MATHEMATICAL MODEL OF OFFSET TYPE SOLAR PARABOLIC CONCENTRATING COLLECTOR	365
Predrag Živković, Mladen Tomić, Dušan Petković, Ivan Ćirić, Žana Stevanović, Dragana Dimitrijević, Sanja Dobrnjac, Milica Ćirić POSSIBILITIES OF WIND ENERGY USAGE IN THE SKI CENTER KOPAONIK	373
Vladimir V. Jovanović, Nebojša Manić, Dragoslava D. Stojiljković, Pavle Hadžić PRODUCTION OF BIODIESEL IN A BATCH REACTOR BY ALKALINE TRANSESTERIFICATION AT ROOM TEMPERATURE	379
Ivan Komusanac, Boris Ćosić, Luka Perković, Neven Duić EXPERIENCE WITH SOLAR-DRIVEN LiBr/H ₂ O ABSORPTION COOLING SYSTEM IN VODOVOD DUBROVNIK D.O.Ö.	385
Vesna Ranković, Milorad Bojić, Jasna Radulović, Danijela Nikolić, Jasmina Skerlić MODELING OF THE BUILDING THERMAL BEHAVIOUR USING NONLINEAR SYSTEM IDENTIFICATION	391
Sadoon Ayed, Miloš Jovanović, Mladen Tomić, Gradimir Ilić, Predrag Živković, Mića Vukić, Mirko Dobrnjac INSTABILITY OF RAYLEIGH-BERNARD CONVECTION AFFECTED BY INCLINED	

WALL TEMPERATURE VARIATION	397
Ratka Neshkovska	
ELECTROCHROMIC COPPER(I) OXIDE THIN FILM AS A CANDIDATE FOR SMART WINDOW	403
Milorad Bojic, Jasna Radulovic, Vesna Rankovic, Danijela Nikolić, Ljubisa Bojic, Jasmina Skerlic	
FLEXIBLE THIN-FILM SOLAR PHOTOVOLTAICS: RESEARCH AND APPLICATION	409
Vujadin Aleksić, Dejan Momčilović, Bojana Aleksić, Ljubica Milović, Aleksandar Sedmak	
ANALYSIS OF THE STEAM LINE DAMAGES	415
Danijela Nikolić, Milorad Bojic, Jasna Radulovic, Jasmina Skerlic, Saša Jovanović	
ENERGY OPTIMIZATION OF SERBIAN BUILDINGS WITH PV PANELS AND DISTRICT HEATING SYSTEM	421
Sevde Stavreva, Cvete Dimitrieska, Igor Andreevski, Sanja P. Vasilevska, Elizabeta Hristovska	
IMPROVING ENERGY EFFICIENCY OF DATA CENTRES	427
Mila Mihajilović, Vanja Šušteršič, Gordana Bogdanović	
LEED TECHNOLOGY IN URBAN PLANNING	433

MECHANICS AND DESIGN

Filip Zdraveski, Dimitri Kozinakov	
ANALYSIS OF POINT SUPPORTED-GLASS WALL SYSTEM UNDER WIND LOAD	441
Filip Zdraveski, Hristijan Mickoski	
APPLICATION OF SIMILITUDE LAWS FOR EXPERIMENTAL INVESTIGATIONS OF DYNAMIC PROPERTIES OF TALL PROTOTYPE STEEL STRUCTURE	451
Filip Zdraveski, Elisaveta Donceva	
MATHEMATICAL MODEL OF DYNAMIC VIBRATION ABSORBERRESPONSE PREDICTION AND REDUCTION	459
Đorđe Miltenović, Milan Tica, Aleksandar Miltenović, Milan Banić	
LOAD CAPACITY OF WORM GEARS WITH COMPACT DESIGN	469
Luka Panić, Atif Hodžić, Ekrem Nezirević	
MODERN AND SOPHISTICATED PROCESSES OF 3D VENEER PLYWOOD BENDING	475
Stevan Maksimović, Mirjana Đurić, Mirko Maksimović, Ivana Vasović	
FATIGUE LIFE ESTIMATION OF AIRCRAFT STRUCTURAL COMPONENTS WITH SURFACE CRACKS UNDER LOAD SPECTRUM	481
Darko Knežević, Saša Laloš, Mitar Jocanović, Velibor Karanović	
EFFECT OF BULK MODULUS OF FLUID ON THE DYNAMIC BEHAVIOR OF THE HYDRAULIC SYSTEM	487

