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4th International Conference on Road and Rail Infrastructure
23–25 May 2016, Šibenik, Croatia

Road and Rail Infrastructure IV

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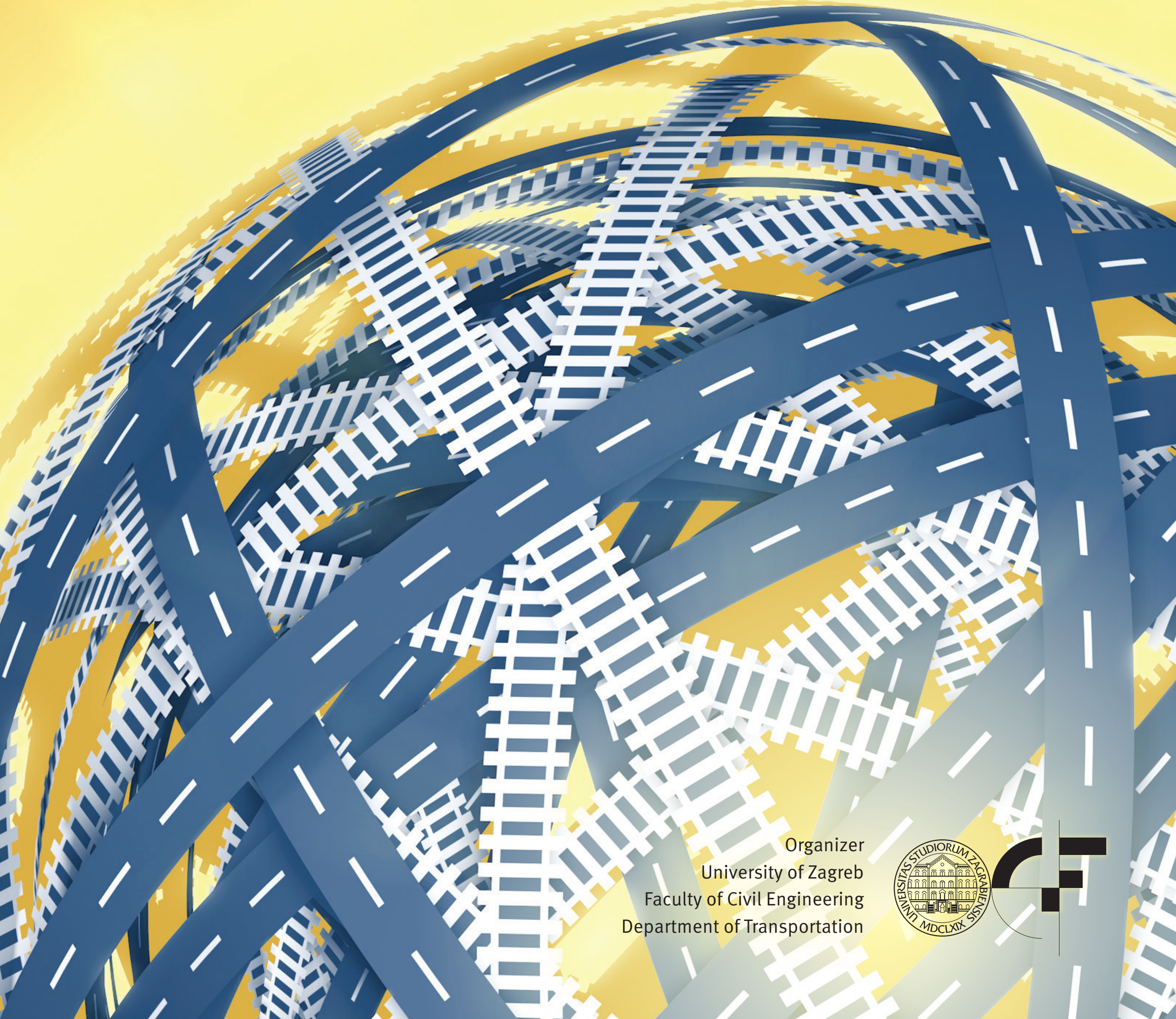

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Road and Rail Infrastructure IV

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SELECTED ASPECTS OF NUMERICAL AND EXPERIMENTAL STUDIES OF PROTOTYPE RAILWAY WAGON FOR INTERMODAL TRANSPORT

