



ORGANIZED BY:  
EUROPEAN FEDERATION FOR WELDING,  
JOINING AND CUTTING  
&  
CROATIAN WELDING SOCIETY



# EUROJOIN 8

PROCEEDINGS OF THE EWF  
EUROJOIN 8 CONFERENCE



May , 24 -26 2012

Pula, Croatia



8<sup>th</sup> European Conference – Pula, Croatia, May, 24<sup>th</sup> – 26<sup>th</sup> 2012

8. Europsko savjetovanje – Pula, Hrvatska, 24. do 26. svibnja, 2012.

## EUROJOIN 8

PROCEEDINGS  
ZBORNIK RADOVA

Conference organized by / Organizatori savjetovanja :  
EUROPEAN FEDERATION FOR WELDING, JOINING AND CUTTING /  
EUROPSKA FEDERACIJA ZA ZAVARIVANJE, SPAJANJE I REZANJE

CROATIAN WELDING SOCIETY /  
HRVATSKO DRUŠTVO ZA TEHNIKU ZAVARIVANJA

Co-organizers / Suorganizatori:  
Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb /  
Fakultet strojarstva i brodogradnje, Sveučilište u Zagrebu;

Mechanical Engineering Faculty Slavonski Brod, J. J. Strossmayer University of Osijek /  
Strojarski fakultet Slavonski Brod, Sveučilište J. J. Strossmayera u Osijeku.

Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture,  
University of Split /  
Fakultet elektrotehnike, strojarstva i brodogradnje, Sveučilište u Splitu.

Faculty of Engineering, University of Rijeka /  
Tehnički fakultet Sveučilišta u Rijeci,

Welding Society of Istria /  
Društvo za tehniku zavarivanja Istra

**PATRON / ПОКРОВИТЕЉИ:**

REPUBLIC OF CROATIA, MINISTRY OF SCIENCE, EDUCATION AND SPORT  
REPUBLIKA HRVATSKA, MINISTARSTVO ZNANOSTI, OBRAZOVANJA I SPORTA

**HOST SPONSORS / SPONZORI DOMAĆINI:**

MONTMONTAŽA N.E.F. d.o.o., Zagreb  
NEXE GRUPA d.d., Našice

**GENERAL SPONSORS / GLAVNI SPONZORI:**

BAJKOMONT d.o.o., Servitec - Zagreb  
CROMATEC d.o.o., Samobor  
ELIMP d.o.o., Zagreb  
EUROTEHNIKA d.o.o., Zagreb  
IDEF d.o.o., Zagreb  
MECAS ESI s.r.o., Bimo, Republika Čelaka  
MONTING d.o.o., Zagreb  
MONTMONTAŽA PLINOVODOVOD d.o.o., Zagreb  
MOTOMAN ROBOTEC - YASKAWA SLOVENIA d.o.o., Ribnica, Republika Slovenija  
RAM d.o.o., Rijeka  
SERVUS d.o.o., Čakovec  
TPK - ZAVOD d.d., Zagreb  
TREA TRADE d.o.o., Vukovo, Rijeka  
TRKUT TEST d.o.o., Zagreb  
VAKSTROI d.o.o., Lendava, Slovenija  
ZAGREB MONTAŽA d.o.o. Zagreb- Dösseldorf

**SPONSORS / SPONZORI:**

A.M.I. COMMERCE LOVREKOVIC d.o.o., Zagreb  
ELEKTRODA ZAGREB d.d., Zaprrešić  
KORDUN d.o.o., Karlovac  
MESSER CROATIA PLIN d.o.o., Zaprrešić  
TEHNOMONT - BRODOGRADILISTE PULA d.o.o., Pula  
ULJANIK TESU SZZ d.o.o., Pula

CIP - zapis dostupian u mehaniziranom katalogu Nacionalne i sveučilišne knjižnice u Zagrebu pod brojem / 806040

CIP catalogue record for this book is available from the National and University Library in Zagreb under number 806040

Međunarodno savjetovanje / International conference:

EUROIRON 8 (svibanj 24. - 26. 2012.; Pula) /  
EUROIRON 8 (May 24. - 26. 2012.; Pula)

Izdavač / Publisher: HRVATSKO DRUŠTVO ZA TEHNIKU ZAVARIVANJA /  
CROATIAN WELDING SOCIETY

Urednik / Editor: Prof. dr. sc. Z. Koržuh

Tehnički urednik / Technical Editor: M. Buišić, dipl. inž. stroj.

Tekst na hrvatskom ili engleskom jeziku / Papers printed in Croatian or English  
Language

Bibliografija uz svaki rad / References supplied with papers

ISBN 978-953-7518-02-8

Nahoda / Issue: 250 kom

**Publisher remarks:**

- all articles have been examined and accepted by the Evaluation Committee
- publisher is not taking any responsibility or liability for statements, results or other data presented in the published articles

**Napomena izdavača:**

- svi radovi su recenzirani i kao takvi prihvaćeni od strane prosudbenog odbora
- izdavač ne odgovara za stavove, rezultate i ostale podatke iznesene u radovima

Conference President / Predsjednik konferencije:  
Prof. dr. sc. Stjepan Kralj

*Scientific Committee / Znanstveni odbor:*

President / Predsjednik: Zoran Kožuh

Mustafa Kocak, TR  
Michal Kubica, PL  
Dorian Marjanović, HR  
Ivan Polajnar, SLO  
Omer Pašić, BH  
Luiza Coutinho, PT  
Ivan Samardžić, HR  
Elona Scutnicu, RO  
Vencislav Grabulov, RS  
Tim Jessop, UK

Boris Anzulović, HR  
Branko Bauer, HR  
Peter Bernasovský, SK  
Lutz Dorn, DE  
Horst Cerjak, AT  
Luca Costa, IT  
Tomislav Filetin, HR  
German Hernandez, SP  
Danut Iordăchescu, SP  
Károly Jarmai, HU  
Ivan Juraga, HR

*Organization Committee / Organizacijski odbor:*

Franjo Javor  
Igor Juvrišen  
Nikša Krmić  
Anle Krole  
Maja Remenar  
Tanja Tomić Kovčević  
Jozef Tunić

Sime Anđić  
Milan Bičić  
Maja Budić  
Ivica Garašić  
Zlatko Glogović  
Maja Horvatić  
Mislav Imbriša

CONTENTS / SAĐRŽAJ :

