Available online at www.sciencedirect.com
ScienceDirect
Transportation Research Procedia 14 (2016) 615 – 624
Transportation Research Procedia
www.elsevier.com/locate/procedia

6th Transport Research Arena April 18-21, 2016

Innovative project of prototype railway wagon and intermodal transport system

Krasoń Wiesław [a,]*, Niezgoda Tadeusz [a], Stankiewicz Michał [a]

[a]*Military University of Technology, Gen. Sylvestra Kaliskiego St. 2, 00-908 Warsaw, 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 the Department of Mechanics and Applied Computer Science in Warsaw. The essence of such reloading is to place the 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 such as tractors, trucks, trailers, semitrailers and cargo containers. The wagon allows quick and fast loading and unloading without any platform infrastructure or terminals. An intermodal transport system based on an innovative concept of the railway wagon, which will use the national railway infrastructure, was developed. The process of loading and unloading the trailers can be performed considering a whole train or individual wagons from any part of the train (no cranes needed). This type of railway wagon will allow transport companies to save time and money for road transport. The advantages of this construction are reduction of the 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 ~~a~~ the wagon and a complete structure was estimated. For this purpose, numerical analysis was used.

Peer-review under responsibility of Road and Bridge Research Institute (IBDiM)

Keywords: Intermodal transport; railway wagon; multibody and FEM simulation

* Corresponding author. Tel.: 22 261 83 9654
E-mail address: wieslaw.krason@wat.edu.pl

Peer-review under responsibility of Road and Bridge Research Institute (IBDiM)
doi:10.1016/j.trpro.2016.05.307

1. Introduction

Intermodal transport benefits in many areas, e.g., reducing of trucks transit time, reducing harmfulness of the influence on the natural environment, reducing the level of damaging public roads by heavy vehicles, increasing capabilities of covering long distances at a time, what is particularly important in the case of transportation of heavy loads, reducing traffic on the roads, increasing safety of public roads, shortening the time of goods delivery to the recipient, among others, owing to lower sensitivity of railway transport to adverse weather conditions (especially during winter time) and elimination of stopovers of trucks at the boarders as well as lowering costs of trucks transit. In European railway transport, in recent years, there have been implemented combined systems based on horizontal or vertical reloading or others Kwasniowski et al. (2008). These systems require developed reloading terminals equipped with, for example, vertical reloading devices of accurate load capacity or other expensive and complicated devices enabling loading and unloading activities.

The latest solution, developed recently in Europe, is the system of transportation of truck type vehicles with the use of railway developed by French company Moda Lohr (fig. 1a). This system requires extended infrastructure, especially, railway ramp as well as proper maintenance of the platform devices, particularly in winter conditions. Figure 1 presents a new intermodal systems developed by the above mentioned French company and Megaswing wagon built by Swedish company Kockums Industrier (fig 1b). Megaswing wagon is equipped with a low-loader rotatable platform, which is rotated in respect to an asymmetrically located rotating junction, placed at the rear part of the wagon over its ‘over-bogie’ part. The other end of the moving platform, shifted outside the outline of the wagon, is equipped with a special running mechanism cooperating with overhanging arms stabilized by hydraulic supports on the surface of the reloading railway platform ramp.

Fig. 1. Wagons for trucks semitrailers transportation: (a) developed by French company Moda Lohr and (b) Megaswing developed by Swedish company Kockums Industrier, www.[..] (2009). www.[...] (2011).

The innovative system proposed in the paper used special railway wagons. In relation to a presently utilized construction of such a type, the presented wagon advantages are as follows; applying repeatable wagons-platforms with an automatic rotating body for fast, safe and easy loading and unloading of trucks, constructional dimensions of the wagon with the load in the form of a semitrailer up to 4 m meet requirements of GB1 gauge, with the special consideration to 130 mm height over the rail head, applying repeatable reloading railway platforms in the form of a system of repeatable segments for quick, easy and safe loading and unloading of trucks without additional crane devices, relatively simple and cheap infrastructure of the proposed system, enabling cheap, ecological and safe transport of truck tractors with a semitrailer with a total length of 17 m, and low exploitation costs of such a system.