Wieslaw Krason, Tadeusz Niezgoda, Michal Stankiewicz
Military University of Technology, Poland

Abstract

A special wagon with a low rotatable loading platform for transportation of truck vehicles by rail was developed in Military University of Technology in Poland. The essence of such reloading is to place a semitrailer on a special rotatable platform with the use of a truck tractor. The structure can be used for transportation of different types of vehicles. The wagon allows quick and fast loading and unloading without any platform infrastructure or terminals. This type of railway wagon will allow transport companies to save time and money spending on road transport. The advantages of this construction are reduction of a negative impact on the environment as well as an increase of road safety by reducing the number of vehicles on the roads. As part of the work on the wagon and the intermodal transport system, a strength test of the wagon structure was carried out and the effort of the basic components of the wagon and a complete structure was estimated. In order to test the correctness of constructional assumptions and initially verify the wagon project, the dynamic analyses of the construction in different stages of its development were also carried out with the use of a multibody method and ADAMS code. Based on the performed strength tests of the wagon, it was verified that the most strenuous component of the wagon with a rotatable loading platform is a lock coupling the side of the rotatable platform with the over bogie part of the frame wagon. The construction of the applied lock allows only the transmission of axial load in respect to the side of the wagon. To analyse a side lock element, FE analysis was performed. The selected aspects of numerical and experimental studies of the prototype railway wagon and its components are presented in the paper.

Keywords: special railway wagon for intermodal transport, the subassemblies separated from the wagon structure, numerical analysis, experimental stand tests of the side lock

1 Prototype railway wagon for intermodal transport

A intermodal wagon [1, 2] with a low rotatable loading floor (Fig.1) for transportation of truck vehicles by rail is the subject of our consideration. This structure consist of the light and lowered bottom of the frame, the rotatable floor of the body for a transported load and the standard railway bogies [3, 4]. The wagon allows quick and fast loading and unloading without any platform infrastructure or terminals. The following constructional assumptions are made in the project of the special wagon for intermodal transport:

- mass of the semitrailer with load up to 40 tons, wagon weight up to 45 tons,
- meeting the requirements of GB 1 railway gauge,
- low placed rotatable loading floor for autonomous loading-unloading allowing individual loading-unloading of the wagon,

• application of standard biaxial bogies of Y25 type with allowed pressure on the axis 22.5 tons,
• the structure can be used for transportation of different type of vehicles such as tractors, trucks, trailers, semitrailers and cargo containers.

