



UNIVERSITY OF NIŠ  
FACULTY OF MECHANICAL ENGINEERING IN NIŠ

THE 2<sup>nd</sup> INTERNATIONAL CONFERENCE

# MECHANICAL ENGINEERING IN XXI CENTURY



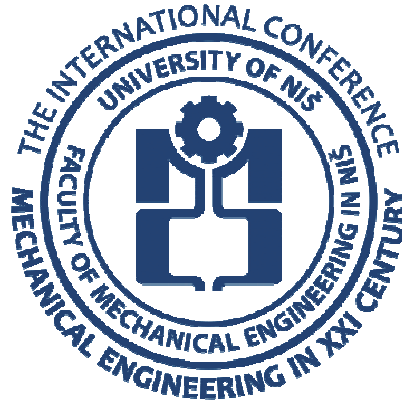
# PROCEEDINGS



313 - 2013.

June 20-21. 2013.

**UNIVERSITY OF NIŠ  
FACULTY OF MECHANICAL ENGINEERING**



**THE 2<sup>nd</sup> INTERNATIONAL CONFERENCE  
MECHANICAL ENGINEERING IN XXI CENTURY**

# **PROCEEDINGS**

**20-21. June 2013, Niš, Serbia**



## ORGANIZERS

UNIVERSITY OF NIŠ  
FACULTY OF MECHANICAL ENGINEERING

WITH SUPPORT OF:

Ministry of Science and Technological Development

*Chairman of the International conference*

Prof. dr Vlastimir NIKOLIĆ, Dean  
Faculty of Mechanical Engineering, Niš

## SCIENTIFIC COMMITTEE

Prof. Dr.-Ing. Axel Gräser, Institute of Automation, University of Bremen, Germany  
Prof. dr Goran Radenković, Mašinski fakultet Univerziteta u Nišu, Srbija  
Prof. dr Gradimir Ilić, Mašinski fakultet Univerziteta u Nišu, Srbija  
Prof. dr Dečan Ivanović, Mašinski fakultet Univerziteta Crne Gore, Crna Gora  
Prof. dr Dragan Djurdjanović, Department of Mechanical Engineering, University of Texas at Austin, USA  
Prof. dr Dragica Milenković, Mašinski fakultet Univerziteta u Nišu, Srbija  
Prof. dr Dragiša Nikodijević, Mašinski fakultet Univerziteta u Nišu, Srbija, predsednik  
Prof. dr Dragoljub Đorđević, Mašinski fakultet Univerziteta u Nišu, Srbija  
Prof. dr Dragoljub Živković, Mašinski fakultet Univerziteta u Nišu, Srbija  
Prof. dr Dušan Golubović, Mašinski fakultet Univerziteta u Istočnom Sarajevu, Bosna i Hercegovina  
Prof. dr Dušan Stamenković, Mašinski fakultet Univerziteta u Nišu, Srbija  
Prof. dr Emil Nikolov, Technical University of Sofia, Bulgaria  
Prof. dr Karl Kuzman, Fakultet za strojništvo Univerza v Ljubljani, Slovenija  
Prof. dr Lena Zentner, Technical University Ilmenau, Germany  
Prof. dr Ljiljana Petković, Mašinski fakultet Univerziteta u Nišu, Srbija  
Prof. dr. Ing. Ljubomir Dimitrov, Technical University of Sofia, Bulgaria  
Prof. Dr.-Ing. habil. Manfred Zehn, Technische Universität Berlin, Deutschland  
Prof. dr Marko Serafimov, Mašinski fakultet Skopje, Makedonija  
Prof. dr Miomir Jovanović, Mašinski fakultet Univerziteta u Nišu, Srbija  
Prof. dr Miroslav Vereš, Slovak University of Technology in Bratislava, Faculty of Mechanical Engineering, Slovakia  
Prof. dr Miroslav Radovanović, Mašinski fakultet Univerziteta u Nišu, Srbija  
Prof. dr Miroslav Trajanović, Mašinski fakultet Univerziteta u Nišu, Srbija  
Prof. dr Mladen Stojiljković, Mašinski fakultet Univerziteta u Nišu, Srbija  
Prof. dr Nenad Gubelj, Fakultet za strojništvo Univerza v Mariboru, Slovenija  
Prof. dr Nenad D. Pavlović, Mašinski fakultet Univerziteta u Nišu, Srbija  
Prof. dr. Niko Samec, Fakulteta za strojništvo, Maribor, Slovenija  
Prof. dr Petar Stankov, Technical University of Sofia, Bulgaria  
Prof. dr Predrag Kozić, Mašinski fakultet Univerziteta u Nišu, Srbija  
Prof. dr Predrag Rajković, Mašinski fakultet Univerziteta u Nišu, Srbija  
Prof. dr Radovan Kovačević, Southern Methodist University RCAM, USA  
Prof. dr Sava Ianici, Faculty of Engineering, University "Eftimie Murgu" of Resita, Romania  
Prof. dr Slobodan Vukićević, Filozofski fakultet Univerziteta Crne Gore  
Prof. dr Todor Neshkov, Technical University of Sofia, Bulgaria  
Prof. dr Hervé Panetto, Université de Lorraine, Francuska  
Prof. dr Valentin Nedeeff, Faculty of Engineering, University of Bacău, Romania

## ORGANIZING COMMITTEE

Prof. Dr Dragan Milčić, president

Prof. Dr Nenad T. Pavlović

Prof. Dr Melanija Mitrović

Prof. Dr Boban Anđelković

Dr Predrag Janković, assistant professor

Dr Miroslav Mijajlović, assistant professor

Dragan S. Jovanović, teaching asisstant

Živojin Stamenković, teaching asisstant

Ivan Pavlović, teaching asisstant

Marko Ignjatović, teaching asisstant

Nikola Petrović, teaching asisstant

Miloš Tasić

Srdan Mladenović

Vesna Grozdanović

Dušanka Nikolić

**Publisher:**

Faculty of Mechanical Engineering  
Prof. dr Vlastimir Nikolić, Dean

**Editor:**

Prof. dr Dragan Milčić

**Technical support, Design & Prepress:**

Saša Đorđević

**Number of copies:**

180

**Printing:**

"Unigraf"

---

**All the publications in this Proceedings have the authorship, whereas the authors of the papers carry entire responsibility for originality and content**

## SPONSORS



Влада Републике Србије

**Министарство просвете, науке и технолошког развоја**

**$\beta$  BETA**  
*CAE Systems SA*



## PREFACE

Half a century of tradition, high standards in education of generations of students, modernly equipped classrooms, professional teaching and associate staff, their references and recognizability position the Faculty of Mechanical Engineering of the University of Niš as the leader in the field of engineering and technological sciences, not only on the territory of the Republic of Serbia, but also on the territory of the Western Balkans.

The proceedings of the Second International Conference **MECHANICAL ENGINEERING IN XXI CENTURY** appear in the year when the Faculty of Mechanical Engineering of the University of Niš celebrates its fifty third anniversary. The Department of Mechanical Engineering of the Faculty of Engineering in Niš was founded on the 18<sup>th</sup> of May, 1960, and it developed into the Faculty of Mechanical Engineering of the University of Niš in 1971. The Faculty of Mechanical Engineering grew intensely, thus becoming one of the most renowned scientific and educational institutions in the country.

The mission of the Faculty is to organize and conduct academic study programmes and to develop and realise scientific and professional work in the field of engineering and technological sciences. Its vision to be recognisable in the european and world academic environment in the area of mechanical engineering.

More than 90 teachers and associates, about 60 non-teaching workers, as well as numerous teachers and associates from other faculties and from the industry, are working hard every day to accomplish the mission and vision of the Faculty.

The Faculty of Mechanical Engineering of the University of Niš is accredited in compliance with the Law on Higher Education within the scientific and educational field of engineering and technological sciences. It conducts the academic studies of the first degree – undergraduate studies, the second degree – master academic studies, and the third degree – doctoral studies, within the scientific area of mechanical engineering and engineering management.

The Faculty of Mechanical Engineering is also a scientific research institution apart from being an educational one. There are 14 international scientific research projects within the frame of FP7, TEMPUS, CEEPUS, DAAD, bilateral and cross-border programmes, as well as 24 national scientific research projects, being realised at the Faculty in this year. The participation of teachers and associates from the Faculty in these projects is of utmost importance for their educational and research work and their further career.

