UNIVERSITY OF EAST SARAJEVO

FACULTY OF MECHANICAL ENGINEERING

3rd INTERNATIONAL SCIENTIFIC CONFERENCE

COMETa2016

„Conference on Mechanical Engineering Technologies and Applications"

PROCEEDINGS

7th-9th December

East Sarajevo-Jahorina, RS, B&H

COMETa 2016
3rd INTERNATIONAL SCIENTIFIC CONFERENCE
7th - 9th December 2016
Jahorina, Republic of Srpska, B&H
University of East Sarajevo
Faculty of Mechanical Engineering
Conference on Mechanical Engineering Technologies and Applications

Z B O R N I K   R A D O V A

P R O C E E D I N G S

Istočno Sarajevo – Jahorina, BiH, RS
7 - 9. decembar 2016.

East Sarajevo – Jahorina, B&H, RS
7th – 9th December 2016.

ZBORNIK RADOVA SA 3. MEĐUNARODNE
NAUČNE KONFERENCIJE
”Primijenjene tehnologije u mašinskom inženjerstvu”
COMETa2016, Istočno Sarajevo - Jahorina 2016.

PROCEEDINGS OF THE 3rd INTERNATIONAL
SCIENTIFIC CONFERENCE
”Conference on Mechanical Engineering
Technologies and Applications”
COMETa2016, East Sarajevo - Jahorina 2016.

Organizator:	Univerzitet u Istočnom Sarajevu Mašinski fakultet Istočno Sarajevo
Organization:	University of East Sarajevo Faculty of Mechanical Engineering East Sarajevo
Izdavač:	Univerzitet u Istočnom Sarajevu Mašinski fakultet Istočno Sarajevo
Publisher:	University of East Sarajevo Faculty of Mechanical Engineering East Sarajevo
Za izdavača: *For publisher:*	Prof. dr Ranko Antunović
Urednici:	Prof. Dr Biljana Marković,
Editors:	Prof. Dr Ranko Antunović,
Tehnička obrada i dizajn: *Technical treatment and desing:*	Ranka Gojković, senior asisstant Nikola Vučetić, senior asisstant Aleksija Đurić, senior asisstant
Izdanje:	Prvo
Printing:	1st
Register:	ISBN 978-99976-623-7-8
Register:	COBISS.RS-ID 6240280

REVIEWERS

PhD Adisa Vučina, FMEC Mostar (B&H)
PhD Radoslav Tomović, FME Podgorica (MNE)
PhD Miloš Milovančević, FME Nis (Serbia)
PhD Mirko Blagojević, FE Kragujevac (Serbia)
PhD Miroslav Milutinovic, FME UES (B&H)
PhD Srđan Vasković, FME UES (B&H)
PhD Nikola Tanasić. FME Belgrade (Serbia)
PhD Goran Orašanin, FME UES (B&H)
PhD Lozica Ivanović, FE Kragujevac (Serbia)
PhD Dragoljub Živković, FME Nis (Serbia)
PhD Biljana Markovic, FME UES (B&H)
PhD Milija Kraišnik, FME UES (B&H)
PhD Ranko Antunovic, FME UES (B&H)
PhD Milosav Ognjanović. FME Belgrade (Serbia)
PhD Slaviša Moljević, FME UES (B&H)
PhD Vlado Medaković, FME UES (B&H)
PhD Aleksandar Košarac, FME UES (B&H)
PhD Milan Zeljković, FTS Novi Sad (Serbia)
PhD Jelena Jovanovic, FME Podgorica (MNE)
PhD Snezana Nestic, FE Kragujevac (Serbia)
PhD Dragan Milčić, FME Nis (Serbia)
PhD Novak Nedić, FMCE Kraljevo (Serbia)
PhD Slobodan Tabaković, FTS Novi Sad (Serbia)
PhD Miroslav Živković, FE Kragujevac (Serbia)
PhD Aleksandar Zivkovic, FTS Novi Sad (Serbia)
PhD Vojislav Filipović, FMCE Kraljevo (Serbia)
PhD Mladomir Milutinovic, FTS Novi Sad (Serbia)