Nikola Vučetić, Aleksija Đurić, Miroslav Milutinović EXPERIMENTAL DETERMINATION OF SLIDING BEARING OPERATING TEMPERATURE	497
Slobodanka Boljanović, Stevan Maksimović, Dragi Stamenković FATIGUE STRENGTH SIMULATION OF AIRCRAFT LUG	503
Slobodanka Boljanović, Stevan Maksimović, Strain Posavljak RESIDUAL LIFE EVALUATION OF A THREADED ROUND BAR WITH SURFACE CRACK UNDER CYCLIC LOADING	509
Nenad Miloradović, Rodoljub Vujanac ANALYSIS OF OVERHEAD TRAVELLING CRANE'S MOTION IN HORIZONTAL PLANE	515
Rodoljub Vujanac, Nenad Miloradovic, Snezana Vulovic DYNAMIC STORAGE SYSTEMS	521
Vladimir Čavić, Mirko Dobrnjac, Milan Lečić, Jela Burazer MOGUĆNOSTI PRIMJENE VAKUUMSKOG PNEUMATSKOG TRANSPORTA U PIVARAMA	529
Zoran Majkić ATTACHMENT RESEARCH JUDGEMENTS INDICATORS FOR COMFORT MANAGEMENT OF TRANSPORTATION VEHICLES	535

MECHATRONICS AND INFORMATION TECHNOLOGY

Muhanad D. Almawlawe, Darko Mitic, Marko Milojkovic THE ADVANTAGE OF USING DIGITAL QUASI-SLIDING MODE IN COMPARISON WITH ANALOGUE PID SLIDING MODE CONTROLLER	551
Petar D. Mandić, Mihailo P. Lazarević, Tomislav B. Šekara CONTROL OF THE CART PENDULUM SYSTEM BY USING A FRACTIONAL ORDER PD CONTROLLER	557
Vladimir Savic, Jelena Eric Obucina, Darko Knezevic, Andrea Ivanisevic, Boban Balovic, Sanjin Kizic TECHNICAL-ECONOMIC VIEW OF THE REPLACEMENT OF PUMPS WITH VARIABLE VOLUME PUMPS A CONSTANT VOLUME OF THE FREQUENCY CONVERTER	563
Jelena Živković, Dragan Adamović, Miroslav Živković, Milentije Stefanović, Slobodan Mitrović, Fatima Živić ELECTRONIC DATABASES FOR MATERIALS SELECTION	569
Ivan Ćirić, Žarko Ćojbašić, Vlastimir Nikolić, Milica Ćirić, Mladen Tomić, Emina Petrović, Miloš Simonović NEURAL NETWORK PREDICTION OF PERSON POSITION FOR HUMAN FOLLOWING MOBILE ROBOT PLATFORM	577
Ivan Ćirić, Žarko Ćojbašić, Vlastimir Nikolić, Milica Ćirić, Predrag Živković, Ivan	

