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Modelling of coal in a railway coach

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Analysis and modelling

ABSTRACT

Purpose: Objective of the study was to identify the forces acting on the structural elements of railway wagons. It is part of research conducted under a grant, on the use of composites in the repair and construction of new structural elements of railway wagons.
Design/methodology/approach: The main tool of verification of the research is Siemens PLM Software NX 7.5. Motion simulation has been carried out in one module of the software, Motion Simulation. Connections between components have been made using constraints and connections mapping the real relationship between components.
Findings: The aim of the study was to identify the forces acting on the door, and establish a database of input for further research.
Research limitations/implications: The main limitations of the study were the possibility of mapping all the connections of components, in the same way as in reality. The second limitation was the maximum length of track, depending on the number of possible landmarks in which it was possible the measurement of variables.
Originality/value: Results of the analysis of the wagon constructed with the standard steel components are input data to research on the modification of structural components on the basis of fibrous composite The results obtained are an example of application of the methods of computer analysis, on the basic type of testing wagons. Completed study is the first step in a study of movement railway wagon in further stages will be possible to perform the studies in more complex aspects of the movement.
Keywords: Composites; Computer assistance in the engineering tasks and scientific research; Numerical techniques; CAD/CAM; Materials and engineering databases

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1. Introduction

Transport is a general set of measures, and operations related to the deliberate movement of cargo. Carriage of cargo is carried by various modes of transport such as:
- railway,
- car,
- marine,
- inland waterways,
- by air,
- transmission in the form of conveyors, pipelines, cablecars, etc. [1,2].

Normal operation of the manufacturing plant is possible only by the smooth and uninterrupted functioning of the transport industry, the supply of subtractive raw materials, shipping finished goods, disposal of waste produced during manufacturing processes. Transportation provides a key element of the production links between the production units. It is a kind of component one of the initial phases of production, and in some sense the end of the production process, which is to transport finished products to the place of receipt. Of particular importance in the transport system in Poland plays a railway transport. Railway transport has many advantages, such as the regularity, regular supplies, high-speed transport, mass supply, continuity of work, independence to some extent on weather and climate. Also an important feature is the economic advantages of rail transport, especially on the rolling resistance of the train. The rolling resistance of the wheels wagon railway is approximately 2.5 kG per ton of its weight, while the resistance of the road ordinary gravel road - about 30 kG, and the asphalt road - about 10 kG per ton. A further important feature of the economic rail transport is a transport unit payload, the cost of carrying out the train increases at a much lower ratio than its weight, but most favourable are the big heavy transport units [1,2].

Aim of this study is to determine the forces acting on the door of the wagon train, a series of open wagons Eaos 408 W, while moving along a curve, using advanced graphics software CAx classes. Designated forces will later be used to perform the analysis of strain, stress and displacements, most important structural elements, which act maximum values of force of using the FEM.

A detailed description of the components of the wagon railway (Fig. 1):

- **railway vehicle body** - is designed to perform separate tasks for each type of vehicle. So it is either a box car, or a boiler, tank, or platform. The wagon body consists of side walls, end walls, floor and roof (covered wagons),
- **chassis** - meant to carry the weight of the vehicle and the forces generated from the traffic on the railway track, on surrounding vehicles and the takeover of force.
  The chassis includes components such as:
- **footing** - a frame entire wagon. Site are attached to other parts of the chassis, such as a carriage, bumper, coupler and body,
- **carriage** - is connected to the footing of the wagon through the pivot. This makes it possible to lift the spherical motion of the refuge. carriage is constructed of welded steel frames, guides the wheel set and suspension springs,
- **coupler** - used to link the vehicles. Is located between the bumpers in the longitudinal axis of the vehicle. These devices transmit a traction vehicle traction on all carriages of the train, and so must be very tough, especially given the inevitable jolting train, generated during starting or passing through the longitudinal profile rail,
- **bumpers** - devices attached to the headstock that are used to mitigate the impacts or pressures with each other, generated between adjacent vehicles during the movement of trains, with their braking and manoeuvring at the station.