• R.Fernaz, L.Coutinho, B.Hourmat	THE EWF/IIFW TRAINING AND QUALIFICATION SYSTEM AND THE EUROPEAN QUALIFICATION FRAMEWORK	1 - 8
• I.Samardžić, H.Heuser, I.Kladarić, D.Kozak, B.Despotović	EWE/IIFW SUSTAV OSPOSOBLJAVANJA I KVALIFICIRANJA I EUROPSKI KVALIFIKACIJSKI OKVIR CONTEMPORARY MATERIALS IN STEAMBOILERS PRODUCTION SUVREMENI MATERIJALI U KOTLOGRADNJI	9 - 18
• A.Stern, A.Miriyev, S.Kalabukhov Z. Hooper, E. Tuval, N. Frage	TITANIUM TO STEEL JOINING BY SPARK PLASMA SINTERING (SPS) TECHNOLOGY SPS (SPARK PLASMA SINTERING) POSTUPAK PLAZMA SINTERIRANJA-ZAVARIVANJA TITANSKE LEGURE 6AL-4V NA ČELIK AISI 4330	19 - 28
• I.Čatić, G.Barić, M.Rujnić-Sokele	NEW SYSTEMATISATION OF SUBSTANCES AND MATERIALS NOVO RAZVRSTAVANJE TVARI I MATERIJALA	29 - 38
• E.Engel	NEW PEDAGOGICAL METHODOLOGIES IN TRAINING OF WELDING PERSONNEL NOVI PEDAGOŠKI PRISTUPI U OSPOSOBLJAVANJU ZAVARIVAČKOG OSOBLJA	39 - 48
• M.Suban, B.Bundara, R.Cvelbar	COMPARING ENERGY USE AND ENVIRONMENTAL EMISSIONS OF WELDED VS. BOLTED JOINTS IN CONSTRUCTIONS USPOREDBA UPORABE ENERGIJE I EMISIJA U OKOLIŠU PRI UPORABI ZAVARENIH I VIČANIH SPOJEVA NA KONSTRUKCIJAMA	49 - 58
• H.Staufner, C.Kammerhuber, S.Egerland	APPLYING THE SOLID STATE LASER-GMA HYBRID PROCESS FOR SINGLE-SIDED FULL PENETRATION WELDING OF BULB BAR PROFILES IN SHIPBUILDING PRIMJENA "SOLID STATE" LASER/MAG HIBRIDNOG POSTUPKA ZA JEDNOSTRANO ZAVARIVANJE S PUNIM PROVAROM BULB-PROFILA U BRODOGRADNJI	59 - 70

- P. Bernasovsky,  
M. Palva,  
I. Hamak,  
S. Gruncwald,  
T. Seefeld,  
F. Vollerstedt

PRIMJENA HIBRIDNOG LASERSKOG  
ZAVARIVANJA S OPTIČKIM VLAKNOM U  
ZAVARIVANJU ČJEVODIVA IZ X70 ČELIKA

81 - 90

WELDING OF ALUMINIUM - PORES AND THE  
MEANING OF HOSES

- M. Wolbers,  
Z. Szlopek

ZAVARIVANJE ALUMINIJA - PORE I ZNAČENJE  
CRIJEVNOG PAKETA

91 - 98

INFLUENCE OF DEEP CRYOGENIC TREATMENT ON  
PROPERTIES OF ADI

- S. Šolić,  
S. Jakovljević

UTJECAJ DUBOKOG HLAĐENJA NA SVOJSTVA  
IZOTERMIČKI POBOLJŠANOG NODULARNOG  
LJEVA

99 - 106

WELDABILITY OF ALUMINIUM ALLOY USING FSW

- D. Klošar,  
L. Kosce,  
S. Smolej,  
J. Tušek

ZAVARLJIVOST ALUMINIJSKE LEGURE A1Si12  
KOD PRIMJENE FSW POSTUPKA

107 - 116

CONSIDERATIONS FOR PREHEATING WHEN  
WELDING MILD- AND LOW ALLOYED STRUCTURAL  
STEELS

- F. Neessen,  
V. van der Meer

RAZMATRANJA O PREDGRUVANJU TIJEKOM  
ZAVARIVANJA KONSTRUKCIJSKIH I  
NISKOLEGIRANIH ČELIKA

117 - 124

LPG SPHERE ERECTION FROM TMCP STEEL

- G. Vručinać

MONTAŽA KUGLASTOG SPREMNIKA ZA  
UKAPLJENI FLIN NAČINJENOG OD TMCP ČELIKA

125 - 132

TEMPERATURE FIELD ANALYSIS OF API 5L-X70  
STEEL JOINT PERFORMED BY SUBMERGED DOUBLE  
ARC WELDING

- C. C. Rusu,  
E. Scutelnicu,  
L. R. Mirdodie

ANALIZA TEMPERATURNOG POLJA SPOJA  
IZVEDENOG EPP POSTUPKOM S DVA LUKA NA  
ČELIKU API 5L-X70

133 - 142

INFORMAL TRAINING RECOGNITION AND  
TECHNOLOGIES USED IN EDUCATION AND  
CERTIFICATION OF WELDING PERSONNEL

- M. Uran,  
M. Jovanović,  
P. Šprajc,  
A. Kóvcs

NEFORMALNO PRIZNAVANJE I TEHNOLOGIJE  
KOJE SE KORISTE U ŠKOLOVANJU I CERTIFIKACIJI  
ZAVARIVAČKOG OSOBLJA

- B. Hourmat,  
E. A. Assunção,  
L. Coutinho

NOVI PRISTUPI ŠKOLOVANJU I  
OSPOBLJAVANJU ZAVARIVAČA

149 - 156

EUROPEAN TOOLS FOR TRANSPARENCY,  
RECOGNITION OF QUALIFICATIONS AND MOBILITY  
OF LEARNERS AND WORKERS

- L. Coutinho,  
T. Jessop,  
B. Hourmat

EUROPSKI ALAT ZA PREGLEDNOST, PRIZNAVANJE  
KVALIFIKACIJA I MOBILNOSTI UČENIKA I  
RADNIKA

157 - 166

PROCESS OPTIMIZATION FOR LINEAR FRICTION  
WELDING OF HIGH STRENGTH CHAINS

- K. Mucic,  
F. Fuchs,  
N. Enzinger

OPTIMIZACIJA ZAVARIVANJA TRENJEM U IZRADI  
VISOKOČVRSTIH LANACA

167 - 172

TRAINING AND CERTIFICATION OF WELDERS  
PERFORMING WORKS ON PROCESS PIPELINES WITH  
REFERENCE ON THE TIG WELDING PROCEDURE

- Đ. A. Jukić,  
F. A. Jukić,  
M. Mucić

OBUKA I ATESTACIJA ZAVARIVAČA ZA RAD NA  
PROCESNIM ČJEVODIVIMA SA OSVRTOM NA TIG  
POSTUPAK ZAVARIVANJA

173 - 182

AUTOMATION AND ROBOTIZATION IN PRODUCTION  
OF HEAVY 3D PIPE CONSTRUCTION - PRACTICAL  
EXPERIENCE

- R. Halas,  
R. Gligorin,  
R. Imre,  
J. Treiber,  
R. Laslo,  
D. Zadravec,  
J. Orbán