INTERNATIONAL SCIENTIFIC COMMITTEE

PhD Biljana Marković, FME UES (B&H) – president
PhD Vojislav Novaković, NTNU Trondheim (Norway)
PhD Nenad Gubeljak, TF Maribor (Slovenia)
PhD Athanasios Michailidis, AUT (Greece
PhD Radivoje Mitrović, FME Belgrade (Serbia)
PhD.-Ing. Albert Albers, University of Karlsruhe (Gemrmany)
PhD Aleksandar Veg, FME Belgrade (Serbia)
PhD Ranko Antunović, FME UES (B&H)
PhD.-Ing. Ljubomir Dimitrov TU Sofia (Bulgaria)
PhD Milosav Ognjanović, FME Belgrade (Serbia)
PhD Vojislav Miltenović, FME Niš (Serbia)
PhD Imre Kiss, University Politehnica Timisoara (Romania)
PhD Slavko Krajcar, FER Zagreb (Croatia)
PhD Nebojša Radić, FME UES (B&H)
PhD Tale Geramitčioski, UKLO Bitola (FYROM)
PhD Miroslav Živković, FE Kragujevac (Serbia)
PhD Slavko Arsovski, FE Kragujevac (Serbia)
PhD Zoran Ljuboje, FEE UES (B&H)
PhD Dušan Golubović, FME UES (B&H)
PhD Zoran Markov, FME Skoplje (FYROM)
PhD Adisa Vučina, FMEC Mostar (B&H)

PhD. - Ing. Miroslav Vereš, SUT Bratislava (Slovakia)
PhD Ranko Božičković, FTE UES (B&H)
PhD Dragan Milčić, FME Niš (Serbia)
PhD Radoslav Tomović, FME Podgorica (MNE)
PhD Ljubodrag Tanović, FME Belgrade (Serbia)
PhD Siniša Kuzmanović, FTS Novi Sad (Serbia)
PhD Miroslav Milutinović, FME UES (B&H)
PhD Dragiša Vilotić, FTS Novi Sad (Serbia)
PhD Milija Kraišnik, FME UES (B&H)
PhD Milan Zeljković, FTS Novi Sad (Serbia)
PhD Milenko Obad, FMEC Mostar (B&H)
PhD Novak Nedić, FMCE Kraljevo (Serbia)
PhD Petar Gvero, FME Banja Luka (B&H)
PhD Srđan Vasković, FME UES (B&H)
PhD.-Ing. Sava Ianici, University of Resita "Eftimie Murgu" (Romania)
PhD Fuad Hadžikadunić, FME Zenica (B&H)
PhD Milomir Gašić, FMCE Kraljevo (Serbia)
PhD Mirko Blagojević, FE Kragujevac (Serbia)
PhD Sead Pašić, FME University „Džemal Bijedić“ Mostar (B&H)
PhD Mircea Viorel Dragoi, University Transilvania, Brasov (Romania)
PhD Milentije Stefanović, FE Kragujevac (Serbia)
PhD Stojan Simić, FME UES (B&H)
PhD Ljubomir Lukić, FMCE Kraljevo (Serbia)
PhD Slaviša Moljević, FME UES (B&H)
PhD Zdravko Krivokapić, Podgorica (CG)
PhD Bogdan Marić, FP UES (B&H)
PhD Darko Knežević, FME Banja Luka (B&H)
PhD Dragan Spasić, FTS Novi Sad (Serbia)
PhD Livia Dana Beju, EF UNI SIBIU (Romania)
PhD Nedeljko Vukojević, MFE Zenica (B&H)
PhD Sreten Perić, MA Belgrade (Serbia)
PhD Petar Novak, VŠTS Novo Mesto (Slovenia)
PhD Milovan Jotanovic, FT UES (B&H)
PhD Goran Orasanin, FME UES (B&H)
PhD Vlado Medaković, FME UES (B&H)
PhD Anto Gajic, FME UES (B&H)

ORGANIZING COMMITTEE

PhD Ranko Antunović, FME UES - president
PhD Biljana Marković, FME UES
PhD Slaviša Moljević, FME UES
PhD Miroslav Milutinović, FME UES
PhD Milija Kraišnik, FME UES
PhD Srđan Vasković, FME UES
PhD Saša Prodanović, FME UES
PhD Aleksandar Košarac, FME UES
MSc Aleksija Đurić, assistant, FME UES - Technical Secretary
MSc Nikola Vučetić, senior assistant, FME UES - Technical Secretary
MSc Ranka Gojković,senior assistant, FME UES- Technical Secretary
Vera Stanišić - Secretary

