# EXPERIMENTAL AND NUMERICAL INVESTIGATION OF SLIDING BOLT CONNECTION ON THE TANK WAGON

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## 1. Introduction

The problem considered in this paper relates to the correct modelling of the sliding bolt connection [1,2], in the strength analysis of the tank wagon in accordance to the standard [3]. Due to the complexity of the geometry and the FEA model with large number of contact pairs and bolt connections, it is necessary to find the easiest way for modelling bolt connections, which will fully correspond to the bolt connections on real model.

## 2. Problem description

During exploitation the wagon is exposed to thermal loads. In order to allow free expansion and to avoid the occurrence of significant deformations, one side of the wagon is designed to allow the relative sliding of the tank along the longitudinal direction in relation to the side wings. On the other side the tank is connected with fixed bolt connection for underframe side wings. The wagon structure is made so that there are three basic connection between its parts: connection between the tank and saddle (contact pair), middle connection (combination – contact pair and sliding bolt connection) and side connections between side wings and tank (combination – contact pair and sliding bolt connection; combination – contact pair and fixed bolt connection on the side of hand brake). The tank is leaning on the saddles, which are located above the main transverse girders.

The tank is connected to the side wings with 60 bolts, 15 per one connection, while the middle connection is achieved by the 8 bolts. It means that there are 30 fixed and 38 sliding bolt connections in the FEA model.

Bolt connections are modelled using the beam element. At the place of fixed bolt connection, all degrees of freedom are disabled, while sliding bolt connection using the "beam release" option allows sliding in the direction of the groove. The initial bolt preloads of all bolts in the bolt connections are in accordance with [4].

## 3. Functionality of modeled bolt connections

In order to verify the correct method of modelling and functionality of bolt connections, calculation results are shown to demonstrate the behavior of the FEA model for different types of loads. Due to the fact that the sliding, or relative displacement of the tank in relation to the wagon's chassis, is the most dominant for horizontal loads, in Figure 1, the longitudinal displacement field of the wagon is shown, for load case - compressive force at buffer level; F=1000kN at each buffer.

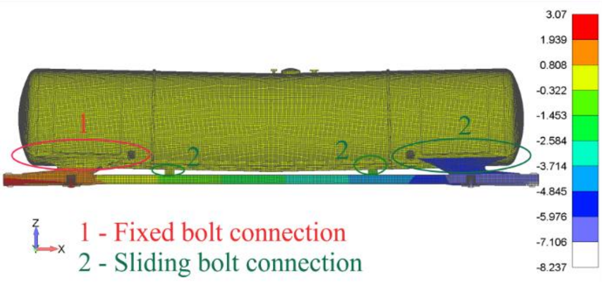


**Fig. 2.** Longitudinal displacement field – compressive force at buffer level; F=1000kN at each buffer.

Based on the displacement field shown in Figure 2, the character of the behavior of bolt connections is clearly seen. At the place of the sliding bolt connection, it can be seen that there is a difference in the values of the tank displacement and displacement of the wagon chassis at the place of the sliding bolt connection, Figure 3. At the place of the fixed bolt connection, it can be seen that there is no relative displacement of the tank in relation to the wagon chassis, Figure 4.

## 4. Comparative analysis of obtained results

Prototype of the tank wagon was made and measurements for all load cases defined in accordance with the relevant standards had done. Strain gauges were set up on prototype of the wagon and measurements were carried out in order to compare the values of the stress obtained by the experimental and numerical FEA analysis [5].

In the Table 1 are shown comparative results obtained by rosettes and appropriate von Mises equivalent stress obtained by FEA. In the Table 2 are shown comparative results obtained by strain gauges and appropriate normal stress obtained by FEA. A special attention is placed on measuring points near the sliding bolt connection, which is also the primary goal of the research in this paper. The results are presented only for those load cases that showed higher stress values at control measuring points (stress values above 200 MPa).

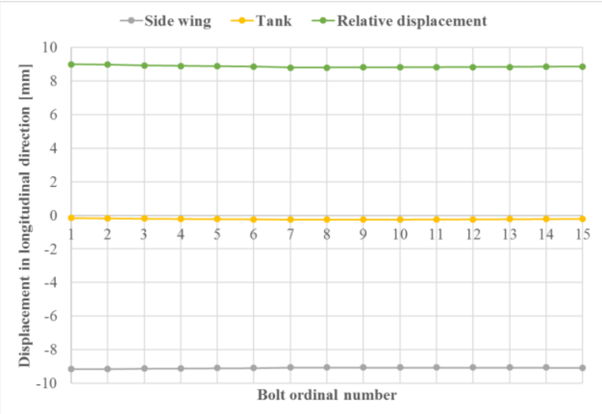


**Fig. 3.** Displacement in longitudinal direction – sliding bolt connection.

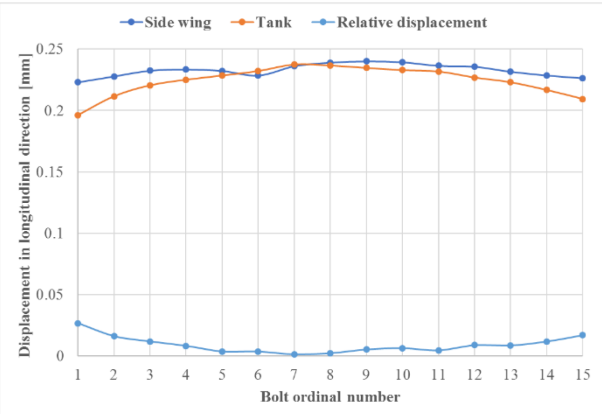


**Fig. 4.** Displacement in longitudinal direction – fixed bolt connection.

**Table 1.** Comparative results obtained by rosettes and FEA.

| Rosette mark | Measured stress [MPa] | FEA [MPa] |
|---|---|---|
| R01 | 282.7 | 259.9 |
| R02 | 221.3 | 218.1 |
| R05 | 230.3 | 258.5 |

**Table 2.** Comparative results obtained by strain gauges and FEA.

| Strain guages mark | Measured stress [MPa] | FEA [MPa] |
|---|---|---|
| T02 | 267.6 | 276.0 |
| T05 | -279.7 | -274.6 |
| T11 | 197.5 | 188.9 |
| T23 | -202.3 | -222.4 |
| T27 | -229.1 | -215.3 |

## 5. Conclusions

The aim of this paper was to take into account the effects of bolt connection on the complex model of tank wagon, which will completely correspond to the real connections. Using the "beam release" option for defining the beam elements for modelling the bolts, sliding was provided in the direction of the groove. Comparing the numerical results with the results of measuring, it is verified that FEA model gives good agreement with the experimental results. According to analysis of results, it has been concluded that modelled bolt connections in the manner shown in the paper really transfer loads to other parts of the wagon construction and can be used for analysis complex structures exposed to different types of loads.

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