AUTOMATIZACIJA I ROBOTIZACIJA IZRADE  
TEŠKIH 3D ČIJEVNIH KONSTRUKCIJA - PRIMJER  
RJEŠENJA IZ PRAKSE

183 - 190

ROBOTISATION OF WELDING PROCESS OF THE  
BRAKE PEDALS FOR BMW PL7 PEDAL ASSEMBLIES

- H. Kosler,  
A. Zupanc,  
D. Širaj,  
S. Novak,  
I. Česarek,  
M. Merkač

ROBOTIZACIJA PROCESA ZAVARIVANJA PEDALA  
KOČNICE ZA PEDALNI SUSTAV BMW PL7

191 - 200

CONFORMITY ASSESSMENT OF EXECUTION OF  
STRUCTURAL STEEL COMPONENTS ACCORDING TO  
STANDARD HRV EN 1090-1:2009

- T. Svagaša,  
Z. Baršić,  
Š. Husić

POTVRĐIVANJE SUGLASNOSTI IZVEDBE  
KONSTRUKCIJSKIH ČELIČNIH KOMONENTI  
PREMA NORMI HRN EN 1090-1:2009

• L. Quinino, R. Ferraz, I. Fernandes	WELDING COORDINATION ACCORDING TO EN 1090 AND THE CONSTRUCTION PRODUCTS DIRECTIVE KOORDINACIJA ZAVARIVANJA PREMA NORMI EN 1090 I DIREKTIVI ZA PROIZVODNJU ČELIČNIH KONSTRUKCIJA	201 - 208
• P. Van Rymenant, W. Peigrimak, D. Yapp	NEW RESISTANCE PROJECTION GEOMETRY DESIGN FOR OPTIMIZED BEHAVIOUR NOVI OBLIK GEOMETRIJE BRADAVICE PRI BRADAVICASTOM ZAVARIVANJU ZA POSTIZANJE OPTIMIZIRANIH SVOJSTAVA SPOJA	209 - 218
• L. Quinino, R. Miranda	OVERVIEW OF MICRO AND NANO JOINING FUSION WELDING PROCESSES PREGLED MIKRO I NANO POSTUPAKA ZAVARIVANJA TALJENJEM	219 - 220
• L. R. Miodić, C. C. Rusu, E. C. Constantina, E. Scutelanica, C. Voicu	COMPARATIVE EXPERIMENTAL STUDY ON MONO AND MULTIARC SUBMERGED ARC WELDING OF API 5L-X70 STEEL USPOREDBA STUDIJA EPP ZAVARIVANJA ČELIKA API 5L - X70 S JEDNIM I DVA ELEKTRIČNA LUKA	231 - 240
• E. Assunção, L. Coutinho, F. Hagglund, M. Troughion, M. Spicer	ADVANCED NDT TECHNIQUES FOR PLASTIC PIPELINE INSPECTION NAPREDNE NDT TEHNIKE ZA PREGLED PLASTIČNIH CJEVOVODA	241 - 248
• P. Dukić	RISK BASED INSPECTION ISPITIVANJE NA BAZI RIZIKA	249 - 254
• M. Beloev, V. Homenko, N. Lolov, P. Darjanov	RESULTS FROM THE RECENT INVESTIGATIONS ON THE FBW PROCESS APPLICATION FOR LONG DISTANCE LARGE DIAMETER PIPELINES REZULTATI NOVIH ISTRAŽIVANJA PRIMJENE FBW POSTUPKA ZA MAGISTRALNE CJEVOVODE VELIKIH PROMJERA	255 - 264
• S. Kastelic, J. Tušek, D. Klobčar, P. Mrvar	JOINING DIFFERENT ALUMINIUM CASTING ALLOYS WITH FRICTION STIR WELDING SPAJANJE RAZNORODNIH ALUMINIJSKIH LJEVAČKIH LEGURA PRIMJENOM ZAVARIVANJA TRENJEM (FRICTION STIR POSTUPAK)	265 - 272

• J.K. Larsson	OPTIMIZING THE RESISTANCE SPOT WELDING PROCESS FOR HIGH QUALITY WELDING OF PRESS- HARDENED AUTOMOTIVE COMPONENTS OPTIMIZACIJA POSTUPKA ELEKTROTPORNOG TOČKASTOG ZAVARIVANJA PRI VISOKOKVALITETNOM SPAJANJU DEFORMACIJSKI OČVRŠNUTIH DIJELOVA ZA AUTOMOBILSKU INDUSTRIJU	273 - 284
• P. Nagy, T. Kovács, J. Dobránszky	LASER WELDING OF AIRBAG CONNECTORS LASERSKO ZAVARIVANJE PRIKLJUČAKA ZRACNOG JASTUKA	285 - 294
• E. Džihó, Ž. Petrović, S. Pašić, E. Nezirić	OPTIMIZATION OF CAPACITY DISCHARGE WELDING PROCESS OF SMALL DIAMETER WIRES OPTIMIZACIJA TEHNOLOGIJE KONDENZATORSKOG ZAVARIVANJA ŽICA MALOG PROMJERA	295 - 302
• B. Alić, S. Pašić	EFFECTS OF NITROGEN ADDING IN ARGON SHIELDING GAS FOR WELDING OF AUSTENITIC STAINLESS STEELS EFEKTI DODAVANJA DUŠIKA U ARGON ZAŠTITNI PLIN KOD ZAVARIVANJA AUSTENITNIH NEHRĐAJUĆIH ČELIKA	303 - 314
• G. Messchut, F. Filggen, T. Olfemann, V. Janzen	MECHANICAL JOINING AND ADHESIVE BONDING OF AUTOMOBILE LIGHTWEIGHT CONSTRUCTIONS MEHANIČKO SPAJANJE I LIJEPLJENJE PRI IZRADI LAKIH AUTOMOBILSKIH KONSTRUKCIJA	315 - 324
• B. Csata	ICE™ THE REVOLUTIONARY SAW TECHNOLOGY FROM ESAB FOR ENHANCED PRODUCTIVITY ICE™ REVOLUCIONARNA TEHNOLOGIJA EPP ZAVARIVANJA ZA POVEĆANJE PRODUKTIVNOSTI RAZVIJENA U ESAB-U	325 - 330
• D. Mičić, M. Mijatlović, D. Mičić, M. Mihić	EXPERIMENTAL INVESTIGATION OF GTAW, GMAW AND FSW WELDING PROCESSES ON ALUMINIUM ALLOY 2024 T351 EKSPERIMENTALNA USPOREDBA MIG, TIG I FSW POSTUPKA ZAVARIVANJA ZA LEGURU ALUMINIUMA 2024-T351	331 - 340