The Second International Conference **MECHANICAL ENGINEERING IN XXI CENTURY** represents a forum for presentation of latest results, basic and development research and application within the topics of:

- Information Production Technologies and Industrial Management,
- Thermal and Process Engineering,
- Mechatronics and Control,
- Machine Constructions, Development and Engineering,
- Traffic Engineering, Transport and Logistic,
- Theoretical and Applied Mechanics,
- Applied Mathematics,
- Engineering Profession: State and Prospects,

as well as the Workshop in honor of Prof. dr Ljiljana Petković "Iterative methods in applied mechanics".



Eighty three papers, whose authors come from 11 countries, are published in these Proceedings. Papers present the research results of numerous projects financed by the Ministry of Education, Science and Technological Development of the Republic of Serbia, as well as the research results within international projects. There is no doubt that the papers published in these Proceedings will contribute to the development of a highly significant area – Mechanical Engineering.

As a Dean of the Faculty of Mechanical Engineering in Niš, I am honoured to greet all participants of the Conference and wish them successful work.

Dean of the Faculty of Mechanical Engineering,  
University of Niš



*Prof. dr Vlastimir Nikolić*

Niš, June 2013.

# Table of Contents

<b>PLENARY SESSION.....</b>	<b>1</b>
ON UNSTEADY TWODIMENSIONAL INCOMPRESSIBLE BOUNDARY LAYER IN ACCELERATING AND DECELERATING FLUID FLOW AROUND CIRCULAR CYLINDER DEČAN IVANOVIĆ.....	3
HIGHER, FARTHER, FASTER – CONSEQUENCES FOR STRUCTURES OF TRUCK-MOUNTED CONCRETE BOOM PUMPS MANFRED ZEHN, DRAGAN MARINKOVIĆ.....	9
MANUFACTURING STRATEGY IN SLOWDOWN ECONOMY LUBOMIR DIMITROV.....	15
<b>APPLIED MATHEMATICS.....</b>	<b>21</b>
OPTIMAL MULTIPOINT ROOT SOLVING METHODS LILJANA D. PETKOVIĆ.....	23
A LIMIT OF THE EXPECTED VALUES FOR TRIALS WITH RANDOM NUMBERS PREDRAG RAJKOVIĆ, SLADANA MARINKOVIĆ, MIOMIR STANKOVIĆ.....	29
A FEW DISCRETE TRANSFORMS AND THEIR INVARIANTS PREDRAG RAJKOVIĆ <sup>1</sup> , NATAŠA SAVIĆ <sup>2</sup> .....	33
<b>THEORETICAL AND APPLIED MECHANICS.....</b>	<b>37</b>
VECTORS IN VECTOR AND TENSOR CALCULUS VELJKO A. VUJIČIĆ.....	39
STABILITY OF A VISCOELASTIC NANOBEM UNDER REAL-NOISE EXCITATION IVAN PAVLOVIĆ, RATKO PAVLOVIĆ, PREDRAG KOZIĆ, GORAN JANEVSKI, IVAN ĆIRIĆ.....	45
RECONSTRUCTION OF ISODYNE OR AIRY STRESS SURFACES IN A SQUARE PLATE DRAGAN B. JOVANOVIĆ.....	49
<b>INFORMATION PRODUCTION TECHNOLOGIES AND INDUSTRIAL MANAGEMENT.....</b>	<b>55</b>
ABRASIVE WATER JET CUTTING IN COMPARISON WITH OTHER NON-CONVENTIONAL CUTTING TECHNOLOGIES PREDRAG JANKOVIĆ, MIROSLAV RADOVANOVIĆ.....	57
CASE STUDIES CONCERNING SINGLE PULSE ELECTRO EROSION LORELEI GHERMAN, OANA DODUN, LAURENȚIU SLĂTINEANU, IONUȚ PALAGHIA ANALYSIS OF THE PLASMA HARDFACING PROCESS DRAGOLJUB LAZAREVIĆ, ANDJELA LAZAREVIĆ, VLADISLAV KRSTIĆ.....	67
NEURAL NETWORKS APPLICATION FOR THE PREDICTION OF TECHNOLOGICAL PARAMETERS OF PLASMA CUTTING PROCESS DRAGOLJUB LAZAREVIĆ, ANDJELA LAZAREVIĆ.....	71
ANALYSIS OF HOT FORGING PROCESS IN OPEN TOOL SAŠA RANĐELOVIĆ, DEJAN MOVRIN, MLADOMIR MILUTINOVIĆ.....	75
A BASIC THEORETICAL STATIC MODEL OF THE SUPPORT OF OPEN STRUCTURAL MEMBERS OF DEFORMATION PROCESSING MACHINES FOR THE APPLICATION OF CALCULATION METHODS DRAGAN TEMELJKOVSKI, STOJANČE NUSEV, DRAGANA TEMELJKOVSKI.....	79
INFLUENCE OF POLISHING METHODS ON SURFACE ROUGHNESS OF DENTAL RESIN-BASED NANOCOMPOSITES ANALYZED BY ATOMIC FORCE MICROSCOPE TIJANA LAINOVIĆ, MARKO VILOTIĆ, LARISA BLAŽIĆ, DAMIR KAKAŠ, DRAGAN KUKURUZOVIĆ, ALJOŠA IVANIŠEVIĆ.....	83
EFFECT OF STAINLESS STEEL PASSIVATION FOR RESISTANCE TO PITTING CORROSION IN HANK'S SOLUTION DUŠAN PETKOVIĆ, GORAN RADENKOVIĆ.....	87
DETERMINATION OF MECHANICAL PROPERTIES OF DENTAL RESIN-BASED NANOCOMPOSITES ALJOŠA IVANIŠEVIĆ, TIJANA LAINOVIĆ, DRAGIŠA VILOTIĆ, LARISA BLAŽIĆ, KATARINA GERIĆ, MARKO VILOTIĆ.....	91