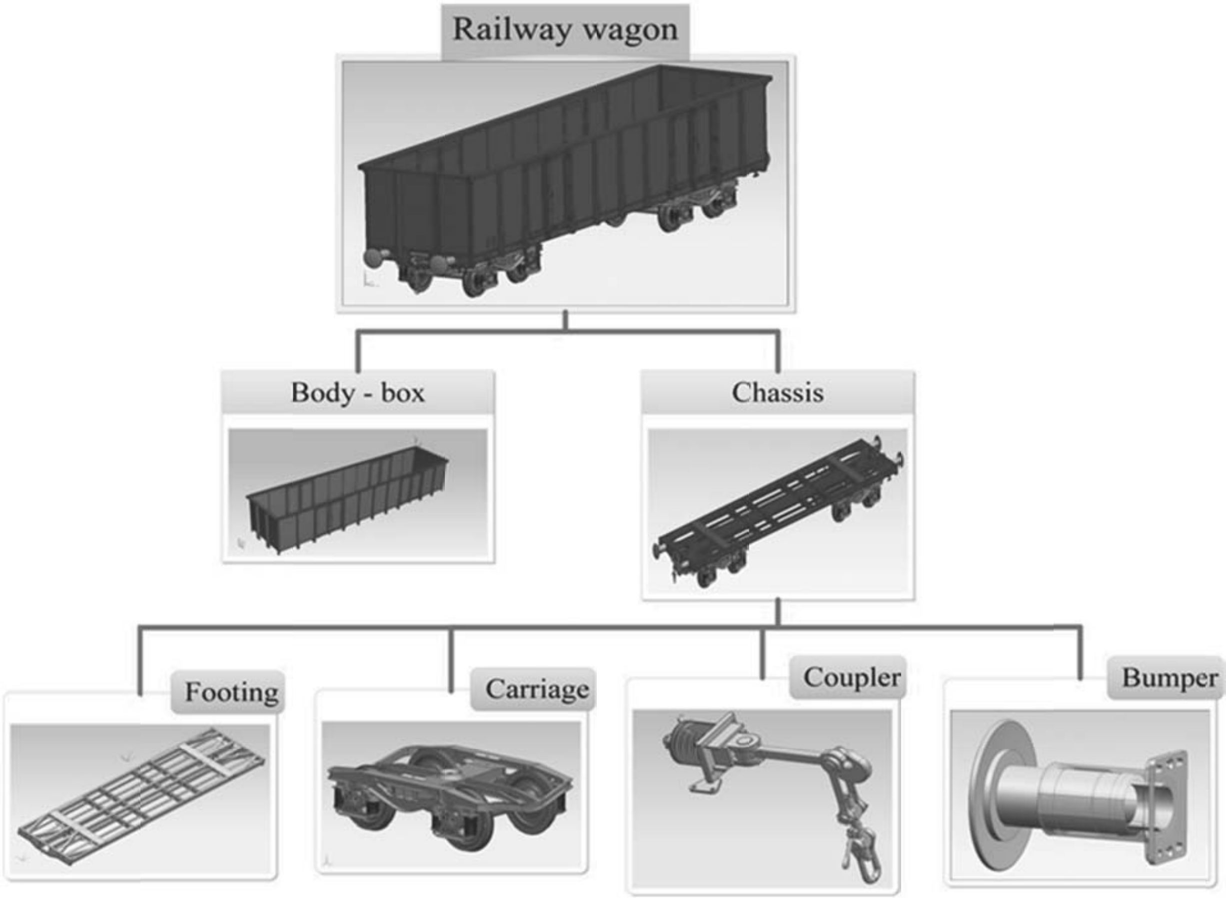


Fig. 1. Diagram of the railway wagon

Computer models of structural elements have been created on the basis of the technical documentation of the wagon railway Eaos 408W series (Figs. 2, 3) [4,7-12].

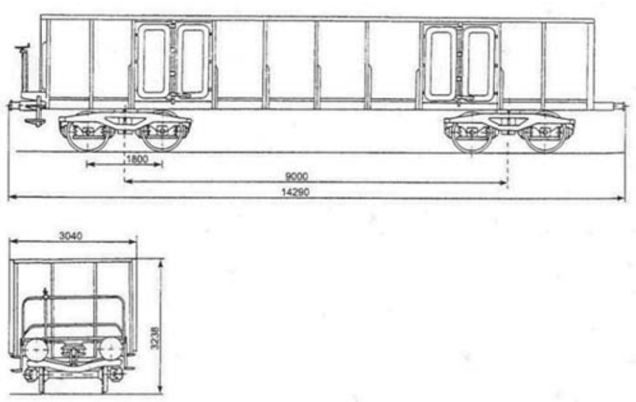


Fig. 2. Overall dimensions of the railway wagon [13]

Fig. 3. Photography of a railway wagon type 408W series Eaos [13]

Wagons of this type are open wagons used to transport bulk cargo, not susceptible to weather conditions, such as coal, coke, ore, gravel, sand, brick.