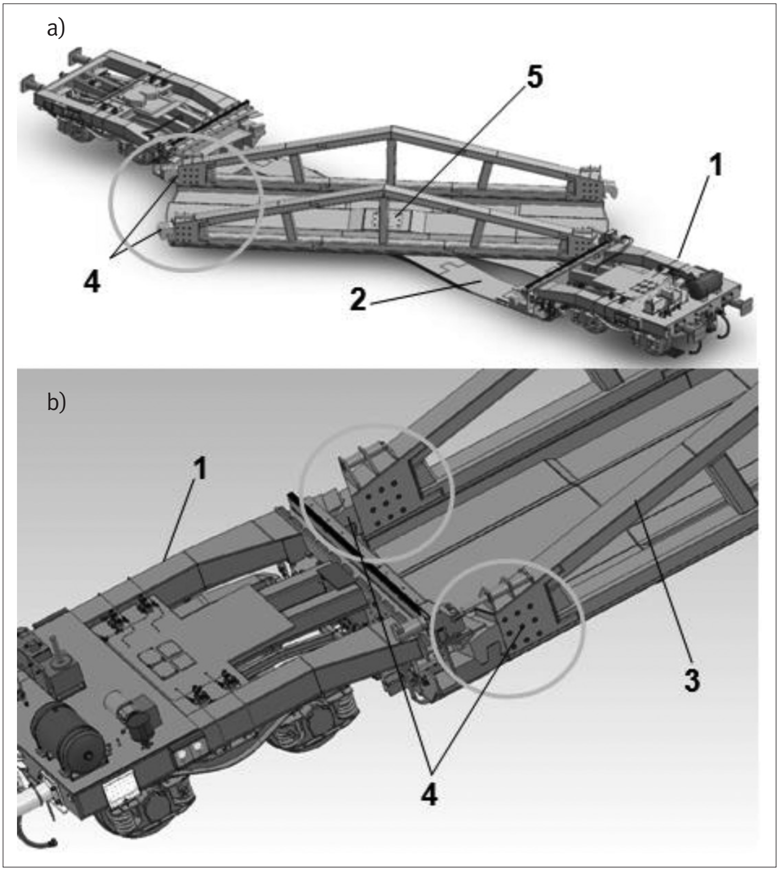

Figure 1 Prototype version of the wagon with :a) the open loading platform, b) the closed loading platform with the view of lock components: 1 – over-bogie part of the wagon , 2 – the lowered fixed frame of wagon , 3 – the side of the moving loading platform, 4 – hook shape locks with suppert area , 5 – central node of the rotatable platform

The paper presents selected aspects of research on the prototype railway wagon [3, 4] and separated subassembly of the locks, connecting a rotatable platform with an immovable over bogie part of the wagon for intermodal transport. Numerical model and analysis of the complete wagon and the most effort part are applied. Different shapes of the lock components are prepared for the experimental tests. The results of the stand investigation are used to verify the numerical model and methodology applied for computer simulations. Selected strength assessments based on the analysis of numerical and experimental results are included in the paper.

2 Numerical investigations of the complete wagon

Different variants of complete railway wagon models are developed for numerical analysis. Simulation of the tests of the wagons in motion with mapping of the appropriate conditions of the track formation was carried out using multibody analyses and MSC Adams software [5].

A model of the railway wagon for a multibody simulation (Fig. 2a) is built of rigid solids based on the design documentation and PN-EN standards [6, 7]. The main components of the wagon and contact connections between them are taken into account.

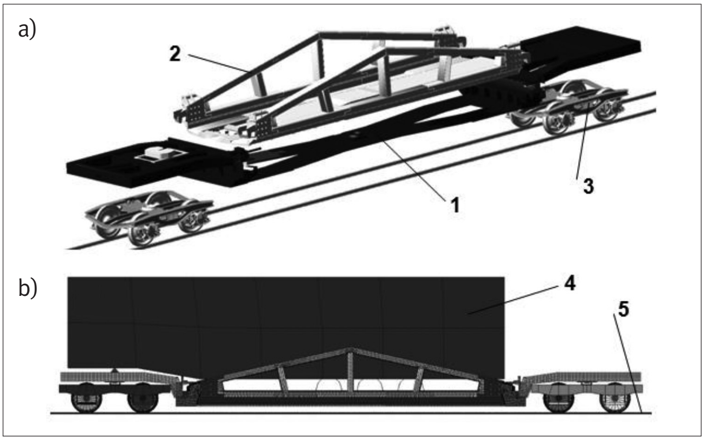

Figure 2 A View of 3D numerical model: a) multibody model with main subsystems; 1 – chassis frame of the wagon, 2 – rotatable platform, 3 – Y25 type bogie with suspension, b) FE model of the complete wagon for dynamic simulation [8]: 4 – semitrailer with load , 5 – railway track

Forces of reaction and forces in contact connectors (Fig. 3) of the most strenuous parts of the wagon are estimated as a result of multibody analyses. The loads values determined in this manner are used in experimental tests of wagon components, including a side lock (the subassembly operating between the rotatable platform and the wagon frame). Selected FE numerical simulations corresponding to the experimental tests of this wagon subassembly are presented in the further parts of the paper.

