



UNIVERSITY OF NIŠ
FACULTY OF MECHANICAL ENGINEERING
Department for Production, IT and Management



34th INTERNATIONAL CONFERENCE ON PRODUCTION ENGINEERING

PROCEEDINGS



Sponsor General

Ministry of Education and Science, Republic of Serbia

September 28-30 2011,
Niš
Serbia

PROCEEDINGS OF THE 34th INTERNATIONAL CONFERENCE ON PRODUCTION
ENGINEERING NIŠ, 2011.

Izdavač: Univerzitet u Nišu, Mašinski
fakultet u Nišu
Aleksandra Medvedeva br 14
18000 Niš
Srbija

Publisher: UNIVERSITY OF NIŠ,
FACULTY OF MECHANICAL
ENGINEERING IN NIŠ
Aleksandra Medvedeva br 14
18000 Niš
Serbia

Za izdavača:
For publisher:

Prof.dr Vlastimir NIKOLIĆ, dekan fakulteta

Glavni i odgovorni urednik:
Editor:

Prof.dr Miroslav TRAJANOVIĆ

Tehnička obrada:
Technical treatment:

Milan Zdravković
Nikola Vitković
Marko Veselinović
Dalibor Stevanović

Rukopis predat u štampu:
Manuscript submitted for publication:
Izdanje:
Printing:
Tiraž:
Circulation:

20.09.2011. godine
Septembar 20.2011
prvo
1st
150

Štampa:
Printed by:

UNIGRAF – X – COPY
18000 Niš, Vojvode Putnika

ISBN: 978 – 86 – 6055 – 019 – 6



Izdavanje zbornika radova, organizovanje i održavanje 34 Međunarodne konferencije proizvodnog mašinstva Srbije pomogao je pokrovitelj
Ministarstvo prosvete i nauke Republike Srbije
Financing of the Proceedings was sponsored by the **Ministry of Education and Science of the Republic of Serbia**



34th INTERNATIONAL CONFERENCE ON
PRODUCTION ENGINEERING
29. - 30. September 2011, Niš, Serbia
University of Niš, Faculty of Mechanical Engineering



ORGANIZING INSTITUTIONS:

Association of production engineering scientific research institutions of Serbia

- Unverzitet u Nišu, Mašinski fakultet u Nišu – Katedra za proizvodno informacione tehnologije i menadžment
- Mašinski fakultet, Beograd
- Mašinski fakultet, Kragujevac
- Fakultet tehničkih nauka – Departman za proizvodno mašinstvo, Novi Sad
- Fakultet tehničkih nauka – Departman za industrijsko inženjering i menadžment, Novi Sad
- Tehnički fakultet, Čačak
- Mašinski fakultet, Kraljevo
- Fakultet tehničkih nauka, Kosovska Mitrovica
- LOLA Institut, Beograd

ORGANIZERS:

UNIVERZITET U NIŠU
MAŠINSKI FAKULTET U NIŠU
Katedra za proizvodno informacione tehnologije i menadžment
Aleksandra Medvedeva br 14
18000 Niš
Tel. +381 (18) 500 – 669; Fax. +381 (18) 588 – 244
Web: <http://www.masfak.ni.ac.rs>
email: spms@masfak.ni.ac.rs

CONFERENCE VENUE:

Niš
Hotel Tami residence
18000 Niš, Durmitorska – prilaz bb
Tel. +381 (18) 505 – 800, 282 – 222
Web: <http://www.tamiresidence.com>
email: info@tamiresidence.com



34th INTERNATIONAL CONFERENCE ON
PRODUCTION ENGINEERING
29. - 30. September 2011, Niš, Serbia
University of Niš, Faculty of Mechanical Engineering



SCIENTIFIC COMMITTEE

1. Prof. dr Velibor MARINKOVIĆ, MF, Niš, SRB, president
 2. Prof. dr Sergey ALEKSANDROV, RA of S, Moscow, RUS
 3. Prof. dr Miroslav BADIDA, ME, Košice, SK
 4. Prof. dr Nikolai BOBYR, KPI, Kiev, UA
 5. Prof. dr Pavao BOJANIĆ, MF, Beograd, SRB
 6. Prof. dr Alan BRAMLEY, University Bath, UK
 7. Prof. dr Aleksandar BUKVIĆ, MF, I. Sarajevo, RS, BIH
 8. Prof. dr Miodrag BULATOVIĆ, MF, Podgorica, MNE
 9. Prof. dr Ilija ČOSIĆ, FTN, N. Sad, SR
 10. Prof. dr Cristian DOICIN, TU, Bucharest, RO
 11. Prof. dr Dragan DOMAZET, FIT, Beograd, SRB
 12. Prof. dr Ljubodrag ĐORĐEVIĆ, VTMŠ, Trstenik, SRB
 13. Prof. dr Kornel EHMANN, Northwestern U., Chic., USA
 14. Prof. dr Miloš GLAVONJIĆ, MF, Beograd, SRB
 15. Dr Peter HARTLEY, University Birmingham, UK
 16. Prof. dr Janko HODOLIĆ, FTN, N. Sad, SRB
 17. Prof. dr Vid JOVIŠEVIĆ, MF, Banja Luka, RS, BIH
 18. Prof. dr Milan JURKOVIĆ, MF, Bihać, BIH
 19. Prof. dr Klaus KABITZSCH, TU, Dresden, D
 20. Prof. dr Damir KAKAŠ, FTN, N. Sad, SRB
 21. Prof. dr Mochael KHEIFETZ, PSU, Novopolotsk, BY
 22. Prof. dr Sergey KLIMENKO, ISM, Kiev, UA
 23. Prof. dr Pavel KOVAČ, FTN, N. Sad, SRB
 24. Prof. dr Karl KUZMAN, FS, Ljubljana, SLO
 25. Dr Vladimir KVRGIĆ, LOLA Institut, Beograd, SRB
 26. Prof. dr Miodrag LAZIĆ, MF, Kragujevac, SRB
 27. Prof. dr Ljubomir LUKIĆ, MF, Kraljevo, SRB
 28. Prof. dr Vidosav MAJSTOROVIĆ, MF, Beograd, SRB
 29. Prof. dr Miodrag MANIĆ, MF, Niš, SRB
 30. Prof. dr Ostoja MILETIĆ, MF, Banja Luka, RS, BIH
 31. Prof. dr Dragan MILUTINOVIĆ, MF, Beograd, SRB
 32. Prof. dr Bogdan NEDIĆ, MF, Kragujevac, SRB
 33. Prof. dr Mircea NICOARA, FM, Temisoara, RO
 34. Prof. dr Herbert OSANNA, TU, Wien, A
 35. Prof. dr Zoran PANDILOV, MF, Skopje, MK
 36. Prof. dr Miroslav PILIPOVIĆ, MF, Beograd, SRB
 37. Prof. dr Miroslav PLANČAK, FTN, N. Sad, SRB
 38. Prof. dr Snežana RADONJIĆ, TF, Čačak, SRB
 39. Prof. dr Bela SABO, FTN, N. Sad, SRB
 40. Prof. dr Mirko SOKOVIĆ, FS, Ljubljana, SLO
 41. Prof. dr Bogdan SOVILJ, FTN, N. Sad, SRB
 42. Prof. dr Victor STARKOV, Stankin, Moscow, RUS
 43. Prof. dr Milentije STEFANOVIĆ, MF, Kragujevac, SRB
 44. Prof. dr Ljubodrag TANOVIĆ, MF, Beograd, SRB
 45. Prof. dr Tomislav TODIĆ, FTN, K. Mitrovica, SRB
 46. Prof. dr Velimir TODIĆ, FTN, N. Sad, SRB
 47. Prof. dr Dragiša VILOTIĆ, FTN, N. Sad, SRB
 48. Prof. dr Frank VOLLERTSEN, BIAS, Bremen, D
 49. Prof. dr Radomir VUKASOJEVIĆ, MF, Podgorica, MNE
 50. Prof. dr Miomir VUKIĆEVIĆ, MF, Kraljevo, SRB
 51. Prof. dr Milan ZELJKOVIĆ, FTN, N. Sad, SRB
-

Members of the Honorary Committee

1. Dipl. ing. Mile BENEDETIĆ, LOLA Institut, Beograd
2. Prof. dr Branislav DEVEDIĆ, MF, Kragujevac
3. Prof. dr Ratko GATALO, FTN, Novi Sad
4. Prof. dr Branko IVKOVIĆ, Mašinski fakultet, Kragujevac
5. Prof. dr Ratimir JEČMENICA, Tehnički fakultet, Čačak
6. Prof. dr Milenko JOVIĆIĆ, Mašinski fakultet, Beograd
7. Prof. dr Milisav KALAJDŽIĆ, Mašinski fakultet, Beograd
8. Prof. dr Vučko MEČANIN, Mašinski fakultet, Kraljevo
9. Prof. dr Vladimir MILAČIĆ, Mašinski fakultet, Beograd
10. Prof. dr Dragoje MILIKIĆ, FTN, Novi Sad
11. Prof. dr Mihajlo MILOJEVIĆ, Mašinski fakultet, Kraljevo
12. Prof. dr Predrag POPOVIĆ, Mašinski fakultet, Niš
13. Prof. dr Jožef REKECKI, FTN, Novi Sad
14. Prof. dr Sava SEKULIĆ, FTN, Novi Sad
15. Prof. dr Joko STANIĆ, Mašinski fakultet, Beograd
16. Prof. dr Vojislav STOILJKOVIĆ, Mašinski fakultet, Niš
17. Prof. dr Sreten UROŠEVIĆ, Tehnički fakultet, Čačak
18. Prof. dr Svetislav ZARIĆ, Mašinski fakultet, Beograd
19. Prof. dr Dragutin ZELENOVIĆ, FTN, Novi Sad

