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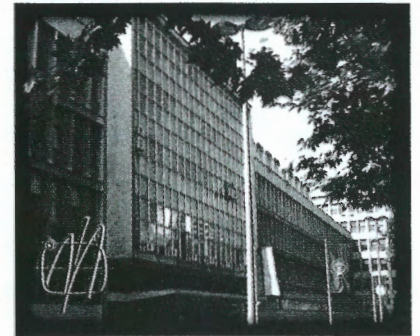
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University
of Belgrade



Faculty of
Mechanical Engineering



**Proceedings of the
29th Danubia-Adria-Symposium
on Advances in Experimental Mechanics**



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Experimental Mechanics**



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**AIRPORT
NIKOLA TESLA
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**Military Technical Institute
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Preface

Welcome to the 29th Danubia-Adria Symposium dealing with methods and applications in experimental mechanics as means for verifying quality of structures from the point of view of integrity, service and residual life, and technical safety. The DA Society has the objective to promote experimental mechanics, covering all aspects from the development to applications of the methods for quality improvement of processes and products to the development of a new model of education in experimental mechanics. To achieve this purpose, the Society aims to encourage exchanges of teachers, researches and students between Universities and other technical and scientific institutions.

Danubia-Adria Symposiums on Advances in Experimental Mechanics has a long tradition, since 1984. The 29th Symposium in Belgrade presents continuation of this tradition. Serbia joins to Danubia-Adria Society in 2008 year and got active member in organization and participation of DAS which take place every year in one of DA member country. This year Belgrade has been chosen as the Conference venue and we offering the hospitality for our Symposium. Serbian society for mechanics is the member of DA Society and University of Belgrade, Faculty of Mechanical Engineering is executive organizer of DAS-29.

University of Belgrade has been funded at the end of 19th century and Faculty of Mechanical Engineering in the mid of 20th century. Today our Faculty has more than 16 hundreds active students at all three levels, Bachelor, Master and PhD in relation of 3+2+3 nominal education years. At the master level education process contains about 20 branches (education modules) of engineering (not mechanical only). For majority of these branches experiments in research and in education is the main tool.

This year's DAS has received 111 accepted submissions from 12 countries (Austria-7, Croatia-14, Czech Republic-4, Germany-3, Hungary-9, Italy-5, Poland-13, Romania-6, Slovakia-6, Slovenia-4, Bosnia & Herzegovina-1, Serbia-39). The Program Committee selected 12 papers for podium presentation and 99 papers for poster presentation. I believe that the present Symposium, with its aim to exchange ideas concerning the search for new models, design solutions, and manufacturing technologies, will constitute the next, very important step in the development of experimental mechanics.

On behalf of the Organizing Committee of the 29th DANUBIA-ADRIA Symposium on Advances in Experimental Mechanics, organizers wish a warm WELCOME to all the participants in Belgrade, and hope that all the guests will have a pleasant time in Serbia.

Chairman of 29th DAS on Advances in Experimental Mechanics



Milosav OGNJANOVIĆ

Content

MICRO-CT/MICROMECHANICS-BASED FINITE ELEMENT MODELS AND QUASI-STATIC UNLOADING TESTS DELIVER CONSISTENT VALUES FOR YOUNG'S MODULUS OF RAPID-PROTOTYPED POLYMER-CERAMIC TISSUE ENGINEERING SCAFFOLD <i>Krzysztof Wojciech Luczynski, Alexander Dejaco, Olaf Lahayne, Jakub Jaroszewicz, Wojciech Swieszkowski, Christian Hellmich</i>	2
INVESTIGATION OF EFFECTS OF STRENGTHENING OF A BRIDGE PIER ON THE FLOOD FLOW OF THE RIVER DANUBE <i>Boris Huber, Norbert Krouzecky</i>	4
DRYING SHRINKAGE OF CONCRETE STRUCTURES STRENGTHENED BY OVERLAYS <i>Yvonne Theiner, Günter Hofstetter</i>	6
NANOINDENTATION TO STUDY WITHIN-TREE VARIABILITY OF WOOD CELL WALL STIFFNESS <i>Leopold Wagner, Thomas K. Bader, Karin de Borst, Josef Eberhardsteiner</i>	8
HELICAL COMPOSITE SPRINGS <i>Richard Zemann, Friedrich Bleicher</i>	10
AUTOMATIC DETERMINATION OF CRACK PARAMETERS FOR TMF LOADED SPECIMEN <i>Aleksandar Stanojevic, Gerhard Winter, Florian Grün</i>	12
MODEL FOR THE REDUCTION OF COMPONENTS OF DEVIATIONS FOR COORDINATE MEASURING MACHINES <i>Rene Prah, Reinhard Zisser-Pfeifer</i>	14
DETECTION OF STRUCTURAL DAMAGES IN CRP MATERIALS BASED ON INFRARED IMAGING AND FFT <i>Lovre Krstulović-Opara, Endri Garafulić, Branko Klarin, Željko Domazet, Petar Jurić</i>	16
APPLICATION OF THE OPTICAL SYSTEM ARAMIS FOR DETERMINING THE STABILITY OF EXTERNAL FIXATOR <i>Frane Pamuković, Martin Surjak, Janoš Kodvanj</i>	18
DETECTION OF OSMOTIC DAMAGES IN GRP BOAT HULLS <i>Lovre Krstulović-Opara, Endri Garafulić, Željko Domazet</i>	20

