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Development of numerical-experimental model of connecting lugs and application on the lugs calculation of container terminals

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Abstract

The present paper describes numerical and experimental methodology and development of the model for stress and deformation state analysis of the connecting lug of container terminals. Numerical analysis was conducted by applying the finite element method in a "KOMIPS" software package. Experiments were performed at the Laboratory for stress and deformation measurements, Faculty of Mechanical Engineering, Belgrade University, using "GOM" equipment and "ARAMIS" software application. This paper demonstrates how it is possible to anticipate the results by applying FEM. This paper will present how experimental results can be predicted using the finite element method. The paper presents an overview of the existing research and review of previous results achieved in this field. Container terminal used to supply electrical energy and management system of conveyor belts that are used in the exploitation of the mining basins. Stress and deformation state analysis of the connecting lugs is carried out at the loading of the container.

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Keywords: connecting lug; FEM; experiment; stress; deformation

1. Introduction

This section presents a review of hitherto conducted research and results achieved in the area of stress and deformation state of structural elements with geometrical discontinuities. It is necessary to reliably determine exploitation behavior of structural elements by applying contemporary numerical-experimental methods. The

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objective of the paper is to investigate stress and deformation field at the points of geometrical discontinuities of structural elements under the action of axial loading. Theoretical and experimental investigations show that in the zones, where the loaded element contour changes abruptly the local increase of stress occurs. Such zones are notches, holes of different shapes, points of abrupt curvature, as well as contact points between two elements mutually acting upon each other. Peterson earlier reported the results from this field [1]. The most common examples causing stress concentration are given in [1-3]. The investigation was carried out using the connecting lug type models loaded by axial forces. Numerical results for the problem of stress distribution around the hole of axially loaded plates are given in [4]. Experimental results and the results obtained by numerical methods from above mentioned fields were reported in [5-7]. All designed and constructed structures inevitably have a change in geometry that causes stress concentration. Current standard methods of calculations and testing cannot accurately determine and anticipate the intensity of geometrical discontinuity effect on the structure deformation and stress. At the end of the paper, the developed model was applied to the lug calculation of the container terminal at the loading.

2. Analysis of connecting LUG

Geometric shape of analyzed connecting lug structural element made of structural steel S355 is presented in Fig. 1. The analysis included three connecting lug with dimensions as shown in Tab. 1.

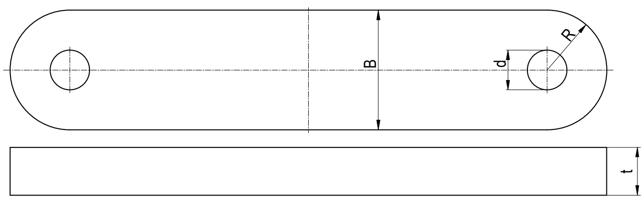


Figure 1. Geometric shape of analyzed connecting lug

Table 1. Dimensions of connecting lug according to Fig. 1

Designation of con. lug	d mm	R mm	B mm	t mm
U1	8	12,5	25	10

The connecting lug U1 is loaded with axial force. The value of the axial force is F = 10000N. The values of the mechanical characteristics of the S355 material are shown in Tab. 2 [8].

Table 2. Mechanical characteristics of the material S355

Yield stress R_e MPa	Tensile strenght R_m MPa	Yuong modulus MPa	Poisson's ratio mm
355	490-630	$2,1\ 10^5$	0,3

3. Finite Element Analysis

The FEM analysis is one of the most widely used engineering analysis techniques to solve different engineering problems. In this paper, numerical analysis was conduced by the application of finite elements using „KOMIPS“ software [9, 10].

A model was created to consist of two components: the plate type and the bar type. The contact between the axle and the lug was modelled via stiff bars. The axle was considered to be a stiff component and loading was entered through it. Figure 2 presents finite element meshes of the appropriate connected lug. Figure 3 shows deformation of a connecting lug U1.