Pavlović, Emina Petrović INTELLIGENT CONTROL OF MOBILE ROBOT FOR OBJECT RECOGNITION AND GRASPING	583
Dragan Pršić, Novak Nedić, Ljubiša Dubonjić, MASS FLOW RATE CHARACTERISTIC OF THE FLAPPER-NOZZLE PNEUMATIC VALVE	589
AUTOMOTIVE AND TRAFFIC ENGINEERING	
Aleksandar Milašinović, Indir Mujanić, Željko Bulatović, Željko Đurić OUTPUT TORQUE OF THE FLYWHEEL OF THE IC ENGINE VARIATIONS DURING AN ENGINE CYCLE	597
Branislav Aleksandrović, Rajko Radonjić, Aleksandra Janković RESEARCHING ABOUT BEHAVIOUR OF CYBERNETIC SYSTEM, DRIVER – MOTORCYCLE AT LIMITED REGIMES MOVEMENT	609
Danijela Miloradović, Rajko Radonjić, Jasna Glišović APPLICATION OF VERTICAL ACCELERATION RECORDS ACQUIRED AT THE CENTRES OF THE VEHICLE WHEELS	615
Jasna Glišović, Jovanka Lukić, Danijela Miloradović, Slavica Mačužić TRENDS IN THE DEVELOPMENT OF BRAKE SYSTEMS OF THE AGRICULTURAL TRACTORS AND TRAILERS	621
Jovan Dorić, Atila Kovač, Nebojša Nikolić, Stjepan Galamboš, Ivan Klinar IMPROVING PERFORMANCE OF SPARK IGNITION ENGINE USING VARIABLE LENGTH INTAKE MANIFOLD	627
Jovanka Lukić, Jasna Glišović, Danijela Miloradović, Slavica Mačužić METHOD OF DISK BRAKE NOISE ASSESSMENT	633
Melisa Kustura, Aleksandra Kostic A MODEL OF ACC – ADAPTIVE CRUISE CONTROL	639
Milan Milovanović, Zoran Jovanović, Milentije Stefanović ANALYSIS OF THE EFFECTS OF NEW MATERIALS APPLICATION ON CAR BODIES	645
Stojko Biočanin, Željko Bulatović, Aleksandar Milašinović, Indir Mujanić, Ranko Božičković CRANKSHAFT ANGULAR VELOCITY OF A TEN-CYLINDER DIESEL ENGINE AS A DIAGNOSTICS PARAMETER	651
Stojko Biočanin, Željko Bulatović, Aleksandar Milašinović, Indir Mujanić, Ranko Božičković ENGINE MISFIRE IDENTIFICATION BY MONITORING EXHAUST PRESSURE AND TEMPERATURE PULSATION IN THE EXHAUST MANIFOLDS	667
Saša Milojević, Radivoje Pešić APPLICATION OF BIOMETHANE IN PROPULSION AND MOBILE SYSTEMS	681

Slobodan Mišanović, Zlatomir Živanović ANALYSIS OF RENEWAL BUS FLEET GSP "BEOGRAD" FROM THE ENVIRONMENTAL AND ENERGY ASPECTS	687
Stjepan Galamboš, Jovan Dorić DESIGN AND ANALYSIS OF CAR BODY USING CFD SOFTWARE	693
Velimir Petrović, Branka Grozdanić, Zlata Bračanović, Stojan Petrović THE PROBLEM OF REAL DRIVING EMISSIONS CONTROL	697
Aleksandar Davinić, Radivoje Pešić, Dragan Taranović, Saša Milojević THE USE OF MODERN FUELS IN DIESEL ENGINES OF THE OLDER GENERATION	703
Dušan Petković, Miloš Madić, Goran Radenković, Miloš Milošević APPLICATION OF MCDM METHODES FOR AUTOMOBILE'S BUMPER MATERIAL SELECTION	713
Nebojša Nikolić, Ivan Klinar, Jovan Dorić, Nenad Raspopović INFLUENCE OF THE FAULTY MAP SENSOR ON SOME OPERATION PARAMETERS OF AN AUTOMOBILE SPARK-IGNITION ENGINE	719
Dobrivoje Ninković THE USE OF PARAMETRIC SPECTRAL ESTIMATION FOR EXTRACTING ANGULAR VELOCITY VARIATIONS FROM THE EXHAUST PRESSURE PULSATIONS IN IC ENGINES	723
Petković Snežana, Hnatko Emil, Stefanović Radmilo, Veinović Stevan ENVIRONMENTAL ASSESSMENT OF BIO RESOURCES AND RENEWABLE/ RECURRENT ENERGY SOURCES IN AGRICULTURE	733
Saša Milojević, Radivoje Pešić, Aleksandar Davinić, Dragan Taranović COATED AL PISTON AS TECHNOLOGICAL SOLUTION TO LOWERING OF FRICTION LOSSES INSIDE IC ENGINE	741

