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Jahorina, B&H, Republic of Srpska



University of East Sarajevo

Faculty of Mechanical Engineering

Conference on Mechanical Engineering Technologies and Applications

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# Z B O R N I K   R A D O V A

# P R O C E E D I N G S

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# CONTENTS

## PLENARY LECTURES

1. **Stefan Wagner**  
IMPROVED FAILURE DESCRIPTION IN FORMING OF AUTOMOTIVE SHEET METAL PARTS 1
2. **Gorazd Hlebanja**  
CHARACTERISTICS OF NON-INVOLUTE GEARS 9
3. **Aleksandar Veg, Emil Veg**  
DEVELOPMENT OF A HAND-HELD VIBRODIAGNOSTIC INSTRUMENT 21
4. **Milosav Ognjanović**  
TECHNICAL SYSTEMS DEVELOPMENT TOWARDS TO ACTUAL TRENDS AND METHODOLOGY IN ENGINEERING DESIGN 31

## INVITED PAPERS

5. **Ljubodrag Tanovic**  
INVESTIGATIONS IN DEVELOPING A NEW GENERATION OF MACHINE TOOLSS 37
6. **Ranko Antunović, Aleksandar Veg**  
ANALYSIS OF DYNAMIC BEHAVIOR OF ROTATING MACHINES 43
7. **Vojislav Miltenović, Biljana Marković, Milan Banić, Aleksandar Miltenović**  
FUTURE TECHNOLOGY AND EDUCATION OF ENGINEERS 53

## Session I

### MANUFACTURING TECHNOLOGIES AND ADVANCED MATERIALS

*Chair: Milan Zeljković, Ljubodrag Tanović, Obrad Spaić*

8. **Milan Zeljkovic, Aleksandar Zivkovic, Slobodan Tabakovic**  
COMPUTER AND EXPERIMENTAL AIDED ANALYSIS OF HIGH-SPEED SPINDLE ASSEMBLY DYNAMIC BEHAVIOR 63
9. **Dejan Jeremić, Nebojša Radić**  
IMPLEMENTATION OF CARBON FIBER IN THE AUTOMOTIVE INDUSTRY 75
10. **Obrad Spaić, Budimirka Marinović**  
INFLUENCE OF WEARING DRILLS ON DRILLING AXIAL FORCE 83
11. **Obrad Spaić, Zdravko Krivokapić, Slavoljub Grče**  
MODELING OF AXIAL CUTTING FORCE USING NEURAL NETWORKS 91
12. **Milija Krašnik, Dragiša Vilotić, Leposava Šiđanin, Žarko Petrović**  
EXPERIMENTAL VERIFICATION OF DIFFERENT THEORETICAL APPROACHES FOR DEFINING FLD 99
13. **Aljoša Ivanišević, Igor Kačmarčik, Dejan Movrin, Miroslav Plančak, Sergei Alexandrov, Dragiša Vilotić**  
INFLUENCE OF FRICTION AND NUMBER OF DEFORMATION PHASES ON FORMABILITY OF STEEL C45E 109

14.	<b>Aleksandar Košarac, Saša Prodanović, Milan Zeljković</b> POSSIBILITIES FOR INTERACTIVE CONTROL OF MACHINE TOOLS IN THE VIRTUAL REALITY ENVIRONMENT	117
15.	<b>Saša Živanović, Zoran Dimić, Nikola Slavković, Dragan Milutinović, Miloš Glavonjić</b> CONFIGURING OF VIRTUAL ROBOT FOR MACHINING AND APPLICATION IN OFF-LINE PROGRAMMING AND EDUCATION	125
16.	<b>Zorica Djordjević, Mirko Blagojević, Saša Jovanović, Vesna Marjanović, Nenad Kostić</b> MATERIAL TYPE INFLUENCE ON STATIC AND DYNAMIC CHARACTERISTICS OF COMPOSITE SHAFTS	133
17.	<b>Slobodan Stojadinović, Jasmina Pekez, Nikola Bajić, Eleonora Desnica</b> HARDENING OF AlMgSiCu ALLOYS AS A FUNCTION OF THE THERMO-MECHANICAL TREATMENT	141
18.	<b>Zdravko Božičković, Dragoslav Dobraš, Milorad Poljašević</b> THE INFLUENCE OF THE DEFORMATION IN THE PROCESS EXTRACTION ON QUALITY OF WIRES FOR REINFORCEMENT MESH	145
19.	<b>Svetislav Marković, Dragoljub Veličković, Marijana Marković, Marija Popović, Jelena Milić, Ljubiša Milovanović</b> THE ABILITIES AND PRACTICAL APPLICATIONS OF LASER CONTOURING CUTTING OF MATERIALS IN THE MAINTENANCE OF MECHANICAL SYSTEMS	153