	APPLICATION OF OPTICAL MEASUREMENT FOR SIMULATION IMPROVEMENT	
	<i>Marko Jurišić, Nenad Drvar</i>	22
UASI-	TESTING OF THE RAILWAY BRIDGE "SAVA JAKUŠEVAC" AFTER REPARATION	
JNG'S	<i>Marina Frančić, Domagoj Damjanović, Mladenko Rak</i>	24
BRING	EXPERIMENTAL INVESTIGATION OF THE COLLAPSED STEEL BRIDGE DEFORMATION	
	<i>I. Duvnjak, M. Rak, J. Krolo, M. Bartolac, M. Frančić</i>	26
owski,		
.....		2
OOD	TESTING THE TIMBER – LIGHTWEIGHT CONCRETE COMPOSITE GIRDER SAMPLES	
	<i>Nenad Turčić, Miljenko Haiman, Joško Krolo</i>	28
.....		4
YS	EXPERIMENTAL TESTING OF PRECAST CONCRETE POLES FOR OVERHEAD ELECTRICAL LINES	
.....	<i>Marko Bartolac, Joško Krolo, Ivan Paska</i>	30
6	STATIC, DYNAMIC AND FATIGUE TESTING OF RAILWAY SLEEPERS	
'ALL	<i>Domagoj Damjanović, Mladenko Rak, Ivan Duvnjak, Marina Frančić, Slaviša Planić</i>	32
.....		8
... 10	DEPENDENCE OF CABLE FUNDAMENTAL FREQUENCY ON BENDING STIFFNESS, STRESS AND BOUNDARY CONDITIONS	
DED	<i>Tanja Ilijaš, Domagoj Damjanović, Joško Krolo</i>	34
... 12	TWO SCALE FULL-FIELD MEASUREMENT ON SPHEROIDAL GRAPHITE CAST IRON	
ATE	<i>Zvonimir Tomičević, François Hild, Janoš Kodvanj, Stéphane Roux, Ante Bakić</i>	36
.. 14	SHEAR MODULUS TESTING METHOD FOR ELASTOMERIC BEARINGS	
ED	<i>Ana Skender, Domagoj Damjanović, Želimir Šimunić</i>	38
. 16	STABILITY OF THIN-WALLED SYMMETRICAL AND NON-SYMMETRICAL OPEN-SECTION BEAMS	
TY	<i>Diana Šimić, Ana Radić</i>	40
. 18	A FOUR ELEMENT VISCO-ELASTIC WINDKESSEL MODEL OF THE ARTERIAL TREE	
20	<i>Zdravko Virag, Fabijan Lulić, Ivan Korade</i>	42
	MICROPLASTIC LIMIT AS DETERMINED BY THE INDUCTANCE AND RESISTANCE METHOD	
	<i>Lubomír Gajdoš, Martin Šperl</i>	44

IMPACT DAMAGE DETECTION USING PIEZOELECTRIC SENSORS/ACTUATORS NETWORK <i>Milan Růžička, Peter Košťár</i>	46
METHODOLOGY OF MULTIAXIAL FATIGUE TEST SIMPLIFICATION <i>Jakub Vágner, Bohumil Culek jr., Bohumil Culek</i>	48
INVESTIGATION OF VERTICAL RESPONSE OF MECHANICAL SYSTEMS <i>Fillemon N. Nangolo</i>	50
INTRODUCTION IN THE SYSTEM OF THE SPLIT HOPKINSON PRESSURE BAR AND VALIDATION OF THE METHOD <i>Tabea Wilk, Matthias Bartholmai, Werner Daum</i>	52
FAST MICROMILLING WITH JET ELECTROCHEMICAL MACHINING <i>Matthias Hackert-Oschätzchen, Gunnar Meichsner, André Martin, Henning Zeidler, Andreas Schubert</i>	54
ACCELERATED PRECISION MANUFACTURING THROUGH ELECTRO DISCHARGE MACHINING WITH ULTRASONIC VIBRATION ASSISTANCE <i>Henning Zeidler, Martin Hahn, Jörg Schneider, Matthias Hackert-Oschätzchen, Andreas Schubert</i>	56
COMPLEX DIAGNOSTICS OF THE CUTTING PROCESS OF METAL COMPOSITE STRUCTURES <i>Ferenc Dömötör</i>	58
A COMPUTER-BASED MEASUREMENT METHOD FOR EXPLANTED CORONARY STENTS <i>M. Bán, A. Kertész, E. Bognár</i>	60
THE EFFECT OF ORIGINATION METHOD OF ANATOMICAL COODINATE SYSTEM OF HUMAN KNEE TO THE PROSTHESIS DESIGNING AND IMPLANTATION <i>Gábor Katona, Béla M. Csizmadia</i>	62
THE EFFECT OF STENT POSITIONING DURING ELECTROPOLISHING <i>Ákos Lengyel, Eszter Bognár, János Dobránszky</i>	64
BIODEGRADABLE POLYMER COATINGS FOR STENTS <i>Torda László Sélley, András Szilágyi, Eszter Bognár</i>	66
VALIDATION OF NUMARICAL ANALYSIS RESULTS IN CASE OF RAPID PROTOTYPING BY EXPERIMENTS USING OPTICAL TECHNIQUES <i>Peter Ficzer, Lajos Borbás</i>	68