A demonstrator of a single wagon with a rotatable platform for an intermodal system on a scale 1:14 was developed in the Laboratory of Materials Strength of the Department of Mechanics and Applied Computer Science, Military University of Technology. The model mapped essential components of the wagon and infrastructure of the loading/unloading railway platform. The discussed model will be used to demonstrate the principle of operation and visualization of basic functions of the railway wagon for transport of trucks. An idea of the intermodal system and simulations of basic functions and loading/unloading operations with innovative railway wagons and used constructional solutions will be presented in the paper.

2. Detailed solutions – construction of the wagon in a prototype version

Within the framework of the design works, a number of changes of the initial wagon concept EU Patent (2012), EU Patent (2013), Niezgoda et al. (2012), connected with reduction of construction mass and meeting the technological assumptions, were introduced. They included, optimization and strengthening of construction of over-bogie parts and the lowered wagon frame, modifications in the areas of fixing the tailboard joints of the rotatable platform, stiffening and optimizing of the floor shape in order to reduce displacement during loading with a transport load, optimization of dimensions of a loading platform tailboard, developing an alternative (in respect to the initial concept with pin type locks Niezgoda et al. (2012)) solution of a mechanism of tailboard locks and a rotation mechanism of the loading platform.

The described works allowed the constructional assumptions, necessary for intermodal transport adjusted to GB1 gauge, to be met and, at the same time, avoid an excessive mass of individual subsystems, increase their efficiency, service susceptibility or reduce costs of wagon construction and minimize necessary adjustment of standard infrastructure (e.g., for PKP) of the loading ramp. These works resulted in a prototype version of a special wagon for intermodal transport.

The considered wagon consists of the following elements: chassis with biaxial standard bogies, frame, platform body, pneumatic systems, buffer devices, other external devices, electric equipment and hydraulic systems. A general view of a prototype version prepared for transport and with a loading platform rotated to the loading-unloading position is presented in Figure 2. The ends of platform 2 after rotation are supported with rolls on a ramp of the railway platform.

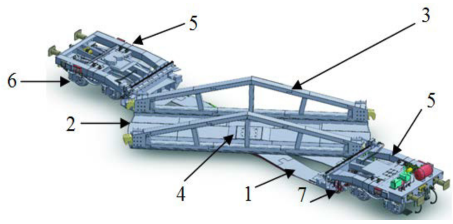

Fig. 2. A view of a prototype wagon with a loading platform after rotation to the loading/unloading position.

According to this solution (Fig. 2), a wagon has been equipped with a low located frame of the chassis (1) meeting the requirements of gauge GB1 and a rotatable platform of the body (2) with a strengthen construction of tailboards (3) equipped with rotatable rolls located under the end of the platform. The rolls have been built up in the form of sets – five items on each side of the plate of the platform floor. They support the rotation of the platform as well as are used for a steady onset of the platform, during the rotation, onto the ramp of the railway platform for loading or unloading of a semitrailer.

The platform is rotated in respect to a chassis and a loading/unloading platform owing to application of a rotating junction (4) located in the central part of the wagon. Moreover, the wagon is equipped with an over-bogie part of the frame (5) located over standard bogies (6) on the both ends of the chassis.

Additionally, the wagon can be equipped with stabilizers in the form of additional hydraulic supporters (7) fixed – two on each side of the frame – under a lowered plate of the chassis and adjusted for lifting the wagon on the rails during loading and unloading. The main aim of the supports system is addition of stiffening and stabilizing to the frame of the wagon when the locks of the side wall joints connecting the over-bogie part of the frame with the platform tailboards are unfasten (during loading/unloading operations). This mechanism is fixed under the wagon frame, in the configuration as shown in Fig. 3.

The mechanism is started with hydraulic actuators which lower the additional support directly onto a head of the rail, thus lightening the standard biaxial rail bogies.The rotatable movement of the loading part of the body (2) is extorted by mechanisms (8) – Fig. 3 – located on the both sides of the over-bogie part of the wagon. Fig. 3 presents the construction of such a mechanism rotating a loading platform and a view of a fragment of the over-bogie part with tailboard locks and stabilizing supports. The mechanism consists of a plate with a fixed toothed bar (9), hydraulic engine (10) driving the mechanism of rotation, toothed wheel (13) cooperating with toothed bar and holder (11), fixed in the body, steering the tailboards of the wagon loading platform, with the use of an extension arm-guide (12), during the operation of rotation.