#### **Session II**

#### **APPLIED MECHANICS AND MECHATRONICS**

**Chair: Aleksandar Veg, Ranko Antunović, Nebojša Radić**

20.	<b>Nebojša Radić, Dejan Jeremić</b> BUCKLING ANALYSIS OF DOUBLE-ORTHOTROPIC NANOPATE USING NONLOCAL ELASTICITY THEORY	161
21.	<b>Ljupco Trajcevski, Tale Geramitchioski</b> DYNAMIC RESPONSE SIMULATION OF PLANETARY GEAR BY NEWMARK METHOD	171
22.	<b>Tale Geramitchioski, Ljupco Trajcevski, Vangelce Mitrevski</b> COMPUTER SIMULATION A VIBRATION SIGNAL FOR THE GEAR FAULT DIAGNOSTICS	179
23.	<b>Rusmir Bajrić, Ninoslav Zuber, Denijal Sprečić</b> REVIEW OF VIBRODIAGNOSTIC METHODS FOR PLANETARY GEARBOX GEARS CONDITION MONITORING	187
24.	<b>Ninoslav Zuber, Rusmir Bajrić</b> REVIEW OF VIBRODIAGNOSTIC METHODS FOR ROLLER ELEMENTS BEARING CONDITION MONITORING	195
25.	<b>Saša Nikolić</b> MOTOR CURRENT SIGNATURE ANALYSIS TO DETECT FAULT OF INDUCTION MOTOR	205
26.	<b>Nenad Marjanović, Biserka Isailović, Vesna Marjanović, Nenad Kostić</b> INTEGRATED APPROACH TO STRUCTURAL OPTIMIZATION IN CAD SOFTWARE	213

27.	<b>Vladimir Milovanović, Dragan Rakić, Miroslav Živković, Snežana Vulović, Miroslav Milutinović</b> THERMO-MECHANIC ANALYSIS OF CEMENT TRANSPORT WAGON - IDENTIFICATION OF THE CAUSE OF CRACKS	221
28.	<b>Nedeljko Vukojević, Fuad Hadžikadunić</b> EXPERIENCES OF APPLICATION OF VIBRATORY RESIDUAL STRESS RELIEVING METHODOLOGY ON LARGE WELDED CONSTRUCTIONS	229
29.	<b>Boris Rakić, Nikola Beloica, Danica Josifović, Lozica Ivanović, Andreja Ilić</b> STRESS - STRAIN ANALYSIS OF HYDRAULIC CYLINDER AT EXCAVATOR BUCKET MECHANISM	235
30.	<b>Lozica Ivanović, Danica Josifović, Mirko Blagojević, Blaža Stojanović, Andreja Ilić</b> DETERMINATION OF GEROTOR PUMP THEORETICAL FLOW	243
31.	<b>Aleksandar Nikolić, Milan Blagojević, Vladimir Milovanović, Miroslav Živković, Miroslav Milutinović</b> ANALYSIS OF HEAT TRANSFER THROUGH THE BEAM SUPPORT OF THE WAGON STRUCTURE CALCULATED BY SOFTWARE PAK MULTYPHISICS	251
32.	<b>Marko Topalović, Miroslav Živković, Nenad Busarac, Snežana Vulović</b> IMPROVEMENT AND INTEGRATION OF FEM SOLUTION USED FOR R&D INTO FEMAP	255

### Session III

#### DEVELOPMENT OF PRODUCTS AND MECHANICAL SYSTEMS

##### Session III-1: DESIGN OF POWER TRANSMISSIONS

Chair: Miloslav Ognjanović, Siniša Kuzmanović, Dragan Milčić

33.	<b>Miloš Ristić, Milosav Ognjanović</b> RELIABILITY-BASED DESIGN OF BUCKET WHEEL EXCAVATOR GEAR DRIVE UNITS	263
34.	<b>Milan Rackov, Siniša Kuzmanović, Željko Kanović, Miroslav Vereš</b> SOME IRREGULARITIES WHICH MAY OCCUR DURING IMPLEMENTATION HCR GEARING	269
35.	<b>Dragan Milčić, Miroslav Mijajlović, Dragoljub Živković, Slobodan Miladinović</b> CALCULATION OF LOAD CAPACITY OF AXLES AND SHAFTS ACCORDING TO DIN 743	277
36.	<b>Predrag Živković</b> EXPERIMENTAL IDENTIFICATION OF FAILURE AND RELIABILITY CALCULATION OF ELEMENTARY PLANETARY GEARS POWER TRANSMISSIONS	285
37.	<b>Radoslav Tomović</b> NEW APPROACH TO THE MODELING OF ROLLING BEARINGS	293
38.	<b>Dragan Milčić, Miroslav Mijajlović, Boban Anđelković, Miodrag Milčić</b> SOFTWARE SYSTEM FOR CALCULATIONS OF MACHINE PARTS – PROGRAM MODULE FOR FRICTION TRANSMISSION CALCULATIONS	303

39. **Dragoslav Janošević, Nikola Petrović, Vesna Nikolić, Jovan Pavlović**  
ANALYSIS OF HYDRAULIC CRAWLER TRACTORS TRANSMISSION 309
40. **Marko Miletić, Mirko Blagojević, Snežana Vulović, Ivan Miletić**  
CONTACT SURFACE ANALYSIS ON CYCLOID DRIVES WITH SINGLE, DOUBLE AND TRIPLE MESHING 315
41. **Miroslav Milutinović, Milosav Ognjanović, Spasoje Trifković**  
DESIGN PARAMETERS IDENTIFICATION OF AUTOMOTIVE GEARBOX BASED ON DESIRED RELIABILITY 323