ORGANISATIONAL COMMITTEE

1. Dr Miroslav Trajanović, president
 2. Dr Miodrag Stojiljković
 3. Dr Dragan Temeljkovski
 4. Dr Miroslav Radovanović
 5. Dr Peča Milosavljević
 6. Dr Predrag Janković
 7. Dr Vladislav Blagojević
 8. Mr Nikola Korunović
 9. Mr Milan Zdravković
 10. Nikola Vitković
 11. Dr Dragoljub Lazarević
 12. Dr Bojan Rančić
 13. Dr Goran Radenković
 14. Dr Saša Rančelović
 15. Dr Dragan Mišić
 16. Mr Miloš Stojković
 17. Mr Jelena Milovanović
 18. Dušan Petković
 19. Milan Trifunović
-



34th INTERNATIONAL CONFERENCE ON
PRODUCTION ENGINEERING
29. - 30. September 2011, Niš, Serbia
University of Niš, Faculty of Mechanical Engineering



*ORGANIZER OF CONFERENCE ON PRODUCTION ENGINEERING OF
YUGOSLAVIA / SERBIA AND MONTENEGRO / SERBIA 1965-2011*

I	Beograd	Mašinski fakultet	1965.
II	Zagreb	Fakultet za strojarstvo i brodogradnju	1966.
III	Ljubljana	Fakultet za strojninstvo	1967.
IV	Sarajevo	Mašinski fakultet	1968.
V	Kragujevac	Mašinski fakultet	1969.
VI	Opatija	Fakultet za strojarstvo i brodogradnju Zagreb	1970.
VII	Novi Sad	Mašinski fakultet	1971.
VIII	Ljubljana	Fakultet za strojninstvo	1973.
IX	Niš	Mašinski fakultet	1974.
X	Beograd	Mašinski fakultet	1975.
XI	Ohrid	Mašinski fakultet Skoplje	1977.
XII	Maribor	Visoka tehnička škola	1978.
XIII	Banja Luka	Mašinski fakultet	1979.
XIV	Čacak	Pedagosko-tehnički fakultet	1980.
XV	Novi Sad	Fakultet tehničkih nauka	1981.
XVI	Mostar	Mašinski fakultet	1982.
XVII	Budva	Mašinski fakultet Podgorica	1983.
XVIII	Niš	Mašinski fakultet	1984.
XIX	Kragujevac	Mašinski fakultet	1985.
XX	Beograd	Mašinski fakultet	1986.
XXI	Opatija	Tehnički fakultet Rijeka	1987.
XXII	Ohrid	Mašinski fakultet Skoplje	1989.
XXIII	Zagreb	(nije održano)	1991.
XXIV	Novi Sad	Fakultet tehničkih nauka	1992.
XXV	Beograd	Mašinski fakultet	1994.
XXVI	Podgorica	Mašinski fakultet	1996.
XXVII	Niš	Mašinski fakultet	1998.
XXVIII	Kraljevo	Mašinski fakultet	2000.
XXIX	Beograd	LOLA Institut	2002.
XXX	Čacak	Tehnički fakultet i Viša tehnička škola	2005.
XXXI	Kragujevac	Mašinski fakultet	2006.
XXXII	Novi Sad	Fakultet tehničkih nauka	2008.
XXXIII	Beograd	Mašinski fakultet	2009.
XXXIV	Niš	Univerzitet u Nišu, Mašinski fakultet u Nišu	2011.

FOREWORD

The first Scientific conference on production engineering of ex Yugoslavia was held in Belgrade, in 1965, initiated by Prof. Vladimir Šolaja. This also marked the forming of the Association of scientific and research institutions in production engineering, which included faculties of mechanical engineering and research institutes of almost all major cities of the former federation. The Association of scientific and research institutions in production engineering was reinstated, under new circumstances, in 1994. In 2009, the Executive Board of the Association delegated the organization of 34rd Conference to the University of Niš, Faculty of Mechanical Engineering in Niš.

The organizer of this Conference, the Department for Production, IT and Management of the Faculty of Mechanical Engineering, University of Niš, has ambitiously approached the task of organizing this Conference, setting two primary goals: (1) to point to the current state of research in the area of production engineering in the region of SEE as well as rest of Europe, (2) to use presence of highly competent professionals to initiate discussions on boosting of production in SEE.

In order to meet these goals, the organizing committee has made efforts to attract production engineering community to present the results of their research. A total of 180 papers were registered. All papers submitted for presentation passed through a double blind review process and were evaluated by two reviewers. After peer review process 119 papers were accepted for presentation. Those authors whose papers were chosen for presentation at the conference submitted manuscripts to be published in these Proceedings. The authors are from 16 European countries: Austria, Bosnia and Herzegovina, France, Germany, Montenegro, Slovenia, Slovakia, Czech, Croatia, Poland, Romania, Belarus, Macedonia, Greece, United Kingdom and Serbia.

Also, four invited lectures will be given by distinguished professors. One of these lectures is an introduction to a roundtable on the theme: "Boosting production in SEE".

The Ministry for Education and Science of Serbia, together with donors from industry, have financially supported the organization of this Conference, for which the organizer wishes to express gratitude on this occasion.

On behalf of the organizing committee, I wish to express my gratitude to all domestic and foreign contributors, as well as the editing board for the performed reviews.

Niš

September 20, 2011

*President of the organizing
committee*

Prof. Dr. Miroslav Trajanović

*President of the Executive Board
of the Association*

Prof. Dr. Velibor Marinković



Contents

PLENARY PRESENTATIONS:

Invited lets to res

Herve Panetto SYSTEM ENGINEERING FOR SYSTEMS INTEROPERABILITY IN MANUFACTURING ENVIRONMENT.....	3
Vidosav Majstorović QUALITY MANAGEMENT – STATE OF THE ART AND FUTURE DEVELOPMENT.....	5
Dorian Marjanović DESIGN RESEARCH – THE MOMENTUM AND EXPECTATIONS.....	13
Petar Petrović, Vladimir Milačić NATIONAL TECHNOLOGY PLATFORMS OF SERBIA.....	15

SECTION A:

Machining technologies

Uros Zuperl, Franc Cus NEURAL NETWORK ALGORITHM FOR ON-LINE TOOL BREAKAGE DETECTION.....	29
Milan Milutinović, Ljubodrag Tanović THE EFFECTS OF TOOL FLANK WEAR ON TOOL LIFE.....	33
Obrad Spaić, Zdravko Krivokapić, Rade Ivanković MATHEMATICAL MODELLING OF CUTTING FORCE AS THE MOST RELIABLE INFORMATION BEARER ON CUTTING TOOLS WEARING PHENOMENON.....	37
Ljubodrag Tanović, Pavao Bojanić, Radovan Puzović, Mihajlo Popović, Goran Mladenović ANALYSIS OF STONE MICRO-CUTTING MECHANISM USING THE EXAMPLE OF GRANITE AND MARBLE GRINDING.....	41
Marko Kovačević, Miloš Madić, Velibor Marinković SOFTWARE PROTOTYPE FOR ANALYZING MANUFACTURING PROCESS MODELS.....	45
Diana Baila CONTRIBUTIONS TO MANAGEMENT SWARF HIGH-SPEED MACHINE TOOLS.....	49



Dijana Nadarević, Mirko Soković STEEL VALVE PLATE GRINDING.....	53
Milenko Sekulić, Miodrag Hadžistević, Zoran Jurković, Pavel Kovač, Marin Gostimirović APPLICATION OF TAGUCHI METHOD IN THE OPTIMIZATION OF FACE MILLING PARAMETERS.....	57
Jozef Peterka, Martin Kováč, Marek Zvončan INFLUENCE OF TOOL BALANCING ON MACHINED SURFACE QUALITY IN HIGH SPEED MACHINING.....	61
Aco Antić, Milan Zeljković, Aleksandar Tivković FEM MODELING AND EXPERIMENTAL VERIFICATION OF CUTTING TOOL VIBRATIONS.....	65
Miloš Madić, Goran Radenković, Miroslav Radovanović PREDICTION OF MECHANICAL PROPERTIES AND MACHINABILITY OF CAST COPPER ALLOYS USING ANN APPROACH.....	69

SECTION B:

Surface engineering and nanotechnologies

Ilare BORDEASU, Mircea Octavian POPOVICIU, Ion MITELEA, Alin Dan JURCHELA RESEARCH ON CAVITATION EROSION BEHAVIOR OF STAINLESS STEELS WITH CONSTANT CHROMIUM AND VARIABLE NICKEL CONTENT.....	75
Damir Kakaš, Branko Škorić, Aleksandar Miletić, Pal Terek, Lazar Kovačević, Marko Vilotić INFLUENCE OF SUBSTRATE ROUGHNESS ON ADHESION STRENGTH OF HARD TiN FILMS.....	79
Damir Kakaš, Branko Škorić, Pal Terek, Aleksandar Miletić, Lazar Kovačević, Marko Vilotić MECHANICAL PROPERTIES OF TiN COATINGS DEPOSITED AT DIFFERENT TEMPERATURES BY IBAD.....	83
Bogdan Nedić, Desimir Jovanović, Gordana Lakić Globočki SCRATCH TESTING OF Zn COATING SURFACES.....	87
Sebastian Baloš, Lepasava Sićanin, Đagan Rajnović, Olivera Erić ADI MATERIALS FOR BALLISTIC PROTECTION.....	91
Jasna Radulović, Predrag Petrović OBSERVATION ON THE USE OF THIN FERROMAGNETIC PLATES IN PRESENCE OF EXTERNAL MAGNETIC FIELD.....	95