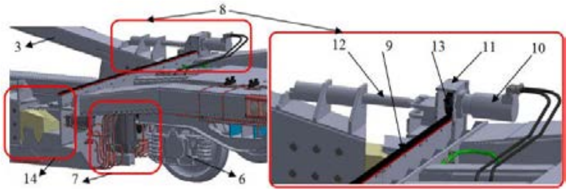

Fig. 3. A view of an over-bogie part with tailboard locks (14) and stabilizing supports (7) and a mechanism (8) rotating the wagon loading platform.

Standardized king-pins are the moving connection of an over-bogie part of the wagon frame with bogies (Fig. 4). An additional king-pin has been adopted as a central node 4 of the rotation of the loading platform and it has been located in the central cross-section of the wagon, as shown in Fig. 4. Its aim is to enable two-way rotation of the loading platform. The subsystems of king-pin, functioning as a central node, are fixed both on the bottom of the low located loading platform 2, and on the surface of the upper plate of the bottom of the wagon frame 1 – Fig. 4.

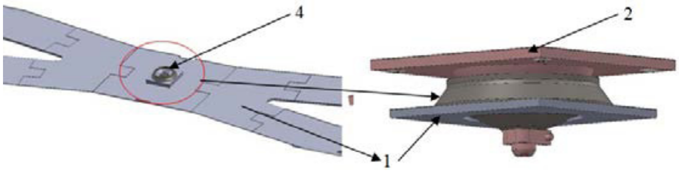

Fig. 4. A profiled plate of the wagon frame bottom and a standard king-pin adopted as a central node of rotation of the loading platform.

A mechanism blocking the rotation of a rotatable platform during transport of the load is very important from a point of view of functionality and strength of the considered system of the constructional wagon. In the presented constructional solution, connection of the tailboards of the rotatable platform with the immovable part (17) of the wagon frame is performed through an appropriately shaped lock in the form of a hook (14). Figure 5 presents its shape, the manner of connecting with a tailboard of the rotatable platform and transverse blocking with the use of a hydraulically driven wedge (15).

Construction of such a lock – Fig. 5 allows only transmission of longitudinal load, therefore, it does not block rotation of the platform and its movement in a transverse direction. This function is performed by a wedge (15) which is pressed to a lock-hook and blocked with the use of a hydraulic actuator (16). Steering the wedge precisely is guaranteed by two diagonal surfaces, cut on the upper surface of lock, on which it slides.

Formation of both the lock-hook and the wedge is selected in such a manner that provides reduction of any clearances vertical and transverse to the wagon axis during pushing the wedge closer. It is possible owing to a cut made in the hook and a key joint in the form of the pyramids of a triangle-base type. During loading or unloading operations, the actuator push the wedge away from the lock, the hook blockade is released simultaneously enabling the mechanism to open the wagon.

The moving platform, while rotating, is supported on the central rotatable node in the centre of the wagon and on two raceways on which the hooks move. The raceways create arches with the centre corresponding to the centre of the platform rotation. In this stage of operations, the mechanism of the loading platform rotation is aided with the use of a set of rolls which, as in the case of the previous concept Niezgoda et al. (2012), enable displacement of the ends of the rotatable platform in respect to the bottom plate of the frame and, subsequently, the appropriately prepared surface of the ramp-platform gauge.

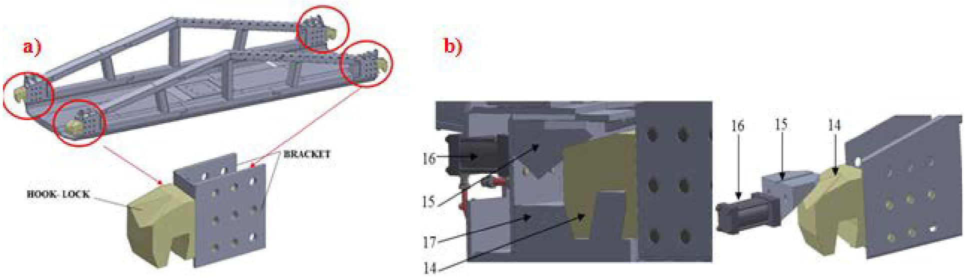

Fig. 5. A view of a loading platform with: (a) tailboard lock and a single tailboard lock – a hook and (b) a manner of connecting with a tailboard of the rotatable platform and transverse blocking with the use of a hydraulically driven wedge.