DRS	INTELLIGENT LOAD CELL AS A NEW MEDICAL AID	
.. 46	<i>Péter Molnár, István Németh, László Farkas, Tibor Juhász</i>	70
	QUALIFICATION METHODS ON SPECIFIC STRUCTURES: KNEE PROSTHESES	
. 48	<i>Gábor Péter Balassa, Gábor Katona</i>	72
	NEW PROCEDURE TO COMBINE CAD MODELING FEM SIMULATION AND	
	BARKHAUSEN-NOISE STRESS ANALYSIS IN SHEET METAL FORMING	
50	<i>Gábor Balogh, István Szabó</i>	74
ND	QUANTITATIVE STRUCTURAL ASSESSMENT OF RAT TIBIAL EPIPHYSEAL EXPLANTS	
	KEPT IN MICROGRAVITY CONDITIONS	
52	<i>Francesca Cosmi, Salvatore Scozzese, Nathalie Steimberg, Giovanna Mazzoleni</i>	76
	FAILURE PROBABILITY EVALUATION OF TURBOGENERATOR COIL RETAINING	
	RINGS BASED ON LCF EXPERIMENTAL DATA AND LOCAL STATES OF LOAD	
54	<i>Giorgio Olmi, Alessandro Freddi</i>	78
iE	FATIGUE STRENGTHENING OF CRANKSHAFTS BY DEEP ROLLING	
56	<i>G. Nicoletto, E. Riva, A. Saletti</i>	80
E	EFFECT OF MICROSTRUCTURE ON MECHANICAL BEHAVIOUR OF SPHEROIDAL AND	
	COMPACTED CAST IRONS	
8	<i>Nenad Radović, Andrea Morri, Alessandro Morri, Giangiacomo Minak</i>	82
7	HYDROELASTIC SLAMMING OF COMPOSITE PLATES	
	<i>Riccardo Panciroli, Giangiacomo Minak</i>	84
7	FATIGUE DAMAGE OF AL/SIC COMPOSITES – MACROSCOPIC AND MICROSCOPIC	
	ANALYSIS	
	<i>Zbigniew L. Kowalewski, Agnieszka Rutecka, Katarzyna Makowska, Krystyna Pietrzak</i>	86
	MICROSTRUCTURE AND MECHANICAL PROPERTIES OF POWER TURBINE BLADES	
	AFTER 25 YEARS OF OPERATION	
	<i>Alyona Bashir, Włodzimierz Dudziński, Piotr Śmietana, Marek Dudziński</i>	88
	QUALITATIVE EVALUATION OF STRUCTURAL DEGRADATION AND MECHANICAL	
	PROPERTIES BY MEANS OF BARKHAUSEN AND MAGNETOACOUSTIC EMISSION	
	<i>Katarzyna Makowska, Zbigniew L. Kowalewski</i>	90
	THE ANALYSIS OF THE LOCAL MATERIALS PROPERTIES IN THE WELDED JOINTS	
	<i>Robert SOŁTYSIAK</i>	92

QUALITY OPTIMIZATION OF MEASUREMENT PATHS INCLUDED IN THE EXPERIMENTAL CRYOGENIC STAND FOR TENSILE TESTING AT ULTRA-LOW TEMPERATURES <i>Jakub Tabin</i>	94
EXPERIMENTAL ANALYSIS OF THE STABILITY OF THE OBLIQUE FEMUR FRACTURE, SECURED WITH INTRAMEDULLARY RODS <i>Marek Kulig</i>	96
AN INFLUENCE OF CYCLIC TORSION PARAMETERS ON TENSILE CHARACTERISTIC VARIATION <i>Zbigniew L. Kowalewski, Tadeusz Szymczak</i>	98
INFLUENCE OF PRESTRAIN ON THE MECHANICAL PROPERTIES OF AW-6063 ALUMINUM ALLOY <i>Tomasz Tomaszewski, Janusz Sempruch</i>	100
MAGNETIC FIELD INVESTIGATIONS FOR A MAGNETOCALORIC LABORATORY TEST STAND <i>Agata Czernuszewicz, Jerzy Kaleta, Daniel Lewandowski, Przemysław Wiewiórski</i>	102
BASIC ANALYSIS OF SINGLE CRYSTAL NIMNGA MICROSTRUCTURE <i>Jerzy Kaleta, Daniel Lewandowski, Dajana Sawicka</i>	104
APPLICATION OF MAGNETORHEOLOGICAL ELASTOMERS IN VIBRATION DAMPER <i>Michał Przybylski, Jerzy Kaleta, Danie Lewandowski, Michał Królewicz</i>	106
MAGNETOSTRICTIVE COMPOSITES BASED ON TERFENOL-D PARTICLES WITH DEFINED POLARIZATION <i>Jerzy Kaleta, Daniel Lewandowski, Rafał Mech</i>	108
PRELIMINARY TESTING OF ZIRCONIUM DIOXIDE – A COMPARISON OF SELECTED DENTAL CERAMIC <i>Mateusz Wirwicki, Tomasz Topoliński</i>	110
MULTIPOINT GENERATION OF GUIDED WAVES IN PIPES. EXPERIMENTAL VALIDATION. <i>Cristian Catalin PETRE, Mihai Valentin PREDOI, Marian SOARE</i>	112
MULTIPOINT GENERATION OF GUIDED WAVES IN PIPES. FINITE ELEMENTS MODEL. <i>Mihai Valentin PREDOI, Cristian Catalin PETRE</i>	114