QUALITY AND ECOLOGY

Biljana Milutinović, Gordana Stefanović, Ksenija Denčić-Mihajlov, Petar Djekić ECONOMIC INDICATORS OF WASTE-TO-ENERGY TREATMENT	749
Borut Kosec, Blaž Karpe, Aleš Nagode, Dragan Gogić, Gorazd Kosec, Igor Budak, Zorana Tanasić, Goran Janjić, Miroslav Bobrek, Mirko Soković LCA METHOD AS AN USEFUL TOOL IN PRODUCTION ENGINEERING	755
Srdjan Pelkic, Stevan Salatic, Radivojka Vucnic THE CAPACITY OF MUNICIPALITY NEVESINJE IN DEVELOPING WOODPROCESING INDUSTRIES	761
Zorana Tanasić, Borut Kosec, Goran Janjić, Mirko Soković, Goran Jotić INTEGRATING LEAN AND GREEN INTO A HOLISTIC PRODUCTION SYSTEM	767
Miroslav Bobrek, Jugoslav Tepić, Duška Radmanović QUALITY ASSURANCE INSTRUMENTS IN HIGHER EDUCATION SYSTEM OF	

REPUBLIKA SRPSKA	771
Miloš Madić, Marko Kovačević, Miroslav Radovanović POSSIBILITIES OF USING DISCRETE MONTE CARLO METHOD FOR SOLVING MACHINING OPTIMIZATION PROBLEMS	781
Željko Pavićević, Leonid Albijanic INTELLIGENT INVESTMENTS MANAGEMENT; TRANSITION U-TURN	787
Nataša Đalić, Irena Đalić THE IMPACT OF INFORMATION SYSTEMS ON IMPROVEMENT OF BUSINESS ACTIVITIES IN MANUFACTURING ENTERPRISES	795
Marko Serafimov, Sevde Stavreva, Igor Shesho COST – OPTIMAL METHODOLOGY	801
 MAINTENANCE OF ENGINEERING SYSTEMS AND OCCUPATIONAL SAFETY ENGINEERING	
Aleksandar Majstorović THERMAL IMAGES AND THEIR APPLIANCE IN THE FIRE UNITS	811
Dejan Brankovic, Boris Latinovic, Zdravko N. Milovanovic THE OPTIMIZATION OF THE PAPER MACHINE DEWATERING PROCESS BY USING THE NEW POLYURETHANE SUCTION PRESS ROLL COVER	817
Dragan Milčić, Erdinč Rakipovski, Tasko Smileski, Miodrag Milčić RELIABILITY ANALYSIS OF DISTRIBUTOR VALVE OF THE AIR BRAKE SYSTEM	825
Dragoljub Vujić STRUCTURAL HEALTH MONITORING TECHNOLOGIES AND APPLICATIONS IN AIRCRAFT STRUCTURES	831
Mitar Jocanović, Velibor Karanović, Darko Knežević, Marko Orošnjak MODEL FOR MONITORING OF THE PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE OIL FILLING IN HYDRAULIC SYSTEMS	837
Mladen Todić, S. Petkovic, B. Milinovic HARMFULNESS OF EXHAUSTED SYSTEM MOTOR SUS IN CONFINED SPACE	843
Biljana Vranješ, Zorana Tanasić DETERMINING THE CAUSE OF ACCIDENTS AT WORK – ROOT CAUSE ANALYSIS	849



MODELING OF THE BUILDING THERMAL BEHAVIOUR USING NONLINEAR SYSTEM IDENTIFICATION

Vesna Ranković¹, Milorad Bojić², Jasna Radulović³, Danijela Nikolić⁴,
Jasmina Skerlić⁵

Summary: Model-based predictive control is a very modern powerful control strategy that uses a model of the plant to predict its future behaviour and has been in focus of researchers in the area of buildings energy management. The aim of this paper is to develop and analyze NARX (Nonlinear AutoRegressive with eXogenous inputs) structure for the modeling of the building thermal behavior. A database was generated using simulation in EnergyPlus software. The NARX identification model was designed using the MATLAB System Identification Toolbox. The input variables analyzed in this paper are: outdoor temperature, heating or cooling power, and direct solar radiation. Simulation results demonstrate that the proposed nonlinear structure can be effective identification tool for development of nonlinear buildings predictive control.