**Session III-2**

**ENGINEERING EDUCATION AND INNOVATION IN DESIGN**  
**Chair: Vojislav Miltenović, Gorazd Hlebanja, Biljana Marković**

42. **Tihomir Mačkić, Mirko Blagojević, Živko Babić**  
ANALYSIS OF PARAMETERS THAT HAVE AN IMPACT ON CYCLO DRIVE EFFICIENCY 331
43. **Nenad Kostić, Mirko Blagojević, Vesna Marjanović, Zorica Đorđević, Nenad Marjanović**  
INFLUENCE OF CYCLOIDAL GEAR PROFILE CORRECTION TO THE NUMBER OF CONTACTS BETWEEN THE ELEMENTS OF A CYCLOIDAL SPEED REDUCER 339
44. **Nada Bojić, Dragan Milčić**  
EFFECTS OF VARIOUS PARAMETERS TO SLIDING BEARINGS 347
45. **Miroslav Živković, Miloš Janošević, Snežana Vulović, Nenad Busarac, Marko Topalović**  
THERMAL ANALYSIS OF HIGH POWER REDUCTION GEARBOX 355
46. **Biljana Marković, Milan Banić**  
REQUIREMENTS FOR DEVELOPING ENGINEERS EDUCATION – HOW TO PARTICIPATE IN INTERNATIONAL PROJECTS? 359
47. **Mirko Blagojević, Zorica Đorđević, Vesna Marjanović, Nenad Marjanović, Blaža Stojanović, Rodoljub Vujanac**  
STRESS AND STRAIN STATE OF CYCLOID DISC 367
48. **Dejan Krstić**  
IMPACT OF EURO NCAP TESTS ON BODY MODIFICATION IN AUTOMOTIVE INDUSTRY 375

**Session IV**

**ENERGETICS AND THERMO - TECHNIQUE**

**Chair: Dušan Golubović, Mirko Dobrnjac, Buzatu Gabriel Cosmin**

49. **Milan Plavšić, Zdravko Božičković, Dušan Golubović**  
MATERIALS-RELATED ISSUES IN CATALYTIC AND BOILER-TURBINE PLANTS 383
50. **Miljan Savić, Biljana Marković**  
ESTABLISHING ENERGY EFFICIENCY SYSTEM IN ACCORDANCE WITH THE REQUIREMENTS OF EN ISO 50001 391
51. **Vangelce Mitrevski, Tale Geramitcioski, Vladimir Mijakovski, Monika Lutovska**  
RISK ASSESSMENT IN NATURAL GAS TRANSMISSION SYSTEM 399
52. **Saša Jovanović, Zorica Đorđević, Milorad Bojić, Slobodan Savić, Biljana Stepanović**  
WEATHER CONDITIONS IMPACT ON ELECTRICITY CONSUMPTION 409



53.	<b>Buzatu Gabriel Cosmin, Mircea Paul Mihai, Dinu Radu Cristian</b> ENERGY EFFICIENCY OF A COGENERATION SYSTEM	415
54.	<b>Šefik Bajmak</b> ANALYSIS OF ENERGY EFFICIENCY AND ECONOMIC SEPARATED SYSTEMS WITHIN THE SUPPLY CENTRALIZED HEAT AND COOLING ENERGY	423
55.	<b>Jela Burazer, Dragana Kalabić, Mirko Dobrnjac</b> CALCULATION CHOICE AT THE VERTICAL PNEUMATIC TRANSPORT OF THE DUST MATERIAL	431
56.	<b>Slobodan Stefanovic, Zivoslav Adamovic, Radoje Cvejic, Imre Kiss</b> MATHEMATICAL MODEL OF THE SYSTEM FOR REGULATION OF ROLLING THICKNESS ON FIVE STRANDS TWIN TRAIN	435
57.	<b>Velibor Karanović, Mitar Jocanović, Darko Knežević, Milija Krašnik</b> DEVELOPMENT OF ELECTROHYDRAULIC ACTUATOR FOR ROBOTS	447
58.	<b>Dragoljub Živković, Marko Mančić, Dragan Milčić</b> SYMULATION OF A HYBRID TRIGENERATION SYSTEM DESIGNED FOR DEMANDS OF A RESIDENTIAL BUILDING	457

**Session V**  
**RENEWABLE ENERGIES AND ENVIRONMENTAL PROTECTION**  
**Chair: Petar Gvero, Stojan Simić, Mircea Paul Mihai**

59.	<b>Srđan Vasković, Petar Gvero, Vlado Medaković, Davor Milić</b> THE IMPORTANCE OF ANALYSIS ENERGY CHAINS BASED ON BIOMASS FOR ENERGY PRODUCTION	465
60.	<b>Stojan Simić</b> RECYCLABILITY-SIGNIFICANT REQUEST FOR DESIGN AND CONSTRUCTION IN THE METAL INDUSTRY	471
61.	<b>Stojan Simić, Snježana Vujić, Omer Kovač</b> ADEQUATE WASTEWATER MANAGEMENT SIGNIFICANT SEGMENT OF CONSERVING OF ENERGY IN REFINERIES	479
62.	<b>Mircea Paul Mihai, Sanda Diana (Firincă) Enache, Cătălin Mihai, Sorin Abagiu, Ivan Felicia Elena Stan</b> SMART GRIDS CONCEPT USED IN RURAL AREAS	487
63.	<b>Dejan Krstić</b> MANAGEMENT OF THE INNOVATIVE PROJECTS FOR CONQUEST OF MANUFACTURING SOLAR PHOTOVOLTAIC MODULE	495
64.	<b>Roganović D., Đurović D.</b> DETERMINATION OF HEAVY METALS IN THE BARK OF CYPRESS (CUPRESSUS SEMPERVIRENS L.) IN THE VICINITY ALUMINIUM PLANT PODGORICA (KAP) - MONTENEGRO	503
65.	<b>Panaiteescu F.V., Panaiteescu M., Stan, L.C.</b> ANTHROPIC IMPACT WATER QUALITY IN THE PORT MARINE MANGALIA	511
66.	<b>Panaiteescu M., Panaiteescu F.V., Panaiteescu I.I., Panaiteescu V.A.</b> A NEW TECHNOLOGY FOR SHIP HEAVY FUEL OIL SYSTEM	517
67.	<b>Mina Radić, Jovana Arsić, Marija Džaleta, Svetlana Stevović</b> IMPROVEMENT OF ENVIRONMENTAL QUALITY BY SETTING UP THE EXTERNAL VERTICAL GARDEN ON THE EXISTING BUILDING	525