Aleksandar Todić, Dejan Ćikara, Tomislav Todić, Branko Pejović, Bogdan Ćirković, Ivica Ćamagić THE EFFECT OF VANADIUM CONTENT ON MECHANICAL PROPERTIES AND STRUCTURE OF SELF-TEMPERED STEEL X160CrMo12-1.....	99
Radovan Ćirić, Emil Veg, Biljana Savić, Zvonimir Jugović, Radomir Slavković ANALYSIS OF THE IMPACT OF EXPLOSION HARDENING PROCEDURE ON CHARACTERISTICS OF SURFACE LAYER OF ELEMENTS EXPOSED TO ABRASION.....	103
SECTION C:	
Production engineering – new technologies and globalisation of engineering	
Mijodrag Milošević, Velimir Todić, Dejan Lukić WEB-BASED COLLABORATIVE ENVIRONMENT FOR PROCESS PLANNING	109
Slobodan Tabaković, Cvijetin MlaĀenović, Milan Zeljković, Ratko GATALO ANALYSIS OF KINEMATIC CHARACTERISTICS OF MACHINE TOOLS USING A VIRTUAL MODEL.....	113
ĐorĀeĀiĀa, M. Zeljković, G. Lakić-GloboĀki, B. Sredanović, S. Borojević MODELING OF DYNAMICAL BEHAVIOR SPINDLE – HOLDER – TOOL ASSEMBLY.....	117
Bogdan Ćirković, Ivica Ćamagić, Nemanja Vasić COMPOSITE MATERIALS SUCH APSORPTION MATERIALS FOR SUPPORTING STRUCTURES OF MACHINES.....	121
Predrag Āosić, Dragutin Lisjak, Valentina Latin MULTIOBJECTIVE OPTIMIZATION – POSIBILITY FOR PRODUCTION IMPROVEMENT.....	125
Vladimir KvrĀić, Miroslav Vasić, Vladimir Āarapić, Jelena Vidaković, Velimir Komadinić C RESEARCH AND DEVELOPMENT OF THE NEW GENERATION FIVE AXIS VERTICAL TURNING CENTRES.....	129
Robert Cep, Jan Strbka, Lenka Cepova DEPENDENCE OF SURFACE ROUGHNESS FOR SHAFT PACKING.....	133
SECTION D:	
Metrology, quality systems and quality management	
Milan Blagojević, Miroslav Ťivković, Ana Pavlović QUALITY CONTROL OF CONTOUR VERIFIER USING PHOTOGRAMMETRIC MEASURING SYSTEMS.....	139



Miodrag Hadži istević, Janko Hodolić, Igor Budak, Đorđe Vukelić, Branko Štrbac RESULTS OF THE ANALYSIS ON STYLUS CALIBRATION OF COORDINATE MEASURING MACHINE (CMM).....	143
Krzysztof Stepień RESEARCH ON INFLUENCE OF THE SENSOR POSITION ON THE RESULT OF THE V-BLOCK CYLINDRICITY MEASUREMENT.....	147
Milan Kolarević, Branko Radićević, Miomir Vukićević, Mišo Bjelić, Ljubinko Cvetković IMPROVING PRODUCT QUALITY OF SECURITY EQUIPMENT USING SPC...	151
Vladan Radlovački, Radmila Jovanović, Bato Kamberović, Milan Delić, Srđan Vulanović THE ROLE OF MANAGERS IN IMPLEMENTING QUALITY MANAGEMENT STANDARDS.....	155
Peđa Milosavljević, Dragoljub Tivković, Predrag Janković, Srđan Mladenović THE POSSIBILITIES FOR IMPROVEMENT OF THE MAINTENANCE PROCESSES IN THE COMPANIES.....	159
Bojan Rančić, Predrag Janković, Srđan Mladenović, Slaviša Planić DESIGN AND TENSIOMETRIC ANALYSIS OF THE C-CLAMP FOR RAILROAD TRACKS.....	163
Slavenko Stojadinović, Vidosav Majstorović METROLOGICAL PRIMITIVES IN PRODUCTION METROLOGY – ONTOLOGICAL APPROACH.....	167
Remigiusz Labudzki THE USE OF MACHINE VISION TO RECOGNIZE OBJECTS.....	171
Jelena Micevska, Zoran Spiroski, Jasmina Čaloska, Atanas Kočov PRODUCT QUALITY CONTROL BY USING REVERSE ENGINEERING.....	175

SECTION E:

Cax technologies (CAD/CAM/CAPP/CAE systems) and CIM systems

Jozef Novak-Marcincin, Miroslav Janak, Ludmila Novakova-Marcincinova, Veronika Fecova, Jozef Barna APPLICATION OF THE COMPUTER AIDED SELECTION OF OPTIMAL CNC MILLING STRATEGY.....	181
Janko Hodolić, Tatjana Puškar, Igor Bešić CURRENT STATUS AND FUTURE TRENDS IN DENTAL CAM RESTORATIVE SYSTEMS.....	185



Goran Devedđić, Sasa Ćuković, Branko Ristić, Suzana Petrović, Michele Fiorentino, Tanja Luković COMBINED REGISTRATION OF HUMAN MUSCULOSKELETAL SYSTEM...	189
Radomir Slavković, Zvonimir Jugović, Ivan Milićević, Marko Popović, Radomir Radiša OPTIMIZATION OF CAD/CAM/CAE DESIGN OF THE CONNECTING PART OF EXCAVATOR'S TOOTH THROUGH THE SIMULATION OF MANUFACTURING TECHNOLOGY.....	193
Stevo Borojević, Vid Jovišević, Gordana Globočki Lakić, Đorđe Ćića, Branislav Sredanović IDENTIFICATION OF FACE FUNCTIONALITY WITH PROGRAM SYSTEM FOR PURPOSE OF MODULAR FIXTURE DESIGN.....	197
Dragan Marinković, Manfred Zehn FEM IN VIRTUAL REALITY CONCEPT.....	201
Ionut Ghionea, Ioan Tanase, Adrian Ghionea, Cristian Tarba APPLICATIONS BY CAM AND FEM SIMULATIONS IN ESTABLISHING THE MILLING CONDITIONS FOR PARTS WITH THIN WALLS.....	205
Nikola Korunović, Miroslav Trajanović, Miloš Stojković, Nikola Vitković, Milan Trifunović, Jelena Milovanović TIRE TREAD MODELING FOR FEA	209
Ivan Matin, Miodrag Hadđistević, Janko Hodolić, Đorđe Vukelić AN INTERACTIVE CAD/CAE SYSTEM FOR MOLD DESIGN.....	213
Miroslav Pilipović, Ivan Danilov, Nikola Lukić, Petar Petrović VIRTUAL MANUFACTURING – ADVANCED MANUFACTURING EXAMPLES.....	217

SECTION F:

Education in the field of production engineering

Engineering ethics

Product development – product design

Production system management

Revitalization, reengineering and maintenance of manufacturing systems

Miloš Ristić, Miodrag Manić, Boban Cvetanović MANUFACTURABILITY ANALYSIS OF DIE-CAST PARTS.....	223
Sofija Sidorenko, Jelena Micevska, Ile Mircheski DESIGN OF MODULAR WHEELCHAIR FOR CHILDREN WITH CEREBRAL PALSY.....	227



Dragan Rajnović, Olivera Erić, Milica Damjanović, Sebastian Baloš, Leposava Sićanin THE CRACK PROPAGATION STUDY IN ALLOYED ADI MATERIALS.....	231
Suzana Petrović, Milan Erić, Goran Devedžić, Miodrag Manić, Saša Ćuković, Miloš Ćirović COLLABORATION AND COMMUNICATION IN INTEGRATED SYSTEM OF DIGITAL MANUFACTURING.....	235
Vladimir Simić, Branka Dimitrijević MODELLING OF PRODUCTION SYSTEMS FOR END-OF-LIFE VEHICLES PROCESSING.....	239
Dragan Mišić, Nikola Vitković, Miloš Stojković, Milan Zdravković, Miroslav Trajanović RESOURCES MANAGEMENT IN WORKFLOW MANAGEMENT SYSTEMS...	243
Nedim Ganibegović, Sandira Eljsan STEAM TURBINE CASINGS REVITALIZATION.....	249
Tadej Tasner, Darko Lovrec COMPARISON OF MODERN ELECTROHYDRAULIC SYSTEMS.....	253
Goran Slavković, Tarko Spasić HYBRID CONTROLLER FOR SYSTEM MANAGEMENT OF INTEGRATED UNIVERSITY.....	257
Guenther Poszvek ESTABLISHMENT OF A LECTURE SERIES ON LIFE CYCLE DESIGN – ECODESIGN.....	263
Dragan Temeljkovski, Predrag Popović, Bojan Rančić, Petar Đekić EVALUATION OF PRODUCT AND PRODUCTION TECHNOLOGIES QUALITY METHOD OF SUPERIORITY AND INFERIORITY.....	267

SECTION G:

Forming and shaping technologies

Neculai Nanu, Gheorghe Brabie THE INFLUENCE OF RESIDUAL STRESS DISTRIBUTION ON THE SPRINGBACK PARAMETERS IN THE CASE OF CYLINDRICAL DRAWN PARTS.....	273
Srbislav Aleksandrović, Tomislav Vujinović, Milentije Stefanović, Vukić Lazić, Dragan Adamović VARIABLE CONTACT PRESSURE AND VARIABLE DRAWBEAD HEIGHT INFLUENCE ON DEEP DRAWING OF Al ALLOYS SHEETS.....	277