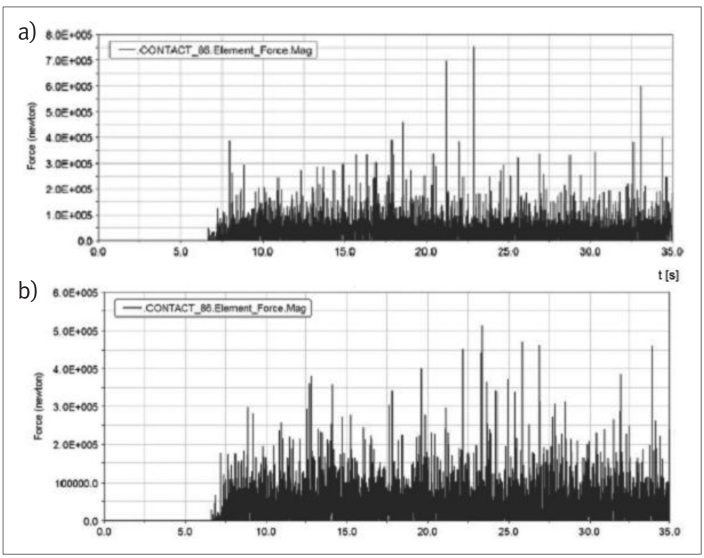

Figure 3 The chart of contact forces in the selected lock as the result of 3D multibody analysis: a) during passage of the wagon on the curved track at a speed of 60km/h, b) during passage of the wagon on the curved track at a speed of 80km/h

Numerical FE analyses of a complete wagon are carried out as well [8 ÷10]. The deformation strain and stresses (Fig. 4) of particular elements of such a construction in different configurations are determined. Boundary and initial conditions corresponding to strength tests of cargo wagons and specified in the standard EU-PN were taken into consideration [6, 7]. The most strenuous and vulnerable to damages area of the railway wagon structure is indentified based on the FE numerical results. For this purpose, a numerical 3D model (Fig. 2b) of the complete wagon is used.

3 Stand tests and the object of investigations

The locks coupling the side of the rotatable platform with the over bogie part of the frame of the special wagon (Fig. 1) are identified as the most strenuous component of the wagon with a rotatable loading floor [8 ÷10]. Therefore, stand tests and numerical analysis of the separated components of the side lock are performed.

The parts of the lock, in the close configuration (Fig. 1b), are loaded mainly with longitudinal tensile and compressive forces. The design of the applied lock allows only transmission of axial load in respect to the side of the wagon. The purpose of the joint is also to relieve the central node, which is used mainly for positioning and rotation loading platform of the wagon. Rotations of the wagon platform to the load-unload position (Fig. 1a, 4b) are possible after unblocking the locks (4).

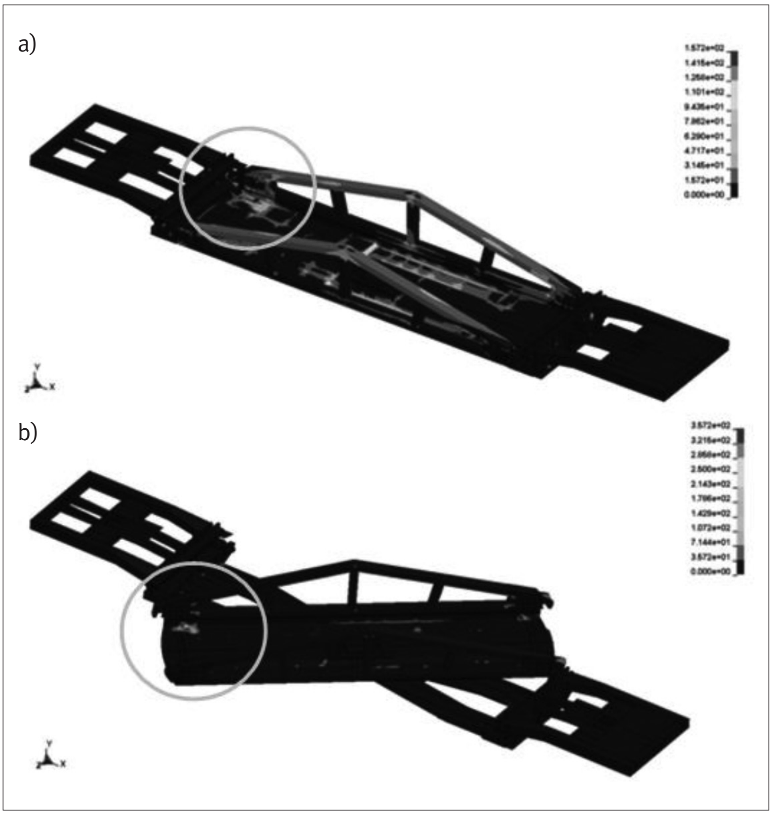

Figure 4 FE numerical result – HMH stress of the lock components areas in the special wagon with the 1.95*Q load and: a) closed platform after unblocking the side locks – σ_{max}=157 MPa, b) opened platform with load and rotated by an angle of 50° – σ_{max}=357 MPa