**Session VI**  
**QUALITY, MANAGEMENT AND ORGANIZATION**  
**Chair: Rade Ivanković, Slavko Arsovski, Slaviša Moljević**

68. **Slavko Arsovski, Zora Arsovski, Miladin Stefanović**  
INFLUENCE OF SIZE OF ORGANIZATION AND NUMBER OF  
INTEGRATED MANAGEMENT SYSTEMS (IMS) ON ORGANIZATION  
OF IMS PROCESSES 533
69. **Rade Ivanković, Zdravko Krivokapić, Đurđica Kučinar**  
IMPACT OF PRODUCT QUALITY ON COMPANY PROFITABILITY  
BY MEANS OF EXPERT SYSTEMS 541
70. **Biljana Marković**  
APPLICATION OF REQUIREMENTS OF INTERNATIONAL  
STANDARD EN 9100:2009 IN AIRSPACE INDUSTRY 549
71. **Slaviša Moljević, Dragan Rajković, Bogdan Marić,  
Vlado Medaković, Slavoljub Đurđević**  
INTEGRATED SYSTEMS MANAGEMENT IN SMALL AND MEDIUM  
ENTERPRISES 557
72. **Ljubica Duđak**  
PERSONAL MANAGEMENT AND HUMAN RESOURCE  
MANAGEMENT – DIFFERENCES 567
73. **Nina Đurica, Maja Đurica, Miha Marič**  
THE ROLE AND USE OF INFORMATION-COMMUNICATION  
TECHNOLOGY IN HIGHER EDUCATION 577
74. **Vlado Medaković, Bogdan Marić, Slaviša Moljević, Srđan Vasković**  
ORGANIZATIONAL MODELS AND DEVELOPMENT GENERIC  
TECHNOLOGIES FOR THE MANUFACTURING INDUSTRY 587

**Session VII**  
**MAINTENANCE AND TECHNICAL DIAGNOSIS**  
**Chair: Milan Blagojević, Radoslav Tomović, Ranko Antunović**

75. **Andreja Ilić, Lozica Ivanović, Danica Josifović, Vukić Lazić**  
THE METHODOLOGY ASPECTS FOR MONITORING THE MACHINE  
ELEMENTS, COMPONENTS AND SYSTEMS 593
76. **Milan Blagojević, Miroslav Živković, Aleksandar Nikolić**  
THE INFLUENCE OF THE DSLR CAMERA SHUTTER COUNT ON  
THE ACCURACY OF THE PHOTOGRAMMETRIC MEASUREMENTS 601
77. **Željko Batinić, Zoran Radović, Petar Nikšić, Ranko Antunović**  
NEW TECHNOLOGIES AS A FUNCTION OF CONTROL OF  
MECHANICAL SYSTEMS 607
78. **Mihajlo Vujičić, Radoslav Tomović**  
APPLICATION OF TECHNICAL DIAGNOSTIC IN MAINTENANCE OF  
GEOTECHNICAL MACHINES 615
79. **Vojin Vukotić, Dragan Čabrilo**  
REENGINEERING OF MECHANICAL EQUIPMENT ON  
THE BUCKET WHEEL EXCAVATOR 623
80. **Mitar Jocanović, Velibor Karanović, Đorđe Vukelić,  
Darko Knežević, Milija Krašnik**  
DIAGNOSTIC EQUIPMENT FOR EXAMINATION PHYSICAL AND  
CHEMICAL CHARACTERISTICS OF UTTO, STOU TRACTOR OILS 631
81. **Marko Šolaja, Vladimir Gluhović**  
SENSOR SYSTEM ON CHAIRLIFT „OGORJELICA 1“ 641

<b>82. Goran Orašanin, Dalibor Vlaški</b>	PRESSURE MANAGEMENT IN THE WATER SUPPLY SYSTEMS	647
<b>83. Rajko Tanasijević</b>	IMPORTANCE OF MAINTENANCE BY MEANS OF INFORMATION SYSTEM PRODUCTION SYSTEM	655

**Session VIII**

**STUDENT SECTION**

**Chair: Milija Kraišnik, Srđan Vasković, Ranko Antunović**

<b>84. Zoran Radović, Željko Batinić, Nemanja Prorok, Srđan Vasković</b>	APPLICATION OF VIRTUAL INSTRUMENTATION IN MONITORING OF MECHANICAL SYSTEMS	663
<b>85. Nikola Vučetić</b>	CONSTRUCTIONAL SOLUTION FOR INSTALLATION OF GAS (LPG) ON MOTORCYCLE	673
<b>86. Nikola Vučetić</b>	END OF LIFE MOTOR VEHICLES RECYCLING	683
<b>87. Vladimir Gojković, Ranka Gojković</b>	DEVELOPMENT AND PROSPECT OF NEW HYDROPOWER SYSTEM IN THE REPUBLIC OF SRPSKA	693
<b>88. Vladimir Gluhović, Marko Šolaja</b>	SNOWMAKING SYSTEM ON MOUNTAIN JAHORINA	701
<b>89. Ranka Gojković, Vladimir Gojković</b>	IMPLEMENTATION SOLAR AND WIND ENERGY FOR IRRIGATION OF AGRICULTURAL LAND	707
<b>90. Marina Kondić</b>	APPLICATION OF INDUSTRIAL ROBOT „LIMAT RT 280-6“ IN THE PROCESS OF WELDING	715