3. Multibody analyses of a special railway wagon

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. The tests assume that a given system is composed of many stiff modules joined with kinematic constraint. Individual modules of the system are joined with a kinematic pair meant as an additional internal constraint in the form of moving joint. The module contact punctually and superficially with each other, which determines a number of degrees of freedom. All the modules constitute one system defined as a multibody system. The method of multibody systems is a general name for the methods of modelling, analyses and joining the real systems considered as multibody systems.

The simulation with the use of the multibody methodology enables the investigation of kinematic and dynamic values describing the motion of a complete wagon on the track selected test section Matej et al. (2009). To carry out multibody analyses with the both versions a numerical model of the wagon and semitrailer with the load, MSC Adams code MSC Adams (2005) was applied. The main subsystems of the prototype wagon were used in this rigid model (Fig. 6 and 7).

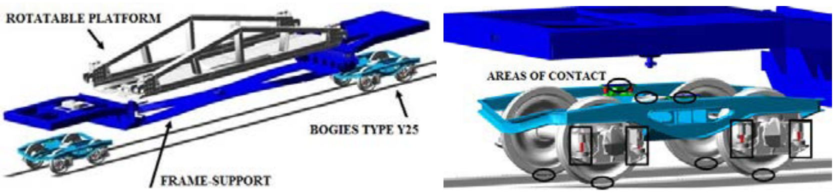

Fig. 6. Chart of 3D numerical model with main subsystems.

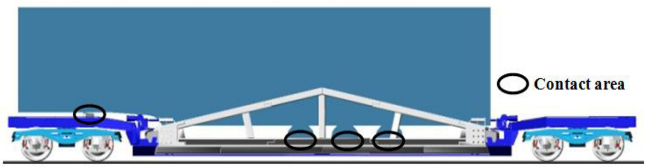

Fig. 7. Constraints mapping fixing the semitrailer in the saddle and additional contact areas of semitrailer wheels with wagon model.

Constraints and conditions of cooperation (contact) in connections of wagon subsystems were defined. The following kinematic pairs and constraints were introduced into the model of the frame and the bogie Fig. 6:

- bogies axes are equipped with constraint mapping fixing the axis in the axle box and enabling the accurate rotatable motion of the axis along with the wheel,
- contact was defined between bogies wheels and tracks,

- frame-support is supported on side slides and contact conditions enabling cooperation, as in the case of in a spherical pin joint, were mapped in the bogie swivel pin,
- bogie frame can perform independent vertical movements, in respect to axle boxes slides and bogies sets (axis with wheels), limited by contacts conditions in axle boxes slides and springs with accurate stiffness modelling the suspension of the bogie,
- movement of the frame-support is limited by side slides supported on the bogie frame and on the transverse beam.

Separate kinematic pairs and constraints were defined in the locks connecting tailboards of the rotatable platform and a part of frame-support.

The following initial conditions were considered in simulations:

1. classical gravity (wagon dead weight) was taken into consideration in all analyses,
2. the wagon moves on the 500m long straight track and then enters the horizontal arch with the radial of 250m (minimal radial according to the standard PN-EN 13232-1 (2004)),
3. the wagon movement was obtained through defining an accurate characteristic of angular velocity on bogies axes,
4. the wagon accelerates to velocity of 60km/h on the rectilinear section of the track and then moves with the constant velocity on the arch.

On the basis of the analyses results, there were defined the changes in time of contact forces values in individual pairs: wheel-rail (forces values were recorded on all the wheels), wedge-hook (blocking buckle), bogie-support, rotatable platform-support. The changes of accelerations of the semitrailer located on the wagon were also analysed. The values of both the contact forces and accelerations were recorded for the time duration of whole simulation. Figures 8 demonstrates changes of the resultant contact force occurring in the tailboard locks located behind the semitrailer (the rear part of the rotatable platform). It was found that the forces in the locks change significantly, however, after averaging, they oscillate in respect to the value of approximately 100kN.