THE STUDY OF INCREASED HEIGHT AT MIG - CMT CONTINUOUS OR PULSE COMBINED BRAZE-WELDING OF THE THIN SHEETS OF GALVANIZED STEEL AND ALUMINUM ELENA STELA C. MUNCUȚ, GHEORGHE G. SIMA .....	95
MATHEMATICAL AND SIMULINK MODEL OF THE X-Y TABLE FOR A CNC MACHINE IVAN MARINKOVIĆ, VLADISLAV BLAGOJEVIĆ, DUŠAN PETKOVIĆ .....	99
PULSE WIDTH MODULATION HYDRAULIC CYLINDER CONTROL VLADISLAV BLAGOJEVIĆ, MIODRAG STOJILJKOVIĆ .....	103
MORPHOMETRIC ANALYSIS OF THE HIP BONE AS THE BASIS FOR REVERSE ENGINEERING MIROSLAV TRAJANOVIĆ, MILICA TUFEGDŽIĆ, STOJANKA ARSIĆ, DRAGANA ILIĆ .....	107
REVERSE MODELING OF HUMAN RADIUS BASED ON REFERENTIAL GEOMETRICAL ENTITIES JELENA MITIĆ, MIODRAG MANIĆ, NIKOLA VITKOVIĆ, DALIBOR STEVANOVIĆ, MARKO VESELINOVIĆ .....	111
THE STUDY OF MORPHOLOGICAL PARAMETERS OF HUMAN ACETABULUM SIGNIFICANT FOR HIP ARTHROPLASTY STOJANKA ARSIĆ, DRAGANA ILIĆ, MILORAD MITKOVIĆ, MILICA TUFEGDŽIĆ, SONJA JANKOVIĆ, MIROSLAV TRAJANOVIĆ .....	115
IMPORTANCE OF NETWORKING IN CROSS-BORDER COOPERATION PROJECTS ON INNOVATION CAPACITY OF SME PEĐA MILOSAVLJEVIĆ, MLADEN VUČKOVIĆ, DRAGAN PAVLOVIĆ, MILENA TODOROVIĆ .....	121
THE DECISION PROCESS AS A PARADIGM OF QUALITY ACHIEVEMENTS GORAN MANOJLOVIĆ, NADA BOJIĆ, IVICA NIKOLIĆ .....	125
LEAN SIX SIGMA APPLICATION IN HEALTH SERVICE SRĐAN MLADENOVIĆ, PEĐA MILOSAVLJEVIĆ, DRAGAN PAVLOVIĆ .....	129
<b>ENERGETICS AND PROCESS ENGINEERING .....</b>	<b>133</b>
AXISMETRICAL IONIZED GAS BOUNDARY LAYER ON A PORUS WALL OF THE BODY OF REVOLUTION BRANKO OBROVIĆ, SLOBODAN SAVIĆ .....	135
APPLICATION OF PARAMETRIC METHOD TO THE SOLUTION OF UNSTEADY TEMPERATURE MHD BOUNDARY LAYER ON THE POROUS ARBITRARY SHAPE BODY DRAGIŠA NIKODIJEVIĆ, METODIJA MIRCEVSKI, ŽIVOJIN STAMENKOVIĆ, ALEKSANDAR BORIČIĆ, MILOŠ KOCIĆ .....	139
HEAT AND MASS TRANSFER ON UNSTEADY MHD DYNAMIC, TEMPERATURE AND DIFFUSION BOUNDARY LAYER FLOW OVER A HORIZONTAL CIRCULAR CYLINDER ALEKSANDAR BORIČIĆ, MILOŠ JOVANOVIĆ, BRANKO BORIČIĆ .....	145
FLOW AND HEAT TRANSFER OF ELECTROCONDUCTIVE FLUID IN THE PRESENCE OF UNIFORM MAGNETIC FIELD ŽIVOJIN STAMENKOVIĆ, DRAGIŠA NIKODIJEVIĆ, DRAGAN ŽIVKOVIĆ, MILICA NIKODIJEVIĆ .....	151
ANALYSIS OF WATER HAMMER IN A LONG PIPELINE HYDROPOWER PLANT WITH PELTON TURBINE DRAGICA MILENKOVIĆ, DRAGAN SVRKOTA, JELENA NIKODIJEVIĆ .....	155
PRESSURE DROP CALCULATION OF TRANSPORT AIR IN RECTILINEAR PIPELINE SECTIONS IN THE HIGH PRESSURE PNEUMATIC CONVEYING BOŽIDAR BOGDANOVIĆ, JASMINA BOGDANOVIĆ-JOVANOVIĆ, SAŠA MILANOVIĆ, ŽIVAN SPASIĆ .....	159
CONSIDERATIONS FOR HYDROPOWER DEVELOPMENT IN A GRAVITATIONAL WATER DISTRIBUTION SYSTEM DRAGICA MILENKOVIĆ, BOŽIDAR BOGDANOVIĆ, MILICA NIKODIJEVIĆ .....	163
EXPERIMENTAL MEASUREMENTS OF TURBULENT INTENSITY AND REYNOLDS STRESSES AROUND SMOOTH SPHERE AND SPHERE WITH DIMPLES JASMINA BOGDANOVIĆ-JOVANOVIĆ, MILOŠ KOCIĆ, JELENA NIKODIJEVIĆ .....	167
THERMAL NONUNIFORM CONDITIONS AND LOCAL DISCOMFORT GRADIMIR ILIĆ, ŽANA STEVANOVIĆ, MIĆA VUKIĆ, PREDRAG ŽIVKOVIĆ, MLADEN TOMIĆ .....	171
STATIONARY METHOD ON SITE EVALUATION OF U-VALUE OF BUILDING ELEMENTS ŽANA STEVANOVIĆ, GRADIMIR ILIĆ, MIĆA VUKIĆ, PREDRAG ŽIVKOVIĆ, MLADEN TOMIĆ .....	175
ANALYSIS OF DYNAMICAL SMULATION OF ENERGY CONSUMPTION OF ZERO ENERGY EFFICIENT HOME DESIGNED FOR THE AREA OF NIŠ MARKO MANČIĆ, DRAGOLJUB ŽIVKOVIĆ, VLADANA STANKOVIĆ, GORAN JOVANOVIĆ .....	179
REVIEW OF SOFTWARE FOR SIMULATION AND OPTIMIZATION OF MIDDLE AND HIGH TEMPERATURE SOLAR COLLECTORS SAŠA PAVLOVIĆ, VELIMIR STEFANOVIĆ, MILAN ĐORĐEVIĆ .....	183
PERFORMANCE ANALYSES OF A THERMALLY STRATIFIED SENSIBLE HEAT STORAGE IN A SOLAR POWERED ABSORPTION COOLING SYSTEM MILAN ĐORĐEVIĆ, SAŠA PAVLOVIĆ .....	189

ENERGY AND EXERGY ANALYSIS OF A HOT WATER GAS FIRED BOILER MILENA TODOROVIĆ, DRAGOLJUB ŽIVKOVIĆ, MARKO MANČIĆ, GRADIMIR ILIĆ .....	193
COST-BENEFIT ANALYSIS OF ELECTRONIC WASTE RECYCLING BIJANA MILUTINOVIĆ, GORDANA STEFANOVIĆ, MARKO ILIĆ, DEJAN JOCIĆ .....	199
<b>MACHINE CONSTRUCTIONS, DEVELOPMENT AND ENGINEERING .....</b>	<b>203</b>
ANALYZING EXISTING CALCULATION METHODS OF GROUP BOLTS JOINTS LOADED WITH MOMENT PERPENDICULAR TO THE JOINT PLANE SINISA KUZMANOVIĆ, MILAN RACKOV, KLARA RAFA, MILAN TICA.....	205
THE RESEARCH OF DYNAMIC BEHAVIOR OF RIGID ROTOR INSIDE THE ROLLING ELEMENT BEARING RADOSLAV TOMOVIĆ .....	209
USE OF SINTERED STEEL GEAR IN APPLICATION WORM-AND-GEAR SET ALEKSANDAR MILTENOVIC, JELENA STEFANOVIĆ-MARINOVIĆ, MILOŠ MILOVANČEVIĆ, ĐORĐE MILTENOVIC, SANJIN TROHA.....	213
EXPERIMENTAL TESTS ON BOUND FREQUENCY OF AXIAL BALL BEARINGS FOR FIXING THE BALL SCREWS VLADISLAV KRSTIĆ, DRAGAN MILČIĆ, MIROSLAV MIJAJLOVIĆ, MIROSLAV VERES, MIODRAG MILČIĆ.....	217
AN APPLICATION OF MULTICRITERIA OPTIMIZATION TO THE WIND TURBINE POWER TRANSMISSION JELENA STEFANOVIĆ-MARINOVIĆ, BOBAN ANĐELKOVIĆ, MILOŠ MILOVANČEVIĆ AND MILAN BANIĆ.....	223
IMPLEMENTATION OF VIRTUAL PRODUCT DEVELOPMENT PROCESS ON RUBBER-METAL SPRINGS MILAN BANIĆ, DUŠAN STAMENKOVIĆ, VOJISLAV MILTENOVIC, MILOŠ MILOŠEVIĆ, ALEKSANDAR MILTENOVIC .....	227
METODOLOGY OF DEVELOPMENT OF ENGINE COOLING FAN FOR AUTOMOTIVE INDUSTRY PURPOSE FROM REALIABILITY ASPECT BRANISLAV POPOVIĆ, BIJANA MARKOVIĆ .....	233
PREPARATION OF COATED STEEL SHEETS FOR WELDING MIOMIR VUKIČEVIĆ, BOJANA VELIČKOVIĆ, MARIJA MARKOVIĆ, IMRICH LUKOVICS, MIŠO BJELIĆ .....	239
DEVELOPMENT OF SIMULATION MODELS IN WELDING MIŠO BJELIĆ, MIOMIR VUKIČEVIĆ, SAVA ĐURIĆ, MARIJA MARKOVIĆ .....	243
APPLICATION OF TRIZ FOR DEVELOPMENT OF THE WELDING TOOL FOR FRICTION STIR WELDING MIODRAG MILČIĆ, MIROSLAV MIJAJLOVIĆ, DRAGAN MILČIĆ.....	247
<b>MECHATRONICS AND CONTROL .....</b>	<b>253</b>
ON THE INFLUENCE OF FLEXURE HINGE GEOMETRY ON THE MOTION RANGE AND PRECISION OF COMPLIANT GRIPPING MECHANISMS SEBASTIAN LINß, ANDRIJA MILOJEVIĆ, LENA ZENTNER.....	255
ADAPTIVE COMPLIANT GRIPPER DALIBOR PETKOVIĆ, NENAD D. PAVLOVIĆ.....	261
CHARACTERIZATION OF FLEXURE HINGES AND DEVELOPMENT OF A HIGH-PRECISION MICRO MANIPULATOR IVAN IVANOV, BURKHARD CORVES .....	267
NEW SOFTWARE FOR SYNTHESIS OF COMPLIANT MECHANISMS ANDRIJA MILOJEVIĆ, NENAD D. PAVLOVIĆ, MILOŠ MILOŠEVIĆ, MIŠA TOMIĆ .....	273
SENSOR-BASED CONTROL OF ROBOTIC FOLLOWER ADRIAN LEU, DANIJELA RISTIĆ-DURRANT AND SYED JAAD UL HAQUE .....	279
HUMAN TRACKING WITH A PERSON FOLLOWING ROBOT BASED ON EXTENDED KALMAN FILTER EMINA PETROVIĆ, MIŠA TOMIĆ, VLASTIMIR NIKOLIĆ, ŽARKO ČOJBAŠIĆ, VUKAŠIN PAVLOVIĆ, IVAN ĆIRIĆ .....	283
DETERMINATION OF IMAGE INTENSIFIER MODULATION TRANSFER FUNCTION VUKAŠIN PAVLOVIĆ, MILAN PAVLOVIĆ, NENAD T. PAVLOVIĆ, ACA MARJANOVIĆ, MIROSLAV KOKALOVIC, NEMANJA CVETKOVIĆ .....	287
A LABVIEW BASED VIRTUAL INSTRUMENT FORCE TRANSDUCER SLAVENKO ĐUKIĆ, PREDRAG JANKOVIĆ, JELENA MANOJLOVIĆ.....	293
SELF-ASSEMBLED MONOLAYERS IN LUBRICATION ON ATOMIC LEVEL JELENA MANOJLOVIĆ .....	297
ENERGY EFFICIENT CONTROL OF HEATING BY THE EU NORM – CASE STUDY OF AN AMPHITHEATRE MILAN RISTANOVIĆ, SLAVICA STOJILJKOVIĆ, ŽARKO ČOJBAŠIĆ, IVAN ĆIRIĆ.....	301