**INDEX OF AUTORS**

723

**PRESENTATIONS OF PARTICIPANTS**



## THERMO-MECHANIC ANALYSIS OF CEMENT TRANSPORT WAGON - IDENTIFICATION OF THE CAUSE OF CRACKS

Vladimir Milovanović<sup>1</sup>, Dragan Rakić<sup>2</sup>, Miroslav Živković<sup>3</sup>, Snežana Vulović<sup>4</sup>,  
Miroslav Milutinović<sup>5</sup>

**Summary:** *The paper represents a solution example of a specific engineering problem using thermo-mechanical analysis. The paper provides theoretical basis of numerical solving the problem of heat conducting through continuum using the finite element method. Calculation of heat conducting using the finite element method determines the temperature field used as an input for thermo-mechanical calculation. The basic task of thermo-mechanical calculation was the identification of the cause of cracks on the powder material transport wagon. After the analysis of the wagon crack causes, repair of the cracks is suggested. Repeating of the FEM analysis on the reconstructed model confirms that the wagon satisfies the criteria of static and fatigue strength appointed by the standards.*

**Key words:** *heat conducting, FEM analysis, cracks, wagon strength*

### 1. INTRODUCTION

Modern constructions of various purposes as a rule represent a combination of thin-wall elements such as shells, plates or beams being under the influence of different type of loads. Some of these loads have a completely defined character and elaborate methods of calculations. Use of software for integrating of differential equations enabled solving numerous practical examples of continuum mechanics.

Finite element method – FEM represents the most general numerical method being unavoidable in solving scientific and practical examples in almost all the fields of the science and technics. FEM is today successfully used for solving the problem of physical quantities such as heat conducting, heat and mass transfer, fluid mechanics, electrotechnics and other.

The paper presents theoretical bases of numerical solving the problem of heat conducting through continuum using the finite element method. FEM analysis identifies the main causes of cracks on powder material transport wagon. Constructive solutions of crack repair are offered as well. Thermo-mechanical calculation of the strengthened

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<sup>1</sup> Vladimir Milovanović, PhD student, Faculty of Engineering, Kragujevac, (vladicka@kg.ac.rs)

<sup>2</sup> Dragan Rakić, PhD student, Faculty of Engineering, Kragujevac, (drakic@kg.ac.rs)

<sup>3</sup> PhD, Miroslav Živković, Full professor, Faculty of Engineering, Kragujevac, (zile@kg.ac.rs)

<sup>4</sup> PhD, Snežana Vulović, Associate professor, Metropolitan University, Belgrade, (vsneza@kg.ac.rs)

<sup>5</sup> Miroslav Milutinović, PhD student, University of East Sarajevo, East Sarajevo, Faculty of Mechanical Engineering, (m.milutinovic82@gmail.com)

construction should confirm that such strengthened construction satisfies the criteria of static and dynamic strength.

## 2. THEORETICAL BASES

Differential equation of the energy balance is based on the fundamental conservation of energy principle. Namely, change of the inner material energy in the unit of time, in elementary volume, is equal to the quantity of heat energy accumulated in that same volume in the unit of time, or it is valid for [1].

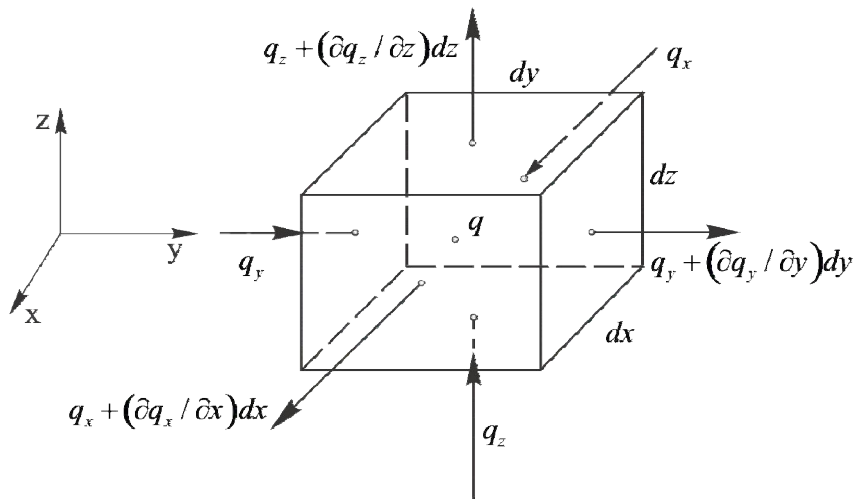
$$\frac{dQ}{dt} = \frac{dU}{dt} \quad (1)$$

Where  $dQ$  and  $dU$  are changes of the heat and inner energy in the volume  $dV$  in elementary time interval  $dt$ . Change of the inner energy can be formulated as:

$$\frac{dU}{dt} = \rho C_p \frac{dT}{dt} dV \quad (2)$$

where:  $\rho$  – material density,  $C_p$  – specific heat, a  $T$  – temperature. Using figure 1,  $dQ/dt$  can be formulated as:

$$\begin{aligned} \frac{dQ}{dt} = & \left( q_x + \frac{\partial q_x}{\partial x} dx - q_x \right) dydz + \left( q_y + \frac{\partial q_y}{\partial y} dy - q_y \right) dx dz + \\ & \left( q_z + \frac{\partial q_z}{\partial z} dz - q_z \right) dx dy - q dV \end{aligned} \quad (3)$$



Sl.1 Elementary volume  $dV$  with heat flux components

where  $q_x, q_y$  and  $q_z$  are the components of heat flux vector. These components represent the heat quantity, which in the unit of time passes through the unit surface. Power of heat source  $q$  represents the heat quantity in the unit of time and unit of volume. In the equation (3) signs of flux components are considered. Positive sign corresponds to the positive flux projection on the direction of the outer normal unit

vector on the surface whereas negative flux through the surface corresponds to the accumulation of heat energy  $dV$ . It is considered that  $q > 0$  if there is a heat source in the volume  $dV$  (in the point of the material), but  $q < 0$  in the case of the heat sink.