Figure 9 presents the changes of the resultant contact forces occurring between the wheels and the outer railway track (wheel – rail pair) at the velocity of 60km/h.

It was found that from the forty-eighth second, when the wagon enters the arc at the fix velocity, the contact force increases, what is caused by tilting of the structure resulting from the centrifugal force. It causes the increase of the pressure on the wheels moving on the outer railway track. Averaging the results of the results obtained during the ride on the line segment (from 0 to the 48th s of simulation), it was observed that the value of contact force in this variant amounts to approximately 100kN (the red part of the graph - Fig. 9), what corresponds to the weight of a rotatable platform. On the arc (from the 48th s of simulation) this value increases to 250kN (blue line – Fig. 9).

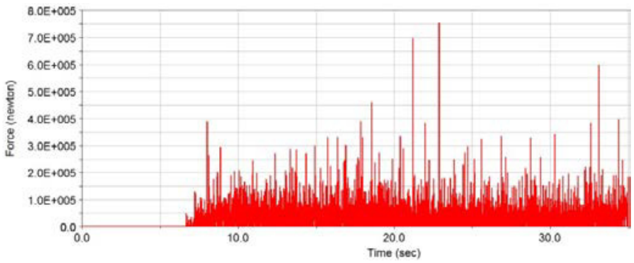

Fig. 8. Change in time of contact forces in the left tailboard lock located behind the semitrailer.

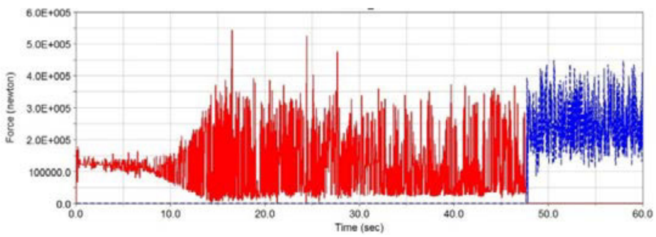

Fig. 9. Change in time of contact forces in the wheel – rail pair during the transit at 60km/h velocity.

Based on the realized simulations of the transit of the special wagon at different velocities on the standard section of the track, there was determined the boundary – maximum velocity of the wagon at which it can move on the arc of 250 m radius. After conducting a number of analyses, it was found that at velocity of 120 km/h a wagon with a loaded semitrailer tilts to the side after entering the arc, what results in derailment of a whole structure (Fig. 10).

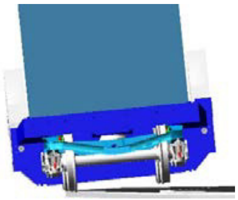

Fig. 10. Wagon moving at velocity of 120km/h on the arc of 250m radius with a view of detachment of wheels from the rails on the inner side of the arc.

The boundary – maximal velocity at which a wagon can move on this type of arc with a gravity centre located halfway of semitrailer height without danger of derailment is 115km/h.

The simulation with the use of the multibody methodology enables the investigation of kinematic and dynamic values describing the motion of a complete wagon on the track selected test section.

4. Side lock research

Based on the performed strength tests of the wagon (Krason et al. 2012, Niezgoda et al. 2012), it was verified that the most strenuous component of the wagon with a rotatable loading platform is the lock coupling the side of the rotatable platform with the over bogie part of the frame of the special wagon (Fig. 3). The design of the applied lock allows only the transmission of axial load in respect to the side of the wagon. Thus, a rotation of the platform to the load-unload position (Fig. 2) after unblocking the locks was possible. The elements of the lock, in the close configuration (Fig. 11), are loaded mainly with longitudinal tensile and compressive forces. The purpose of the joint is also to relieve the central node, used mainly for positioning and rotation loading platform of the wagon.

One of the solids of such a connection is a track-bound guide with a fixed frame – Fig. 11. The second part of the lock is connected with the side of the moving loading platform with the use of nine screws. This element meshes with the raceway on the over bogie frame in the rotation process of the floor in respect to the central node. These locks, according to preliminary design assumptions, should relieve the area of the central node used mainly for rotation of the loading platform in respect to the wagon frame and the platform ramp.