<b>TRAFFIC ENGINEERING, TRANSPORT AND LOGISTIC .....</b>	<b>305</b>
EXPERIMENTAL IDENTIFICATION OF RESPONSIBLE STRUCTURES' DYNAMICAL CHARACTERISTICS MIOMIR JOVANOVIĆ, DANIJEL MARKOVIĆ, VOJISLAV TOMIĆ, GORAN RADOIČIĆ .....	307
CASE STUDY OF DYNAMIC STRUCTURAL RESPONSE DURING FRACTURE OF A SEVERAL RESPONSIBLE MEMBERS MIOMIR JOVANOVIĆ, GORAN RADOIČIĆ, DANIJEL MARKOVIĆ, VOJISLAV TOMIĆ .....	313
MULTI-CRITERIA ANALYSIS OF MANIPULATIVE MEANS DURING THE DEVELOPMENT AND DESIGN OF CONTAINER TERMINAL IN NIŠ NIKOLA PETROVIĆ, VOJISLAV TOMIĆ, ZORAN MARINKOVIĆ, SAŠA MARKOVIĆ .....	319
THE QFD AS A TQM TOOL IN THE TRANSPORT SECTOR TANJA PAREZANOVIĆ, SNEŽANA PEJČIĆ TARLE, MARIJANA PETROVIĆ .....	325
INTEROPERABILITY IN AUTOMOTIVE EMBEDDED SYSTEM WITH FOCUS ON CAN NETWORK TECHNOLOGIES SAŠA PETROVIĆ, JASMINA LOZANOVIĆ ŠAJIĆ, SRETEN PERIĆ, TIJANA KNEŽEVIĆ .....	331
DYNAMIC STABILITY ANALYSIS OF HYDRAULIC EXCAVATORS DRAGOSLAV JANOŠEVIĆ, NIKOLA PETROVIĆ, VESNA JOVANOVIĆ, JOVAN PAVLOVIĆ .....	335
THE LOAD SPECTRUM OF AXIAL BEARING OF HYDRAULICS EXCAVATOR WITH SHOVEL ATTACHMENT VESNA JOVANOVIĆ, DRAGOSLAV JANOŠEVIĆ, PREDRAG MILIĆ .....	339
STRUCTURAL ANALYSIS USING ISOGEOMETRIC FEM BASED ON NURBS FUNCTIONS PREDRAG MILIĆ, DRAGAN MARINKOVIĆ .....	343
<b>ENGINEERING PROFFESION: STATE AND PROSPECTS .....</b>	<b>347</b>
ENGINEERS: JOB SATISFACTION DANIJELA VOZA, MILOVAN VUKOVIĆ .....	349
INFLUENCE OF TECHNOLOGY AND THE SUCCESS OF SCIENTIFIC AND TECHNOLOGICAL POTENTIAL IN MODERN SOCIETY RADOŠ RADIVOJEVIĆ, SRDJAN RADIVOJEVIĆ .....	353
GENDER ANALYSIS OF ENGINEERING PROFESSIONS IN SERBIA DANIJELA GAVRILOVIĆ, DRAGANA ZAHARIJEVSKI .....	357
STATUS AND PERSPECTIVE OF ENGINEERS IN SERBIA AT THE TURN OF 21 <sup>ST</sup> CENTURY NIKOLA CEKIĆ, SVETLANA VREČIĆ, IGOR BJELIĆ .....	361
THE ROLE OF ENGLISH IN THE MODERN ENGINEERING PROFESSION MILOŠ TASIĆ, DUŠAN STAMENKOVIĆ .....	365
ENGINEERS AND SUSTAINABLE DEVELOPMENTAMPLE VESNA MILTOJEVIĆ .....	369
RECREATION ROLE IN ENGINEERING VLADAN PETROVIĆ .....	373
VEBLEN, ENGINEERS, AND SOCIO-ECONOMIC POSITIONS ALPAR LOŠONC, ANDREA IVANIŠEVIĆ .....	377
ENGINEERING PROFESSION: STATE AND PROSPECTS DRAGOLJUB B. ĐORĐEVIĆ .....	381
ENGINEERS, ETHICS AND SUSTAINABLE DEVELOPMENT IVANA ILIĆ KRSTIĆ .....	385
<b>WORKSHOP: "ITERATIVE METHODS IN APPLIED MATHEMATICS" .....</b>	<b>389</b>
ON AN EFFICIENT SIMULTANEOUS METHOD FOR FINDING POLYNOMIAL ZEROS MIODRAG S. PETKOVIĆ, LJILJANA D. PETKOVIĆ, JOVANA DŽUNIĆ .....	391
MODIFIED NEWTON'S METHOD WITH MEMORY JOVANA DŽUNIĆ .....	397
POINT ESTIMATION OF CUBICALLY CONVERGENT ROOT FINDING METHOD OF WEIERSTRASS' TYPE LIDIJA RANČIĆ .....	403
ON AN INTERVAL METHOD FOR THE INCLUSION OF ONE POLYNOMIAL ZERO DUŠAN M. MILOŠEVIĆ, MIODRAG S. PETKOVIĆ, MIMICA R. MILOŠEVIĆ .....	409
INDEX OF AUTHORS .....	415

# Application of Triz for Development of the Welding Tool for Friction Stir Welding

Miodrag MILČIĆ, Miroslav MIJAJLOVIĆ, Dragan MILČIĆ

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

miodrag21@gmail.com, mijajlom@masfak.ni.ac.rs, milcic@masfak.ni.ac.rs

**Abstract**— One of the latest welding procedures – friction stir welding, has become a common welding procedure used in situations where no other welding procedures give adequate results. Advantages of this procedure are of greatest interest in welding of aluminum and its alloys, different materials etc. Friction stir welding is a typical example of usage of indirect frictional heat generation where welding is performed by the welding tool. Welding tool is a specialized tool consisting of shoulder and pin with the thread at the side. The profile of the thread is different from case to case and usually firmware. This paper is giving an example of development of the friction stir welding tool using the contradictions overcoming procedure – TRIZ. Welding tool is mentioned to be used for welding of thick parts made of high strength materials.

**Keywords**— friction stir welding, the theory of inventive problem solving, welding tool

## I. INTRODUCTION

Friction stir welding (FSW) is invented and experimentally verified by Wayne Thomas and his colleagues from the Institute of Welding, London, UK (The Welding Institute UK - TWI) during December 1991. The participant in the research process and the first user of FSW was the company Hitachi (Hitachi Ltd.). At the end of 1991 and the middle in 1992, Hitachi developed machine which was possible to process FSW weld on 25 meter long aluminum chassis for light, exo- rail vehicles used for the required underground railways of Japan, called. "Hitachi A-Train."