U1

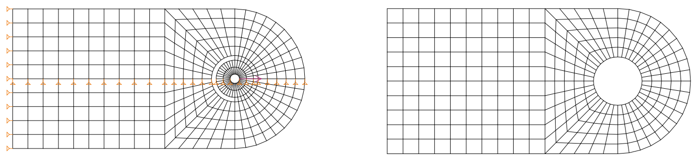


Figure 2. Calculation model of the connecting lug

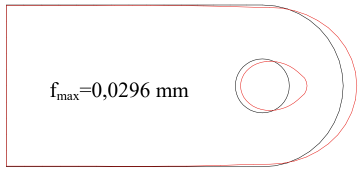


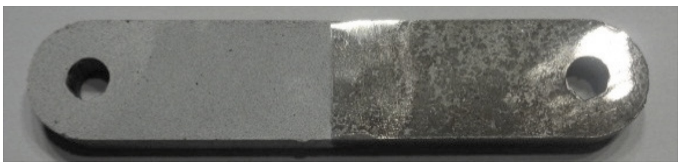
Figure 3. Deformation of the U1 model

Figure 4. Representation of von Mises stress field (σ) with associated scale for connecting lug U1

4. Experimental work

The aim of experimental investigation was to verify the numerical calculation of the model using physical (previously built) laboratory models. The experiment was performed at the Laboratory for stress and deformation measurements, Faculty of Mechanical Engineering, Belgrade University. A fairly new experimental method for contactless measurements, for threedimensional optical strain and stress analysis based on Digital Image Correlation (Aramis−system) was used [11, 12].

To perform the measurements, a stochastic pattern must be applied onto the measuring points. The stochastic pattern is formed in such a way as to first apply white matte spray paint, and later black paint is lightly applied from a certain distance, so that black spots are formed (Fig. 5).



U1

Figure 5. Stochastic pattern applied onto measuring points

Experiment setup is presented in Fig. 6. The vertical force is caused by the hydraulic cylinder leaning against the upper horizontal beam. The aim was to keep loading in a closed contour of the rigid frame, where two horizontal beams of the frame and vertical beams make up a closed contour. Arrangement of measuring equipment is presented in Fig. 7. Each performed measurement implied gradual input of the force by using the hydraulic cylinder, at a 10 kN pitch. Reading and control of force input was done using a dynamometer with measuring tapes, which was attached to a data acquisition device (Fig. 8).