341 - 350	REPAIRATION OF THE BIDON SHELL BY MAG SURFACING PROCESS SAMACJA OŠTEĆENJA OMOĆAČA BIDONA NAVARIVANJEM MAG POSTUPKOM	D. Mitić, A. Zivković, S. Radović, S. Nikolić, B. Aleksić	435 - 446
351 - 362	INFLUENCE OF THE TYPE OF A SHIELDING GAS ON THE SHAPE AND SIZE OF LACK OF FUSION DEFECTS IN MIG/MAG WELDING UTJECAJ VRSTE ZAŠTITNOG PLINA NA OBLIK I VELIČINU GREŠKE STALJIVANJA MIG/MAG ZAVARIVANJA	M. Jovanović, M. Uroša, L. Kostec, B. Zec	447 - 454
363 - 372	HOT TAPPING ON MAIN PIPELINE FOR TRANSPORT OF NATURAL GAS TOPLI UBOD MAGISTRALNOG PLINOVODA	V. Stojmanovski, V. Stojmanovski	455 - 464
373 - 380	COMPARISON OF VARIOUS MODES OF TRANSFER IN GMAW FOR COATING APPLICATIONS USPOREDBA RAZLIČITIH NAČINA PRIJENOSA KOD MAG POSTUPKA ZA PREVLAČENJE	S. Fauriol, F. Lescoeur	465 - 464
381 - 392	MONITORING AND PROCESSING OF WELDING PROCESS PARAMETERS PRAĆENJE I OBRADA PARAMETARA POSTUPAKA ZAVARIVANJA	I. Samardžić, M. Dunder, D. Bojić	465 - 474
393 - 404	INVESTIGATION OF REPAIR WELDING TECHNOLOGY FOR DISSIMILAR STEEL JOINTS ON A HYDRO POWER PLANT TURBINE PARTS ISTRAŽIVANJE OPTIMALNIH PARAMETARA ZAVARIVANJA ZA SPAJANJE RAZNORODNIH ČELIKA PRI GRADNJI PLAŠTA VODNE TURBINE	V. Grabulov, A. Vukosavljević, Z. Odanović, M. Arsić	475 - 484
405 - 420	AN OVERVIEW OF METAL FOAM PRODUCTION AND JOINING TECHNOLOGIES PREGLED TEHNOLOGIJA PROIZVODNJE I SPAJANJA METALNIH PIJENA	S. Kralj, Z. Kožuh, M. Bušić	485 - 498
421 - 434	EFFECTS OF METAL TRANSFER MODE UPON THE SENSITIVITY OF ELECTRIC ARC SENSOR UTJECAJ PRIJENOSA METALA NA OSJETLJIVOST ELEKTROLUČNOG SENZORA	S. Kralj, Z. Kožuh, I. Garašić, M. Remenar, L. Bilic	499 - 506
	FRICION STIR WELDING OF ALUMINUM ALLOY 2024 - NUMERICAL MODELING FSW ZAVARIVANJE ALUMINUSKE LEGURE 2024 - NUMERIČKO MODELIRANJE	D. Veljić, M. Rakin, M. Perović, B. Medjo, A. Sedmak, D. Bajčić	
	POSSIBILITIES OF APPLYING TECHNOLOGY VIBRATIONAL RELAXATION ON RESIDUAL STRESSES IN WELDING JOINTS AND ITS IMPACT ON THE QUALITY OF WELD CHARACTERISTICS MOGUĆNOST PRIMJENE VIBRORELAKSACIJE ZAOSTALIH NAPREZANJA ZAVARENIH SPOJEVA I NJENOG UTJECAJA NA KVALITETU KARAKTERISTIKA ZAVARA	M. Torlo, M. Behmen, A. Topić	
	CORROSION RESISTANCE OF DUPLEX STAINLESS STEELS WELDED JOINTS KOROZIJSKA OTPORNOST ZAVARENIH SPOJEVA OD DUPELKS NEHRĐAJUĆIH ČELIKA	I. Juraga, I. Stojanović, V. Štumanović, B. Ljubenković, D. Kretković, M. Lovrić	
	CORROSION FATIGUE FAILURE OF A 24" PIPE LINE OTKAZ 24" CJEVOVODA UZROKOVAN KOROZIJSKIM ZAMOROM	M. H. El-Sayed	
	CORROSION OF ALUMINUM AND PROTECTION METHODS IN ELECTRICAL ENGINEERING KOROZIJA ALUMINIJA I METODE ZAŠTITE U ELEKTROTEHNICI	V. Biskup, J. Biskup	
	NEW, FAST AND ACCURATE HEAT EXCHANGER TUBE INSPECTION TECHNIQUE USED BEFORE GALVANIZATION FOR DETECTING CONDENSED WATER NOVA, BRZA I PRECIZNA METODA ZA ISPITIVANJE CIJEVI U IZMJENJIVAČU TOPLINE KOJA SE KORISTI ZA OTKRIVANJE KONDENZATA PRIJE GALVANIZACIJE	Z. N. Abdelaziz, P. Popovsingjiev	
	QUALITY ASSURANCE IN THE PRODUCTION OF WELDING CONSUMABLES OSIGURANJE KVALITETE U PROCESU PROIZVODNJE DODATNIH MATERIJALA ZA ZAVARIVANJE	M. Mirdin, J. Alešković	

**EKSPERIMENTALNA USPOREDBA MAG, TIG I FSW POSTUPKA  
ZAVARIVANJA ZA LEGURU ALUMINIJUMA 2024 T351**

**EXPERIMENTAL INVESTIGATION OF GTAW, GMAW AND FSW  
WELDING PROCESSES ON ALUMINIUM ALLOY 2024 T351**

Dragan Mikić, Univerzitet u Nišu Mašinski fakultet, Aleksandra Medvedeva 14, 18000 Niš,  
Srbija, mitec@masfak.ni.ac.rs  
Miroslav Mijajlović, Univerzitet u Nišu Mašinski fakultet, Aleksandra Medvedeva 14, 18000  
Niš, Srbija, mijajlovi@masfak.ni.ac.rs  
Dragan Mitić, Zavod za zavarivanje, Grčića Milenkova 67, 11030 Beograd, Srbija,  
draganmitic@zzz.co.rs  
Miodrag Mikić, Univerzitet u Nišu Mašinski fakultet, Aleksandra Medvedeva 14, 18000 Niš,  
Srbija, miodrag21@gmail.com