This method is routinely used, especially in many cases where no other method gives satisfactory results, but the main advantages of FSW are mostly reflected in the welding of materials such as aluminum and its alloys, austenitic stainless steels difficult to be weld by conventional methods, titanium, non-metal materials, etc. [1]. In real applications is irrefutably demonstrated that this process provides a homogeneous welds with good mechanical properties, often for parts difficult to be welded by conventional methods and techniques. The process is most applicable to components which are flat and long (plates, strips, etc.), but some adaptations can be welding of pipes of different elements as well hollow spot welding.

## II. FRICTION STIR WELDING

FSW welding process is a typical example of the use of indirect method of generating heat by friction. FSW procedure (Figure 1) is implemented as follows: sheets

(workpieces, the parts to be joined, base metals) are pressed together and fixed to the under panel. Welding is performed using a special tool having cylindrical shape, which consists of a large body diameter shoulder and smaller diameter pin usually sliced and left-hand thread.

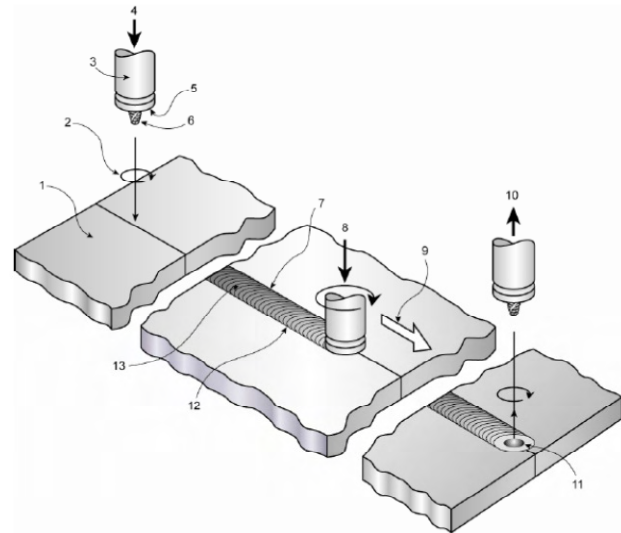


Figure 1 Nomenclature of the friction stir welding, 1-base metal, 2-tool rotation direction (clockwise), 3-welding tool, 4-plunging of the tool, 5-shoulder, 6-pin, 7 - advancing side of the weld 8-axial force, 9-direction of the welding 10-pulling out, 11-exit hole, 12-retreating side of the weld 13-weld face [2, 4]

At the beginning of the welding, tool is located above the plates and the work pieces so that its axis is usually perpendicular to the line of contact sheets. In this position, the tool rotates and starts downward translational movement, the pin penetrates through both plates simultaneously at a point on the joint line, the friction generated heat heats plates and continuously, stirs, deforms and mixes the material of workpieces. When shoulder touches the surface of the plate, the frontal area of the welding tool is very close to the anvil, tools downward movement is interrupted while continuing rotation of the tool. For some time tool remains in that position, and then starts moving horizontally along the line of plates. In the further course of the process, the pin heats both new layers of sheet material and mixes them, and deposits it behind, creating a zone of deformed material that hardens thus forming a monolithic structure. Tool shoulder seam forms a flat surface on the top sheet and the bottom does the same base-base plate. The process ends with termination of translational motion and

drawing tools from the base material. An important kinematic characteristic of FSW tool is that it always has a continuous rotational movement of the main and most often performed simultaneously on both translational extra movement, although it is possible to perform translational motion base plate with work pieces.

### III. THE BASIC SHAPE OF THE WELDING TOOL

Because of the specific function and the purpose, the welding tool must have a geometric, metallurgical and chemical properties adapted to the shape, mechanical properties, metallurgy and chemical composition of the base metal, and the technological parameters of the welding process. The basic form of the tool is cylindrical in shape and consists of two main components:

- probe,
- shoulder.

Both parts are necessary for the successful formation of the welded joint, each in their own way. Wedge tool is usually cylindrical or conical in shape with the wedge height  $h$  which is equal to or slightly less than the thickness of the base material, while the diameter of the pin  $d$  should be approximately equal to that of the base material [5, 6]. If welding tool has a cone-shaped pin, cone angle tool is taken as the value of  $\beta \leq 20^\circ$ . The pin has to initiate contact with metal, but also directly affects the formation of weld.

Shoulder is cylindrical part of the welding tool that "carries" a pin, and is used to connect all tools with clamping jaws of the machine. Diameter of the tool holder  $D$  is larger than the diameter  $d$  of the pin, in order to push out the pin material to the shoulder during the welding process to be shaped and aligned with the front surfaces of tool.

More advanced versions of the tools have a thread on the pin (Figure 2). They are used as metric threads, spherical, and of a special form. The purpose of the thread is to:

- increase the contact surface between welding tool and workpieces,
- influence the type of contact and contact pressure distribution between the tool and the base material (over point, line or area),
- increases the deformation of materials necessary for creating of a weld (stirring material),
- improving the movement of materials from workpieces (improved mixing),
- helps weld shaping,
- minimizes welding resistances.

There are welding tools with a constant pitch of thread  $P$ , while often changeable tread pitch is used. It is often used thread with left direction, especially if the rotation tool is done "to the right" - in the clockwise direction.

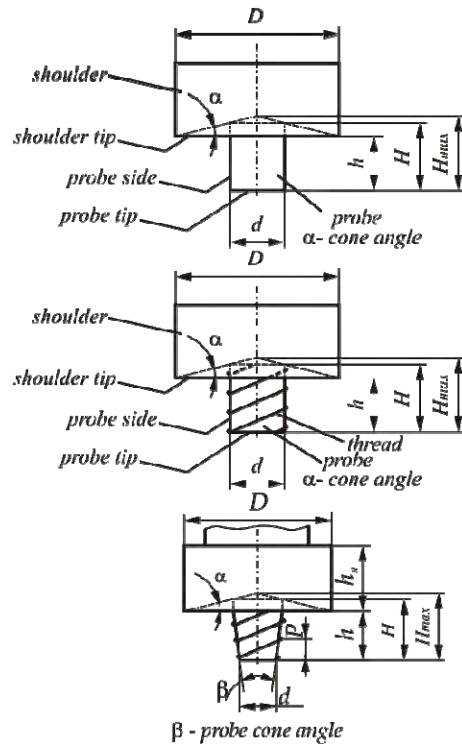


Figure 2 Shape of tools with threaded and tapered pin

There are many different designs of tool, but all agree with the basic shapes. There are structures with additional grooves on the wedge (Fig. 3), with a molded wedge forehead, with a cylindrical recess in the head carrier etc. There are structures that preclude the use of anvils because the controlling of resistance force is much simpler in such a design. The use of appropriate design of tools affects the quality of welded joints to the same extent as the technological parameters of the welding process (rpm, travel rate, etc.).

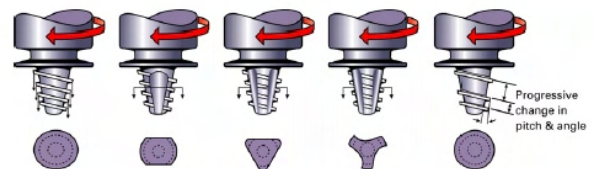


Figure 3. Shapes of the welding tool

### IV. THE THEORY OF INVENTIVE PROBLEM SOLVING – TRIZ METHOD

During 1946 in the city of Baku (now Azerbaijan), a young Soviet officer, engineer and inventor Genrih Altshuller with his second coworker Rafael Schapiro began work on the methodology of solving inventive problems - TRIZ (Theory of inventive problem solving). Then and today, the ruling method of "trial and error" has become inefficient for the growing needs of technical and technological innovations.

Based on a thorough review of more than 200,000 patents from prestigious technical fields, they have developed a criterion for ranking the findings at 5 inventive levels of technical improvements up to scientific discovery. They pointed out the 40,000 patents and another higher level after the comprehensive analyzes - they have identified about 1,200 types of contradictions that are generated, couples than 39 technical parameters (e.g. if the product should increase the speed of vehicles -



engine mass increases, i.e. improving one parameter leads to a deterioration in the second) and 40 inventive principles which these contradictions overcome (e.g. segmentation, use of composite materials, etc.).

This is how the famous Altshuller matrix of contradictions has appeared, as a kind of knowledge base extracted from 40,000 high quality patents. Unlike methods which are improved by the classical method of trial and error principle (e.g. brain storming, morphologically blocks, etc.) that allowed inventors to generate more ideas, TRIZ methodology was based on the objective laws of the development of technical systems and has generated the objective ideas which are directed towards the ideal/optimal final solution and that may be valorized by the newly discovered objective criteria.