GENERAL SPONSOR

Ministry of Science and Technology Republic of Srpska

SPONSORS

The conference has been supported by:

IFToMM

International Federation for the Promotion of Mechanism and Machine Science

ADEKO

Association for Design, Elements and Constructions

EPC

ELEKTROPRIVREDA RS

Olimpijski centar JAHORINA

ИСТОЧНО САРАЈЕВО

ИСТОЧНО НОВО САРАЈЕВО

KOLEKTOR

MODRIČA OIL REFINERY

BOKSIT a.d. MILIĆI

alumina

NOVA BANKA

Turistička organizacija Istočno Sarajevo

PREFACE

Production in developed countries is based on the modernization and optimization of the production processes with the application of new technologies that are the result of scientific research. The application of new technology enables company's efficient production and competitiveness in the world market.

Faculty of Mechanical Engineering, University of East Sarajevo, organizes the Third international conference "COMETa2016 - Conference on Mechanical Engineering Technologies and Application", which has tasks: to increase economic competitiveness in the region and to give an contribution to creation of unique European Research Area.

Globally, we are witnessing a rapid development and a host of new technological solutions, which occur primarily in the multidisciplinary development (mechatronics) but also in development of completely new technologies, such as nanotechnology, biomaterials, bioengineering, new energy sources, intelligent machines and processes, micro-technique, etc. All of this puts researchers and engineers in the new challenges and creates opportunities for products and technologies that provide a precondition for economic recovery and creation of new jobs.

COMETa2016 conference program structure is consisted of the following thematic areas: Production technologies and advanced materials, Energy and environment, Applied mechanics and mechatronics, Development of products and mechanical systems, Quality and management and Organization and maintenance.

Participation in international conference COMETa2016 was achieved by: 202 authors from 9 countries, with a total of 78 papers, including 3 plenary lectures.

Inside of conference COMETa2016 has been planned organization of one working meeting and two round table discussion based on actual topics of conference. During the conference, it will be presented some of technical solutions produced in companies from our region.

The presence of a large number of participants from Bosnia and Herzegovina and abroad as well as the problems which are processed at the conference, coincide with the themes promoted by the European Union in its development programs.

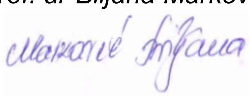
On the basis of previous exposure, a gathering of scientists and researchers at the international conference COMETa should be understood not only as an exchange of knowledge and achievements of the narrower set of scientists and researchers, but also as a constant and serious attempt to focus social consciousness and social life on activities that ensures progress and prosperity of any society, and that is productive work, creating new knowledge and economic development.

On behalf of the Organizing Committee and Scientitific Committiee of the Conference COMETa2016, we want to express our gratefullness to all authors, reviewers, as well as institutions, companies and individuals who contributed to realization of the Conference.

East Sarajevo, November 19th, 2016.

President of the Scientific Committee

Prof. dr Biljana Marković



President of the Organizing Committee

Prof. dr Ranko Antunović

C O N T E N T

APPLIED MECHANICS AND MECHATRONICS

Chairpersons: Vlatko Določek, Miroslav Živković, Novak Nedić

MACHINE DESIGN, SIMULATION AND MODELING

Chairpersons: Dragan Milčić, Mirko Blagojević, Lozica Ivanović

MANUFACTURING TECHNOLOGIES AND ADVANCED MATERIALS

Chairpersons: Milentije Stefanović, Milan Zeljković, Ljubodrag Tanović

PRODUCT DEVELOPMENT AND MECHANICAL SYSTEMS

Chairpersons: Radivoje Mitrović, Adisa Vučina, Siniša Kuzmanović

RENEWABLE ENERGY AND ENVIRONMENTAL

Chairpersons: Slavko Krajcar, Petar Gvero, Stojan Simić

MAINTENANCE, QUALITY AND ORGANIZATION

Chairpersons: Mitar Jocanović, Ranko Božičković, Snežana Nestić

STUDENT SESSION

Chairpersons: Saša Prodanović, Aleksandar Košarac, Srđan Vasković

CIP - Каталогизација у публикацији
Народна и универзитетска библиотека
Републике Српске, Бања Лука