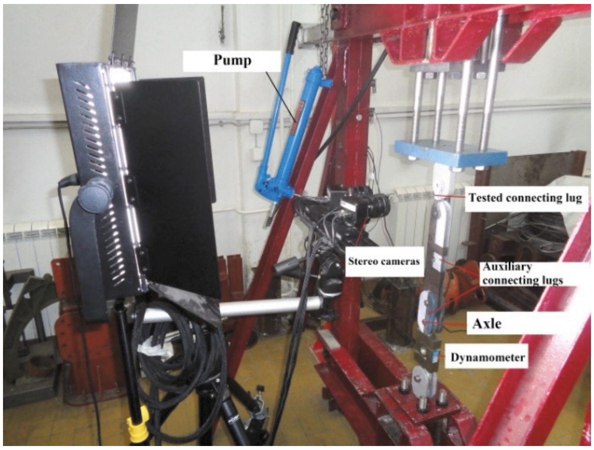


Figure 6. Experiment setup

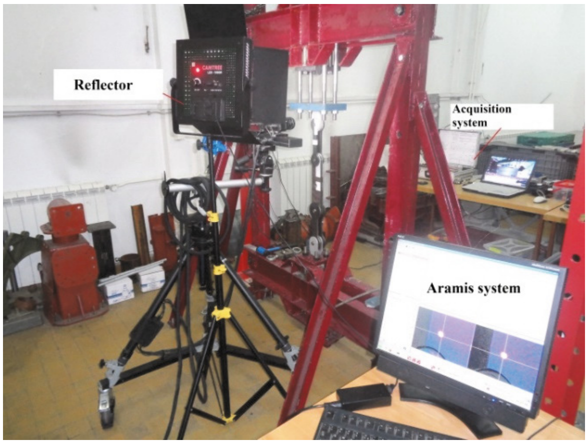


Figure 7. Arrangement of measuring equipment

Figure 8. Appearance of data acquisition system

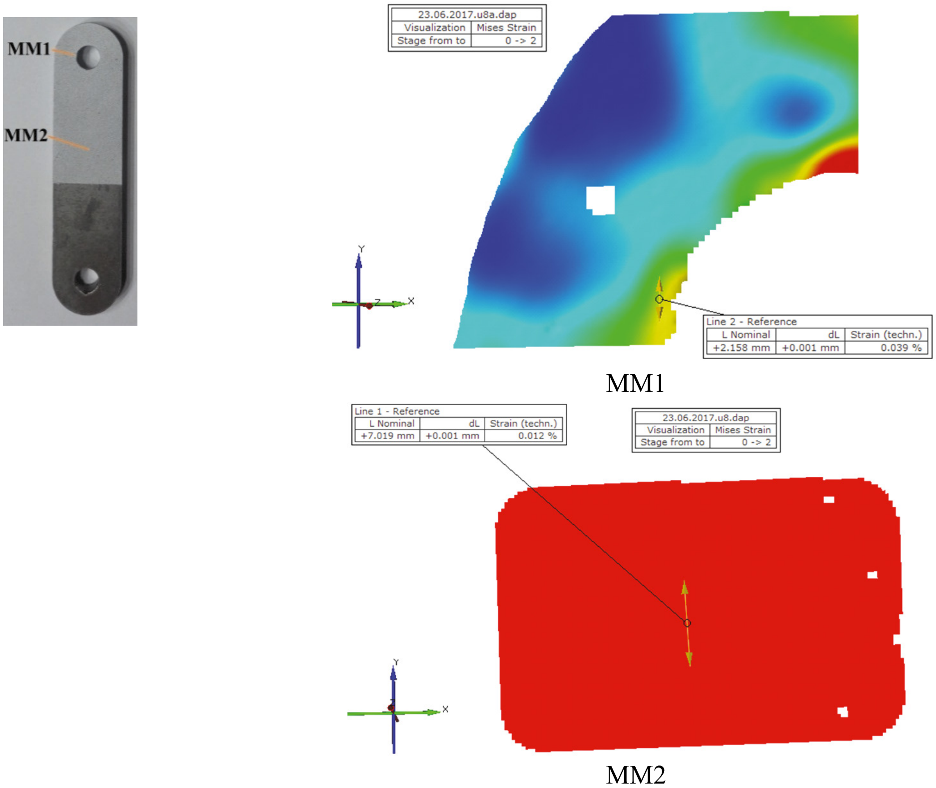


Figure 9. Appearance of data acquisition system (MM1-measuring place 1, MM2-measuring place 2)

5. Discussion

The equivalent Von Mises stress around the lug hole, obtained numerically by applying MKE analysis and experimentally, is shown in Tab. 4. The stress obtained experimentally is calculated in such a way so that values from the table in Fig. 9 are calculated according to the expression (1).

$$\sigma = \frac{\mathrm{dL}}{\mathrm{L\ Normal}} \mathrm{E} \quad (1)$$

where E is modulus of elasticity of the material.

Table 3. Comparative analysis of the obtained results

Designation of con. lug	FEM Analysis σ MPa	Experiment for MM1 σ MPa
U1	100	93

Table 3 shows the results obtained by KOMIPS software package, as well as the results obtained experimentally. It can be concluded that the values obtained for Von Mises stress are approximate. Based on the experiments, future work in this field may employ numerical models from our paper, because conducting experimental investigations on real structures are complicated and costly.