Key words: building, NARX, identification, thermal behaviour

1. INTRODUCTION

Model predictive control (MPC) has been in focus of researchers in the area of buildings [1]. Model predictive control denotes a wide range of control techniques which apply a model to the prediction of future system behavior and calculate the control signals through the optimization of the objective function. The basic conditions that each model should satisfy are practical simplicity, well estimated system dynamics and satisfactory prediction properties.

Various deterministic approaches which uses knowledge of the structure and physical and material properties of a building and statistical procedures have been applied in order to derive a total model for the heat dynamics of a building. Deterministic models are based on energy and mass balance integral–differential equations and development of such type of model is a very time consuming task.

¹Ph.D., Vesna Ranković, Kragujevac, Faculty of Engineering, University of Kragujevac, (vesnar@kg.ac.rs)

²Ph.D., Milorad Bojić, Kragujevac, Faculty of Engineering, University of Kragujevac,
(milorad.bojic@gmail.com)

³Ph.D., Jasna Radulović, Faculty of Engineering, University of Kragujevac, (jasna@kg.ac.rs)

⁴Assistant, Danijela Nikolić, Faculty of Engineering, University of Kragujevac, (danijelan@kg.ac.rs)

⁵Researcher, Jasmina Skerlić, Faculty of Engineering, University of Kragujevac, (jskerlic@gmail.com)

Prívarva et al. [2] proposed a new methodology to obtain a model combining the building energy performance simulation tools and statistical identification. Bacher and Madsen [3] applied the procedure for identification of the most suitable grey-box models for the heat dynamics of a building on the basis of data from an experiment and prior physical knowledge of the system. Also, the grey box modelling method has been applied to derive a total model for the heat dynamics of a building by Andersen et al. [4]. Jiménez et al. [5] have been presented the application of the MATLAB System Identification toolbox to estimate the thermal properties of building components from outdoor dynamic testing, imposing appropriate physical constraints and assuming ARMAX parametric models. The nonlinear black-box models perform better than linear models (ARX, ARMAX) in predicting buildings thermal behaviour [6-9].

The present paper suggests a procedure for identification and development NARX structure for the modeling of the building thermal behaviour. A database has been generated using simulation in EnergyPlus software.

2. METHODS FOR NONLINEAR SYSTEMS IDENTIFICATION

Different methods have been developed in the literature for linear system identification. These methods use a parameterized model. The parameters are updated to minimize an output identification error.

The linear dynamic systems with an input u and an output y can be described by the ARX (**A**uto **R**egressive **eX**ogenous) model:

$$y(k) = \varphi^T(k)\theta = \theta^T\varphi(k) \quad (1)$$

where: $y(k)$ is the output of the model, $\varphi(k)$ is the regression vector and θ is the parameter vector.

The regression vector ARX structure is:

$$\varphi^T(k) = \{-y(k-1), -y(k-2), -y(k-3), \dots, -y(k-n_a), \\ u(k), u(k-1), u(k-2), u(k-3), \dots, u(k-n_b)\}$$

and the parameter vector is $\theta^T = \{a_1, a_2, \dots, a_{n_a}, b_1, b_2, b_3, \dots, b_{n_b}\}$.

A wide class of nonlinear dynamic systems can be described by the Nonlinear ARX model:

$$y(k) = f(\varphi(k), \theta) \quad (2)$$

where: f is a nonlinear function whose Inputs are the model regressors.

This block diagram of a nonlinear ARX model is shown in Fig. 1.

The nonlinearity estimator block is combine with linear and nonlinear function in parallel and maps the regressors to the model output:

$$f(\varphi) = L^T(\varphi - m) + r + g(Q(\varphi - m)) \quad (3)$$

d is a scalar offset, m is the mean of the regressors, Q is a projection matrix.