621.03(082)(0.034.4)

МЕЂУНАРОДНА научна конференција "Примијењене технологије у машинском инжењерству" COMET а (3 ; 2016 ; Источно Сарајево) Zbornik radova [Elektronski izvor] = Proceedings / 3. Međunarodna naučna konferencija "Primijenjene tehnologije u mašinskom inženjerstvu" COMETa 2016, Istočno Sarajevo - Jahorina 2016 =3rd International Scientific Conference "Conference on Mechanical Engineering Technologies and Applications" COMETa 2016, East Sarajevo - Jahorina 2016. ; [urednici, editors Biljana Marković, Ranko Antunović]. - 1 izd. - Istočno Sarajevo : Mašinski fakultet, 2016. - 1 optički disk (CD-ROM) : tekst ; 12 cm

Sistemski zahtevi nisu navedeni. - Radovi na srp. i engl. jeziku. - Napomene i bibliografske reference uz tekst. - Bibliografija uz svaki rad. - Rezimei na engl. i srp. jeziku.

ISBN 978-99976-623-7-8

COBISS.RS-ID 6240280

ISBN 978-99976-623-7-8

COMETa 2016
3rd INTERNATIONAL SCIENTIFIC CONFERENCE
7th - 9th December 2016
Jahorina, Republic of Srpska, B&H
University of East Sarajevo
Faculty of Mechanical Engineering
Conference on Mechanical Engineering Technologies and Applications

EXPERIMENTAL AND NUMERICAL STRENGTH ANALYSIS OF WAGON FOR CONTAINERS TRANSPORTATION

Vladimir Milovanović[1], Miroslav Živković[2], Gordana Jovičić[3], Aleksandar Dišić[4], Miroslav Milutinović[5]

Abstract: This paper presents comparative experimental and numerical strength analysis of wagon for containers transportation according to the TSI standard and norm EN 12663-2:2010. The aim of this analysis is to show that results of stresses obtained by measuring with strain gauges and stresses obtained by FEM calculation gives good agreement. Based on the results and their good match, it can be concluded that the numerical FEM analysis can be reliably used for structural analysis. According to this fact, FEM analysis can reduce number of the testing new products. This leads to great savings in the design of new prototypes, in order to immediately start the process of mass production. This would lead to significantly less cost of products.

Key words: FEM, Wagon analysis, Fatigue strength analysis

1 INTRODUCTION

Numerical simulations are widely used for solving various problems in industry because they reduce time and cost in developing new products. Simulation results provide very useful information about the product and can indicate the potential problems that can be eliminated in design phase.

The next step in projecting phase is making a prototype, based on the results obtained using FEM. When the prototype testing is finished, it is very important to make a comparative analysis of the results obtained by FEM calculation and by measurements on a prototype. Measurement results and results obtained by FEM calculation must meet all requirements for static and fatigue strength according to standards.

According to TSI standard [1] and norm BS EN 12663-2:2010 [2], static and

[1] PhD, Vladimir Milovanović, Faculty of Engineering University of Kragujevac, Kragujevac, Serbia, vladicka@kg.ac.rs (CA)

[2] PhD, Miroslav Živković, Faculty of Engineering University of Kragujevac, Kragujevac, Serbia, miroslav.zivkovic@kg.ac.rs

[3] PhD, Gordana Jovičić, Faculty of Engineering University of Kragujevac, Kragujevac, Serbia, gjovicic.kg.ac.rs@gmail.com

[4] PhD student, Aleksandar Dišić, Faculty of Engineering University of Kragujevac, Kragujevac, Serbia, aleksandardisic@gmail.com

[5] PhD, Miroslav Milutinović, Faculty of Mechanical Engineering University of East Sarajevo, East Sarajevo, B&H, m.milutinovic82@gmail.com

fatigue strength analysis of wagon for for containers transportation are done. Measurement of stresses with strain gauges was done on a prototype, and those results were compared with stresses obtained by FEM calculation.

2 FEM MODEL

The Sgmns wagon is designed for the transportation of containers and swap bodies (SBs), within block trains. According to detailed analysis [3] it was concluded that strength of the bottom part of underframe does not satisfy requirements according to the standards and the cause of cracking nearby welded joint on the bottom part of underframe at wagon Sgmns type was determined. The new construction solution for the bottom part of underframe is proposed and new analysis of strengthened wagon was done.