2. Research methodology

The aim of the study is to identify the forces acting on structural elements of the wagon railway, traveling along a curved path. During the movement of vehicles on rails, in addition to the basic forward movement are under unfavourable movements, which are harmful both vehicles and for track. During the movement of a railway wagon on the track way are observed following negative types of movement

1. Rotary – feedback:
   - snaking - movement of the vehicle about an axis Z–Z,
   - porpoising - movement of the vehicle about an axis Y–Y,
   - rocking - movement of the vehicle about an axis X–X.
2. Reciprocating:
   - jumping - vehicle movement along the axis Z–Z,
   - throwing - vehicle movement along the axis Y–Y,
   - pulling - move the vehicle along the axis X–X.

All of these movements, appearing simultaneously in the varying degrees, give in the complex level negative movement of the vehicle.

The simulation and analyse of strength belongs to the basic research type of wagon and carriage. So far the study has been conducted on an actual prototype model using strain gauges and hydraulic actuators generating forces on the appropriate elements of the structure.

Stationary tests include:

- Static loading of the wagon is in different places and directions of static forces,
- Fatigue tests is loading of the wagon variable forces pulsating with specific frequency,
- Impact test is a rapid loading of force with a correspondingly high value.

Motion study of railway wagon includes:

- Driving wagons on the line around the track in the the required duty with the measurement of stresses and forces in designated structures,
- Wagon ride on separate training grounds.

The study describes in detail the admission of industry standard ORE B17/Rp 17 [1-3].This is a set of guidelines for static testing, describing in detail the research methodology. The standards set out the basic research such as:

- Strength test of the side walls for action of lateral forces, by the load horizontally in the transverse direction (expanding type) on 4 central pillars of the two side walls by 100 kN force, applied at a height of 1.5 m above the floor of the wagon (Fig. 4.) and the strength of the body-side rail on impact, by the horizontal load in the transverse direction (expanding type) upper body-side rail in the middle of both side walls of the force 25 kN and vertical force of 40 kN.

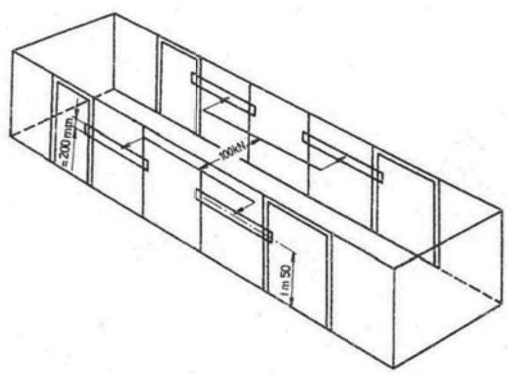


Fig. 4. Strength test of the side walls of the wagon [1-3]

- Checking the strength of the door to load of cargo, with a load of 20 kN horizontal thrust, directed out the wagon, applied at a height of 1 m above the floor in the axis of the door opening

and the body-side load rail level in the transverse direction (expanding type) inside door.
- Unloading the wagon on a tipping. During the test, unloading takes place measuring and registering of stress increments in the most strenuous parts of the box, (mainly in the sidewall and chassis) from the launch of the tipping of the wagon until the return to the starting position. Double-unloading test is carried out openings strength 25 kN.

3. Basic steps for motion simulation

At the stage of development of the submission of individual components, particular emphasis is given to reflect the actual calls. All of the bonds initially fully reflect the relationships between components, but solver was not able to calculate correctly all the steps in the simulation. Therefore it was necessary to carry out the optimization constraints.