Bojan Rančić, Predrag Janković, Dragan Temeljkovski DETERMINING SOME PARAMETERS IN THE OIL HYDRAULIC PROCESS OF SQUARE CUPS DEEP DRAWING.....	281
Bojan Rančić, Predrag Janković, Velibor Marinković ASSESSMENT THE NUMBER OF DEEP DRAWING STEPS OF CYLINDRICAL CUPS WITHOUT CALCULATION.....	285
Dragan Adamović, Milentije Stefanović, Srbislav Aleksandrović, Miroslav Tivković, Zvonko Gulišija, Slaviša Đačić THE INFLUENCE OF TOOL SURFACE CONDITION ON IRONING PROCESS EXECUTION.....	289
Zdravko Božićković, Ranko Radonjić, Ranko Božićković THE SIMULATION OF DISCONTINUOUS TIN BENDING IN THE PROCESS OF FORMING ROUND CONICAL TUBE.....	293
Milan Jurković, Zoran Jurković, Asim Jušić, Vesna Mandić EXPERIMENTAL ANALYSIS AND MATHEMATICAL MODELLING OF THE ROLLING FORCE.....	297
Dragiša Vilotić, Miroslav Plančak, Sergei Alexandrov, Aljoša Ivanišević, Dejan Movrin, Mladomir Milutinović NUMERICAL SIMULATION OF UPSETTING OF PRISMATIC BILLETS BY V- SHAPE DIES WITH EXPERIMENTAL VERIFICATION.....	301
Milan Lazarević, Dejan Lazarević, Miloš Jovanović, Saša Rančdović THE APPLICATION OF ADAPTIVE FEM METHOD TO STRESS AND STRAIN ANALYSIS OF COLD FORGING PROCESS.....	305
Mladomir Milutinović, Dragiša Vilotić, Tatjana Puškar, Dubravka Marković, Aljoša Ivanišević, Michal Potran METAL FORMING TECHNOLOGIES IN DENTAL COMPONENTS PRODUCTION.....	309

SECTION H:

Rapid prototyping

Reverse engineering

Miroslav Plančak, Tatjana Puškar, Ognjan Lužanin, Dubravka Marković, Plavka Skakun, Dejan Movrin SOME ASPECTS OF RAPID PROTOTYPING APPLICATION IN MEDICINE...	315
Nenad Grujović, Jelena Borota, Milan Šljivić, Dejan Divac, Vesna Ranković ART AND DESIGN OPTIMIZED 3D PRINTING.....	319
Nenad Grujović, Milan Radović, Vladimir Kanjevac, Jelena Borota, Đorđe Grujović, Dejan Divac 3D PRINTING TECHNOLOGY IN EDUCATION ENVIRONMENT.....	323



Nikola Milivojević, Nenad Grujović, Dejan Divac, Vladimir Milivojević, Jelena Borota AUGMENTED REALITY ASSISTED PART REMOVAL FOR POWDER-BASED 3D PRINTING SYSTEMS.....	327
Dalibor Nikolić, Branko Ristić, Milovan Radosavljević, Nenad Filipović APPLIED RAPID PROTOTYPING TECHNOLOGY AND MODELING IN THE SPECIFIC PATIENT DAMAGE HIP REPLACEMENT.....	331
Milan Trifunović, Jelena Milovanović, Miroslav Trajanović, Nikola Korunović, Miloš Stojković APPROACHES TO AUTOMATED CREATION OF TISSUE ENGINEERING SCAFFOLDS.....	335
Radomir Vukasojević, Simo Saletić, Ćeljko Raićević 3D DIGITIZING FREE FORM SURFACES BY OPTICAL TRIANGULARING LASER SCANNING.....	339
Milan Blagojević, Miroslav Ćivković, Bojana Rosić QUALITY 3D SURFACE RECONSTRUCTION BASED ON POINT CLOUD GENERATED BY OPTICAL MEASURING TECHNIQUES.....	343
Goran Devedđić, Suzana Petrović, Saša Ćuković, Branko Ristić, Zoran Jovanović, Miloš Ćirović TOWARDS DIGITAL TEMPLATE FOR ARTIFICIAL HIP IMPLANTS SELECTION.....	347
Nikola Vitković, , Jelena Milovanović, Miroslav Trajanović, Nikola Korunović, Miloš Stojković, Miodrag Manić METHODS FOR CREATING GEOMETRICAL MODEL OF FEMUR ANATOMICAL AXIS.....	351
Marko Veselinović, Dalibor Stevanović, Miroslav Trajanović, Miodrag Manić, Stojanka Arsić, Milan Trifunović, Dragan Mišić METHOD FOR CREATING 3D SURFACE MODEL OF THE HUMAN TIBIA...	355
Dejan Petrović, Marko AnĀdković, Ljiljana Tihaćek-Šojić, Nenad Filipović COMPUTER BIOMECHANICAL ANALYSIS OF SPECIFIC TOOTH FOR DIFFERENT APPLIED LOADING.....	359

SECTION I:

Automatization, robotization and mechatronics IT and artificial intelligence in production engineering

Ćivana Jakovljević, Miroslav Pajić, Dragan Aleksendrić, Dragan Milković WIRELESS SENSOR NETWORK APPLICATION IN MONITORING OF MACHINING OPERATIONS.....	365
---	-----



Dušan Kravec, Marian Tolnay, Ondrej Staš, Michal Bachraty IMPLEMENTATION OF PALLET LOADING METHODS AND VIRTUAL REALITY TO THE NEW SOFTWARE PRODUCT.....	369
Jan Slamka, Marian Tolnay, Michal Jedinak LAYOUT DESIGN OF VACUUM EFECTOR HEAD FOR MANIPULATION WITH FLOPPY MATERIALS.....	373
Vladislav Blagojević, Miodrag Stojiljković, Milorad Rančić DC SERVO MOTORS CONTROL OF CNC MACHINES BY SLIDING MODE...	377
Dragan Milutinović, Miloš Glavonjić, Nikola Slavković, Saša Tivanović, Branko Kokotović, Zoran Dimić COMPLIANCE MODELING AND IDENTIFICATION OF 5-AXIS VERTICAL ARTICULATED ROBOT FOR MACHINING APPLICATIONS.....	381
Dalibor Petković, Nenad Pavlović INVESTIGATION AND ADAPTIVE NEURO-FUZZY ESTIMATION OF MECHANICAL /ELECTRIAL PROPERTIES OF CONDUCTIVE SILICONE RUBBER.....	385
Milica Petrović, Zoran Miljković, Bojan Babić, Najdan Vuković, Nebojša Čović TOWARDS A CONCEPTUAL DESIGN OF AN INTELLIGENT MATERIAL TRANSPORT BASED ON MACHINE LEARNING AND AXIOMATIC DESIGN THEORY.....	389
Milan Erić, Miladin Stefanović, Branko Tadić, Slobodan Mitrović SOFTWARE SOLUTION OF REENGINEERING MODEL OF TECHNOLOGICAL PROCESSES OF SMALL ENTERPRISES.....	393
Milan Zdravković, Miroslav Trajanović, Herve Panetto, Alexis Aubry, Mario Lezoche ONTOLOGY-BASED SUPPLY CHAIN PROCESS CONFIGURATION.....	399
Vesna Ranković, Nenad Grujović, Dejan Divac, Nikola Milivojević, Konstantinos Papanikolopoulos, Jelena Borota PREDICTION OF THE NONLINEAR STRUCTURAL BEHAVIOUR BY DIGITAL RECURRENT NEURAL NETWORK.....	403
Darko Stefanović, Andraš Anderla, Cvijan Krsmanović, Aleksandar Ivić ERP IMPLEMENTATION STRATEGIES FOR MANUFACTURING COMPANIES IN E-BUSINESS ENVIRONMENT.....	407

SECTION J:

Nonconventional technologies (Advanced machining technologies)

Laurențiu Slatineanu, Margareta Coteata, Miroslav Radovanović, Stefan Potarniche, Lorelei Gherman, Irina Besliu SURFACE ROUGHNESS AT ABRASIVE JET ENGRAVING OF GLASS PARTS	413
--	-----



Marin Gostimirović, Pavel Kovač, Milenko Sekulić, Borislav Savković THE RESEARCH OF DISCHARGE ENERGY IN EDM PROCESS.....	417
Dragan Adamović, Milentije Stefanović, Branislav Jeremić, Srbislav Aleksandrović THE EFFECTS OF SHOT PEENING ON THE FATIGUE LIFE OF MACHINE ELEMENTS.....	421
AnČeda Lazarević, Miodrag Manić, Dragoljub Lazarević ENERGY BALANCE OF THE PLASMA ARC CUTTING PROCESS.....	425
SrČan Mladenović, Miroslav Radovanović MODEL FOR OPERATING COSTS OF PLASMA CUTTING.....	431
Predrag Janković, Miroslav Radovanović, Jelena Baralić CUT QUALITY IN ABRASIVE WATER JET CUTTING.....	435
Bogdan Nedić, Jelena Baralić, Miroslav Radovanović THE COMPLEXITY OF DEFINING THE QUALITY OF LASER CUTTING.....	439
Jelena Baralić, Bogdan Nedić, Predrag Janković MACHINING PARAMETERS EFFECT ON THE JET RETARDATION IN ABRASIVE WATER JET MACHINING.....	443

SECTION K:

Joining and casting technologies

Processing of nonmetal materials (plastic, wood, ceramics, ...)