Due to Altshuller's arrest and referral to the gulag in Vorkuta (Western Siberia), the first paper [3] on the TRIZ of innovative creativity was published in the late 1956. year. In the following thirty years Altshuller has contributed more than 70 seminars throughout the former USSR. He opened the school's of science and technical creativity and their number in the 1980s grew to over 500. The development of TRIZ included hundreds of students, engineers, researchers and scientists.

Due to ignoring the economic laws and the absence of competition in the socialist economy of USSR, TRIZ is predominantly applied in research and development of military technology and space research programs. TRIZ methodology is experiencing flourishing after the collapse of the USSR when a large number of "TRIZ-ers" emigrated in the United States, the most developed countries of Western Europe, and the Far East Asia region.

Economic growth of many companies in South Korea (especially Samsung Corporation [4]), is credited to applying the methodology of TRIZ. There is no company, not listed in "Fortune 500" that uses no TRIZ principles. . Particularly in the USA, TRIZ has been embedded in many technological areas, including the election campaign, explicitly non technological area of life.

Basic concepts of modern TRIZ are:

- TRIZ – toward the invention,
- TRIZ – how to shape the future,
- TRIZ – goal tending way of thinking.

Modern TRIZ also includes:

- All systems are being developed to meet the specific function.
- There is no rule to come up with ideas and solutions. The basic rule is a particular way of thinking.
- All systems should provide some efficacy but in harmony with the environment.
- All systems are developed to be different from the existing ones. It is a fundamental requirement for improving the level and scope of application and solutions.
- Contradictions between incompatible characteristics and the need to overcome the orientation of the primary functions and technical problems.
- The solution of contradictions is an invention.
- The number of different types of contradictions is limited.
- The method for solving the contradiction can be obtained by analyzing inventions and patents.

- The method for solving the contradiction consists in thinking, imagination, intellect...
- The method for resolving contradictions can be applied to other methods for the development of complex technical systems.

## V. ESTIMATION OF TECHNICAL CONTRADITCTIONS

To achieve a higher temperature (what is a prerequisite for successful welding by FSW) in hard materials, it is required to have a greater axial force, or higher power equipment. The first contradiction is the increased power. This contradiction leads to the necessity of major powers the new contradictions - higher volume of moving objects. The third contradiction in welding material of greater mechanical characteristics is the shorter tool lifespan. Thus, the next contradiction is reliability of the welding tool.

Table 1 is coming from the analysis of contradictions in the development of new FSW welding tool.

TABLE 1 AN OVERVIEW OF CONTRADICTIONS AND PRINCIPLES THAT ARE RECOMMENDED FOR THEIR ELIMINATION

Technical contradiction (with coordinates of the matrix)	Recommended principles	Name of principle
Improving 17: Temperature without damaging 10: Force (Intensity)	35	Parameter changes
	10	Preliminary action
	3	Local quality
	21	Skipping
Improving 17: Temperature without damaging 27: Reliability	19	Periodic action
	35	Parameter changes
	3	Local quality
Improving 10: Force (Intensity) without damaging 7: Volume of moving object	10	Preliminary action
	15	Dynamics
	12	Equipotentiality
	9	Preliminary anti-action
	37	Thermal expansion

### A. Contradiction overcoming

#### 1) Analysis of the principle:

##### 35. Parameter changes

It is not a simple, for example, from a solid to a liquid state, but the transition to a "pseudo" or "quasi-state" ("quasi-liquid") and intermediate, for example, the use of elastic solids.

##### 10. Preliminary action

- Perform, before it is needed, the required change of an object (either fully or partially).
- Pre-arrange objects such that they can come into action from the most convenient place and without losing time for their delivery.

*To apply the principle 10 means that new tools must be installed prior to welding work in its original position and set - pinched by necessary force. The new tool will have no standing as a conventional FSW welding above material, it will have a technological hole drilled in the plates, the tool is set to the operating position and pinched the necessary work force with bolted connections.*

### 3. Local quality

- Change an object's structure from uniform to non-uniform, change an external environment (or external influence) from uniform to non-uniform.
- Make each part of an object function in conditions most suitable for its operation.
- Make each part of an object fulfill a different and useful function.

*The welding tool in a conventional FSW process in the form of a monoblock - homogeneous structure. The new tool will be a non-homogeneous structure composed of multiple components that perform different functions. The new tool will have its own pin and a pin holder, except that, due to the necessity of setting up a working tool and its clamping position, the tool will have two shoulder, which will be on opposite sides of material to be welded.*

### 21. Skipping

- Conduct a process, or certain stages (e.g. destructible, harmful or hazardous operations) at high speed.

### 19. Periodic action

- Instead of continuous action, use periodic or pulsating actions.
- If an action is already periodic, change the periodic magnitude or frequency.
- Use pauses between impulses to perform a different action.

### 15. Dynamics

- Allow (or design) the characteristics of an object, external environment, or process to change to be optimal or to find an optimal operating condition.
- **Divide an object into parts capable of movement relative to each other.**
- If an object (or process) is rigid or inflexible, make it movable or adaptive.

*New detachable tool for the FSW welding must allow welding of parts of different thicknesses, and it will provide new tools designed of several parts that are installed in the operating position before welding.*

### 12. The other way round

- In a potential field, limit position changes (e.g. change operating conditions to eliminate the need to raise or lower objects in a gravity field).

### 9. Preliminary anti-action

- If it will be necessary to do an action with both harmful and useful effects, this action should be replaced with anti-actions to control harmful effects.
- Create beforehand stresses in an object that will oppose known undesirable working stresses later on.

*Placing the tool in the initial working position will be provided with the necessary clamping force which is necessary for the realization of friction at the contact of two f tools and materials to be welded and the contact pins and materials. Necessary force tightening will be achieved by bolted connection.*

### 37. Thermal expansion

- Use thermal expansion (or contraction) of materials.
- If thermal expansion is being used, use multiple materials with different coefficients of thermal expansion.

*Application of this principle gives a welding tool that will be more efficient for welding of material of higher*

*strength and more universal - possibility of welding different thicknesses.*

TRIZ methodology used towards a new tool whose structure is differently from the construction of tools for the "classic" way of FSW, and thus the new way FSW is different from the "classic" FSW. The application of new tools requires pre-drill holes in the parts to be welded, then setting the tightening of the tool, which enables the necessary force of friction due to the physical nature of FSW process. Also, the tightening of the tool holder in the machine used for the FSW welding is needed. Unlike traditional FSW welding method, when using this tool is not required base plate. The new tool, heat is generated and the bottom and the top of the plates that are welded. The initial position of the new FSW tool is shown in Figure 4

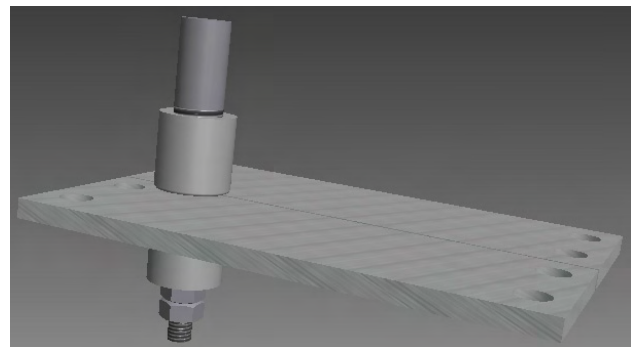


Figure 4 Position of the novel welding tool at the beginning of the FSW

TRIZ methodology provided the tools in four variants shown in Table 2 All design tools are prefabricated with 2 tool holders in which or through which the mandrel is mounted and fixed by bolts. For each offered variant pin on the bottom secures the nut and provides the self-loosening by a nut and a spring washer. It is essential that during the entire process of welding fastening force is constant with intensity defined welding technology (WPS), which influences the friction between tools and materials to be welded. Therefore the heat that is generated in this area in a controlled manner. Offered variants of tools differ in the decision fixing or clamping tool holder and the second part of the pin.