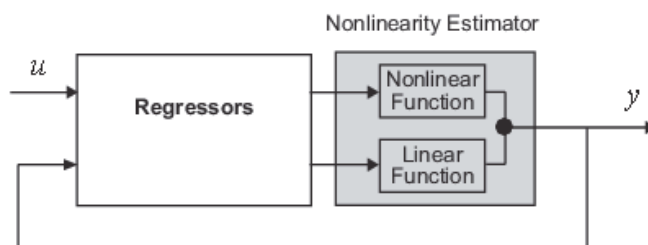


Fig. 1 Structure of Nonlinear ARX Models.

The wavelet network can be trained to approximate function g as:

$$g(\varphi) = \sum_{i=1}^n \alpha_k \kappa(\beta_k(\varphi - \gamma_k)) \quad (4)$$

where: $\kappa(*)$ is the wavelet function, n is the number of nonlinear units and α_k , β_k and γ_k are constant.

3. BUILDING SIMULATION

The analyzed building consists of three zones, Fig. 2.

Basic file description: 1 story building divided into 3 interior conditioned zones. Roof with no plenum. No ground contact with floor. Floor Area: 130.1 m². There is a single window in the west zone south wall. An electric low temperature radiant system is used for heating the floor of each zone, with power ratings of 12 kW, 8 kW and 8 kW for the north, west and east zones respectively. The ambient air temperature profile was of Chicago, IL, USA. The disturbances due to internal heat gain and solar heat gain were different for every zone and time-varying.

In this case study, we used the EnergyPlus model as the ground truth for the building, i.e., it was considered as the “real” building. The program EnergyPlus 6.0 is used, which allows the simulation of thermal behavior of buildings during the analyzed period.

4. SIMULATION RESULTS

In this work, *NARX (Nonlinear AutoRegressive with eXogenous inputs)* structure are chosen to predict zone temperature (North, West and East). The procedure for determining proper NARX models from EnergyPlus data involves three steps: (1) obtaining input-output data by simulating (2) model structure selection (train NARX with different delays), and (3) model validation. The input vector of the considered models is:

$$\mathbf{u} = [T_e \ P_{hc} \ R]^T$$

where: T_e is outdoor temperature, P_{hc} denote heating or cooling power and R is direct solar radiation.

Zone Description Details:

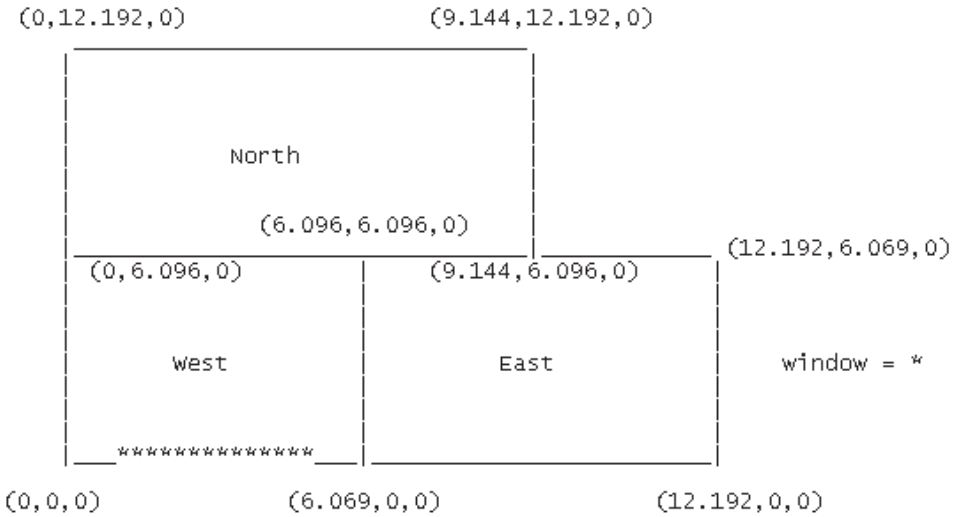


Fig. 2 The analyzed building.

The number of the *NARX* inputs is determined by the input and output lags. In this paper, the satisfactory accuracy is obtained for regression vector:

$$\varphi^T(k) = \{T_i(k-1), T_e(k-1), P_{hc}(k-1), R(k-1)\} \quad (5)$$

The numbers of units wavelets estimator have been automatically chosen by the estimation algorithm. This section presents the results of simulations for the west zone. The wavelets estimator for prediction WEST zone temperature has 94 units.