FEM model is created using the FEMAP software [4]. According to the construction type, rectangular and triangular (four and three nodes respectively) shell elements of the appropriate thickness and 3D eight node elements (for modeling of support plate, compensating ring, traction stop) are used for creating the finite element mesh. The structure is modeled in details with 59583 elements and 61200 nodes. The element length is approximately 40 mm.

3 SAFETY FACTOR, PERMISSIBLE STRESS, LOAD CASES AND REQUIREMENTS

According to BS EN 12663-2:2010 [2], Clause 6.2.2.1, Table 18 and Table 19, and to dependence on mechanical characteristics of material (structural steels S235JRG2 and S355J2+N), permissible stresses in parent material and in parent material in the immediate vicinity of welds can be calculated under the static load cases as defined in BS EN 12663-2:2010. The ratio of yield stress ($R=R_e$) to calculated stress (σ_c) must be greater than or equal to S_1, Table 1.

Table 1. *Safety factor and permissible stress for static loads – parent material and welded joints*

Material	Safety factor S_1	σ_{cmax} [MPa]
S235JRG2	1.0	235
S355J2+N	1.0	355
Parent material in the immediate vicinity of welds S235JRG2	1.1	214
Parent material in the immediate vicinity of welds S355J2+N	1.1	323

Based on that fatigue load is used in the range of $\pm$30% of vertical static load we can calculate the value of the maximum stress at the fatigue load based on static analysis, [3]:

$$\sigma_{\max} = 2.1667 \Delta\sigma_c \tag{1}$$

Table 2 shows limit values for static test to verify fatigue strength which are determined for minimum number of 2 million constant amplitude cycles in accordance with Eurocode 3, Part 1.9 [5], using Figure 7.1 and Table 3.1.

Table 2. *Limit stress values for static test to verify fatigue strength*

Direct stress range $\Delta\sigma_c$ [MPa]	Permissible maximum fatigue stress $\sigma_{\max\lim}$ [MPa]	Limit stress for safe life [MPa]	
		Low consequence ($\gamma_{Mf} = 1.15$)	High consequence ($\gamma_{Mf} = 1.35$)
160[1]	347	301	257
112[2]	243	211	180
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

According to TSI [1] and BS EN 12663-2:2010 [2], it is necessary to calculate the wagon structure in a relation to the different types of loads. Exceptional load cases are specified in TSI [1], Clause 4.2.2.3.2 and BS EN 12663-2:2010 [2], Clauses 5.2.2-5.2.3. For all exceptional load cases maximum value of calculated stress must be lower than the permissible stress shown in the Table 2.3.1. Service (fatigue) loads are specified in TSI [1], Clause 4.2.2.3.3 and BS EN 12663-2:2010 [2], Clause 5.2.5. For service (fatigue) loads maximum value of calculated stress in welded joints must be lower than the limit stress for the safe life in the Table 2.

4 MEASURING AND POSITION OF STRAIN GAUGES

According to the results obtained by FEM calculations for all of the load cases defined in accordance with TSI standard and with British Standard EN 12663-2:2010, strain gauges were set up on prototype of the wagon and measurements were carried out. Strain gauges showed the results of stresses at those locations.

Position of strain gauges is selected so that it covers all the places on the wagon where the numerical calculations showed the stress concentration. For the comparative analysis the most favorable case of vertical load was used. Photos and position of strain gauges is shown in Figure 1.

Figure 1. *Position of strain gauges*

[1] Limit stress for the safe life in parent material in steel S355J2+N

[2] Limit stress for the safe life in parent material in steel S235JRG2

5 COMPARATIVE RESULTS OF STRESSES

For all load cases linear static analysis was performed. Structural steels S235JRG2 (with 235 MPa and 360 MPa as yield limit and failure limit) and S355J2+N (with 355 MPa and 470 MPa as yield limit and failure limit) are used for all structural elements. Both types of steel have same material characteristics ($2.1\ 10^5$ MPa, $7.85\ 10^{-6}$ kg/mm3 and 0.3 as Young Modulus, density and Poisson ratio).

The values of stresses at the locations of strain gauges were obtained for all cases of static loads and static test for verification of fatigue strength. The measured values of stresses at the locations of strain gauges and the values of stresses obtained from the FEM calculations, using software PAK [6], were compared.