Heat conduction through continuum is defined by Fourier's law of heat conduction:

$$q_i = -\lambda_i \frac{\partial T}{\partial x_i} \quad i = 1, 2, 3 \quad (4)$$

where  $\lambda_i$ , or  $\lambda_x$ ,  $\lambda_y$  and  $\lambda_z$ , are coefficients of heat conduction in the case of orthotropic material. In the case of isotropic material, the following is valid:

$$\lambda_x = \lambda_y = \lambda_z = \lambda \quad (5)$$

Replacing (2) and (3) in the equation of energy balance (1) and using (4), differential equation for isotropic material obtains the following form:

$$-\rho C_p \frac{dT}{dt} + \sum_{j=1}^3 \frac{\partial}{\partial x_j} \left( \lambda_j \frac{\partial T}{\partial x_j} \right) + q = 0 \quad (6)$$

In the practical problem solving it is the solution for the temperature field  $T(x, y, z, t)$  that is searched for satisfying given initial and boundary conditions and representing a unique solution. Initial conditions are given only for unsteady problems and they mean that temperature distribution at the initial moment  $t = 0$  is known:

$$T(x, y, z, 0) = f_0(x, y, z) \quad (7)$$

Boundary conditions can be:

- given fluxes on the contact surface:

$$q_n = q_n(x, y, z, t) \quad (8)$$

- given heat convection:

$$q_h = h(T_0 - T_s) \quad (9)$$

Temperature  $T_s$  is surface temperature,  $T_0$  is environment temperature,  $h$  is coefficient of convection. Using Galerkin method, differential equation (6) transforms into the equation of construction balance whose solving is presented in references [1-3].

### 3. PROBLEM DESCRIPTION

The analysis subject is the wagon used for powder material transport. Regarding the construction, manufacture and equipment, the wagon corresponds to the valid regulations defining this field: UIC, RIV and DIN.

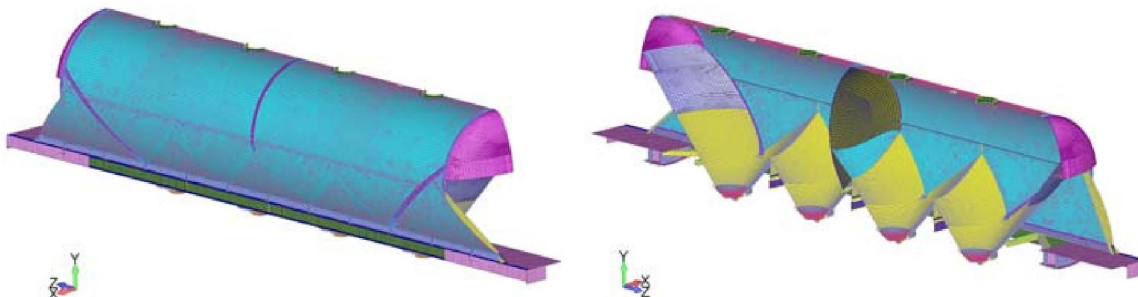
Visual examination of the powder material transport wagon reveals the cracks on the joint of the first and fourth tank with the longitudinal girder (figure 2). Prior to the reconstruction, the strength of wagon was analyzed in order to determine the types of load present in exploitation conditions causing the cracks. Due to that reason, all the combinations present in exploitation conditions of the wagon were analyzed.



Sl.2 Observed cracks on the construction

#### 4. FEM MODEL DESCRIPTION

Wagon was modeled by using the software Femap [4], whereas the analysis was done in the software PAK MULTIPHYSICS [3] based on the finite element method. In accordance with the type of the construction shell elements of appropriate thickness and 3D finite elements were used to create finite element mesh. 3D elements were used for modeling the support plate, relief ring and flange. Apart from the loads present in exploitation conditions, dead load of the wagon was considered as well. The construction was modeled in details with 60408 elements and 61176 nodes. For result presentation and better clarity, we used the half a model mesh without bogies (figure 3). Colors on figure 3 correspond to different thicknesses of shell elements.



Sl.3 FEM model of wagon half

#### 5. CALCULATION VARIATIONS AND CRITERIA

In order to determine the cause of the wagon cracks in exploitation conditions, analyses of the wagon in all load combinations appearing in exploitation conditions were done. Performed calculations are:

- thermo-mechanical calculation of the wagon during filling with heated cement
- thermo-mechanical calculation of the wagon loaded with cement of 50°C temperature, in motion
- calculation of dynamic strength due to the vertical load
- calculation of the wagon during motion in a curve
- calculation of the wagon during braking

### **Thermo-mechanical calculation of the wagon during filling**

Wagon is filled with cement up to the height of filling corresponding to the maximum allowed loading capacity of the wagon, 64.5t. Cement density is  $1400\text{kg/m}^3$ . On the inner model side, which is in contact with cement, temperature increase is given corresponding to the temperature difference between the cement and surrounding. Three calculations were done with given temperature increases of  $50^\circ\text{C}$ ,  $80^\circ\text{C}$  and  $100^\circ\text{C}$ . These temperature increases were used considering that the cement temperature ranges from  $50^\circ\text{C}$  to  $80^\circ\text{C}$ , and the temperature operating mode of the wagon is from  $-20^\circ\text{C}$  to  $50^\circ\text{C}$ . The calculation of the heat conducting was done first to determine the temperature field on the whole wagon and then, the temperature field was used in thermo-mechanical calculation to determine thermal strains. It was given for the heat on the wagon top to be dissipated by convection whereas the heat transfer coefficient  $h=10\text{ W/m}^2\text{K}$  and heat conducting coefficient  $k=45\text{ W/mK}$  were used. The coefficient of linear expansion is given as  $\alpha=12,6\cdot 10^{-6}1/\text{K}$ .