Initially, four components are defined as links (box, carriage, bearing socket, wheelset), and then was given a spherical joint between the box and carriage, revolute joint between the wheelset and socket bearings. Subsequently the relationship connectors: spring between the box and carriage, and between the bearing socket and carriage. Connection 3D contact was defined between the socket and bearing carriage in the order to simulate the friction between these components (Fig. 5).

Schema of other types of bonds were presented in a Table 1. Schema shown in Figure 4 unfortunately not allowed to carry out a proper analysis. However, modifying the number of links and the type and number of constraints it was possible to conduct simulations of the behavior of the fundamental physical dependence.

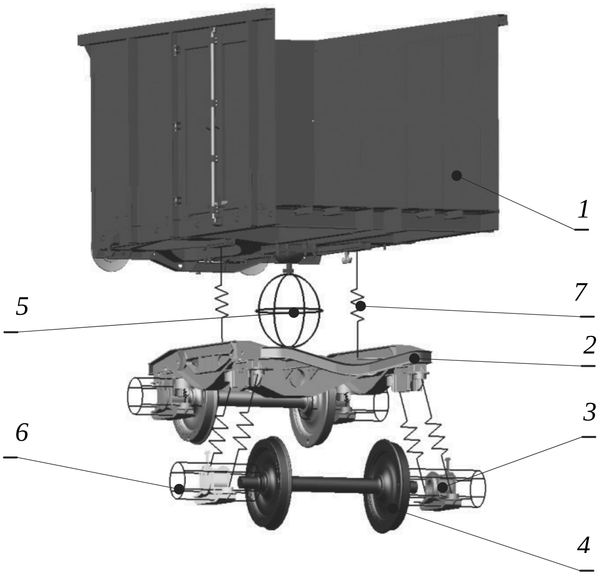


Fig. 5. Referential diagram: 1 - link box, 2 - link carriage, 3 - link socket bearings, 4 - link wheel set, 5 - joint spherical, 6 - joint revolute, 7 - connector spring

Table 1.
Other types of conferred relationships

Relation	Element	No.	Additional information
Type 2			
Relation	Element	No.	Additional information
Link	Box Carriage Socket bearing Wheelset	1 2 4 8	
Joint	spherical revolute	2 4	Box-carriage Wheelset-socket bearing
Connector	spring spring 3D Contact	4 16 8	Box-carriage Wheelset-socket bearing Wheelset-socket bearing
Type 3			
Relation	Element	No.	Additional information
Link	Box Carriage Socket bearing Wheelset	1 2 2 8	
Joint	spherical revolute	2 4	Box-carriage Wheelset-socket bearing
Connector	spring spring 3D Contact	4 16 8	Box-carriage Wheelset-socket bearing Wheelset-socket bearing
Type 4			
Relation	Element	No.	Additional information
Link	Box Socket bearing Wheelset	1 2 8	–
Joint	revolute	8	Wheelset-socket bearing
Connector	spring	4	Box-carriage
Type 5			
Relation	Element	No.	Additional information
Link	Box Carriage Socket bearing Wheelset	1 2 2 8	
Joint	revolute revolute	2 4	Box-carriage Wheelset-socket bearing
Connector	spring 3D Contact	16 8	Wheelset-socket bearing Wheelset-socket bearing

The next step in the preparation of the simulation was to create a model of track. Due to the limitations concerning the maximum length of track, was required to carry out the optimization process of modelling the track. Finally track way was divided into two sections (Fig. 6):

- rectilinear segment - increased friction coefficient, the acceleration of the wagon to the reference speed,
- curved segment- the coefficient of friction decreased to a value of the standard Steel-Steel friction section of arc with a radius of 240 m.

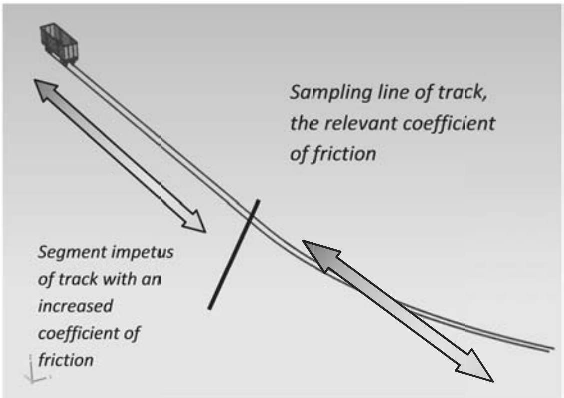


Fig. 6. Movement of a wagon variant used in the work

4. Research

This chapter describes the stages of research. First stage has been presented the purpose and simulation results of movement of an empty railway wagon. In the next stage the same railway wagon was filled with cargo and was carried out a comparative simulation of a full railway wagon. The purpose of the simulation was conducted movement simulation single railway wagon, not connected to the rolling stock.