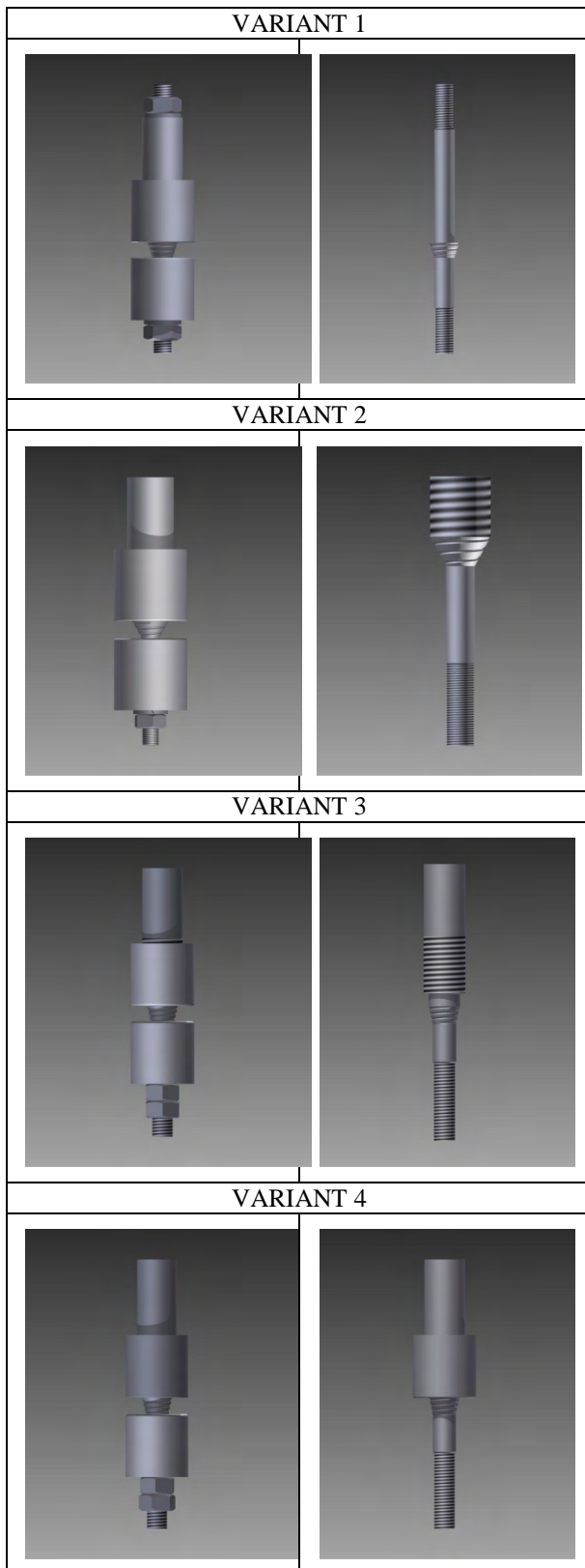
In variant 1: the pin is on the top tool carrier attaches via nuts and spring washers, taking into account the dimensions of the nuts are smaller than the diameter of tool holders, clamped by the jaws of the machine.

In variant 2 the role of a nut is given to the shoulder. It is very important for these variants to know the direction of rotation of the used machine (milling machine, lathe machine, or special welding FSW) and the direction of the thread (left or right).

In variant 3 the body of the tool is as a monoblock, which is partly due to the realization of thread-bolted connections (achieving the necessary clamping force). It is very important with these variants to take into account the direction of rotation of the head machine screw and direction (left or right).

In variant 4 pin is made equal to the tool body and the upper shoulder. Necessary force/torque is achieved through bolted connection pin and the frame on the bottom.

TABLE 2 VARIANTS OF THE WELDING TOOLS GENERATION WITH TRIZ METHODOLOGY



The conceptual design phase in which the TRIZ methodology is used to generate variants of FSW tool has given four possible variants tools Conceptual design phase ends with the choice of variants.

After selection of variants, tools are accessed for implementation - the final formatting of the tools. At this

stage, the material of welding tools is selected. Reviewing past researches, as a starting material tool was adopted X155CrMoV12-1, which was used for welding of copper and brass [6-8].

After the adoption of the tool material, it is necessary to define the diameter of the shoulder and pin. Bolted connection which fixes shoulder and the probe has to be calculated taking into account the temperature cross flow conditions are achieved during welding. Prototypes of all varieties of tools and experimental testing will be carried out tools and based on that we will opt for the best solution tools.

## VI. CONCLUSIONS

The process of FSW is one of the newest welding processes. This procedure is routinely used, especially in situations where no conventional welding method gives satisfactory results. It is mostly applied in the welding of the materials such as aluminum and its alloys, austenitic stainless steels, titanium, non-metal materials, etc. FSW welding process is a typical example of the use of indirect methods of generating heat by friction, where the friction to generate heat using a tool consisting of the - shoulder and tool pin on which is usually sliced left-hand thread.

The problem of application of conventional FSW tools occurred in welding dissimilar materials with different mechanical properties. It has caused the need to develop new tools. For the development of a new concept of FSW tool was used TRIZ methodology. Based on the results obtained by applying TRIZ methods are 4 versions of the new tools for FSW welding. All design tools are prefabricated with 2 tool holders in which or through which the pin is mounted and fixed by bolts. New concept tools require different; FSW welding process:

- Plates must be welded to the thigh, but not necessary because the base plate with a new tool generating heat by friction between a bearer of tools and materials, and the bottom.
- The materials to be welded must have a technological hole.
- The tool must be tightened by bolts - tightening force which is defined by the welding technology.

## ACKNOWLEDGMENT

This paper is part of the technological project TR35034 "The research of modern non-conventional technologies application in manufacturing companies with the aim of increase efficiency of use, product quality, reduce of costs and save energy and materials" at the University of Nis, Faculty of Mechanical Engineering, and was supported by Ministry of Education, Science and Technological Development of the Republic of Serbia

## REFERENCES

- [1] Miltenović, V.: Razvoj proizvoda – strategija, metode, primena, Univerzitet u Nišu Mašinski fakultet, 2003.
- [2] Rajić, D., Žakula, B., Jovanović, V.: Uvod u TRIZ, Beograd, 2006.
- [3] Mijajlović, M., Investigation and development of analytical model for estimation of amount of heat generated during FSW, Ph.D. thesis, University of Nis, Faculty of Mechanical Engineering Nis, 2012.
- [4] Živković, A.: Influence of friction stir welding tool geometry on properties of welded joint of alloys Al 2024,

- Ph.D thesis, University of Belgrade, Faculty of Mechanical Engineering, 2011.
- [5] ISO 25239-1: 2011 Friction stir welding - Aluminium - Part 1: Vocabulary.
- [6] R. Rai, A. De, H. K. D. H. Bhadeshia, T. DebRoy: Review: friction stir welding tools, Science and Technology of Welding and Joining, VOL 16 NO 4, 2011, pp. 325-342.
- [7] Meran, C., Kovan, V.: 'Microstructures and mechanical properties of friction stir welded dissimilar copper/brass joints', Materialwiss. Werkstofftech., 2008, 39, (8), 521–530.
- [8] <http://www.triz-journal.com/>

# Index of Authors

## A

Aca MARJANOVIĆ .....	287
Adrian LEU .....	279
Aleksandar BORIČIĆ .....	139, 145
Aleksandar MILTENOVIĆ .....	213, 227
Aljoša IVANIŠEVIĆ .....	83, 91
Alpar LOŠONC .....	377
Andjela LAZAREVIĆ .....	67, 71
Andrea IVANIŠEVIĆ .....	377
Andrija MILOJEVIĆ .....	255, 273

## B

Biljana MARKOVIĆ .....	233
Biljana MILUTINOVIĆ .....	199
Boban ANDELKOVIĆ .....	223
Bojana VELIČKOVIĆ .....	239
Božidar BOGDANOVIĆ .....	159, 163
Branislav POPOVIĆ .....	233
Branko BORIČIĆ .....	145
Branko OBROVIĆ .....	135
Burkhard CORVES .....	267

## D

Dalibor PETKOVIĆ .....	261
Dalibor STEVANOVIĆ .....	111
Damir KAKAŠ .....	83
Danijel MARKOVIĆ .....	307, 313
Danijela GAVRILOVIĆ .....	357
Danijela RISTIĆ-DURRANT .....	279
Danijela VOZA .....	349
Dečan IVANOVIĆ .....	3
Dejan JOCIĆ .....	199
Đorđe MILTENOVIĆ .....	213
Dragan B. JOVANOVIĆ .....	49
Dragan KUKURUZOVIĆ .....	83
Dragan MARINKOVIĆ .....	9, 343
Dragan MILČIĆ .....	217, 247
Dragan PAVLOVIĆ .....	121, 129
Dragan SVRKOTA .....	155
Dragan TEMELJKOVSKI .....	79
Dragan ŽIVKOVIĆ .....	151
Dragana ILIĆ .....	107, 115
Dragana TEMELJKOVSKI .....	79
Dragana ZAHARIJEVSKI .....	357
Dragica MILENKOVIĆ .....	155, 163
Dragiša NIKODIJEVIĆ .....	139, 151
Dragiša VILOTIĆ .....	91
Dragoljub B. ĐORĐEVIĆ .....	381
Dragoljub LAZAREVIĆ .....	67, 71
Dragoljub ŽIVKOVIĆ .....	179, 193
Dragoslav JANOŠEVIĆ .....	335, 339
Dušan M. MILOŠEVIĆ .....	409
Dušan PETKOVIĆ .....	87, 99
Dušan STAMENKOVIĆ .....	227, 365