3	AUTOMATIC COMPENSATION OF THE LOAD'S BALANCE BY TILTING SYSTEM INSTALLED ON MARINE CRANES.	
7	<i>Cotrumba Mirela, Radoiu Bogdan, Pintilie Alexandru</i>	116
1	EXPERIMENTAL DETERMINATION OF MECHANICAL CHARACTERISTICS OF STEEL FOR NUMERICAL SIMULATION OF THE WELDING PROCESS.	
5	<i>Florin BACIU, Stefan-Dan PASTRAMA, Horia GHEORGHIU, Daniel VLASCEANU</i>	118
2	DENSIFICATION AND ENERGY EFFICIENCY OF POLYURETHANE FOAMS	
1	<i>Dragos Alexandru APOSTOL, Dan Mihai CONSTANTINESCU, Liviu MARSAVINA, Emanoil LINUL</i>	120
1	EVALUATION OF THE FRACTURE TOUGHNESS OF MWNT AND GPL EPOXY NANOCOMPOSITES	
1	<i>Dan Mihai CONSTANTINESCU, Catalin R. PICU, Dragos Alexandru APOSTOL, Marin SANDU</i>	122
1	FATIGUE PROPERTIES OF X70 MICROALLOYED PIPELINE STEEL AFTER SHOT PEENING APPLICATION	
1	<i>Katarina Miková, Mario Guagliano, Otakar Bokůvka, Libor Trško, František Nový</i>	124
1	FATIGUE PROPERTIES OF STRUCTURAL STEEL INFLUENCED BY SAND BLASTING	
1	<i>Libor Trško, Otakar Bokůvka, Wojciech Żórawski, František Nový</i>	126
1	MICROSTRUCTURE AND THE PROPERTIES OF ALSI6CU4 CAST ALLOY AFTER SB- MODIFICATION	
1	<i>Mária Farkašová, Eva Tillová, Mária Chalupová</i>	128
1	THE STRUCTURAL ANALYSIS OF SECONDARY (RECYCLED) ALSI9CU3 CAST ALLOY	
1	<i>Lenka Hurtalová, Eva Tillová, Mária Chalupová</i>	130
1	EFFECTS OF SURFACE FINISHING ON LOCAL CORROSION OF 316-TI STAINLESS STELS	
1	<i>Tatiana Liptáková, Pavol Fajnor, Monika Halamová</i>	132
1	INFLUENCE OF AZ61 STRUCTURE ON THE PLASTIC DEFORMATION AROUND A CRACK	
1	<i>Peter Palček, Ivana Hlaváčová, Mária Chalupová</i>	134
1	ACOUSTIC PROPERTIES OF GRANULAR WASTE TIRES	
1	<i>Andreja Popit, Anatolij Nikonov, Igor Emri</i>	136
1	THE ALGORITHM FOR AUTOMATED TIME-TEMPERATURE SUPERPOSITION	
1	<i>Marina Gergesova, Barbara Zupančič, Ivan Saprunov, Igor Emri</i>	138

LASER ENERGY TECHNOLOGY OF HARDENING <i>Matej Babič, Matjaž Milfelner, Peter Kokol</i>	140
USE FRACTAL ANALISYS FOR DESCRIBE MECHANICAL PROPERTY OF ROBOT LASER HARDENED MATERIAL <i>Matej Babič, Matjaž Milfelner, Peter Kokol</i>	142
EXPERIMENTAL DYNAMIC ANALYSIS OF BRIDGES <i>Valentina Golubović-Bugarški</i>	144
BIOMECHANICS OF TUBULIN, MICROTUBULES AND THEIR ORGANELLES <i>Djuro Koruga</i>	146
AFM SURFACE ROUGHNESS ANALISYS OF EYE POSITIONING CONTACT LENS <i>I. Djuricic, I. Mileusnic, A. Debeljkovic, M. Radovanovic, D. Koruga</i>	150
PRE- AND POST-BRUSHING NANOSCALE SURFACE ROUGHNESS OF MICROHYBRID AND NANOHYBRID COMPOSITE RESIN DENTAL FILLINGS <i>Igor Hut, Marina Marjanović, Jovana Kuzmanović, Lidija Matija</i>	154
HOW INCORPORATED NANOMATERIALS IN CONTACT LENSES AFFECT THEIR MECHANICAL AND OPTICAL PROPERTIES <i>Dragomir Stamenković, Marija Tomić, Aleksandra Debeljković, Jelena Munčan, Lidija Matija</i>	158
EXPERIMENTAL ANALYSIS OF ARTIFICIAL HIP IMPLANT MADE OF TITANIUM ALLOY <i>Katarina Colic, Zarko Miskovic, Mladen Regodic, Aleksandar Veg, Aleksandar Sedmak</i>	162
THE UNIFORMITY OF WHEAT SEEDING OVER AN AREA AND DEPTH <i>Dragan V. Petrović, Rade L. Radojević, Kurt Tomantschger, Zorana Z. Golubović</i>	166
DROPLET SIZE DISTRIBUTIONS OF CONVENTIONAL AND AIR-INDUCED NOZZLES <i>Dragan V. Petrović, Rade L. Radojević, Petar Vukša, Zorana Z. Golubović</i>	170
IMAGE-BASED VISUAL SERVO CONTROL OF ROBOT MANIPULATOR UNDER PARAMETER UNCERTAINTIES <i>Marko Mitić, Zoran Miljković, Mihailo Lazarević, Bojan Babić, Ivan B. Lazarević</i> ,.....	174
KALMAN FILTER FOR ROBOT VISION-BASED HUMAN TRACKING <i>Vlastimir Nikolić, Žarko Čojbašić, Danijela Ristić-Durant, Emina Petrović, Srđan Matić, Ivan Ćirić</i>	178