**Ključne reči:** Zavarivanje, MAG, TIG, FSW, 2024 T351

**Key words:** Welding, GTAW, GMAW, FSW, 2024 T351

**Sažetak:** Zavarivanje je, po definiciji, spajanje dva ili više istorodna ili raznorodna materijala, taljenjem ili pritiskom, postupkom s ili bez dodavanja dodatnog materijala, s ciljem da se dobije homogen monolitni spoj koji zadovoljava standardizirane i nestandardizirane zahtjeve o nesavršenostima, mehaničkim svojstvima, deformacijama itd. Postoji ogroman broj postupaka zavarivanja pri čemu su se neki od njih veoma udomaćili u industriji i smatraju se konvencionalnim postupcima zavarivanja primjenjivim na velikom broju različitih metalnih materijala. Pored njih razvijaju se i nekonvencionalne metode kojima se, pored završljivih materijala mogu zavarivati i materijali koji su konvencionalno teško ili potpuno nezavršljivi. Legura aluminija 2024 T351 spada u materijale koji se teško zavaruju konvencionalnim postupcima. Friction Stir Welding predstavlja nekonvencionalnu metodu zavarivanja metala u čvrstoj fazi koja je svoje najveće prednosti pokazala pri zavarivanju aluminijuma i aluminijumovih legura. Zbog toga se ovaj postupak veoma često koristi za zavarivanje legure aluminijuma iz serije 2xxx. Rad se bavi eksperimentalnim istraživanjima i usporedbom MAG, TIG i FSW postupka primijenjenima na leguru 2024 T351. Istraživanja su obuhvatila ispitivanje mehaničkih i metalografskih svojstava/karakteristika zavarenog spoja.

**Abstract:** Welding is, by definition joining of two or more similar materials with application of pressure or by melting, with or without filler metal with a goal of forming monolith and homogenous joint capable to fulfill standard or nonstandard norms about imperfections, mechanical properties, deformations etc. There are numerous welding techniques and some of them are so much used in industry so they are considered as conventional for the most of different metal materials. Beside them, there are unconventional welding techniques that can be used on materials that are limitedly weldable or non weldable. Aluminium alloy 2024 T351 is a representative of by conventional techniques limitedly weldable material. Friction Stir Welding is a solid state unconventional welding technique that has shown its major advantages on welding of aluminium and aluminium alloy series. That is the main reason why this technique is being used for welding of 2xxx aluminium alloy series. This paper is dealing with investigation of GTAW, GMAW, and FSW applied on 2024 T351 alloy. Investigation included metallographic and mechanical testing of welded joints and comparison of results has been made.



## 1. INTRODUCTION

Welding is the most used joining process in the present industry. Some researches show that more than 40% of overall machining processes are bonded with welding. Welding is defined as the process of joining together two pieces of metal in a manner that bonding accompanied by appreciable inter atomic penetration takes place at their original boundary surfaces. The boundaries of welded parts more or less disappear at the weld, and integrating crystals develop across them. Welding is carried out by the use of heat or pressure or both and with or without added metal (filler material).

The palette of material capable to be joined by welding is huge - from pure metals and alloys to nonmetallic materials such polymers are. The significant number of materials is capable to be welded with materials that chemically and by properties completely differ one to another. Historically speaking, nowadays there are more than 90 recognized welding processes and only some of them just look alike to forging. The largest group of welding processes [1] involves arc welding processes and since all techniques from the group are easy to use, arc welding is considered to be conventional welding technique. Further improvements of all welding techniques aim to the improvements of processes productivity, efficiency increase, as well as application on materials that are limitedly weldable or non weldable.

However, there is still a need for joints on materials that are not weldable and have great application in technology. An example is aluminium alloy group marked 2xxx with alloy 2024 T351 as representative material widely used in automotive, aerospace, naval and railway industry. This alloy is limitedly weldable by GTAW and GMAW arc processes and fully weldable by FSW process, which is still mentioned as unconventional welding process. There are some researches [2, 3, 4, 5] that show comparison of different welding processes applied on 2024 T351; GMAW and FSW, and neglect other welding processes as possible on 2024 alloy. The research done on Faculty of Mechanical Engineering Nis, Serbia was about FSW welding of 2024 alloy and heat generation processes during process [6]. Further work was expanded on application of GTAW and GMAW on 2024 T351 alloy and comparison of all processes. This paper is giving an overview on this research and gives some conclusions about weldability of 2024 T351 alloy.

## 2. Typical welding processes applicable for aluminium and its alloys

### 2.1. GTAW

Gas tungsten arc welding (GTAW), also known as tungsten inert gas (TIG) welding, is an arc welding process that uses a nonconsumable tungsten electrode to produce the weld. The weld area is protected from atmospheric contamination by a shielding gas (usually an inert gas such as argon), and a filler metal is normally used, though some welds, known as autogenous welds, do not require it. A constant-current welding power supply produces energy which is conducted across the arc through a column of highly ionized gas and metal vapors known as a plasma.

GTAW is most commonly used to weld thin sections of stainless steel and non-ferrous metals such as aluminum, magnesium, and copper alloys. The process grants the operator greater control over the weld than competing processes such as shielded metal arc welding and gas metal arc welding, allowing for stronger, higher quality welds. However, GTAW is comparatively more complex and difficult to master, and furthermore, it is significantly slower than most other welding techniques. A related process, plasma arc welding, uses a slightly different welding torch to create a more focused welding arc and as a result is often automated.

Aluminum is most often welded using alternating current, but the use of direct current is also possible, depending on the properties desired. Before welding, the work area should be cleaned and may be preheated to 175 to 200 °C. AC current can provide a self-cleaning effect, removing the thin, refractory aluminium oxide (sapphire) layer that forms on aluminium metal within minutes of exposure to air. This oxide layer must be removed for welding to occur.[25]

When alternating current is used, pure tungsten electrodes or zirconiated tungsten electrodes are preferred over thoriated electrodes, as the latter are more likely to "spit" electrode particles across the welding arc into the weld. Blunt electrode tips are preferred, and pure argon shielding gas should be employed for thin workpieces. Introducing helium allows for greater penetration in thicker workpieces, but can make arc starting difficult.[25]

Direct current of either polarity, positive or negative, can be used well. Direct current with a negatively charged electrode (DCEN) allows for high penetration. Argon is commonly used as a shielding gas for DCEN welding of aluminum. Shielding gases with high helium contents are often used for higher penetration in thicker materials. Thoriated electrodes are suitable for use in DCEN welding of aluminum. Direct current with a positively charged electrode (DCEP) is used primarily for shallow welds, especially those with a joint thickness of less than 1.6 mm. A thoriated tungsten electrode is commonly used, along with a pure argon shielding gas.

### 2.2. GMAW

Gas metal arc welding (GMAW), sometimes referred to by its subtypes metal inert gas (MIG) welding or metal active gas (MAG) welding, is a semi-automatic or automatic arc welding process in which a continuous and consumable wire electrode and a shielding gas are fed through a welding gun. A constant voltage, direct current power source is most commonly used with GMAW, but constant current systems, as well as alternating current, can be used.