The time series of the inputs and output variables are shown in Fig. 3, Fig. 4, Fig. 5 and Fig. 6.

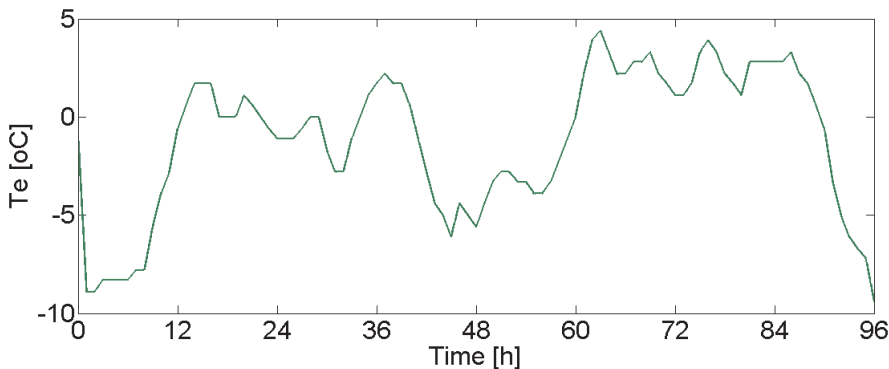


Fig. 3 The outdoor temperature.

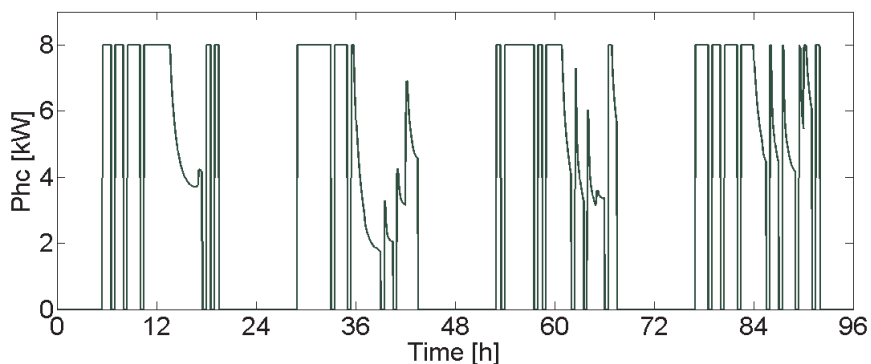


Fig. 4 The power heating or cooling.

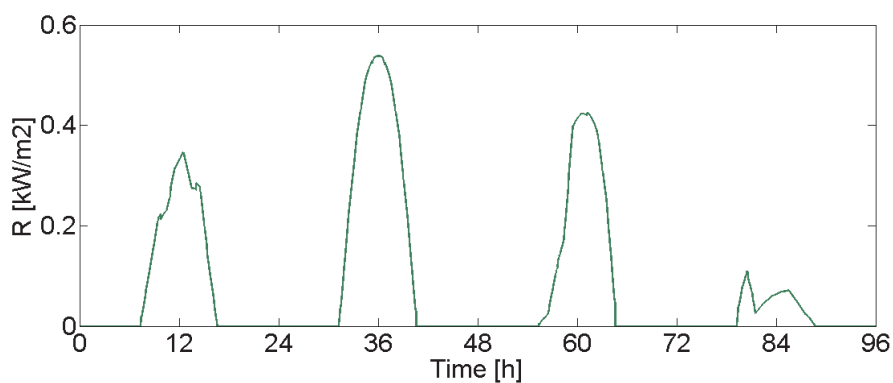


Fig. 5 The direct solar radiation.