One of the solids of such locks areas is the over bogie part (1) connected with the lowered fixed frame (2) of the wagon – Fig. 1. The other part of the lock area is the side of the moving loading platform (3) connected with the use of nine screws. Components of the lock (4) constitute a connection between the raceway on the over bogie frame in the rotation process of the floor in respect to the central node (5). The side locks (4), according to preliminary design assumptions, should relieve the area of the central node positioning the rotatable platform over the lowered part of the wagon frame. The central node (5) is used mainly for rotation of the loading platform in respect to the wagon frame and the platform ramp.
The stand tests of the separated components of the side lock with the use of the experimental equipment of Strength of Materials Laboratory at Military University of Technology were performed. Components of the side lock (Fig. 5, 6), with real dimensions of the connector (1:1 scale) are used during the strength tests. Owing to a large size and considerable mass of the lock subassemblies, it has been decided that the elements used for the experimental research will be plates of a real solids shapes (Fig. 5, 6), which are the clippings with thickness of 30 mm. It corresponds to 1/10 of the width of the actual lock (300 mm). Two different shapes of the connector are used in stand tests. The hook shape connector
(Fig. 5a, 5b) was used at initial version of the side lock. Separated components of the side lock in the form of the dovetail joint (Fig. 5c) are tested in the next stage. Static compression and tensile tests of a separated lock connectors with two different shape are performed on a hydraulically driven machine INSTRON SATEC within a range of forces up to 1200 kN (Fig. 6).

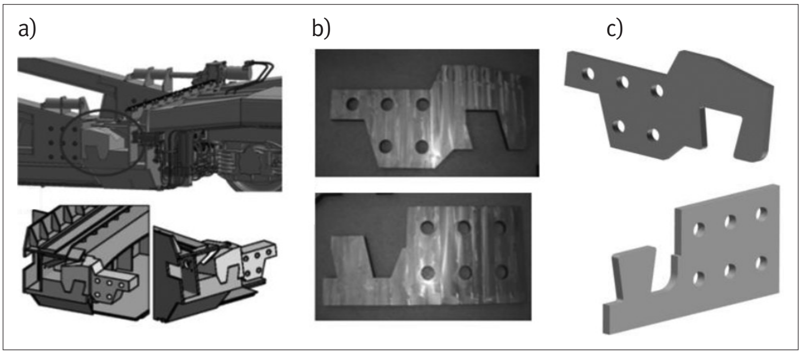

Figure 5 Views: a) side lock area between rotatable platform and over bogie part of the intermodal wagon, b) separated hook-shaped connector prepared to tests, c) 3D draw of dovetail joint

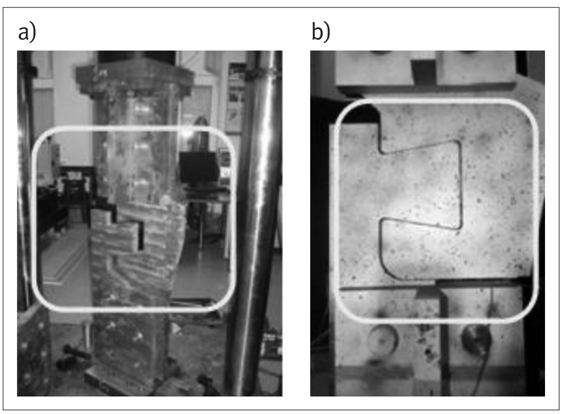

Figure 6 Photos of the tested components of the side lock and the test stand view with INSTRON SATEC machine: a) hook-shaped connector, b) separated component in the form of the dovetail joint

Strength force – displacement curves, presented in Fig. 7, are recorded during the stand test of two type of the side lock connectors.