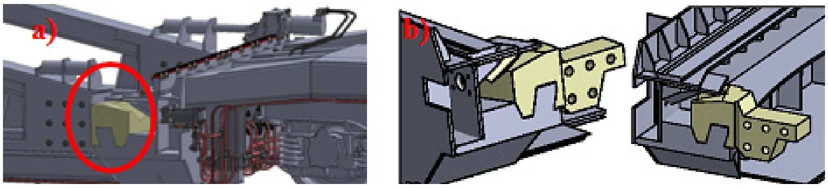

Fig. 11. (a) Side lock between rotatable platform; (b) over bogie part of the railway wagon for intermodal transport.

Due to the character of elements formation of such a connection, the technological notch resulting from their shape and limiting contact surfaces transmit significant loads. The parts of side locks are the most strenuous components of the wagon.

Therefore, stand tests of the separated components of the side lock with the use of the experimental equipment of Strength of Materials Laboratory in the Department of Mechanics and Applied Computer Science in MUT were performed. In the strength tests, a component of the in a 1:1 scale, with real dimensions of the connector (Fig. 12a,b) was used. Owing to the large size and considerable mass of these elements, it was decided that the elements used for the experimental research will be the plate, with a shape of a real lock, which are the clippings with thickness of 30 mm, which corresponds to 1/10 of the width of the actual lock (300 mm). Even at such an assumption, the weight of the lock fragment, used for the stand tests, and the additional mounting elements is more than 400 kg (Fig. 12a). The side lock elements made of heat-treated steel 40H.

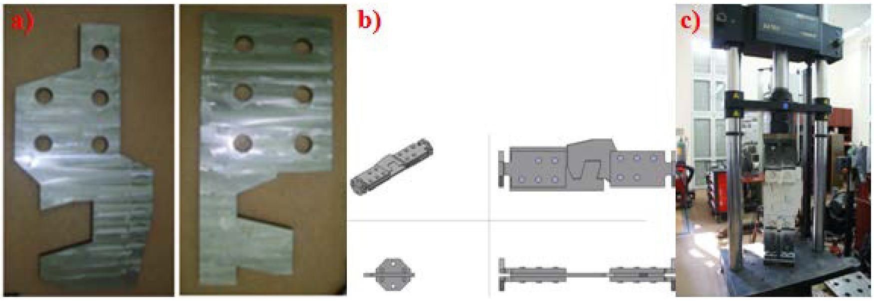

Fig. 12 (a) Photos of the tested components of the side lock; (b) 3D view of the tested system of side lock along with the mounting elements in the strength machine, c) test machine.

Static compression and tensile tests of a separated rail connector were performed on the hydraulically driven device INSTRON SATEC 1200KN. The machine allows testing of components in the range of compression and tension with forces for up to 1200kN. Growth rate of deformation in the loading process is limited to a value of 10 mm / min. The side lock system (Fig. 12b) was loaded with the maximum tensile force equal to P_{max} = 200 kN. With this load value, at the level of 7 mm, there were obtained vertical displacements of lock elements measured in the longitudinal axis of the lock plates. After reaching the maximum load, the test was stopped as the lock elements shifted excessively in respect to each other, what could cause a damage to the testing machine.
Measurements of displacements of the transverse plates of the lock were performed with use of two dial gauges, arranged as one on each connector element. The bases of indicators were fixed to the holder mounting with hydraulic vice jaws the tested elements of the lock.

The obtained results of stand tests were used to verify both the FE models and the methodology of numerical analysis. For this purpose, the results of FE analysis, in the form of transverse displacement between the side lock elements, were compared with the corresponding results recorded during the stand tests of the lock.

4.1. Numerical model and result

In numerical analysis, there were used two models of locks mapping, with different accuracy, the test set which is shown in Figure 12. In Model 1 (Figure 13a), the pivots connecting the plate elements of the set were modelled in a simplified way (Krason et al. 2012). The pivots were modelled in the symmetry axis of holes of locks and handles assembly using beam elements with well-defined, substitute geometric characteristics. In the holes, cooperation with pivots was modelled with use of grids of radially arranged MPC RBE2 elements. In model 2 (Fig. 13b), all the pivots were modelled in the form of solids. In both models, there was defined the contact with taking into consideration friction (μ = 0.2) between the surfaces of the locks (red lines in Figure 13a and 13b at the place of interface between the hooks). In the case of Model 2, the contact between the surfaces of the pivots and the walls of the holes was also defined. Such a developed discrete model of the experimental set contains 76 090 elements.