GMAW is originally developed for welding aluminum and other non-ferrous materials in the 1940s, GMAW was soon applied to steels because it allowed for lower welding time compared to other welding processes. The cost of inert gas limited its use in steels until several years later, when the use of semi-inert gases such as carbon dioxide became common. Further developments during the 1950s and 1960s gave the process more versatility and as a result, it became a highly used industrial process. Today, GMAW is the most common industrial welding process, preferred for its versatility, speed and the relative ease of adapting the process to robotic automation. Unlike welding processes that do not employ a shielding gas, such as shielded metal arc welding, it is rarely used outdoors or in other areas of air volatility. A related process, flux cored arc welding, often does not utilize a shielding gas, instead employing a hollow electrode wire that is filled with flux on the inside.

### 2.3. Friction Stir Welding

Friction stir welding (FSW) is a solid-state welding process introduced during 1991-1992 by TWI London. First application of the FSW was for welding of long aluminium sheets used for railway vehicles in Japan; after that FSW was introduced by marine, aero, space, automobile and other industries around the globe. From that time, FSW is widely known as welding technique mostly used for welding of aluminium and its alloys. However, there are numerous examples of steel, bronze etc. joined by FSW [7].

#### 2.3.1. Principle of the FSW

At the beginning of the welding process, welding tool [8] is mounted into the rotating head of the machine, placed above the joint line on the fixed welding plates and probe tip barely touches the top of the welding plates (Figure 1, a). The main rotation axis of the welding tool is perpendicular with welding plates and the joint line. In that position welding tool starts to rotate (n revolutions per min). Probe of the welding tool (Figure 1, b) plunges into both of the welding plates (base metal) at the start point on the joint line, friction between probe and the welding plates initiates heat generation, welding plates soften in the area of friction contact between tool and plates and thread on the probe stirs the material of the welding plates. When shoulder tip touches welding plates and probe tip is very close to the backing plate, plunging of the welding tool into the welding plates stops and tool starts translation along the joint line. Moving along the joint line, weld tool's probe heats layers of material from the welding plates, cuts and stirs

then and creates a veil of mixed and plasticized metal which hardens and creates necks between welding pieces - weld. Shoulder tip confines upper surface of the weld while backing plate holds welding plates and confines lower surface of the weld as well. Welding process is finished when welding tool stops translation and after pulling out the tool from the joint line weld is completely finished.

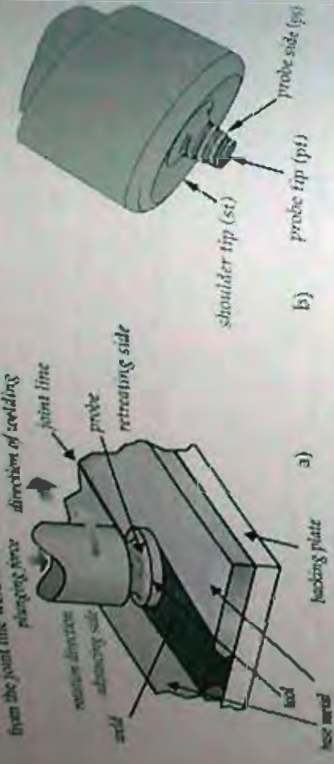


Figure 1. Friction stir welding: a) principle of the FSW, b) welding tool and its active surfaces.

In order to easily analyze the process, complete technological cycle of the FSW is explained throughout five basic phases [9, 10]: plunging, first dwelling, welding, second dwelling and pulling out. All of them are necessary for the correct weld creation. Beside all advantages and disadvantages [9, 10, 11] compared to other conventional welding techniques, FSW has some advantages that are of importance: FSW can be used for welding of conventionally non-weldable alloys such as Al series 2xxx and 7xxx, are, temperature distortions and residual stresses of the parent material are much smaller than with other welding techniques, temperatures are significantly lower than with other welding techniques (80% of melting point temperature).

### 3. Aluminium alloy 2024 T351

Aluminium alloy 2024 is an aluminium alloy, with copper as the primary alloying element (Table 1, 2, 3). It is used in applications requiring high strength to weight ratio, as well as good fatigue resistance. It is poorly weldable, and has average machinability. Due to poor corrosion resistance, it is often clad with aluminium for protection, although this may reduce the fatigue strength.

Table 1. Thermomechanical properties of 2024 T351.

Module of elasticity $E$ , N/mm <sup>2</sup>	73100
Density $\rho$ , kg/m <sup>3</sup>	2780
Thermal Conductivity $\lambda$ , W/(mK)	121
Specific Heat Capacity $c$ , J/(kgK)	875
Electrical Resistivity $\rho_{el}$ , (Ohm <sup>2</sup> /m)	0,0582
Temperature $T$ , °C	20-100/20-300
Coefficient of thermal expansion (average on temperature interval) $\alpha_T$ , 10 <sup>-6</sup> /°C	23,2 24,7

Table 2. Mechanical properties of 2024 T351.

Yield strength $R_{0,2}$ , N/mm <sup>2</sup>	Ultimate tensile strength $R_m$ , N/mm <sup>2</sup>	Elongation $A_5$ , %	Vickers Hardness
370	481 (exp. determined 460 to 500)	17,9	11V
* nucleon value			~143

Table 3. Chemical composition of 2024 T351.

Sample 1		Sample 2	
Chemical element	Mass %	Chemical element	Mass %
Sb	0.005±0.005	Sb	0.003±0.003
Sn	0.006±0.003	Sn	0.003±0.002
Pd	0.000±0.003	Pd	0.000±0.002
Ag	0.006±0.004	Ag	0.004±0.003
Ru	0.000±0.001	Ru	0.000±0.001
Mo	0.000±0.001	Mo	0.001±0.001
Nb	0.000±0.001	Nb	0.000±0.001
Zr	0.001±0.001	Zr	0.001±0.001
Bi	0.000±0.001	Bi	0.000±0.001
Pb	0.001±0.002	Pb	0.002±0.001
Se	0.000±0.001	Se	0.000±0.001
W	0.000±0.013	W	0.000±0.008
Zn	0.087±0.012	Zn	0.085±0.009
Cu	4.430±0.109	Cu	4.090±0.077
Ni	0.015±0.012	Ni	0.016±0.008
Co	0.001±0.010	Co	0.000±0.007
Fe	0.213±0.031	Fe	0.191±0.023
Mn	0.566±0.055	Mn	0.555±0.041
Cr	0.080±0.011	Cr	0.064±0.008
V	0.013±0.007	V	0.016±0.005
Ti	0.036±0.008	Ti	0.034±0.006
Al	93.164±0.489	Al	93.128±0.377
S	0.000±0.001	S	0.000±0.001
P	0.000±0.001	P	0.000±0.001
Si	0.867±0.073	Si	0.378±0.045
Mg	0.509±0.607	Mg	1.426±0.453

Due to its high strength and fatigue resistance, 2024 is widely used in aircraft structures, especially wing and fuselage structures under tension (aircraft fittings, gears and shafts, bolts, as well as clock parts, computer parts, couplings, fuse parts, hydraulic valve bodies, missile parts, munitions, nuts, pistons, rectifier parts, worm gears, fastening devices, veterinary and orthopedic equipment, structures). Additionally, since the material is susceptible to thermal shock, 2024 is used in qualification of liquid penetrant tests outside of normal temperature ranges.