4.1. Safe speed - empty wagon

Studies carried out in an empty carriage, consisted in determining a safe speed train travel in the arc of 240 m. Series of tests was carried out at speeds, 90, 100, 110, 120, 130 km/h. Simulation speed of 130 km/h showed that it is impossible to move this type of wagon to such a radius curve of the track (240 m). Wagon gradually leaned on the outside of the track. For longer arc would probably fell out with of track (Fig. 7).

Due consideration to the fact that the selected railway wagon can be driven with a maximum speed of 100 km/h, the remaining speeds above this value has been studied only for illustrative purposes only.

The chart (Fig. 8) can be seen that in 6.63 second inner circle loses a contract with the rail. This is the moment of entry of all the wheels of an arc of track. At speeds of 120 km/h, it was found that the wagon has better contact with rails. However, the pressure force diagrams showed that the inner wheels sometimes completely lose contact with the rail.

Clear improvement of the situation shows a graph of force for speed 100 km/h. Can be seen the appearance of internal forces on the wheel, and force peaks the show of force peaks appears between the nosing trolley rails. Along with reducing the speed of the vehicle, forces on the inner circle are getting larger and more frequent contact.

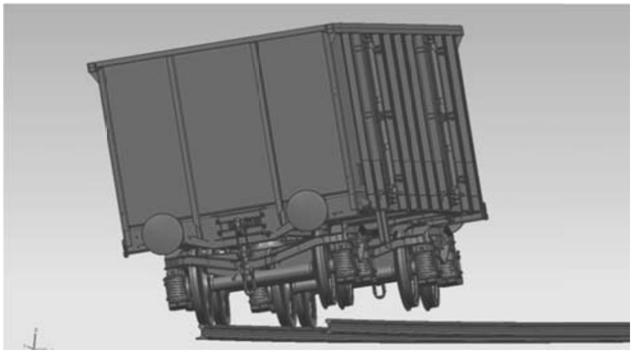
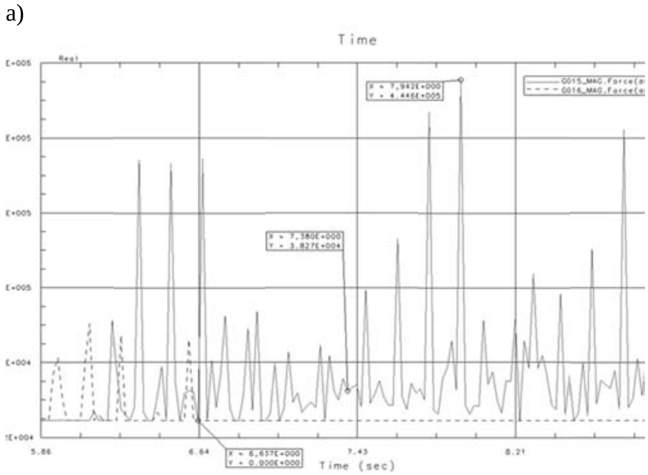


Fig. 7. View heeling a car at a speed of 130 km/h

a)



b)

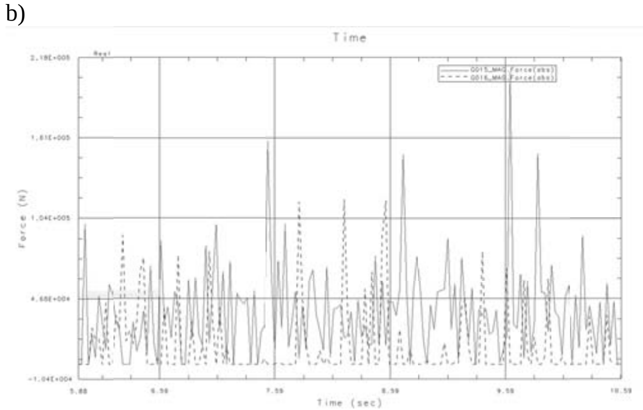


Fig. 8. A chart comparing the pressure forces inner and outer wheels single axes for speeds of: a) 130 km/h, b) 90 km/h. The red graph symbolizes the outer wheel, blue graph inner wheel