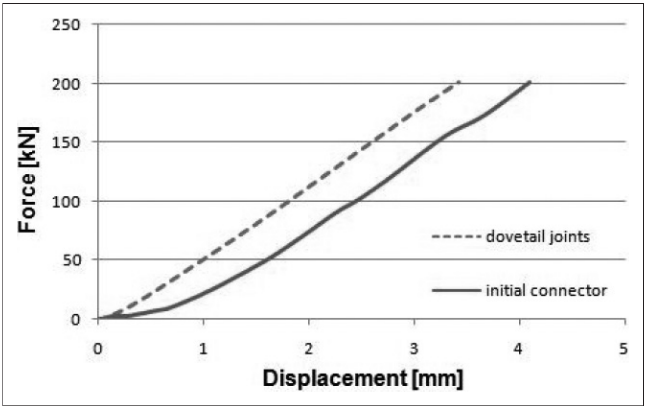

Figure 7 Force – displacement curves recorded during the stand test for two types of the side lock connectors

4 Results of the experimental and numerical study

This part of the paper presents the selected aspects of numerical research on the separated subassembly of a lock. Separated components of the side lock mapping two different shapes of connector (as in the experimental tests described in chapter 3 of the paper – Fig. 5 and 6) are used in numerical FE models as well. The selected results from experimental tests of the side lock components are used to verify a numerical model and FE methodology used for simulations. FE various models (Fig. 8) and numerical analysis of the most effort part of the lock are applied. Numerical analyses of lock tensile within a nonlinear range are performed using MSC software [10]. Load was defined as the reduced force linearly increasing to the value of Pmax=200 kN. Comparison of the results is shown in Table 1. Displacements recorded during the experimental test and the ones determined using FE models and numerical analysis in both variants of the lock connectors are disscused. Figure 9 shows a map of displacements of lock plates determined numerically in FE models. The result for the initial shape of the hook-lock connector are presented in Fig. 9a. The displacement map for a modiffied dovetail joint is shown in Fig. 9b.

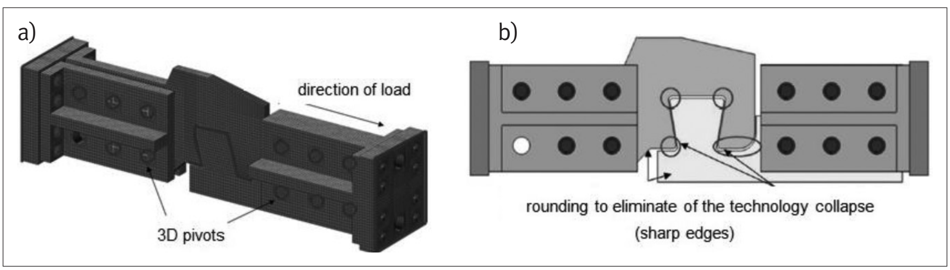

Figure 8 FE models mapping two different shapes of the lock connectors (as in the experimental tests): a) initial hook-shape lock, b) modiffied dovetail joint without sharp edges

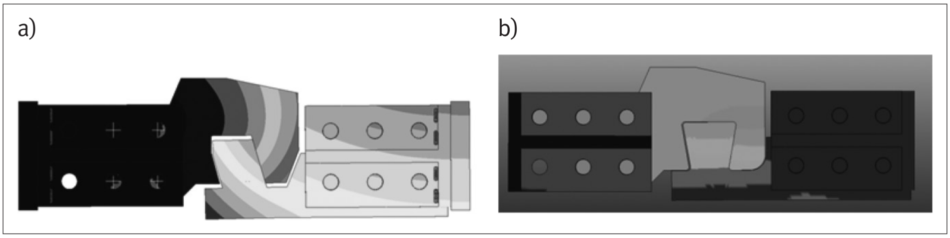

Figure 9 Displacement maps for: a) initial shape of the hook-lock connector, b) modiffied dovetail joint

Table 1 Comparison of the FE and measuring results

Load – P force = 200 kN	Displacements [mm]	
	Initial connector	Dovetail joint
FE models	4.8	3.8
Experiment	4.4	3.3

5 Conclusions

Based on a comparison of displacements from the numerical analysis and the ones experimentally measured, it was verified that both of the discrete models of the tested set with a non-linear material model and load boundary conditions properly and sufficiently reflect the actual construction of the side locks system and the applied holders. It was found that deformability of the modiffied dovetail joint is less than in the case of the initial hook-shape lock. Maximal longitudinal displacements of two type connectors differ up to 25%.
Numerical models and computer simulations, presented in the paper, can be used for further strength tests of the wagon side locks with the use of more complex load states and mapping of dangerous, from the point of view of their exploitation, conditions.

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