Michael Kheifetz, Natalia Pozilova, Alexander Pynkin, Leonid Akulovich ANALYSIS AND DESIGN OF HIGHLY EFFICIENT METHODS OF TREATMENT.....	449
Vladimir Borodavko, Gaiko Victor, Viacheslav Kroutko, Michael Kheifetz, Elena Zeveleva DESIGN OF TECHNOLOGICAL COMPLEXES FOR HIGHLY EFFICIENT TREATMENT.....	453
Radivoje Mitrović, Dejan Momčilović, Olivera Erić, Ivana Atanasovska INFLUENCE OF PRODUCTION PROCESS ON FATIGUE PROPERTIES OF HEAVY CASTINGS - A CASE STUDY.....	457
Dušan Jovanić, Ťeljko Eremić, Miloš Jovanović MODELLING DATABASE OF QUALIFIED WELDERS ACCORDING TO STANDARD SRPS EN 287-1:2008.....	461
Andreja Ilić, Danica Josifović, Vukić Lazić, Lozica Ivanović MECHANICAL PROPERTIES OF WELDED JOINTS AT STEEL TUBES WITH SQUARE CROSS SECTION.....	465



Vukić Lazić, Dragan Milosavljević, Srbislav Aleksandrović, Rajko Ćukić, Božidar Krstić, Gordana Bogdanović DETERMINATION OF OPTIMUM TEMPERING TEMPERATURE IN HARD FACING OF THE FORGING DIES FOR WORKING AT ELEVATED TEMPERATURES.....	469
Vukić Lazić, Dragan Milosavljević, Srbislav Aleksandrović, Rajko Ćukić, Božidar Krstić, Gordana Bogdanović SELECTION OF THE WELDING TECHNOLOGY OF RELIABLE ASSEMBLIES USING GMAW PROCESS.....	473
Dragan Milčić, Aleksandar Ćivković, Miroslav Mijajlović AN OVERVIEW ON FRICTION STIR WELDING OF THE AL 2024 T351.....	477
Nenad Gubelj, Bojan MeĀq, Jozef Predan, Marko Rakin, Goran Radenković, Aleksandar Sedmak DETERMINATION OF TENSILE PROPERTIES OF WELDED JOINTS – INFLUENCE OF SPECIMEN GEOMETRY.....	481
Anka Trajkovska Petkoska MANUFACTURING AND CHARACTERISATION OF FLAKES MADE BY SOFT LITHOGRAPHY TECHNIQUE.....	485
Rok Justin, Davorin Kramar, Janez KopaĀ, Mirko Soković INDUSTRIALIZATION OF EASY BOOM.....	489

SECTION L:

Tribology

Miroslav PlanĀak, Igor KaĀmarĀik, Dejan Movrin, ĐorĀeĀupković PROPOSAL OF A NEW FRICTION TESTING METHOD FOR BULK METAL FORMING.....	495
Plavka Skakun, Igor KaĀmarĀik, TomaĀ Pepelnjak, Ognjan LuĀanin, Aljosa Ivanišević, Mladimir Milutinović COMPARISON OF CONVENTIONAL AND NEW LUBRICANTS FOR COLD FORMING.....	499
Milentije Stefanović, Slaviša ĐaĀić, Srbislav Aleksandrović, Dragan Adamović IMPORTANCE OF TRIBOLOGICAL CONDITIONS AT MULTI-PHASE IRONING.....	503
Vito TiĀ, Darko Lovrec EVALUATION OF PHYSICAL AND CHEMICAL CHANGES IN HYDRAULIC OIL USING ON-LINE SENSORS.....	507
Darko Lovrec, Vito TiĀ USE OF ON-LINE CONDITION MONITORING SYSTEM ON HYDRAULIC MACHINES.....	511



34th INTERNATIONAL CONFERENCE ON
PRODUCTION ENGINEERING
29. - 30. September 2011, Niš, Serbia
University of Niš, Faculty of Mechanical Engineering



Dragoljub Lazarević, Predrag Janković, Miloš Madić, Andjela Lazaravić STUDY ON SURFACE ROUGHNESS MINIMIZATION IN TURNING OF POLYAMIDE PA-6 USING TAGUCHI METHOD.....	515
Slobodan Mitrović, Miroslav Babić, Dragan Adamović, Fatima Ćivić, Dragan Džunić, Marko Pantić WEAR BEHAVIOUR OF Cr HARD COATINGS FOR COLD FORMING TOOLS UNDER DRY SLIDING CONDITIONS.....	519
Ivan Sovilj-Nikić, Bogdan Sovilj, Stanislaw Legutko, Sandra Sovilj-Nikić, Ivan Samarđić, Ivan Kolev INFLUENCE OF WEAR OF CUTTING ELEMENTS OF CONVEX MILLING CUTTERS ON PROCESSED SURFACE TOPOGRAPHY.....	523
Marko Vilotić, Damir Kakaš, Aleksandar Miletić, Lazar Kovačević, Pal Terek INFLUENCE OF FRICTION COEFFICIENT ON WORKPIECE ROUGHNESS IN RING UPSETTING PROCESS.....	527
Božica Bojović, Dušan Kojić, Zoran Miljković, Bojan Babić, Milica Petrović FRICTION FORCE MICROSCOPY OF DEEP DRAWING MADE SURFACES...	531
Previous winners of the charter and plaque "Professor dr Pavle Stanković".....	537
AUTOR INDEX.....	545

AN OVERVIEW ON FRICTION STIR WELDING OF THE AL 2024 T351

Dragan MILČIĆ¹, Aleksandar ŽIVKOVIĆ², Miroslav MIJAJLOVIĆ¹

¹ University of Nis, Faculty of Mechanical Engineering Nis, Aleksandra Medvedeva 14, 18000 Nis, Serbia

² Goša FOM a.d., Industrijska 70, 11420 Smederevska Palanka, Serbia

milcic@masfak.ni.ac.rs, a.zivkovic@gosafom.com, mijajlom@masfak.ni.ac.rs

Abstract: Friction stir welding is a solid state welding technique used for joining soft metals such aluminium and its alloys are. Alloy 2024 is a representative of conventionally unweldable alloys but fully weldable by friction stir welding. In this case, welding is possible only when proper geometry of the welding tool, welding speed etc. are selected. Like for other welding techniques, results of the welding have to be evaluated by testing given by requirements of appropriate standards. However, it is a challenge to select proper parameters and paper presents some successful experimental results on this topic and announces further developments in the technology of the friction stir welding.

Key words: Friction Stir Welding, 2024 aluminium alloy

1. INTRODUCTION

Friction stir welding (FSW) is a solid state welding process predominantly used for joining materials difficult to weld by applying some of conventional processes. Its application is mainly connected with the welding of aluminium alloys and other soft metals/alloys. In comparison to other welding processes, FSW delivers the smallest amount of energy to the base metal, which results in the smallest deformation in the structure of the base metal. However, FSW is still an unconventional welding process because of the complexity of application and the need for long welds in order to have great productivity. FSW is used for plate-shaped parts [1].

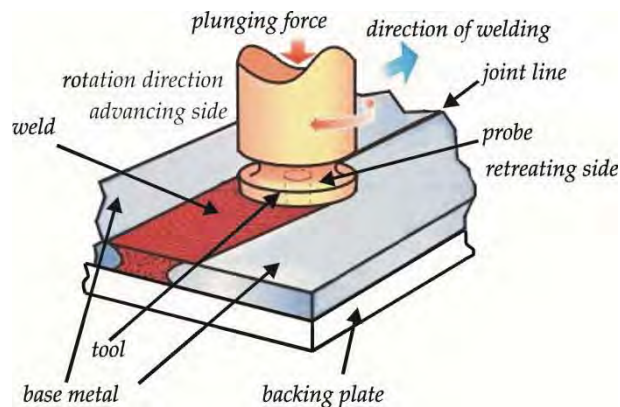


Figure 1 Schematic of the FSW process

In FSW, a cylindrical, shouldered tool (Figure 1) with a profiled threaded probe is rotated at a constant speed and fed at a constant traverse speed into the joint line between two plates, which are butted together. The parts have to be clamped rigidly onto a backing plate to enable welding.

2. WELDING TOOL

Welding tool used in FSW is a specialized rotating component that passes entirely through or partially

through the workpiece(s) along the joint line, and may or may not have a shoulder [1] and the welding tool always has a probe. The probe is usually cone or cylindrical with the thread on the side. It is common to use left sided thread for clockwise rotation of the welding tool or right sided thread for counterclockwise rotation of the welding tool. The type of the thread is various: metric, profiled, oval etc., with changeable/unchangeable thread step. What type of the thread and thread step will be used depends from the material of workpieces (base metal).

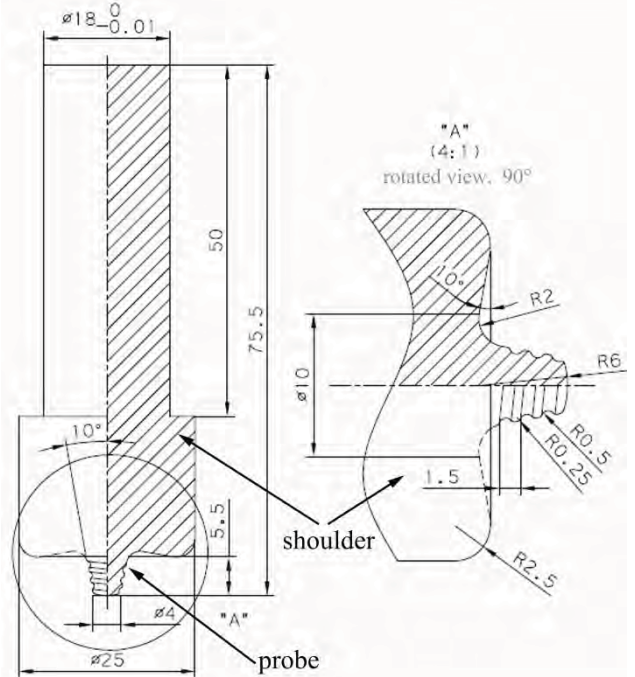


Figure 2 Drawing of the common welding tool [2]

Welding tools must resist high temperatures, and wear and they are manufactured from durable, heat resistant and high strength steels. Active surfaces [1] of the welding tool are usually manufactured by milling or

turning, polished and heat treated after machining – annealed and normalized. Hardness of active surfaces on the welding tool should be at least the same as the hardness of workpieces or higher.

3. WORKPIECES

The first application of FSW was on the groove welds on railway vehicles [1] however it was never intended to be used only for the one type. Development of the FSW was tremendous and it expanded on various fields as well as on application on butt welds, spots welds etc. However, groove welds are primary application of the FSW especially on the plate-shaped parts where pipes are included as well.