0	ACCELERATIONS IN A HIGH PERMANENCE HUMAN CENTRIFUGE <i>Zorana Dančuo, Boško Rašuo, Vladimir Zeljković, Jelena Vidaković, Vladimir Kvirgić</i>	182
2	CONTROL OF A HUMAN CENTRIFUGE <i>Jelena Vidaković, Vladimir Kvirgić, Goran Ferenc, Zorana Dančuo, Mihailo Lazarević</i>	186
4	ASSESSMENT OF AIRCRAFT WING FREQUENCY CHARACTERISTICS <i>Jelena Svorcan, Slobodan Stupar, Aleksandar Simonović, Dragan Komarov, Srđan Trivković</i>	190
6	A PIC32 BASED ACTIVE VIBRATION CONTROL OF SMART COMPOSITE BEAMS <i>Nemanja Zorić, Zoran Mitrović, Aleksandar Simonović, Slobodan Stupar</i>	194
0	EXPERIMENTAL IDENTIFICATION OF DISTURBANCE TRANSMISSION FACTOR <i>Matug Bemur, Sanja Vasin, Valentina Golubović-Bugarski, Milosav Ognjanović</i>	198
2	COMPARATIVE ANALYSES OF SERIAL LINKED EXPERIMENTAL TESTED WIRE ROPE ABSORBERS <i>Kari Aleksandar, Momčilo Milinović, Olivera Jeremić, Damir Jerković</i>	202
4	EXPERIMENTAL RESEARCH OF COMBINED TUBES COLLISION ENERGY ABSORBER <i>Jovan Tanasković, Dragan Milković, Vojkan Lučanin, Radivoje Mitrović</i>	206
8	TURBULENCE INTENSITY IN A SMOOTH TUBE MEASURING WITH HOT WIRE ANEMOMETER <i>Marko Mančić, Milan Đorđević, Emina Petrović, Jelena Milisavljević</i>	210
2	VARIABLE SPEED WIND GENERATOR AERO TURBINE OPTIMAL FUZZY CONTROL <i>Ivan Ćirić, Žarko Čojbašić, Vlastimir Nikolić, Emina Petrović, Jelena Milisavljević, Saša Nikolić</i>	214
6	EXPERIMENTAL CHARACTERISATION OF TWO-PHASE REACTIVE FLOWS IN PROPELLANT CHAMBER <i>Dejan Micković, Slobodan Jaramaz, Predrag Elek</i>	218
0	INCLINATION EFFECTS OF OUTLET NOZZLE ON SENSITIVITY OF PNEUMATIC COMPARATOR <i>Dragiša Skoko, Cvetko Crnojević, Mileta Ristivojević</i>	222
4	EXPERIMENTAL INVESTIGATION OF INDUSTRIAL STEEL STACK TEMPERATURE DISTRIBUTION <i>Zorana Posteljnik, Slobodan Stupar, Aleksandar Simonović, Dragan Komarov, Jelena Svorcan</i>	226

COLD COMPACTION ALUMINUM ALLOYS SWARF <i>Nikola Petrašinović, Slobodan Stupar, Aleksandar Simonović, Srđan Trivković, Ognjen Peković</i>	230
CLASSICAL AND MODERN MEASURING METHODS IN EXPERIMENTAL ANALYSIS OF G – BEAM STRUCTURE <i>Taško Maneski, Ana Petrović, Miloš Milošević, Nenad Mitrović, Nikola Momčilović</i>	234
EXPERIMENTAL DETERMINATION OF GUY WIRE TENSION <i>Ognjen Peković, Slobodan Stupar, Aleksandar Simonović, Danilo Petrašinović, Nemanja Zorić</i>	238
WAYSIDE MONITORING SYSTEM FOR WHEEL-RAIL CONTACT FORCES MEASUREMENTS <i>Dragan Milković, Goran Simić, Živana Jakovljević, Jovan Tanasković, Vojkan Lučanin</i>	241
BUCKLING BEHAVIOUR OF DENTED ALUMINIUM ALLOY CYLINDRICAL SHELL SUBJECTED TO UNIFORM AXIAL COMPRESSION <i>Miloš Stanković, Miloš Ristić, Aleksandar Simonović, Miroslav Jovanović</i>	244
EXPERIMENTAL STRAIN ANALYSIS IN DOUBLE LAYER PRESSED JOINT <i>Mirjana Šojić Radić</i>	251
MODELING OF WELDED STEEL X20 AND X22 <i>Jasmina Lozanović Šajić, Saša Mladenović, Emina Dzindo</i>	254
DAQ AND TRIBOLOGY PERFORMANCES FOR EXPERIMENTAL INVESTIGATION OF BEARINGS <i>Aleksandar Marinković, Tatjana Lazović, Miloš Stanković</i>	257
FRETTING WEAR GENERATED IN SPLINE JOINT OF BACK-TO-BACK GEAR TESTING RIG <i>Marija Milojević, Milosav Ognjanović, Božidar Rosić</i>	260
TENSILE TESTING FOR DIFFERENT TYPES OF POLYMERS <i>Jelena Milisavljević, Emina Petrović, Ivan Ćirić, Marko Mančić, Dušan Marković, Milan Đorđević</i>	263
LOW VELOCITY IMPACT ON A COMPLEX COMPOSITE STRUCTURE <i>S. Ćirić Kostić, Z. Šoškić, A. Pavlović, G. Minak</i>	266
RELATIONSHIP BETWEEN THE RELIABILITY AND THE LENGTH OF CONVEYOR RUBBER BELT <i>Miloš Tanasijević, Uglješa Bugarić, Predrag Jovančić, Dragan Ignjatović, Dragan Polovina</i>	269