### **Thermo-mechanical calculation of the wagon loaded with $50^\circ\text{C}$ temperature cement during transport**

Thermo-mechanical calculation during filling determined a significant influence of temperature increase on stresses. For that reason, the calculation of dynamic strength due to the vertical load of heated cement was done. It was adopted that the heated cement causes the temperature increase of  $50^\circ\text{C}$ , as it was stated on the wagon. Also, in this case, vertical loads are increased for 1.3 times (30%), in order to include both thermal loads and dynamic loads during transport [6,7].

### **Calculation of dynamic strength due to the vertical load**

According to the standards TSI [5] and BS EN 12663:2000 [6], calculation of dynamic strength of freight car wagons due to the vertical load is done in the case of maximum allowed vertical load increased for 1.3 times (30%), in order to include dynamic loads during transport [6].

Based on the technical characteristics of the wagon, maximum vertical wagon load is obtained as the sum of maximum capacity of 64.5t and dead wagon load. Cement load of density  $1400\text{kg/m}^3$  is given by using the pressure effective up to the height of filling.

### **Calculation of the wagon during motion in a curve**

According to the technical wagon characteristics, maximum velocity of the wagon with maximum vertical load is  $100\text{km/h}$ , whereas the minimum radius of curve is  $250\text{m}$ . Load of cement of density  $1400\text{kg/m}^3$  is given through hydrostatic pressure up to the height of filling, whereas the effect of inertial forces is considered by giving the adequate horizontal acceleration in the radial direction [6].

### **Calculation of the wagon during braking**

According to the technical wagon characteristics, maximum velocity of the wagon with maximum vertical load is  $100\text{km/h}$ , whereas the stopping distance when braking is  $700\text{m}$ . Load of cement of density  $1400\text{kg/m}^3$  is given through hydrostatic pressure up to the height of filling. Also, in this case, inertial forces are considered by giving the adequate horizontal acceleration in the longitudinal direction.



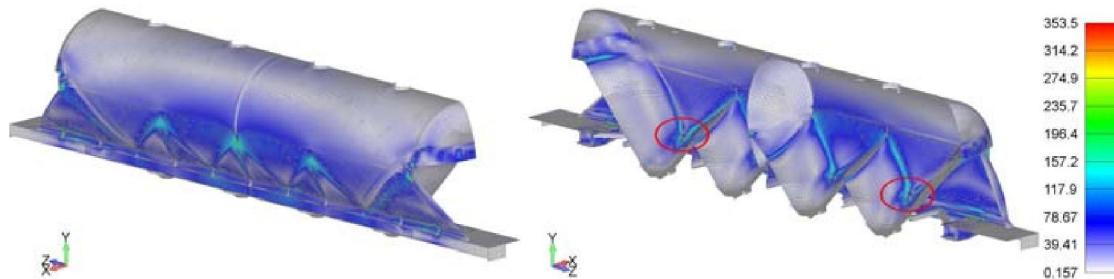
## 6. CALCULATION RESULTS BEFORE RECONSTRUCTION

The analyses were done for all the variations of load defined in the previous chapter. Results are presented only for the most favorable combinations of load as a base for identification of the causes of cracks on the joint of the first and fourth tank with the longitudinal girder.

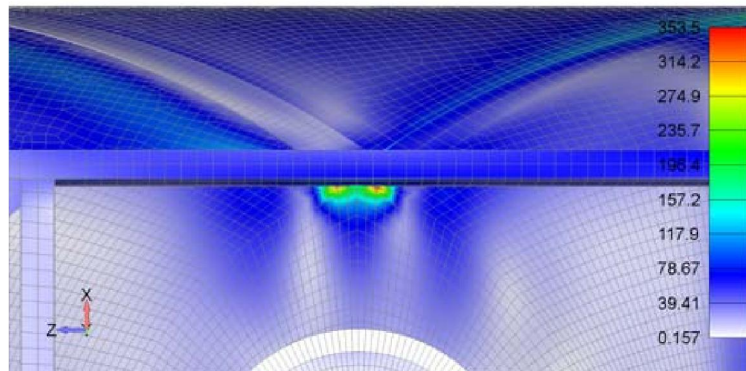
### Thermo-mechanical calculation of the wagon during filling with 100°C temperature increase

Three calculations were done with the temperature increases of 50°C, 80°C and 100°C on the inner surface of the tank in contact with warm cement. Heat conduction calculation was done in order to determine the temperature field on the whole wagon and then, the temperature field was used in thermo-mechanical calculation for thermal strain determination.

Effective stress field for the case of 100°C temperature increase, is presented on the figure 4. Zone of maximum stress value is presented on the figure 5.