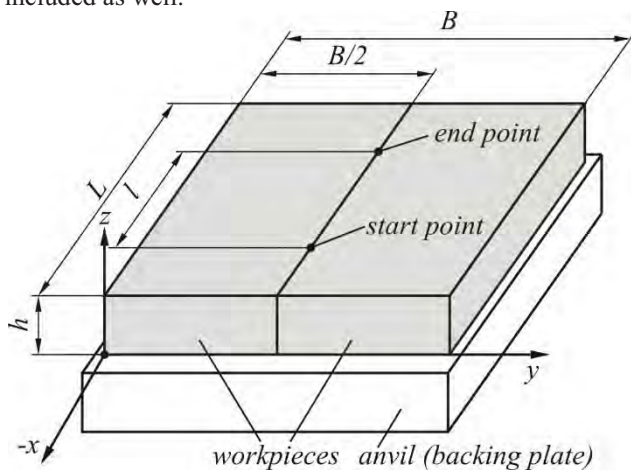


Figure 3 Scheme of the positioned workpieces in position for welding

Before the welding start workpieces are set on an anvil (backing plate), connected to each other on the joint line and clamped to the work table of the machine. Workpieces must be rigidly clamped since forces that appear during welding have to be used for deformation, stirring and mixing of material instead of moving workpieces. Anvil assists in weld root creation and supports workpieces during welding. It has to be manufactured from stiff, rigid, with low thermal conductivity material capable to maintain stability of the system and reduce thermal losses.

3.1. Material of workpieces

FSW is widely used for the joining of softer metals such aluminium and aluminium alloys are. Aluminium alloys are always a challenge for welding, without concern on weldability or unweldability of base metal. Like other arc welding processes, FSW is applicative for welding of 5xxx and 6xxx series of Al alloys but its advantages over other processes are seeable when welding 2xxx class of Al alloy. A representative of the 2xxx class is alloy 2024 and it is widely used in FSW processes.

Aluminium alloy 2024 is an Al alloy, with Cu and Mg as the alloying elements. It is used in applications requiring high strength to weight ratio, as well as good fatigue resistance. It is not weldable, and has average machinability. Due to poor corrosion resistance, it is often clad with Al or Al-Zn for protection, although this procedure may reduce the fatigue strength. It has a density

of 2.73 g/cm³, Young's modulus of 73 GPa across all tempers, and begins to melt at about 500 °C. Due to its high strength and fatigue resistance, 2024 is widely used in aircraft structures, especially wing and fuselage structures under tension. Because the material is susceptible to thermal shock, 2024 is used in qualification of liquid penetrant tests outside of normal temperature ranges.

Table 1. Chemical composition and mechanical properties of alloy EN AW 2024 T351

Chemical composition		Mechanical properties	
Chemical element	Mass %		
Al	~	0.2% Proof Stress $R_{p0.2}$	266-274 N/mm ²
S	0.12		
Fe	0.28		
Cu	4.52	Tensile Strength R_m	404-424 N/mm ²
Mn	0.65		
Mg	1.60		
Cn	0.01		
Zn	0.09	Elongation A_5	22.00%
Ti	0.016		
B	0.009		
N	0.02		

Data in Table 1 is taken from the Approved Certificate data: Alcoa International, inc, No 47831, for sheet of 2100 mm × 6000 mm × 8mm, material EN AW 2024 T351 used for the FSW process (experiments).

4. TECHNOLOGICAL PARAMETERS

FSW is effective and productive only when the right combination of the welding tool (material, geometry, surface condition etc.) is used on proper workpieces (material, geometry, type of joint etc.) with proper technological parameters of the FSW process (travel speed, tool rotation speed, plunging time, dwelling time etc.). Only in that case appear adequate tribological processes and phenomena (contact pressure, friction, wear, lubrication, heat generation, deformation, adhesion, material exchange etc.) which result with monolith joint between workpieces and qualitative weld.

Technological parameters are the few properties of FSW directly changeable and/or adjustable during welding process. However, selection of proper technological parameters, meaning, travel speed v_{ts} and tool rotation speed v_{rot} , as the most important ones is a difficult task. From the beginning of FSW's industrial application (mid 1992.) until present days, selection of travel speed and tool rotation speed is done by „try and error“ principle. Usable data about the technological parameters for specific processes/materials are usually hidden.

In most of the cases technological parameters of FSW are given over the welding step determined as the ration of tool rotation speed and travel speed v_{rot} / v_{ts} .

Ђivković [2] has estimated that 2024 alloy can be successfully welded for the weld step varying from 30 to 5, where the best results were achieved for parameters given in the Table 2. Welding was performed more than 100 times.

Table 2. Experimental welding step values for successful welding of the 2024 alloy [2]

v_{rot} / v_{ts}			
1180/116=10.17	1180/46=25.65		
750/150=5.00	750/116=6.64	750/93=8.06	750/73=10.27

5. VERIFICATION OF RESULTS

The final result of the FSW has to be a product that must fulfill its projected purpose. Decomposing this statement to the primary level: FSW joint has to be qualitative and should at least maintain properties of the base metal in projected range if not possible to improve them. According to the existing standards in FSW [3], verification of the results and FSW process has to be done by testing of specimens that have to be specially prepared and extracted from the welded structure (Figure 4).

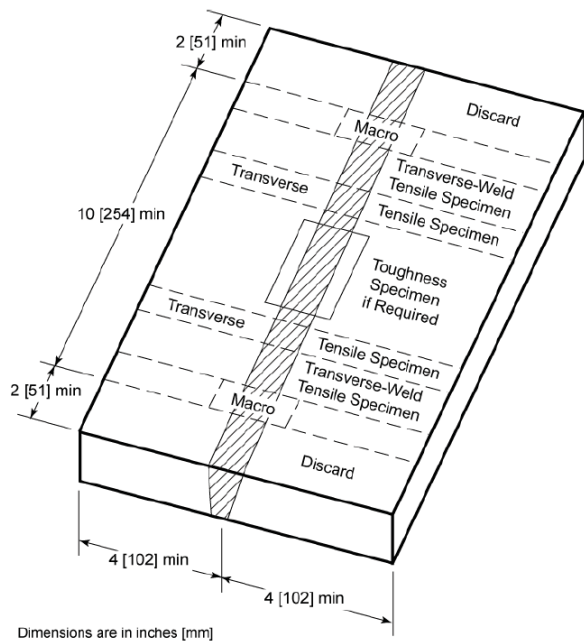


Figure 5 Location of Square Groove Weld Test Specimens—Plate [3]

5.1. Mechanical properties

Welded structures can be overmatched or undermatched from the aspect of the weld joint's strength. FSW process applied on 2024 alloy mostly gives overmatched structures: values of the strength, yield stress, hardness, elongation etc. slightly drop in the area of the weld or heat affected zone (HAZ) (Table 3).

Table 3 Experimental values of mechanical properties of FSW processed 2024 alloy in HAZ [2]

Test N ^o .	$R_{p0.2}$, MPa	R_m , MPa	A_5 , %	v_{rot} / v_{ts}
1	323	398	6,0	1180/116=10,17
2	316	319	7,1	1180/46=25,65
3	324	330	4,8	750/150=5,00
4	318	395	7,5	750/73=10,27
5	/	210	2,2	750/150=5,00
6	313	365	4,2	750/73=10,27

The common hardness diagram of 2xxx class has a specific W-shape: hardness of the material on join (center) line has some median value and distancing from the center line it gradually drops until the center of the HAZ than it rises and stabilizes its value outside the HAZ.

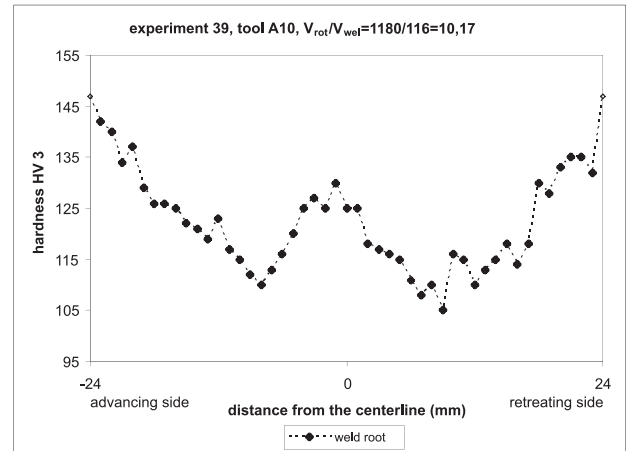


Figure 5 Hardness distribution in FSW, for 2024 alloy [2]

Hardness peak on the centerline is a result of the nugget zone (N). Nugget is the zone of fully recrystallized material that appears on the very center of the joint line and it is a product of intensive plastic deformation initiated by the welding tool and heat treatment of material (during the welding process) (Figure 6).



Figure 6 Macroscopic section on nugget zone of the FSW weld on 2024 alloy [2]

6. FUTURE WORK, DISCUSSION AND CONCLUSIONS

During past 20 years of application of FSW, science has given the great tribute to its improvement and better understanding the process itself. Numerous researches on the FSW application were aimed in recognition of dominant parameters that influence the process and the possibilities of their adjustments in order to reach optimal or desired characteristics of welds [4].

As mentioned earlier, some parameters of the FSW process are adjustable and simple to change since they depend only on possibilities of the system or fabricator. Challenge is to manipulate with other, nonadjustable or difficult to be adjusted parameters that depend not only from the process but from various physical phenomena as well. From the early beginning of application it is recognized that dominant processes in weld creation during FSW are deformation and heating. Literature explains differently these two processes: somewhere this

is stirring and heat generation, somewhere adhesion, diffusion, wear and friction, and some authors explain it as a pure mechanical process with the influence of other processes.

If some accepts any of the proposed explanation to be satisfactory accurate, FSW will still remain elusive from some point of view, either on macro or micro level, and the shade of our (human) no-understanding of the physics keeps us away from perfect design of the FSW. Anyhow, this challenge is overcome by numerous experiments and researches, and analysis of the processes that appear during FSW – good explanation of these processes helps in understanding the FSW in general.

With the goal of better design of the FSW (meaning: proper selection of technological parameters, geometrical parameters of the welding tool, workpieces' preparation etc.) mathematical model for the heat generation during FSW is developed. Heat is a necessity of the FSW process and its tribute in better weld creation lies dominantly in softening of the workpieces and easing the deformation/adhesion/stirring... process during weld creation.