CONVEYOR IDLERS TESTING MACHINE <i>Radivoje Mitrović, Žarko Mišković, Milan Tasić, Zoran Stamenić, Nataša Soldat, Nebojša Matić.....</i>	278
WEAR AND RELIABILITY OF PLANETARY GEAR SET CENTRAL PINION <i>Predrag Živković, Miloš Ristić, Milosav Ognjanović.....</i>	282
DETERMINING RELIABILITY OF FUEL INJECTORS IN EXPLOITATION <i>Dejan Jankovic, Mileta Ristivojevic.....</i>	286
VERIFICATION OF DEFORMATION MEASUREMENTS RESULTS USING OPTICAL MEASURING SYSTEM TRITOP <i>Milan Blagojević, Aleksandar Dišić, Miroslav Živković, Radovan Slavković.....</i>	290
SOME ASPECTS IN DESIGN OF SPLIT HOPKINSON TENSION BAR <i>Aleksandar Dišić, Miroslav Živković, Vladimir Milovanović, Milan Blagojević.....</i>	294
COMPARATIVE RESULTS OF WAGON STRESSES OBTAINED BY MEASURING WITH STRAIN GAUGES AND STRESSES OBTAINED BY FEM CALCULATION <i>Vladimir Milovanović, Miroslav Živković, Aleksandar Dišić, Dragan Rakić.....</i>	298

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COMPARATIVE RESULTS OF WAGON STRESSES OBTAINED BY MEASURING WITH STRAIN GAUGES AND STRESSES OBTAINED BY FEM CALCULATION

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1. Introduction

Numerical simulations are a well-proven and extremely useful tool for solving problems in industrial production. Numerical simulations reduce time and cost in developing of new products. The advantage of simulations is that potential problems on product are eliminated in design phase, which leads to significant reducing of product's cost. The most widely applied and powerful tool for the numerical simulation is finite element method (FEM).

Based on results of numerical simulations next step in projecting phase is working on the prototype. The information obtained during the design of prototype and theirs testing are the key factors in deciding whether to go into serial production or to give up from it. Because of that it is very important to make a comparative analysis of the FEM calculation results and measurements on a prototype and verify their mutual matching. Measurement result and the results obtained by FEM calculation must meet all requirements for static and fatigue strength according to standards.

The paper presents one example of this. According to TSI standard [1] (Clause 4.2.2.3.1) and requirements from Clause 3, British Standard EN 12663:2000 [2], static and fatigue strength analysis of wagon for transportation scatter materials are done. Tests and measurements were performed on a prototype made, and then conducted a comparative analysis of stresses obtained by measuring with strain gauges and stresses obtained by FEM calculation.

2. FEM Model

Wagon is intended for transportation of scatter materials, resistant on the atmospheric influence. Wagon was modeled using FEMAP software [3]. According to the construction type shell elements

with specified thickness and 3D elements are used for creating the finite element mesh.

Figure 2 shows a quarter of the model, which will be used, taking in consideration correspondent symmetry, for the load cases. Full model was used for unsymmetrical load cases and half model for analysing of wagon lifting. Colors on Figure 2 match the various thicknesses of shell elements.

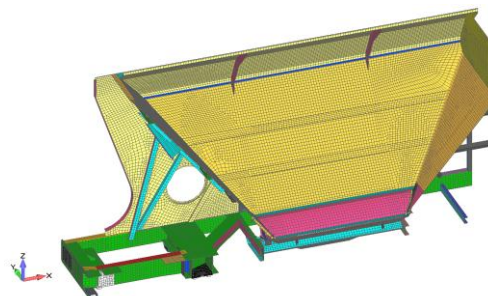


Fig. 1: Finite element mesh – quarter wagon model

3. Safety factor and permissible stress

According to EN 12663:2000, Clause 5.4, calculated permissible stress using Clause 3.4.2 is lower than calculated stress using Clause 3.4.3. Therefore, under the static load cases as defined in EN 12663:2000, Clauses 4.1 to 4.5, the ratio of yield stress ($R=R_e$) to calculated stress (σ_c) must be greater than or equal to S_1 , Table 1.