Boundary conditions were defined in the same way in both models:

- left part of connector – mounting by depriving all of translational (UX, UY, UZ) and rotational (RX, RY, RZ) degrees of freedom, the constraints were applied to outer wall of the intermediate element of the connector
- right part of connector –blocking two translational degrees of freedom (UY, UZ) and defining kinematic extortion or loading with tensile force P on X direction of the outer wall of the intermediate element,
- pivots –one degree of freedom in UZ direction was deprived

Numerical analyses of lock tensile in the nonlinear range were carried out (MSC et al. 2005, Krasoń et al. 2012). Load was defined as force linearly increasing to the value of P_{max} and kinematic extortion determined on the basis of the experiment. Comparison of the results in the form of displacements obtained in models 1 and 2 in both load variants are shown in Table 1. Figure 14 shows a map of displacements of lock plates determined numerically in Model 1, and in Figure 10 the map of equivalent H-M-H stress in Model 2 is shown.

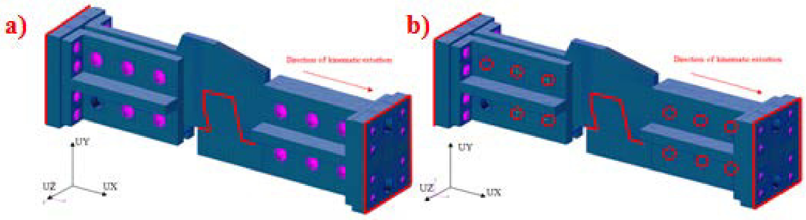

Fig. 13. (a) Model 1 of the tested set; (b) Model 2 of the tested set.

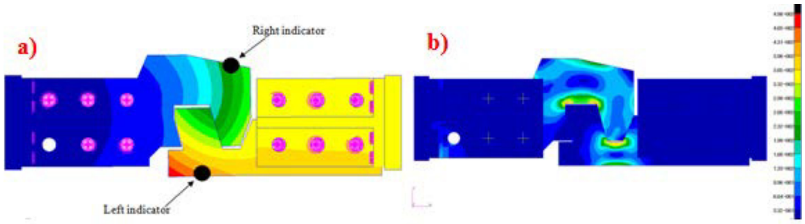

Fig. 14 (a) Map of displacements of the lock plates determined numerically in Model 1; (b) Map of H-M-H stresses in the tested set.

Table 1. Comparison of the results of numerical tests in Models 1 and 2 at applying options of constrains.

Kinematic extortion	Displacements [mm]	
	Left indicator	Right indicator
FE Model 1	2,34	0,65
FE Model 2	2,26	0,67
Experiment	1,32	0,8

The maximum stresses in the tested set occur in the areas of constructional notches and in the places of contact between lock plates. The maximum value of the equivalent H-M-H stresses in these areas are σ_{max} = 498MPa (R_e = 750MPa). Based on a comparison of displacements from the numerical analysis and the ones experimentally measured, it was verified that both discrete models of the tested set with a non-linear material model and kinematic boundary conditions properly and sufficiently (maximum relative differences are less than 16%) reflect the actual construction of the side locks system and the applied holders. These models and computer simulations can be used to 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.

5. Conclusions

The purpose of the design team was to develop a rail-road transport system adjusted to the present condition of the existing railway infrastructure in Poland. A developed technology allows elimination of the expensive terminal loading devices from the utilization. Such a solution enables shortening the loading time and lowering the direct costs of loading terminal operations. An important advantage of the proposed solution is a possibility of trains production by national companies. Introduction of an innovative system of truck sets developed at Military University of Technology will enable the following profits:

- lowering the social costs of transport through its safety improvement as well as lowering the negative interaction of the road transport on the natural environment,
- improvement of railway infrastructure condition through competent usage of the European Union's structural funds,
- reduction of expenditures for road infrastructure maintenance through limitation of degradation of routes resulting from limitation of road sets,
- improving the quality and extending the range of railway transport services,
- increase in competition of national transporters within the framework of liberalization of the European Union's transport policy.