### 4. Experimental welding on 2024 T351

By chemical composition of the 2024 alloy and its highly non-weldable properties, it is recommended for GMAW and GTAW to use filler metal based on aluminium and silicon. Experimental welding was performed on plates made of 2024 T351 with dimensions 160mm x 55mm x 6mm. Plates were plasma-cut from sheet 6000 mm x 2000 mm x 8 mm and grinded to height ± 6mm.

The first experimental welding was done by GTAW process. Welding was performed with Fronius TransPuls Synergie 2700 power source, filler metal was AISI12 (EL-AISI 12, DIN1732, manufacturer: Elektrode Jesenice). Welded plates are shown in Figure 2.



Figure 2. Welded plates: GTAW process, face of the weld.

The second experimental welding was done by GMAW process. Welding was performed with Fronius MagicWave 2600 power source, and filler metal was AlMg5 (EL-ALMn 1, DIN1732, manufacturer: Elektrode Jesenice). Welded plates are shown in Figure 3.



Figure 3. Welded plates: GMAW process, face of the weld.

The third experimental welding was performed by FSW. As welding machine a lathe was used. Lathe is not regular machine used for FSW but due to the needs of measuring (torque, forces, temperature etc.) it was necessary to adapt the lathe for the welding needs (Figure 5). This is, probably, the first recorded usage of lathe as FSW machine. Welding tool was made of steel DIN 50NiCrMoV7, annealed and tempered. Tool has cone probe (Figure 1, b) and conical shoulder tip.



Figure 4. Welded plates: FSW process, face of the weld.

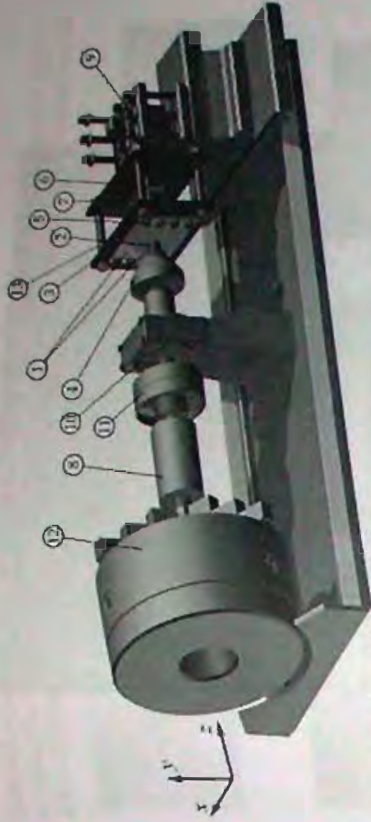


Figure 5. FSW welding place, 1-workpiece, 2-welding tool, 3-anvil, 4-welding tool spindle, 5-bolts, 6-backing plate, 7-force sensor, 8-torque sensor, 9-tool rest, 10-housing, 11-coupler, 12-machine spindle, 13-fundamental bolts

The anvil is made of  $\approx 16$  mm height austenite steel plate X5CrNi18-10 (EN 10088-2) with purpose of low heat loss at the root of the weld. Welding was performed with 910 rpm and travel rate of 0,904 mm/s along 100 mm long joint line. Welded plates are shown in Figure 2, 3, 4.

### 5. Results and discussion

Visual inspection of plates welded by GTAW and GMAW has shown numerous imperfections of the welded joints - minor distortion, cracking, inclusions, gas inclusions, lack of fusion, incomplete penetration. Overall conclusion was that imperfections are coming from poor process conditions, operator error, wrong technique, and probably incorrect consumables. Visual inspection of plates welded by FSW implied minor distortion and significant toe and face flash [11].

Radiograph of welded plates joined by GMAW and GTAW only has confirmed conclusions of visual inspection (Figures 6, 7 and 8).



Figure 6. Radiograph of welded plates, GTAW.



Figure 7. Radiograph of welded plates, GMAW.



Figure 8. Radiograph of welded plates, FSW.

Radiograph of plates welded by the FSW has shown existence of 12 mm long and 0.8 mm wide longitudinal cavity [12] - on advancing side of the weld, near the midpoint of the welding spot. This cavity is probably result of the axial force drop due to the poor process conditions and operator error - usage of lathe as FSW machine requires manual correction of the plunge and heel plunge depth; axial force is very important for proper weld creation during FSW and cavity is directly affected by low axial force [6]. At the moment when experimental welds were performed, there were no standards about FSW destructive testing and test samples for destructive testing (DT) were non-standard for all welded plates. The schematic of DT samples extraction is show in Figure 9.

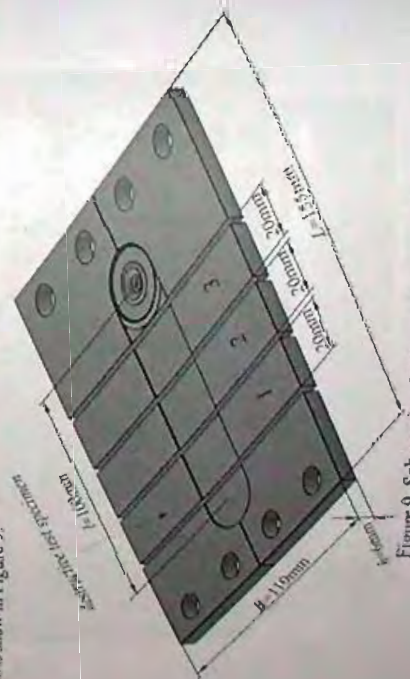


Figure 9. Schematic of DT samples extraction.

Extracted samples were used for macro- and micro- scoping investigations (Figures 10 and 11), as well as for the surface hardness investigation. Further more, specimens were used for tensile and bend testing (Table 4).



Figure 10. Macroscopic images of joints.



Figure 11. Microscopic images of joints.



Figure 12. Hardness of joints.

Table 4. Experimental results of tensile and bend testings.

Maximal force and ultimate tension stress	Specimen		Bending angle	
	GMAW	GTAW	FSW	
$F_u$ , kN	1	10	15	31
	2	10.5	18	45
$\sigma_u$ , N/mm <sup>2</sup>	1	76.92	115.38	238.46
	2	80.77	138.46	346.15

Destruction of all specimens happened in the weld metal.