Material	Safety factor S_1	σ_{cmax} [MPa]
S355J2+N	1.15	309

Tab. 1: Safety factor and permissible stress for static loads – parent material

According to Clause 3.4.2 of EN 12663:2000, safety factor S_1 may be taken as 1.0 for superposition of load cases.

Table 2 shows limit values for static test to verify fatigue strength accordance with Eurocode 3, Part 1.9 [4], using Figure 7.1 and Table 3.1.

Direct stress range $\Delta\sigma_c$ [MPa]	Permissible maximum fatigue stress σ_{maxlim} [MPa]	Limit stress for safe life [MPa]	
		Low consequence ($\gamma_{Mf}=1,15$)	High consequence ($\gamma_{Mf}=1,35$)
160	347	301	257
100	217	188	160
90	195	170	144
80	173	151	128
71	154	134	114
63	136	119	101
56	121	106	90
50	108	94	80

Tab. 2: Limit stress values for static test to verify fatigue strength in steel S355J2+N

4. Load cases and requirements

According to TSI, Clause 4.2.2.3.1, wagon structure is necessary to calculate in relation to different types of load:

- Exceptional loads, which cover: longitudinal design loads, maximum vertical load, load combinations, lifting and jacking and other exceptional loads;
- Service (fatigue) loads

Exceptional load cases are specified in TSI, Clause 4.2.2.3.2 and EN 12663:2000. For all exceptional load cases maximum value of calculated stress must be lower than the permissible stress shown in the Table 1.

Service (fatigue) loads are specified in TSI, Clause 4.2.2.3.3 and EN 12663:2000. For service (fatigue) loads maximum value of calculated stress in welded joints must be lower than the limit stress for safe life in the Table 2.

5. Measuring and position of strain gauges

According to results obtained by FEM calculations for all load cases defined in accordance with the TSI standard, and with British Standard EN-12663:2000 on wagon set up strain gauges and measurements were carried out. At the locations of strain gauges stresses were obtained.

Position of strain gauges mounted so that it covers all the places on the wagon, on which the numerical calculations shows a stress concentration. Schematic of the strain gauges are shown on Figure 2.

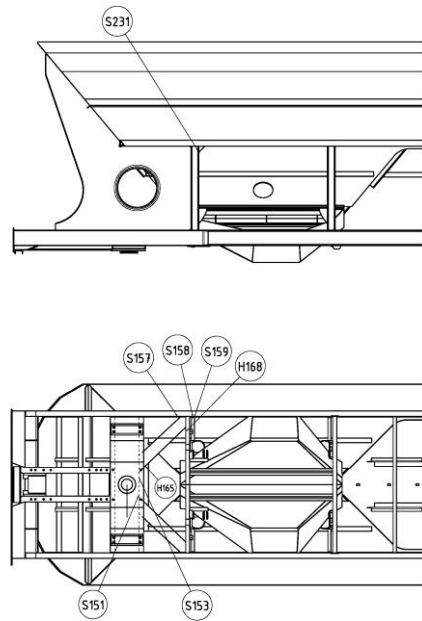


Fig. 2: Position of strain gauges

6. Comparative results of stresses

For all cases of static and dynamic loads were read values of stresses at the locations of strain gauges. It compared the measured stresses at the locations of strain gauges and the stresses obtained from the FEM calculations, using software PAK [5].

The aim of the analysis is to show that on the basis of measurements and calculations based on FEM obtained similar values of stress, below values of permissible stress defined according to TSI and EN 12663:2000

At the place of strain gauge 158 normal stress of 322MPa was measured for longitudinal case of load, when compressive force acting at coupler level; $F=2000kN$.

Stresses shown in report obtained by measuring with strain gauges actually are normal stresses in direction of strain gauge.

Places of strain gauge 158, as strain gauges 157 and 159 are shown on Figure 3. Results obtained by FEM analysis are shown on Figure 4.



Fig. 3: Strain gauges 157, 158 and 159

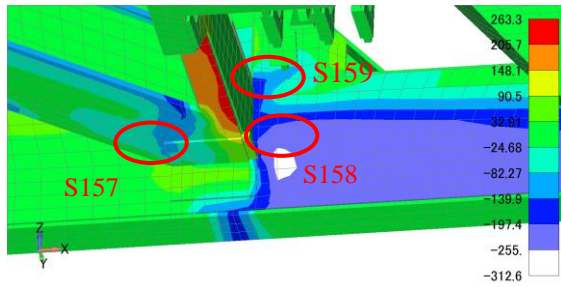


Fig. 4: X Normal stress field

In the Table 3 are shown comparative results obtained by strain gauges and appropriate normal stresses obtained by FEM analysis.

Strain gauge number	Stress σ_{xx} [MPa]		Difference in %	Figure number	
	Strain gauge	FEM analysis		Strain gauge	FEM analysis
157	-31	-30.9	0.3	3	4
158	-322	-312.6	2.9		
159	-248	-258.7	4.1		

Tab. 3: Comparative results obtained by strain gauges and FEM analysis for longitudinal case of load when compressive force acting at coupler level; F=2000kN

Difference between results obtained by strain gauges and FEM analysis is lower than 5% which is acceptable. It can be observed that stress is higher than 309MPa and that does not meet safety factor 1.15. It should be noted that stress 332MPa is lower than $R_e=355\text{MPa}$ for material S355J2+N. According to BS EN 12633 Clause 3.4.2, S_1 may be taken as 1.0 where the design load cases are to be verified by test.