Mathematical model relies on mathematical analysis, theoretical assumptions, state of the art in measuring techniques, recognition of dominant physical phenomena etc (Figure 7).

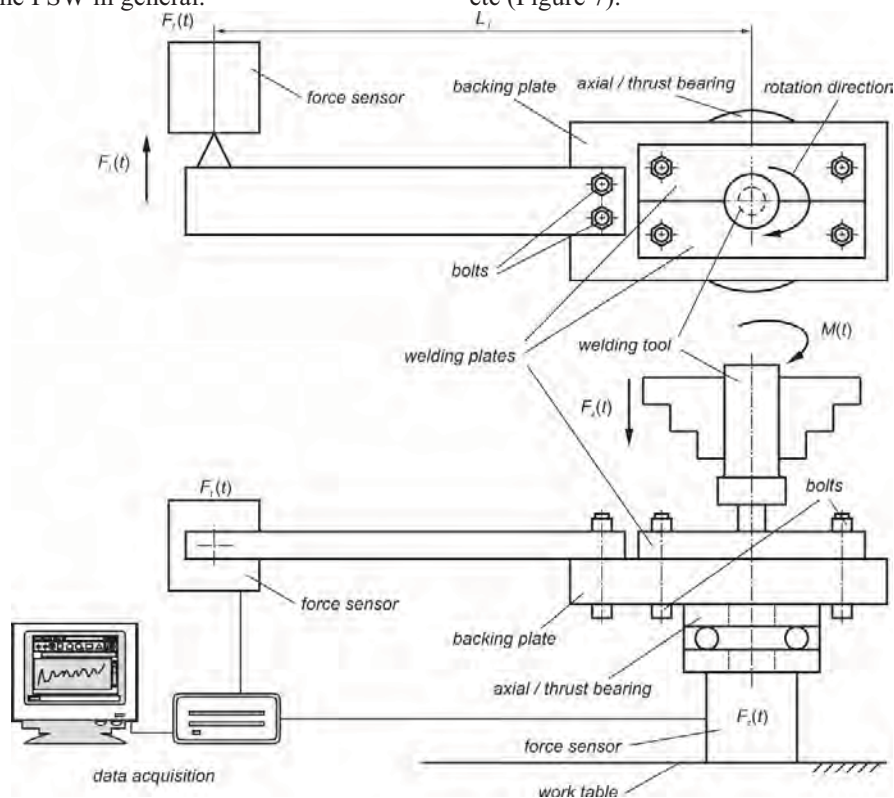


Figure 7 Scheme of the experimental setup for the FSW process

Further research in this area of FSW requires:

1. Recognition and precise determination of active/reactive forces in the system welding tool-workpieces, its influence and possibilities of increase/decrease of their magnitude.
2. Estimation of tribological parameters in contact between welding tool and workpieces (friction coefficient, contact pressure, adhesion, wear, selfaligning, selflubrication etc.)
3. Possibilities of the process efficiency increase (energy consumption, heat losses cuts etc.).

ACKNOWLEDGMENT

The paper presents and preliminary research observations needed for the realization of the research project TR35034 – “An investigation into modern non-conventional technologies: applications in manufacturing companies with the aim of increasing efficiency of use and product quality, of reducing costs and of saving energy and materials”. The project is supported by the Ministry of Education and Science of the Republic of Serbia.

REFERENCES

- [1] Mijajlović, M, Milčić, D, Stamenković, D, Tivković, A: Mathematical Model for Generated Heat Estimation During Plunging Phase of FSW Process, Transactions of Fama, Faculty of Mechanical Engineering and Naval Architecture, Zagreb, Croatia, XXXV-1/2011, April 2011, pp 39 - 54, ISSN 1333-1124, UDC 621.791.1.
- [2] Tivković, A: Influence of friction stir welding tool geometry on properties of welded joint of alloys Al 2024, PhD thesis, University of Belgrade, Faculty of Mechanical Engineering, 2011.
- [3] AWS D17.3/D17.3M:2010 Specification for Friction Stir Welding of Aluminum Alloys for Aerospace Applications, 2010.
- [4] Thomas W M et al. 1991 Friction stir butt welding International Patent Application No PCT/GB92/02203; Thomas W M et al. 1995 Friction stir butt welding GB Patent Application No 9125978.8; Thomas W M et al. 1995 Friction stir butt welding UP Patent No 5 460 317.



AUTHOR INDEX

A

Aco ANTIC	65
Adrian GHIONE	205
Aleksandar IVIĆ	407
Aleksandar MILETIĆ	79, 83, 527
Aleksandar SEDMAK	481
Aleksandar TODIĆ	99
Aleksandar ŢIVKOVIĆ	65, 477
Alexander PYNKIN	449
Alexis AUBRY	399
Alin Dan JURCHELA	75
Aljoša INAVIŠEVIĆ	309
Aljosa IVANISEVIC	301, 499
Anđela LAZAREVIĆ	425, 515
Andraš ANDERLA	407
Andreja ILIĆ	465
Anka TRAJKOVSKA PETKOSKA	485
Asim JUŠIĆ	297
Atanas KOČOV	175

B

B. SREDANOVIC	117
Baila DIANA	49
Bato KAMBEROVIĆ	155
Biljana SAVIĆ	103
Boban CVETANOVIĆ	223
Bogdan ĆIRKOVIĆ	99, 121
Bogdan NEDIĆ	87, 439, 443
Bogdan SOVILJ	523
Bojan BABIĆ	389, 531
Bojan MEDJO	481
Bojan RANĀIĆ	163, 267, 281, 285
Bojana ROSIĆ	343
Borislav SAVKOVIC	417
Bozica BOJOVIC	531
BoŢidar KRSTIĆ	469, 473
Branislav JEREMIĆ	421
Branislav SREDANOVIĆ	197
Branka DIMITRIJEVIĆ	239
Branko KOKOTOVIC	381
Branko PEJOVIĆ	99
Branko RADIĆEVIĆ	151
Branko RISTIĆ	331, 347, 189
Branko ŠKORIĆ	79, 83
Branko STRBAC	143
Branko U. TADIĆ	393

C

Cristian TARBĂ	205
Cvijan KRSMANOVIĆ	407
Cvijetin MLAĐENOVIĆ	113

D

Dalibor NIKOLIĆ	331
Dalibor PETKOVIĆ	385
Dalibor STEVANOVIĆ	355
Damir KAKAŠ	79, 83, 527
Danica JOSIFOVIĆ	465
Darko LOVREC	253, 507, 511
Darko STEFANOVIĆ	407
Davorin KRAMAR	489
Dejan ĆIKARA	99
Dejan DIVAC	319, 323, 327, 403
Dejan LAZAREVIC	305
Dejan LUKIĆ	109
Dejan MOMĀILOVIĆ	457
Dejan MOVRIN	301, 315, 495
Dejan PETROVIĆ	359
Desimir JOVANOVIĆ	87
Dijana NADAREVIĆ	53
Dorian MARJANOVIĆ	13
Dragan ADAMOVIĆ	277, 289, 421, 503, 519
Dragan ALEKSENDRIĆ	365
Dragan DŢUNIĆ	519
Dragan MARINKOVIC	201
Dragan MILĀIĆ	477
Dragan MILKOVIC	365
Dragan MILOSAVLJEVIĆ	469, 473
Dragan MILUTINOVIC	381
Dragan MISIĆ	243, 355
Dragan RAJNOVIC	91, 231
Dragan TEMELJKOVSKI	267, 281
Dragisa VILOTIĆ	301, 309
Dragoljub LAZAREVIC	425, 515
Dragoljub ŢIVKOVIĆ	159
Dragutin LISJAK	125
Dubravka MARKOVIĆ	309, 315
Dusan JOVANIC	461
Dusan KOJIC	531
Dušan KRAVEC	369

Đ

Đorđe ĀIĆA	117, 197
Đorđe ĀUPKOVIĆ	495
Đorđe VUKELIĆ	213



34th INTERNATIONAL CONFERENCE ON
PRODUCTION ENGINEERING
29. - 30. September 2011, Niš, Serbia
University of Niš, Faculty of Mechanical Engineering



E, F

Elena ZEVELEVA	453
Emil VEG	103
Fatima ȚIVIĆ	519
Franc CUS	29

G, H

G. LAKIĆ-GLOBOČKI	117
George GRUJOVIC	323
Gheorghe BRABIE	273
Goran DEVEDŽIĆ	189, 235, 347
Goran MLADENOVIC	41
Goran RADENKOVIĆ	69, 481
Goran SLAVKOVIĆ	257
Gordana BOGDANOVI	469, 473
Gordana GLOBOČKI LAKIĆ	197
Gordana LAKIĆ GLOBOČKI	87
Guenther POSZVEK	263
Hervé PANETTO	3, 399

I

Igor BEŠIĆ	185
Igor BUDAK	143
Igor KAĆMARČIK	495, 499
Ilare BORDEASU	75
Ile MIRCHESKI	227
Ioan TĂNASE	205
Ion MITELEA	75
Ionuț GHIONEA	205
Irina BEȘLIU	413
Ivan DANILOV	217
Ivan KOLEV	523
Ivan MATIN	213
Ivan MILICEVIC	193
Ivan SAMARDŽIĆ	523
Ivan SOVILJ-NIKIĆ	523
Ivana ATANASOVSKA	457
Ivica ČAMAGIĆ	99, 121

J

Ján SLAMKA	373
Jan STRBKA	133
Janez KOPAČ	489
Janko HODOLIC	143, 185, 213
Jasmina ČALOSKA	175
Jasna RADULOVIĆ	95
Jelena BARALIĆ	435, 439, 443
Jelena BOROTA	319, 323, 327, 403
Jelena MICEVSKA	175, 227
Jelena MILOVANOVIĆ	209, 335, 351
Jelena VIDAKOVIĆ	129
Jozef BARNA	181