The aim of the analysis was to show that the results obtained by measurement and calculations based on FEM gave similar values of stress, bellow the values of permissible stress defined according to TSI and BS EN 12663-2:2010.

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

Table 3. *Comparative results obtained by strain gauges and FEM analysis for* the most favorable case of vertical load

Stresses [MPa]			
Strain gauge number	Measured value	FEA	Permissible stress
1	49	47.9	239
4	52	56.3	309
5	-44.2	-46.8	239
7	114.1	116.8	309
8	87.3	91.6	309
9	-56.3	57.7	239
10	-61.6	-63.0	239
11	114.8	137.3	309
13	-52	-88.6	209
16	95.1	97.1	239
18	203.8	206.0	309
19	185.5	191.2	309
21	-46.6	-70.1	209
22	-74.6	-76.8	239
25	-46.7	-73.2	239
27	179.9	191.7	309
30	126.3	139.6	309
31	120.6	138.8	309

The aim of this comparative analysis was to compare the values of stresses obtained experimentally by strain gauges and stresses obtained by FEM calculation. By comparing the numerical results with measurement results it was confirmed good agreement of results. The difference between the results obtained by strain gauges, and the results obtained by FEM analysis is less than 5%.

6 FATIGUE LOADS - CALCULATION RESULTS

For the most conventional wagon designs, the loading defined in Table 14 of EN12663 is considered as sufficient to represent the full effective combination of fatigue load cycles. Source of fatigue loading is determined according to TSI, Annex CC. Based on the results obtained by analyzing the static strength of the wagon and considering the good match of results obtained by experiment and by FEM analysis, it can be concluded that the fatigue strength of the wagon can be checked using the results of the static test, Table 2.