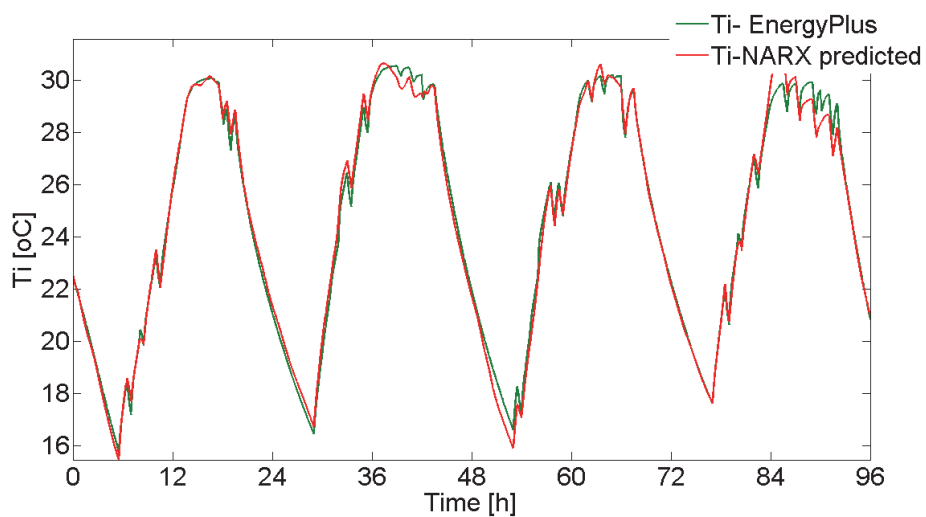


Fig. 6 The indoor temperature.

5. CONCLUSION

In this paper, a procedure for using MATLAB System Identification Toolbox for modeling building thermal behaviour is proposed. Nonlinear ARX model is more suitable than the linear estimator because room temperatures is governed by nonlinear equation. The result of the simulation show that NARX model predicted values are in accordance with the values obtained by the simulation.

The future research should include the application of the proposed technique on a real input–output data collection from measurements.

ACKNOWLEDGMENT

Research presented in this paper was supported by Ministry of Science and Technological Development of Republic of Serbia, Grants TR 33015 and III 42006.

LITERATURE

- [1] Freire, R., Oliveira, G., Mendes, N. (2008). Predictive controllers for thermal comfort optimization and energy savings, *Energy and Buildings*, vol. 40, no. 7, p. 1353–1365.
- [2] Prívar, S., Cigler, J., Váňa Z., Oldewurtel, F., Sagerschnig C., Žáčková, E. (2013). Building modelling as a crucial part for building predictive control, *Energy and Buildings* vol. 56, p. 8–22.
- [3] Bacher, P., Madsen, H. (2011). Identifying suitable models for the heat dynamics of buildings. *Energy and Buildings*, vol. 43, no. 7, p. 1511–1522.
- [4] Andersen, K.K., Madsen, H., Hansen, L.H. (2000). Modelling the heat dynamics of a building using stochastic differential equations. *Energy and Buildings*, vol. 31, no. 1, p. 13–24.
- [5] Jiménez, M.J., Madsen, H., Andersen, K.K. (2008). Identification of the main thermal characteristics of building components using MATLAB. *Building and Environment*, vol. 43, no. 2, p. 170–180.
- [6] Mechaqrane, A., Zouak, M. (2004). A comparison of linear and neural network ARX models applied to a prediction of the indoor temperature of a building. *Neural Computing & Applications*, vol. 13, no. 1, p. 32–37.
- [7] Ruano, A.E., Crispim, E.M., Coincecao, E.Z.E., Lucio, M.M.J.R. (2006). Predictions of building's temperature using neural networks models. *Energy and Buildings*, vol. 38, no. 6, p. 682–694.
- [8] Patil, S.L., Tantau, H.J., Salokhe, V.M. (2008). Modelling of tropical greenhouse temperature by autoregressive and neural network models. *Biosystems Engineering*, vol. 99, no. 3, p. 423–431.
- [9] Mustafaraj, G., Lowry, G., Chen, J. (2011). Prediction of room temperature and relative humidity by autoregressive linear and nonlinear neural network models for an open office. *Energy and Buildings*, vol. 43, no. 6, p. 1452–1460.



Tempus

530577-TEMPUS-1-2012-1-RS-
TEMPUS-JPCR

**Improvement of Product
Development Studies in Serbia
and Bosnia and Herzegovina**