## E

Elena Stela C. MUNCUȚ .....	95
Emina PETROVIĆ .....	283

## G

Gheorghe G. SIMA .....	95
Goran JANEVSKI .....	45
Goran JOVANOVIĆ .....	179
Goran MANOJLOVIĆ .....	125
Goran RADENKOVIĆ .....	87
Goran RADOIČIĆ .....	307, 313
Gordana STEFANOVIĆ .....	199
Gradimir ILIĆ .....	171, 175, 193

## I

Igor BJELIĆ .....	361
Imrich LUKOVICS .....	239
Ionuț PALAGHIA .....	61
Ivan ĆIRIĆ .....	45, 283, 301
Ivan IVANOV .....	267
Ivan MARINKOVIĆ .....	99
Ivan PAVLOVIĆ .....	45
Ivana ILIĆ KRSTIĆ .....	385
Ivica NIKOLIĆ .....	125

## J

Jasmina BOGDANOVIĆ-JOVANOVIĆ .....	159, 167
Jasmina LOZANOVIĆ ŠAJIĆ .....	331
Jelena MANOJLOVIĆ .....	293, 297
Jelena MITIĆ .....	111
Jelena NIKODIJEVIĆ .....	155, 167
Jelena STEFANOVIĆ-MARINOVIĆ .....	213, 223
Jovan PAVLOVIĆ .....	335
Jovana DŽUNIĆ .....	391, 397

## K

Katarina GERIĆ .....	91
Klara RAFA .....	205

## L

Larisa BLAŽIĆ .....	83, 91
Laurențiu SLĂTINEANU .....	61
Lena ZENTNER .....	255
Lidija RANČIĆ .....	403
Ljiljana D. PETKOVIĆ .....	23, 391
Lorelei GHERMAN .....	61
Lubomir DIMITROV .....	15

## M

Manfred ZEHN .....	9
Marija MARKOVIĆ .....	239, 243
Marijana PETROVIĆ .....	325
Marko ILIĆ .....	199
Marko MANČIĆ .....	179, 193
Marko VESELINOVIĆ .....	111
Marko VILOTIĆ .....	83, 91
Metodija MIRCEVSKI .....	139

Mića VUKIĆ.....	171, 175
Milan BANIĆ.....	223, 227
Milan ĐORĐEVIĆ.....	183, 189
Milan PAVLOVIĆ.....	287
Milan RACKOV.....	205
Milan RISTANOVIĆ.....	301
Milan TICA.....	205
Milena TODOROVIĆ.....	121, 193
Milica NIKODIJEVIĆ.....	151, 163
Milica TUFEGDŽIĆ.....	107, 115
Milorad MITKOVIĆ.....	115
Miloš JOVANOVIĆ.....	145
Miloš KOCIĆ.....	139, 167
Miloš MILOŠEVIĆ.....	227, 273
Miloš MILOVANČEVIĆ.....	213, 223
Miloš TASIĆ.....	365
Milovan VUKOVIĆ.....	349
Mimica R. MILOŠEVIĆ.....	409
Miodrag MANIĆ.....	111
Miodrag MILČIĆ.....	217, 247
Miodrag S. PETKOVIĆ.....	391, 409
Miodrag STOJILJKOVIĆ.....	103
Miomir JOVANOVIĆ.....	307, 313
Miomir STANKOVIĆ.....	29
Miomir VUKIĆEVIĆ.....	239, 243
Miroslav KOKALOVIĆ.....	287
Miroslav MIJAJLOVIĆ.....	217, 247
Miroslav RADOVANOVIĆ.....	57
Miroslav TRAJANOVIĆ.....	107, 115
Miroslav VERES.....	217
Miša TOMIĆ.....	273, 283
Mišo BJELIĆ.....	239, 243
Mladen TOMIĆ.....	171, 175
Mladen VUČKOVIĆ.....	121

## N

Nada BOJIĆ.....	125
Nataša SAVIĆ.....	33
Nemanja CVETKOVIĆ.....	287
Nenad D. PAVLOVIĆ.....	261, 273
Nenad T. PAVLOVIĆ.....	287
Nikola CEKIĆ.....	361
Nikola PETROVIĆ.....	319, 335
Nikola VITKOVIĆ.....	111

## O

Oana DODUN.....	61
-----------------	----

## P

Peđa MILOSAVLJEVIĆ.....	121, 129
Predrag RAJKOVIĆ.....	29, 33
Predrag JANKOVIĆ.....	57, 293
Predrag KOZIĆ.....	45
Predrag MILIĆ.....	339, 343
Predrag ŽIVKOVIĆ.....	171, 175

## R

Radoš RADIVOJEVIĆ.....	353
Radoslav TOMOVIĆ.....	209
Ratko PAVLOVIĆ.....	45

## S

Sanjin TROHA.....	213
Saša MARKOVIĆ.....	319
Saša MILANOVIĆ.....	159
Saša PAVLOVIĆ.....	183, 189
Saša PETROVIĆ.....	331
Sava ĐURIĆ.....	243
Sebastian LINŠ.....	255
Sinisa KUZMANOVIĆ.....	205
Slađana MARINKOVIĆ.....	29
Slavenko ĐUKIĆ.....	293
Slavica STOJILJKOVIĆ.....	301
Slobodan SAVIĆ.....	135
Snežana PEJČIĆ TARLE.....	325
Sonja JANKOVIĆ.....	115
Srđan MLADENOVIĆ.....	129
Srdjan RADIVOJEVIĆ.....	353
Sreten PERIĆ.....	331
Stojanče NUŠEV.....	79
Stojanka ARSIĆ.....	107, 115
Svetlana VREČIĆ.....	361
Syed Jaad UI HAQUE.....	279

## T

Tanja PAREZANOVIĆ.....	325
Tijana KNEŽEVIĆ.....	331
Tijana LAINOVIĆ.....	83, 91

## V

Velimir STEFANOVIĆ.....	183
Veljko A. VUJIČIĆ.....	39
Vesna JOVANOVIĆ.....	335, 339
Vesna MILTOJEVIĆ.....	369
Vladan PETROVIĆ.....	373
Vladana STANKOVIĆ.....	179
Vladislav BLAGOJEVIĆ.....	99, 103
Vladislav KRSTIĆ.....	67, 217
Vlastimir NIKOLIĆ.....	283
Vojislav MILTENNOVIĆ.....	227
Vojislav TOMIĆ.....	307, 313, 319
Vukašin PAVLOVIĆ.....	283, 287

## Ž

Žana STEVANOVIĆ.....	171, 175
Žarko ČOJBAŠIĆ.....	283, 301
Živan SPASIĆ.....	159
Živojin STAMENKOVIĆ.....	139, 151
Zoran MARINKOVIĆ.....	319

CIP - Каталогизација у публикацији  
Народна библиотека Србије, Београд

621(082)  
621:004(082)  
681.5(082)  
007.52(082)

#The #INTERNATIONAL Conference Mechanical  
Engineering in XXI Century (2 ; 2013 ; Niš)  
Proceedings / The 2nd International  
Conference Mechanical Engineering in XXI  
Century, 20-21.June 2013, Niš ; [organized  
by] University of Niš, Faculty of Mechanical  
Engineering ; [editor Dragan Milčić]. - Niš :  
Faculty of Mechanical Engineering, 2013 (Niš  
: Unigraf). - [8], 416 str. : ilustr. ; 29 cm

Tekst štampan dvostubačno. - Tiraž 180. -  
Str. 7-8: Preface / Vlastimir Nikolić. -  
Bibliografija uz svaki rad. - Registar.

ISBN 978-86-6055-039-4

1. Faculty of Mechanical Engineering (Niš)

a) Машинство - Зборници b) Машинство -

Рачунарска технологија - Зборници c)

Примењена математика - Зборници d)

Роботика - Зборници

COBISS.SR-ID 199124236