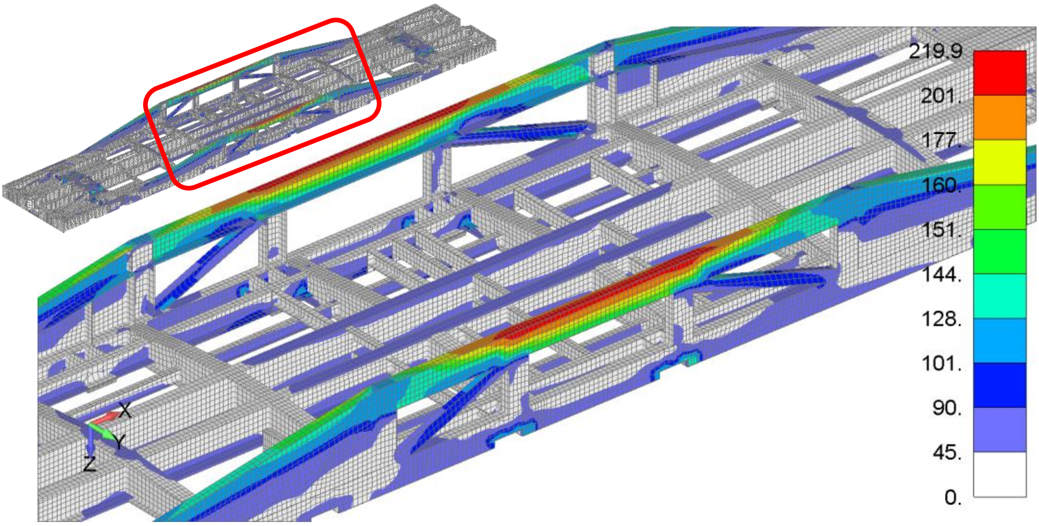


Figure 2. *Von Mises equivalent stress field – underframe*

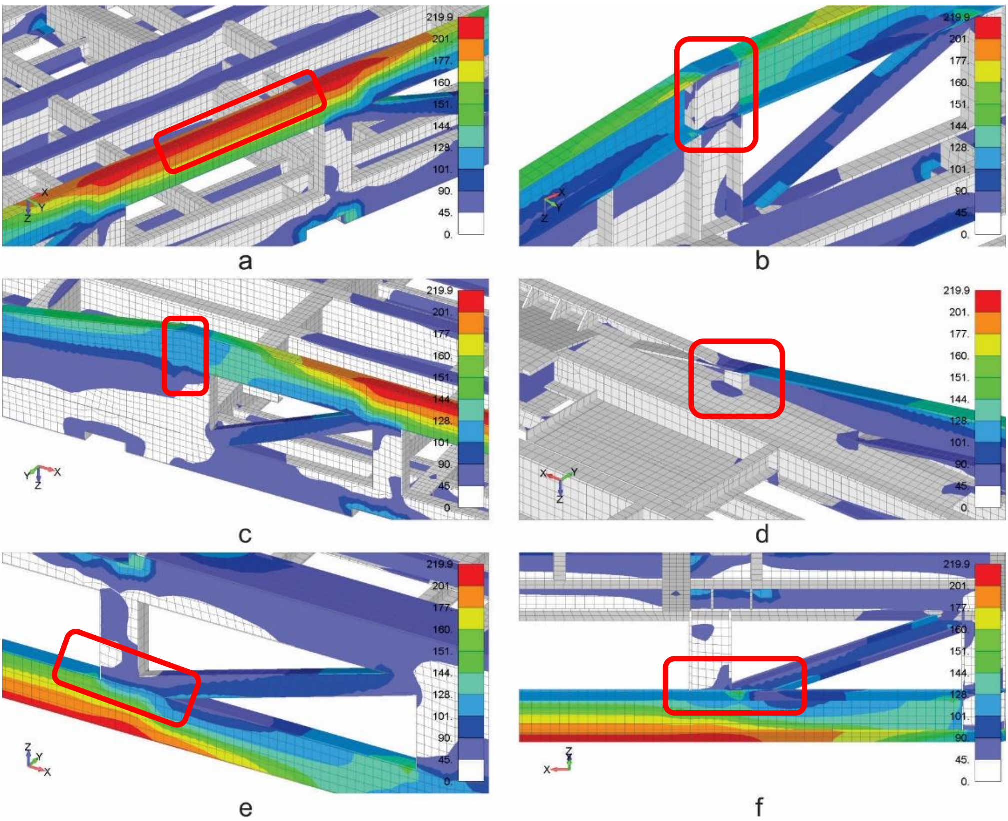


Figure 3. *Von Mises equivalent stress field – underframe; significant loaded zones*

Figure 2 show field of von Mises equivalent stress in underframe for the most unfavorable case of vertical load. Figure 3 shows significant loaded zones in underframe. Stress levels used in the legend in Figures 2 and 3 are defined according to Table 2. Table 3 shows the maximum values of stress in welded joints.

Table 4. *The maximum value of stresses in welded joints*

Figure No	Detail category	Table and detail, Eurocode 3, Part 1.9	Max. calculated stress [MPa]	Limit stress for safe life [MPa]
4a	160	Parent material	219.9	257
4b	100	Table 8.2 – d6	149.0	160
4c	90	Table 8.3 – d6	128.6	144
4d	71	Table 8.3 – d13	95.6	114
4e	100	Table 8.2 – d6	148.3	160
4f	100	Table 8.2 – d6	132.9	160

Based on calculated stresses (Table 3) and limit stresses given in Table 2, it can be concluded that all calculated stresses in the parent material and welded joints are below limit stress for safe life for appropriate weld type.

7 CONCLUSIONS

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

ACKNOWLEDGMENT

The part of this research is supported by Ministry of Education, Science and Technological Development, Republic of Serbia, Grant TR32036.

REFERENCES

[1] TSI Standard – Freight wagons of the trans-European conventional rail system
[2] EN 12663:2000 – Railway applications – Structural requirements of railway vehicle bodies, European Standard
[3] FEMAP Version 10, User Guide, Siemens Product Lifecycle Management Software Inc, Munich – Germany, 2009
[4] Milovanović, V., Dunić, V., Rakić, D., Živković, M.(2013): Identification causes of cracking on the underframe of wagon for containers transportation - Fatigue strength assessment of wagon welded joints, Engineering Failure Analysis, Vol.31, pp. 118-131, ISSN 1350-6307
[5] Eurocode 3: Design of steel structures – Part 1.9: Fatigue
[6] Živković, M., Kojić, M., Slavković, R., Grujović, N.(2003) PAK-S Program for FE structural analysis, Faculty of Mechanical Engineering, University of Kragujevac, Serbia