4.2. Safe speed - full wagon

Simulation studies were carried out on a wagon filled with material with a density of 800 kg/m^3, which ultimately gave the weight of 62 tons of cargo transported. Determination of the safe speed was to simulate the vehicle traffic along the arc of the track at speeds of 100, 90, 80 km/h.

Six models of coal in the form of solid (Fig. 9) in a row, will constitute full compliance of the wagon. Arrangement of coal models has been selected so that the second block was placed in the doorway. So, when a railway wagon will moving in a safe speed, it will be possible to identify the forces that occur at this point the door, using different variants of solid models.

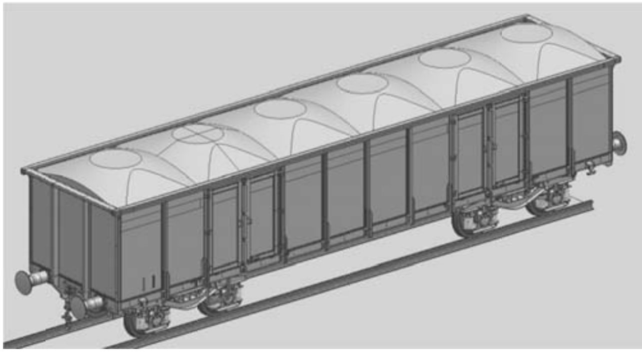


Fig. 9. Railway wagon with a cargo

In order to determine the approximate position of contact between the solid and the walls of the wagon, on the figures were modelled protruding strips of a width of 200 mm and height 1500 mm from the floor (Fig. 10)

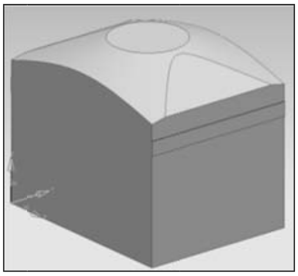


Fig. 10. The model lumps of coal

At a speed of 90 km/h, observed a temporary detachment of the inner wheel of the wagon railway. The chart (Fig. 11), shows the places where contact force, between the wheel and rail was decreased to zero. This means that at this point, wheel loses contact with the inner rail. In 8.7 second of simulation was observed loss of contact wheel/rail, it was a moment of rollover the railway wagon on a curved track section, defined in the literature [1] as one with most dangerous states of a moving of the train. Observed peaks in the chart are the result of the phenomenon snaking of the wagon from single the rail to another. After 10 seconds of animation, you can see how the frequency of the separation of carriage from the inner rail is decreasing.

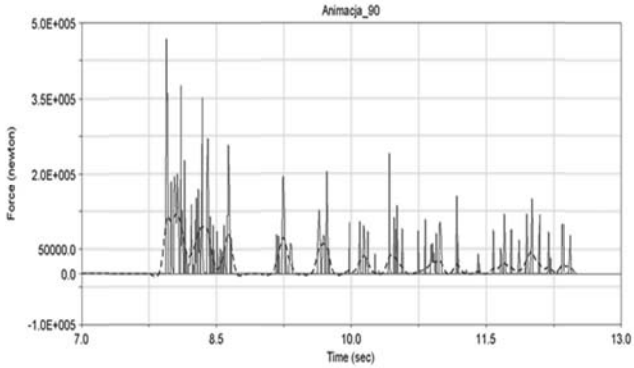


Fig. 11. Graph of pressure force between wheels and rail at speed of 90 km/h

In Fig. 12 can be seen a clear improvement of contact between the rail and the wheel of the wagon. The continuous red line is a plot of the actual value of the force, while the dotted - blue line is the trend line generated by the program. Analysing the chart can be concluded that there are still states in which the contact is zero, but this condition occurs in such a short moment of time that you can take the speed of 80 km/h, as a safe speed wagon journey full arc with a radius of 240 m.