**5. Conclusions**  
 Experimental weldings of 2024 T351 alloy have showed that it represents a challenge for conventional weldings of 2024 T351 alloy. GTAW, GTAW, FSW has shown to be fully operational on 2024 alloy. GTAW and GTAW have shown very poorly: welds were with numerous flaws, inconsistent penetration and high porosity. Flaws indicated that welding process, welding operator and consumables might be inadequate for the proposed parent material. Assuming that all parameters were correctly selected, it is obvious that parent material is a member of the limitedly weldable materials. FSW has shown some advantages over other tested welding processes: almost flawless with minor flaws in welding operation (axial force drop), good penetration and full mixture of material. FSW has shown good properties of tensile and hardness preservation along weld section. However, neither one of the welding processes has shown good bending properties.

Besides all, it is obvious that FSW has given the best results on welding of the 2024 T351 alloy, but it must be pointed out that 2024 alloy has to be treated with caution when being welded.

**References**

[1] ISO 4063:1988 Welding and allied processes -- Nomenclature of processes and reference numbers.  
 [2] HE Zhen-bo *et al.*: Comparison of FSW and TIG welded joints in Al-Mg-Mn-Sr-Zr alloy pulcs. *Transaction of Nonferrous Metals Society of China*, 21(2011), pp 1685-1691, 2011.  
 [3] A. Squillac *et al.*: A comparison between FSW and TIG welding techniques: modifications of microstructure and pitting corrosion resistance in AA 2024-T3 butt joints. *Journal of Materials Processing Technology*, Volume 152, Issue 1, 1 October 2004, Pages 97-105. <http://dx.doi.org/10.1016/j.jmatprotec.2004.03.022>, 2004.  
 [4] Haidam Kasim Mohammed: A Comparative Study between Friction Stir Welding and Metal Inert Gas Welding of 2024-T4 Aluminum Alloy. *ARPN Journal of Engineering and Applied Science*, VOL. 6, NO. 11, ISSN 1819-6608, November 2011.  
 [5] Mustafa Kemal Kulekci *et al.*: Experimental Comparison of MIG And Friction Stir Welding Processes For En Aw-6061-T6 (Al Mg 1 Si Cu) Aluminium Alloy. *The Arabian Journal for Science and Engineering*, Volume 35, Number 1B, April 2010.  
 [6] Mijajlović, M.: Investigation and development of analytical model for estimation of amount of heat generated during FSW. PhD thesis, University of Nis, Faculty of Mechanical Engineering Nis, 2012 (work in progress).  
 [7] Soandarajan, V *et al.*: An Overview of R&D Work in Friction Stir Welding at SMU, u *MOSM, Metallurgija - Journal of Metallurgy, Association of Metallurgical Engineers of Serbia*, Vol. 12, No. 204, pp. 277-295.  
 [8] ISO 25239-1: 2011 Friction stir welding - Aluminium - Part 1: Vocabulary  
 [9] Đurđanović, M. *et al.*: Heat Generation During Friction Stir Welding Process. *Tribology in Industry*, no. 1-2, Journal, vol. 31, pp. 8-14, no. 1-2, Faculty of Mechanical Engineering Kragujevac, Kragujevac, Serbia, May, 2009, ISSN 0354-8996.  
 [10] Mijajlović, M. *et al.*: Mathematical Model for Analytical Estimation of Generated Heat during Friction Stir Welding. Part 1. *Journal of Balkan Tribological Association*, Vol. 17, No 2, 2011, pp. 179-191, ISSN 1310-4772, Sofia, Bulgaria, 2011.  
 [11] [http://en.wikipedia.org/wiki/friction\\_stir\\_welding](http://en.wikipedia.org/wiki/friction_stir_welding), January, 2012.  
 [12] ISO 25239-1: 2011 Friction stir welding - Aluminium - Part 1: Vocabulary.  
 [13] AWS D17.3/D17.3M:2010 Specification for Friction Stir Welding of Aluminum Alloys for Aerospace Applications.  
 [14] Miodrag Milić: Eksperimentalno upoređenje MAG, TIG i FSW postupka zavarivanja za leguru aluminijuma 2024-T351, Diplomski rad, Mašinski fakultet Univerziteta u Nišu, 2011.

**SANACIJA OŠTEĆENJA OMOTAČA BIDONA NAVARIVANJEM MAG POSTUPKOM**

**REPARATION OF THE BIDON SHELL BY MAG SURFACING PROCESS**

dipl.maš.inž. Dragan Mitić IWE/IWI,  
 dr.Aleksandar Živković EWE  
 dipl.maš.inž. Srdjan Radlović IWE,  
 dipl.maš.inž.Siniša Nikolić IWE,  
 dipl.maš.inž.Boško Aleksić IWE/IWI,

Zavod za zavarivanje Beograd  
 Gosta Fom Smederevska Palanka  
 Zavod za zavarivanje Beograd  
 Kolubara Prerada Vreoci  
 Certilab Pančevo

**Key words:** high pressure vessels, repairation, corrosion, surfacing, anti corrosion protection

**Abstract:**

The paper discusses the causes and types of damage at the bidon shell at the plant for drying coal Kolubara Prerada Vreoci. Pressure vessels - bidons are made in 2002 of steel P 355 NH, as a replacement for the previous bidons, who had been in operation only 50% of the estimated service life, and are made of a A16term 55. Special attention is given to the technology of GMAW (MAG) surfacing process on corrosively damaged spoils, as well as on adequate application of corrosion protection on bidon shell.

## POKROVITELJ / PATRON:



MINISTARSTVO ZNANOSTI OBRAZOVANJA I ŠPORTA

MINISTRY OF SCIENCE, EDUCATION AND SPORT

## SUORGANIZATORI / CO-ORGANIZERS:



TEHNIČKI FAKULTET  
Sveučilište u Rijeci



## DOMAĆINI / HOSTS:



**nexe**  
GRADIMO POVJERENJE

## GLAVNI SPONZORI / GENERAL SPONSORS:

**Bajkmont**

**ZM**

Zagreb-Montaža Grupa

**varstroj**®

**R·A·M**

**CROMATEC**

**ELIMP** d.o.o.

**esi** get it right®



**EuroTehnika** s.r.l.

**monumc**

**trokutttest**group

**TREA TRADE** d.o.o.

**DEF**  
Industrijska defektoskopija

**YASKAWA**  
MOTOMAN



1991 2011  
**servis**  
20 godina

## SPONZORI/SPONSORS:



**ULJANIK TESU** d.d.  
since 1952

**DURO ĐAKOVIĆ**  
**MONČAŽA**

**Kordun**  
1916

**MESSER**  
Gases for Life



**tehnomont**  
Brodogradilište PULA