



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

COMET α 2016

3rd INTERNATIONAL SCIENTIFIC CONFERENCE

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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.

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

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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 Scientific Committee of the Conference COMETA2016, we want to express our gratefulness 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



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PRESENTATIONS OF PARTICIPANTS

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 a (3 ; 2016 ;
Источно Сарајево) Zbornik radova [Elektronski izvor] =
Proceedings / 3. Међународна научна конференција
"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

Системски захтеви нису наведени. - Радови на срп. и енгл. језику. -
Напомене и библиографске reference уз текст. - Библиографија уз
сваки рад. - Резимеи на енгл. и срп. језику.

ISBN 978-99976-623-7-8

COBISS.RS-ID 6240280

ISBN 978-99976-623-7-8





EXPERIMENTAL AND NUMERICAL STRENGTH ANALYSIS OF WAGON FOR CONTAINERS TRANSPORTATION

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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

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fatigue strength analysis of wagon 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]:

$$\sigma_{max} = 2.1667 \Delta \sigma_c \quad (1)$$

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 $\sigma_{\max \text{ lim}}$ [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 ($2.1 \cdot 10^5$ MPa, $7.85 \cdot 10^{-6}$ 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, below 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.

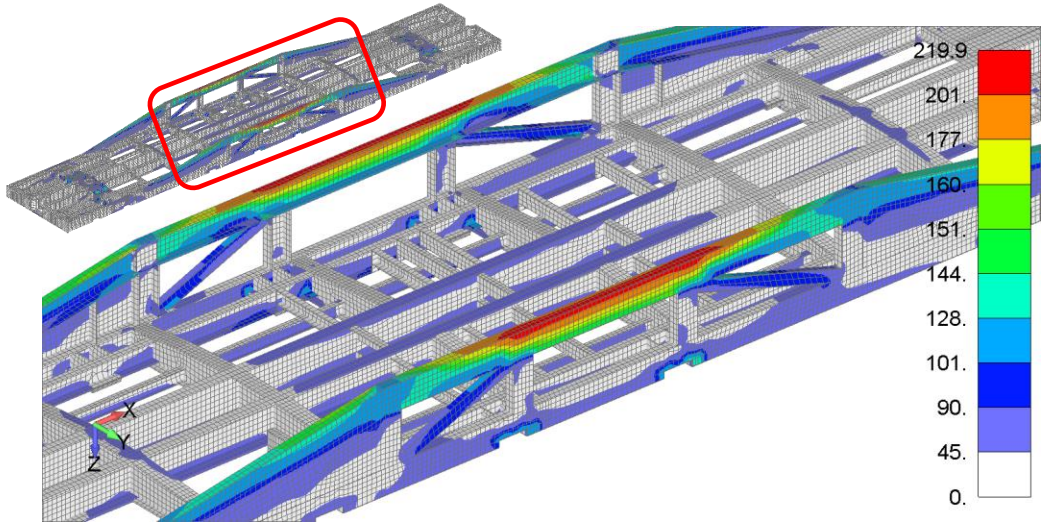


Figure 2. Von Mises equivalent stress field – underframe

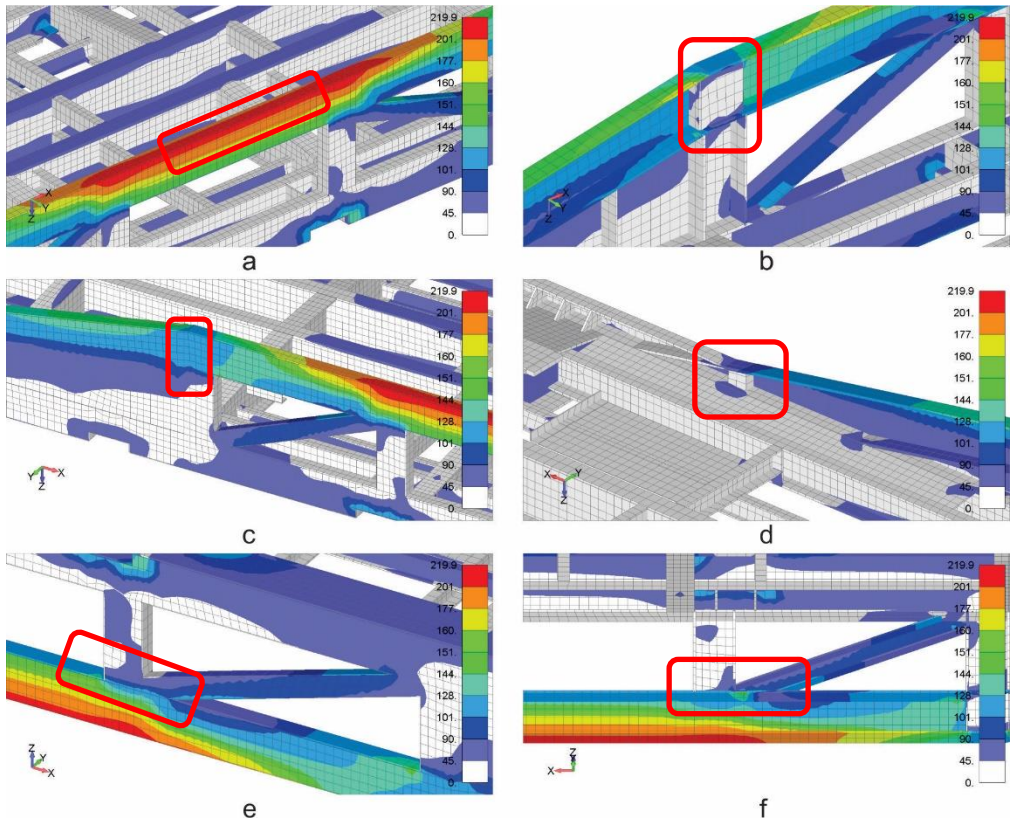


Figure 3. Von Mises equivalent stress field – underframe; significant loaded zones

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.

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