Sl.4 Effective stress field on the wagon half



Sl.5 Effective stress field on the welding of the first tank and longitudinal girder

Maximum effective stress value is 353.5MPa being on the welding of the first tank for the longitude girder as seen on the figures 5 and 4, (marked details). Obtained stress is above allowed stress in the case of the static load [5-6]. Crack on this spot from the inner side is presented on the figure 2 to the right whereas the welding spot from the outer side is seen on the figure 2 to the left.

According to the obtained values, it can be concluded that the load in the case of high temperature increases has a significant influence on appearing of the cracks on the joint of the first and fourth tank with the longitudinal girder, (figure 2).

## 7. RECONSTRUCTION AND CALCULATION RESULTS OF THE RECONSTRUCTED WAGON

According to the analysis of the stress and strain cause of cracks on the joint of the tank and longitudinal girder are thermal loads.

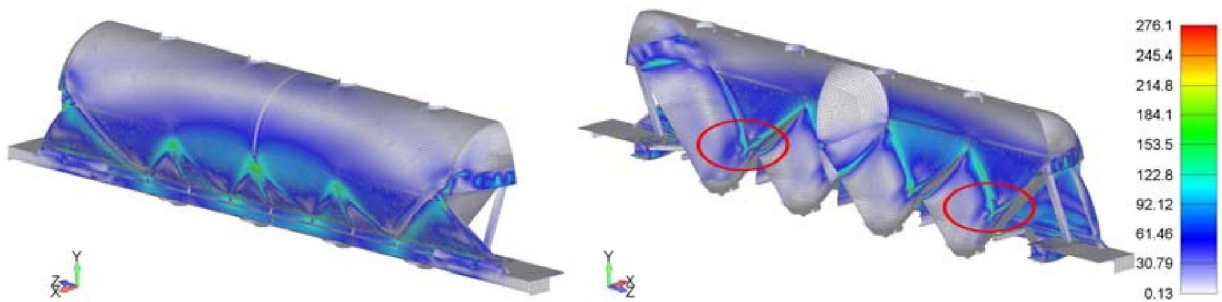
Crack repair is suggested on the cistern tank as well as the removal of weldings connecting the tank with the longitudinal girder (figure 6) with the clearance of at least.



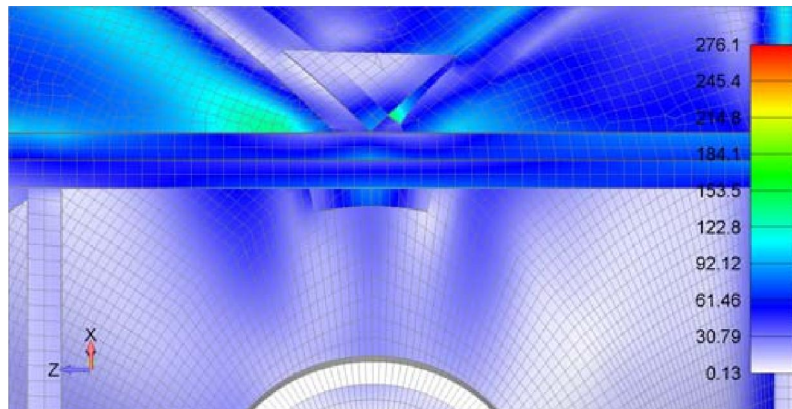
SI.6 Crack repair on the tanks

### Thermo-mechanic wagon calculation during filling with 100°C temperature increase

Effective stress field in the case of 100°C temperature increase, is presented on the figure 7. Figure 8 shows the effective stress field in the zone of repaired crack on the first tank. Obtained stresses in the whole construction, as well as the stresses in the zone of repaired cracks, are below allowed stress for the static loads [5-7].



SI.7 Effective stress field on the reconstructed model



Sl.8 Effective stress field in the zone of repaired crack on the first tank

## 8. CONCLUSION

The aim of this paper was to discover the causes of cracks on the heated cement transport wagon from the presented basic equations for heat conducting, implemented in the program PAK MULTIPHYSICS. Thermo-mechanic analyses of the existing construction identified the combinations of load causing damages on the wagon. In order to solve the problem, repair of the tank cracks is suggested as well as the removal of weldings connecting the tank with the longitudinal girder so the clearance of at least 5mm is reached. Repeated analyses, for all the load combinations, confirmed that all the stresses in the construction, as well as on the repair spots, are below allowed values. According to the presented results, it can be concluded that the reconstructed wagon for powder material transport satisfies all the requests in terms of the static and fatigue strength appointed by the mentioned standards.

## ACKNOWLEDGMENT

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## LITERATURE

- [1] Kojić M., Slavkovic R., Zivkovic M. Grujovic N., Finite Element Method I – Linear Analysis (in Serbian), Faculty of Mechanical Engineering, University of Kragujevac, Kragujevac, Serbia, 2003.
- [2] Bathe K. J., Finite Element Procedures in Engineering Analysis, Prentice-Hall, Engelwood Cliffs, New Jersey, USA, 1996.
- [3] Zivkovic M, Kojic M, Slavkovic R, Grujovic N. PAK MULTIPHYSICS. University of Kragujevac, Serbia: Faculty of Mechanical Engineering; 2012.
- [4] FEMAP Version 10 (2009) User Guide, Siemens Product Lifecycle Management Software Inc, Munich – Germany
- [5] TSI Standard - Freight wagons of the trans-European conventional rail system, 2006.
- [6] British Standard. Railway applications Structural requirements of railway vehicle bodies. BS EN 12663-2:2007.
- [7] European Standard. Eurocode 3: Design of steel structures - Part 1.9: Fatigue. prEN 1993-1-9:2003.