For the load case of maximal vertical load at positions 151, 153, 165 and 231, comparative results obtained by strain gauges and appropriate normal stress obtained by FEM analysis are given in the Table 4.

Strain gauge number	Stress [MPa]		Difference in %	Figure number	
	Strain gauge	FEM analysis		Strain gauge	FEM analysis
151	-126	-121.7	3.4	5	6
153	-127	-121.7	4.2		
165	114	106	7	7	8
231	-122	-116	4.9	9	10
168	112	125	10	11	12

Tab. 4: Comparative results obtained by strain gauges and FEM analysis for longitudinal case of load when compressive force acting at coupler level; F=2000kN



Fig. 5: Strain gauges 151 and 153

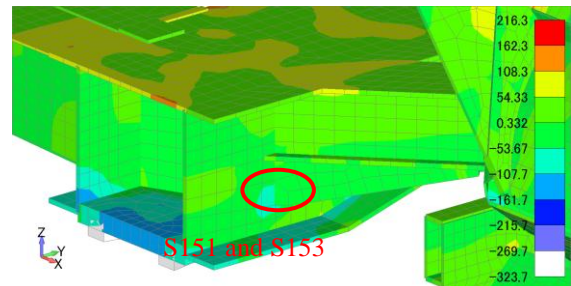


Fig. 6: Y Normal stress field



Fig. 7: Strain gauge 164 and 165

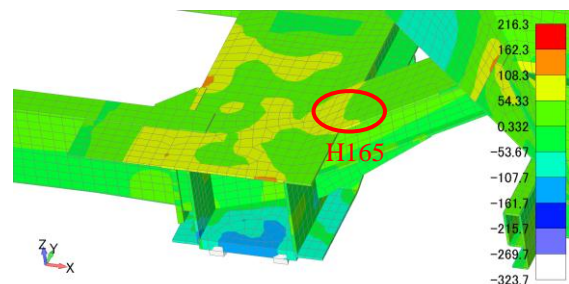


Fig. 8: Y Normal stress field



Fig. 9: Strain gauge 231, 233 and 235

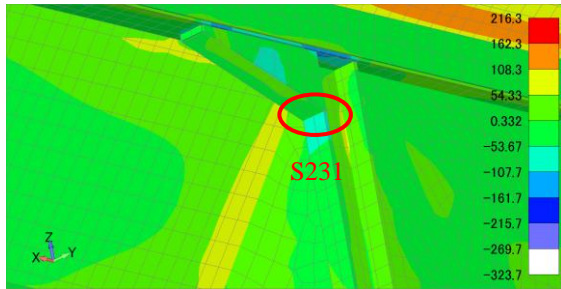


Fig. 10: Y Normal stress field

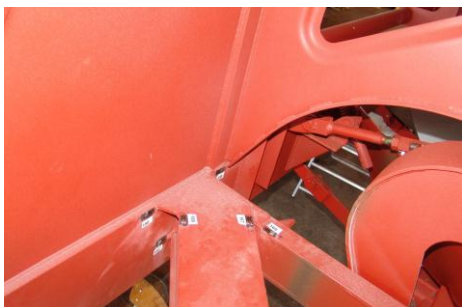


Fig. 11: Strain gauge 166, 167 and 168

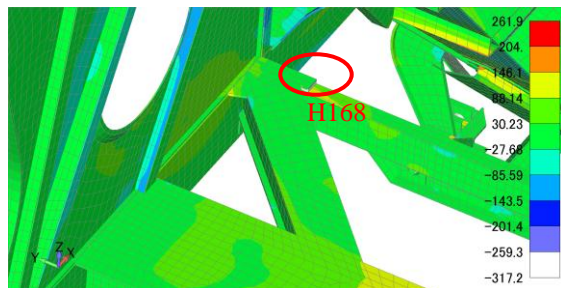


Fig. 12: X Normal stress field

Based on measured and calculated stresses given in the Table 4 and limit stresses given in Table 2, it can be concluded that the measured and calculated stresses are below limit stress for safe life (high consequence $\gamma_{Mf}=1.35$) for the parent material and welded joints (detail category 100).

Conclusions

The aim of this paper was to compare results of stresses obtained by measuring with strain gauges and stresses obtained by FEM calculation. Example demonstrates applying of the most common European standards for calculating static

and dynamic strength of wagon. Comparing the numerical results with the results of measuring, it is verified that software gives good agreement with the experimental results. Difference between results obtained by strain gauges and FEM analysis is lower than 10%. According to presented results it can be concluded that FEM analysis can reduce number of the testing new products. This would lead to big savings and significantly less cost of products.

7. Acknowledgement

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8. References

- [1] TSI Standard - Freight wagons of the trans-European conventional rail system
- [2] EN 12663 - Railway applications – Structural requirements of railway vehicle bodies, European Standard
- [3] FEMAP Version 10 (2009) User Guide, Siemens Product Lifecycle Management Software Inc, Munich – Germany
- [4] Eurocode 3: Design of steel structures - Part 1.9: Fatigue
- [5] Zivkovic M., Kojic M., Slavkovic R., Grujovic N., PAK-S Program for FE structural analysis, Faculty of Mechanical Engineering, University of Kragujevac (2003)