The main advantage of the described system is durable and steady construction assuring accurate and safe operations both during the transport and during loading-unloading operations. Wagon construction, optimized through application of modern design methods, allowed achievement of suitable strength and considerable stiffness during the transport of the semitrailer with the load of total up to 40 tones. A characteristic property of the described solution is high resistance to loads assured through application of accurately stiff locks-joints fixing the moving loading platform to the over-bogies part of the frame, in the configuration of the wagon ready for transport.

Special wagons with rotatable loading platforms, discussed in the paper, can be assembled into sets for transport of trucks semitrailers. To load and unload such sets, there are needed final railway stations or intermediate railway stations with an access to a track and a ramp with suitable dimensions enabling loading-unloading operations Stokłosa (2014). The innovative system for intermodal transport with the use of wagons with rotatable loading platform, thus, additionally consists of loading-unloading terminals – Fig 15. It is assumed that tractors serving for loading and unloading of semitrailers would operate in direct neighbouring of loading-unloading terminals. Their purpose would be delivering the semitrailers with freight intended for transportation to the designated terminal with a waiting set of special wagons and then loading the semitrailers with a freight on the wagons. After the semitrailer is detached and left on the wagon, the tractor can be reused for transport and loading the semitrailer waiting on the parking lot. Loading-unloading terminals can be located in convenient border points having standard railway lines well communicated with junction stations in a country with a special attention paid to transhipment border stations on the main west-east and north-south directions for servicing intermodal transports.

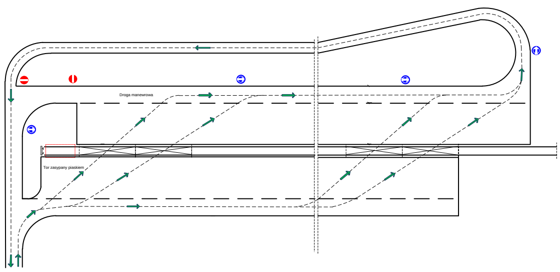

Fig. 15. Terminal and traffic organization during loading the set with special wagons.

References

Krason W., Niezgoda T., Damaziak K., 2012. Some aspects of numerical tests of special railway wagon for intermodal transport of heavy semitrailer, European Congress on Computational Methods in Applied Sciences and Engineering ECCOMAS,

Krasoń W., Niezgoda T., Stankiewicz M. 2014. Numerical and experimental tests of the side lock of railway wagon loading platform for intermodal transport, Shell structures, theory and application', Volume 3, CRC Press Taylor&Francis Group, Balkema Book

Kwasniowski S., Nowakowski T., Zajac M., 2008, Transport intermodalny w sieciach logistycznych, Oficyna Wydawnicza Politechniki Wroclawskiej, (in polish).

Matej J., Piotrowski J., Wojtyra M., Fraczek J., 2009. Modelling and safety examination of the long bimodal train on curved track using ADAMS/Rail, Institute of Vehicles, Warsaw University of Technology,

Military University of Technology, 2012. A railway wagon and a mechanism for rotating and blocking a loading floor of a railway wagon for combined transportation, EU Patent EP 2 532 562 A1,

Military University of Technology, 2012. The innovative technology of railway transport of TIR type trucks, National Center of Research and Development, Report,

Military University of Technology, 2013. A railway wagon with a rotatable loading floor", EU Patent, EP10461528,.

MSC.ADAMS, 2005. Release Guide, Published by MSC,

Niezgoda T.,. Krason W, Barnat W., 2012. Idea and tests of the railway wagon with a rotatable platform for intermodal transport, 2nd International Conference on Road and Rail Infrastructure CETRA, 1041-1047,

PN-EN 13232-1, 2004. Railway applications, PN-EN Standards, Warsaw,

Stokłosa J., 2011. Transport intermodalny technologia i organizacja, Wydawnictwo Naukowe Wyższej Szkoły Ekonomii i Innowacji, Lublin

www.kockumsindustrier.se/en-us/start/, 2011. Intermodal wagons, MEGASWING

www.lohr.fr/index_gb.htm, 2009. Rail-road, LOHR 11