6. Application of developed model to lug calculation of container terminal

Control of connecting lug container terminal was carried out at its loading onto the truck that will transport it. A crossbar was used at the loading, on which there are lugs to attach loading ropes diagonally across the container base so as to avoid the bending of lugs about the axis, with a minimum moment of inertia. The crossbar lugs for the connection with the container lugs are vertically positioned, so that the container terminal lugs are loaded in one direction. The loading ropes are positioned at the angle of 60° relative to the container base diagonals. By decomposing the forces from the rope, it is possible to obtain the forces that load the connecting lug container terminal. Container structure is displayed in Fig. 11. The material that the structure is made from is steel S235. Values of basic mechanical characteristics of the material S235, shown in Tab. 4, [8]. The container terminal model is shown in Fig. 10.

Table 4. Mechanical characteristics of the material S235

Yield stress R_e MPa	Tensile strenght R_m MPa	Yuong modulus MPa	Poisson's ratio mm
235	340-470	2,1 10^5	0,3

Figure 10 Container terminal

Model and working drawing of the lug container terminal is represented in Fig. 11. The lug is welded to the container column by angular seams. The analysis of the entire structure included calculations of the welded joints as well. The load with the load of the container is F=68670 N. The force is obtained by decomposing the force in the loading rope. Figs 12-14 present FE mesh and results fro displacements and stresses.

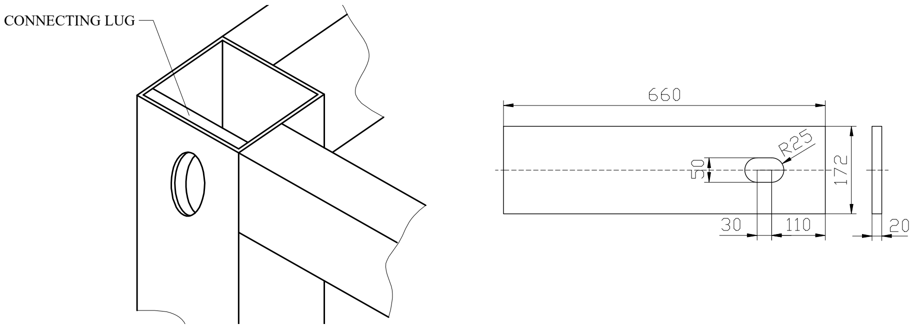


Figure 11 Drawings of the connecting lug of container terminal

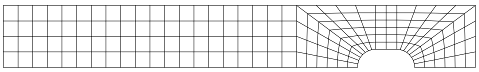


Figure 12 Calculation model of the connecting lug of container terminal

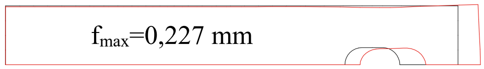


Figure 13 Deformation of the model of the connecting lug of container terminal

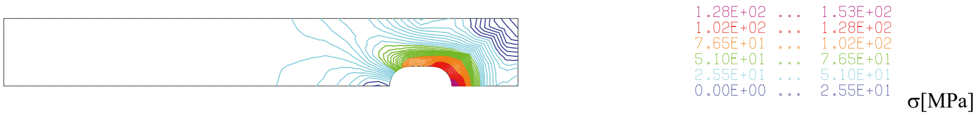


Figure 14 Representation of von Mises stress field (σ) with associated scale for connecting lug of container terminal

7. Conclusion

This paper presents the results of investigations in the field of stress and deformation state of the connecting lugs. A numerical-experimental model is developed and applied to a real structure. Stresses and deformations are situated within allowable limits. Lifting of the container onto the truck was safely done. Lifting of the container can be performed only by a licensed person with appropriate lifting equipment and devices. During container loading and unloading nobody should stand in the zone of container within radius of 15 m. All manipulation equipment (hoists, ropes, carrier belts, hooks, etc.) should have adequate carrying capacity and a valid control documentation.

Acknowledgements

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