Jozef NOVAK-MARCINCIN	181
Jozef PETERKA	61
Jože f PREDAN	481

K, L, Lj

Konstantinos PAPANIKOLOPOULOS	403
Krzysztof STĘPIEŃ	147
L. KOVAČEVIĆ	83
Laurențiu SLĂTINEANU	413
Lazar KOVAČEVIĆ	79, 527
Lenka CEPOVA	133
Leonid AKULOVICH	449
Leposava SIDJANIN	231
Leposava SIDJANIN	91, 231
Lorelei GHERMAN	413
Lozica IVANOVIĆ	465
Lj. TANOVIĆ	33, 41
Ljiljana TIHAČEK-ŠOJIĆ	359
Ljubinko CVETKOVIĆ	151

M

M. MILUTINOVIĆ	33
Manfred ZEHN	201
Marek ZVONČAN	61
Margareta COTEAȚĂ	413
Marián TOLNAY	369, 373
Marin GOSTIMIROVIC	57, 417
Mario LEZOCHÉ	399
Marko ANDJELKOVIĆ	359
Marko KOVAČEVIĆ	45
Marko PANTIĆ	519
Marko POPOVIC	193
Marko RAKIN	481
Marko VESELINOVIC	355
Marko VILOTIĆ	79, 83, 527
Martin KOVÁČ	61
Michael KHEIFETZ	449, 453
Michal JEDINÁK	373
Michal POTRAN	309
Michele FIORENTINO	189
Mihajlo POPOVIC	41
Mijodrag MILOŠEVIĆ	109
Miladin Ț. STEFANOVIĆ	393
Milan BLAGOJEVI	139, 343
Milan ERIĆ	235, 393
Milan DELIĆ	155
Milan JURKOVIĆ	297
Milan KOLAREVIĆ	151
Milan LAZAREVIC	305
Milan RADOVIĆ	323
Milan ŠLJIVIĆ	319
Milan TRIFUNOVIĆ	209, 335, 355
Milan ZDRAVKOVIC	243, 399



34th INTERNATIONAL CONFERENCE ON
PRODUCTION ENGINEERING
29. - 30. September 2011, Niš, Serbia
University of Niš, Faculty of Mechanical Engineering



Milan ZELJKOVIĆ	65, 113, 117	P	
Milenko SEKULIĆ	417	Pal TEREK	79, 83, 527
Milentije STEFANOVIĆ	277, 289, 421, 503	Pavao BOJANIĆ	41
Milica DAMJANOVIĆ	231	Pavel KOVAČ	57, 417
Milica PETROVIĆ	389, 531	Peđa MILOSAVLJEVIĆ	159
Milorad RANČIĆ	377	Petar PETROVIĆ	15, 217
Miloš ĆIROVIĆ	235, 347	Petar ĐEKIĆ	267
Milos GLAVONJIC	381	Plavka SKAKUN	315, 499
Milos JOVANOVIĆ	305, 461	Predrag ĆOSIĆ	125
Miloš MADIĆ	45, 69, 515	Predrag	
Miloš RISTIĆ	223	JANKOVIĆ	159, 163, 281, 285, 435, 443, 515
Miloš STOJKOVIĆ	209, 335, 243	Predrag PETROVIĆ	95
Milovan RADOSAVLJEVIĆ	331	Predrag POPOVIĆ	267
Miodrag HADŽISTEVIĆ	57, 143, 213	R	
Miodrag MANIĆ	223, 235, 351, 355, 425	Rade IVANKOVIĆ	37
Miodrag STOJILJKOVIĆ	377	Radivoje MITROVIĆ	457
Miomir VUKIĆEVIĆ	151	Radmila JOVANOVIĆ	155
Mircea Octavian POPOVICIU	75	Radomir RADIŠA	193
Mirko SOKOVIĆ	53, 489	Radomir SLAVKOVIĆ	103, 193
Miroslav BABIĆ	519	Radomir VUKASOJEVIĆ	339
Miroslav JANAK	181	Radovan ĆIRIĆ	103
Miroslav MIJAJLOVIĆ	477	Radovan PUZOVIĆ	41
Miroslav PAJIC	365	Rajko ČUKIĆ	469, 473
Miroslav PILIPOVIĆ	217	Ranko BOŽIĆKOVIĆ	293
Miroslav PLANCAK	301, 315, 495	Ranko RADONJIĆ	293
Miroslav R.		Ratko GATALO	113
RADOVANOVIĆ	69, 413, 431, 435, 439	Remigiusz LABUDZKI	171
Miroslav TRAJANOVIĆ	209, 243, 335, 355, 399	Robert CEP	133
Miroslav VASIĆ	129	Rok JUSTIN	489
Miroslav ŽIVKOVIĆ	139, 289, 343	S	
Mišo BJELIĆ	151	S. BOROJEVIĆ	117
Mladimir MILUTINOVIĆ	301, 309, 499	Sandira ELJŠAN	249
Najdan VUKOVIĆ	389	Sandra SOVILJ-NIKIĆ	523
Natalia POZILOVA	449	Saša ĆUKOVIĆ	189, 235, 347
Nebojša ĆOVIĆ	389	Sasa RANDJELOVIĆ	305
Neculai NANU	273	Sasa ZIVANOVIĆ	381
Nedim GANIBEGOVIĆ	249	Sebastian BALOS	91, 231
Nemanja VASIĆ	121	Sergej ALEXANDROV	301
Nenad D. PAVLOVIĆ	385	Simo ŠALETIĆ	339
Nenad FILIPOVIĆ	331, 359	Slavenko M. STOJADINOVIĆ	167
Nenad GRUJOVIĆ	319, 323, 327, 403	Slaviša ĐAČIĆ	289, 503
Nenad GUBELJAK	481	Slaviša PLANIĆ	163
Nikola KORUNOVIĆ	209, 335, 351	Slobodan MITROVIĆ	519, 393
Nikola LUKIĆ	217	Slobodan TABAKOVIĆ	113
Nikola MILIVOJEVIĆ	327, 403	Sofija SIDORENKO	227
Nikola SLAVKOVIC	381	Srbislav	
Nikola VITKOVIĆ	209, 243, 351	ALEKSANDROVIĆ	277, 289, 421, 469, 473, 503
O		Srđan MLADENOVIĆ	159, 163, 431
Obrad SPAIĆ	37	Srđan VULANOVIĆ	155
Ognjan LUŽANIN	315, 499	Stanislaw LEGUTKO	523
Olivera ERIĆ	91, 231, 457	Štefan POTÂRNICHE	413
Ondrej STAŠ	369		



34th INTERNATIONAL CONFERENCE ON
PRODUCTION ENGINEERING
29. - 30. September 2011, Niš, Serbia
University of Niš, Faculty of Mechanical Engineering



Stevo BOROJEVIĆ	197
Stojanka ARSIC	355
Suzana PETROVIĆ	189, 235, 347

T, U

Tadej TAŠNER	253
Tanja LUKOVIĆ	189
Tatjana PUŠKAR	309
Tatjana PUŠKAR	185, 315
Tomaž PEPELNJAK	499
Tomislav TODIĆ	99
Tomislav VUJINOVIC	277
Uros ZUPERL	29

V

Valentina LATIN	125
Velibor MARINKOVIĆ	45, 285
Velimir KOMADINIĆ	129
Velimir TODIĆ	109
Veronika FECOVA	181
Vesna MANDIĆ	297
Vesna RANKOVIĆ	319, 403
Viacheslav KRUTSKO	453
Victor GAIKO	453
Vid JOVIŠEVIĆ	197
Vidosav D. MAJSTOROVIĆ	5, 167
Vito TIĆ	507, 511
Vladan RADLOVAČKI	155
Vladimir BORODAVKO	453
Vladimir ĆARAPIĆ	129
Vladimir KANJEVAC	323
Vladimir KVRGIĆ	129
Vladimir MILIVOJEVIĆ	327
Vladimir R. MILACIC	15
Vladimir SIMIĆ	239
Vladislav BLAGOJEVIĆ	377
Vukić LAZIĆ	277, 465, 469, 473

Z, Ž

Zdravko BOŢIĆKOVIĆ	293
Zdravko KRIVOKAPIĆ	37
Zoran DIMIC	381
Zoran JOVANOVIĆ	347
Zoran JURKOVIĆ	57, 297
Zoran MILJKOVIĆ	389, 531
Zoran SPIROSKI	175
Zvonimir JUGOVIĆ	103, 193
Zvonko GULIŠIJA	289
Žarko SPASIĆ	257
Željko EREMIC	461
Željko RAIĆEVIĆ	339
Živana JAKOVLJEVIC	365

CIP - Каталогизација у публикацији
Народна библиотека Србије, Београд

621.7/.9(082)

621.7/.9:669(082)

681.5(082)

005.6(082)

004.896(082)

INTERNATIONAL Conference on Production
Engineering (34 ; 2011 ; Niš)

Proceedings / 34th International
Conference of Production Engineering,
September 28-30. 2011, Niš, Serbia ;
[organizer by] University of Niš, Faculty of
Mechanical Engineering, Department for
Production, IT and Management ; [editor,
glavni i odgovorni urednik Miroslav
Trajanović]. - 1. izd. = 1st ed. - Niš :
Mašinski fakultet = Niš : Faculty of
Mechanical Engineering, 2011 (Niš :
Unigraf-x-copy). - XX, 548 str. : ilustr. ;
30 cm

Tekst štampan dvostubačno. - Tiraž 150. -
Str. VII: Foreword / Miroslav Trajanović,
Velibor Marinković. - Sergey A. Klimenko:
str. 539. - Velimir Todić: str. 540. -
Velibor Marinković: str. 541. - Napomene i
bibliografske reference uz tekst. -
Bibliografija uz svaki rad. - Registar.

ISBN 978-86-6055-019-6

1. Mašinski fakultet (Niš)

a) Производно машинство - Зборници b)

Метали - Обрада - Зборници c) Системи

аутоматског управљања - Зборници d)

Управљање квалитетом - Зборници

COBISS.SR-ID 186256140