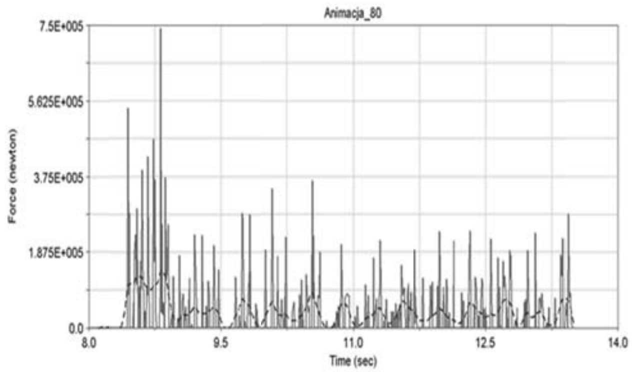


Fig. 12. Graph of pressure force between wheels and rail at speed of 80 km/h

The blue vertical line on the graph (Fig. 13) represents the time at which the car enters the arc. It has been observed that, the forces has a similar order of magnitude, followed by entry into the corner and gets stronger and stronger on the outer wheel and inner decreases. On graph (Fig. 13) can be observed the trend line generated by the program. After the entry into corner, averaged over the scope of the internal wheels oscillates between 32 kN (3.2 tons), and the outer wheel within 175 kN (17.5 tons).

4.3. Measurement of pressure forces on the door of the railway wagon

Series of studies was performed at a constant speed of 80 km/h, previously designated and recognized as safe. For this purpose, has been performed six tests with different settings and options lumps of coal. Based on these studies, we are not able to determine the position of pressure force in the doorway, we can only examine its value by adding together the appropriate charts and reading with these forces.

The averaged value of the force has been presented in Fig. 14. The average value of force oscillate between in a range of 19 kN (1.9 tonnes) to 25 kN (2.5 tonnes). Simulation studies has confirmed that the force is correct and complies with standard UIC OREB12/RP17.

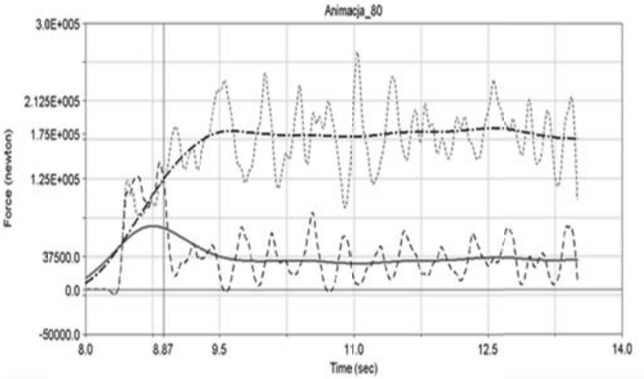


Fig. 13. Graph of pressure force the inside wheel (blue) and external (pink), red and dark blue lines are the averaged values of pressure at individual wheels

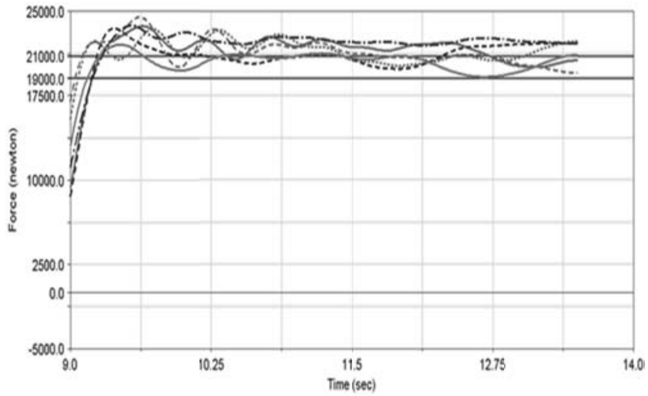


Fig. 14. Averaged results

5. Conclusions

Computer simulation shows the real movement the railway wagon on the track. Phenomena were observed during the motion of the actual object, such as tubing, detachment of the wheels on the rails of the wagon slipped off the track. Computer analysis allowed the identification of the forces acting on structural elements of the wagon train.

The results of motion study (the forces and dynamic phenomena) are the input date to research on the use of composite materials (laminates) in the repair and construction of new component parts and components of railway wagons [4,5,6].

Acknowledgements

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