MODERNISATION OF REPAIRED FREIGHT CARS BY APPLICATION OF COMPOSITE MATERIALS

Marek PŁACZEK[1]

ABSTRACT: In this paper an issue of freight wagon modernisation using composite materials is presented. The aim of this work is to develop a technology of freight wagons modernisation during their periodic repair. The main problem during exploitation of concerned types of freight wagons designed for coal transport is corrosion of the wagon's body shell. The goal is to elongate the period between periodic repairs (by better corrosion protection) and improve conditions of exploitation of modernised freight cars. Application of the composite panels to the freight wagon's body shell is proposed as the solution that can solve mentioned problems. The composite panels composed of fiberglass and epoxy resin were proposed. Assumptions of proposed technology of modernisation and results of computer aided analysis of considered types of the freight cars are presented in this work.
KEY WORDS: freight cars, modelling, modernisation, composite materials, strength analysis.

1 INTRODUCTION

A lot of effort is spent on the development of new materials and new technologies and brings new possibilities for designers and engineers. New materials and new methodology to design devices and systems causes that they are more effective, have better properties and lower costs of production. The possibility of smart materials application causes also new opportunities. On the other hand, computer aided methods of designing, manufacturing and product life cycle management are also powerful tools that help to design and produce modern technical devices. Modern systems include elements from different science areas, such as mechanics, electronics and informatics. Such connection brings new possibilities and new effects, so those systems can be called mechatronic systems.

Railway transport is very important for the development of the modern economy this is why many research works concerning with problems occurring in this way of transport and its development are being carried out all the time. The goal of those works are usually to develop the infrastructure that is used for transport of goods and people, make it more cost-effective, safe and less burdensome for the environment [1-3].

Problems of dynamics of freight wagons during their exploitation in different driving conditions are also very important [1-3]. In all of those works the problem of modelling of real object has a strong influence on obtained results and has to be solved using precise methods. This is why computer-aided methods, include Finite Element Method, are used very often [4-6]. On the other hand, experimental analysis and tests are also very important in order to verify results of calculations and simulations [7].

2 THE AIM OF THIS WORK

The present work deals with the modernization of freight wagons type EAOS 1415 A3 designed for coal and aggregate transport using composite panels. The aim of this is to modernize analysed freight cars during their renovation using new materials [4,8,9]. Effects that are to be achieved by the modernization are:
- better corrosion protection of the wagon elements,
- easier unloading of the wagon in winter conditions (no freezing of the cargo to the floor and sides),
- reduction of the weight of the wagon while its payload increases,
- easier management of the freight wagons during exploitation.

A statistical analysis of data from qualifying protocols were analysed in order to verify if some wagon's elements are the most exposed to damage during exploitation of freight wagons. A number (221) of qualifying protocols in a period of three years (2012-2014) were analysed for BDŻE, CFRE, CSDE, 401W, 408W and 412W types of freight wagons. The percentage of repairs of individual wagons elements was specified on the basis of protocols analysis. Taking into account the aim of the work – the modernization of the freight wagons using composite panels mounted to their body shell, the most important is the information about the damage of its elements. Analysis of qualifying protocols shows that there is no part of the freight wagon's body shell that is

[1] Silesian University of Technology, Faculty of Mechanical Engineering, Institute of Engineering Processes Automation and Integrated Manufacturing Systems, Konarskiego 18A, 44-100 Gliwice, Poland

more exposed to damage during exploitation of the wagons then the other elements. One important issue is the accurate operational documentation in order to obtain more precise information about the process of damage of individual elements of the freight wagons body shell during their exploitation. This documentation must start from the production of wagons and it should take into account operating conditions of carriage, such as the type of transported cargo, as well as all carried out repairs. The mechatronic system for structural health monitoring of freight wagons that is to be developed will also provide data about individual wagon's operation conditions and it may be an important issue in the wagon's documentation. The system should inform about destruction of the wagon's body shell during operation of the wagon. By using the system it will be possible to detect major defects of wagon's body shell without transporting it to the service station. It was necessary to verify the possibility of the inference from the dynamic response of the wagon about the changes in its technical condition during its standard operation in order to develop such system [9].

3 A CAD MODEL AND COMPUTER AIDED ANALYSIS OF EAOS TYPE OF THE FREIGHT CAR

In this work the process of modelling of the analysed freight wagon using Siemens NX software is presented. The 3D model was created on the basis of incomplete documentation and measurements of the real object. Precision of the created model was verified by checking its mass after defining material properties of wagon components and juxtaposing it with the mass of the real wagon. The created 3D model is very detailed and obtained discrepancy is about 5% of the real freight wagon mass. After its verification the model was used in strength analysis using the Finite Element Method in NX software. Stress and displacements of the freight car's elements were calculated. The CAD model of the freight car's type EAOS body is presented in Figure 1.

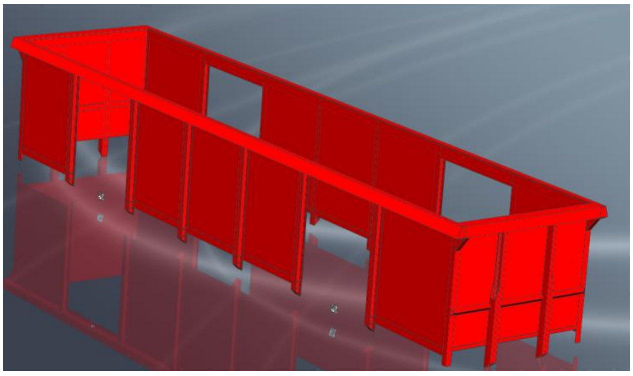

Figure 1. The CAD model of the freight car's body

By juxtaposing the weight of the real object and the CAD model after the material parameters were applied, the created CAD model of the 1415 A3 type of freight wagon was verified. The weight of the considered freight wagon is 20600 kg, while the weight of the CAD model is 19500 kg. The difference in weight is 5,34 % it is caused by omission of the braking system (air pipes, brake pads, etc.). It can be assumed that the created CAD model of the considered freight wagon is very precise and can be successfully used in the analysis of that freight wagon.

As the next step of the presented work the strength analysis of the body of the considered freight wagon type was carried out. It was realized using Siemens NX 8.5 software and Finite Element Method. In accordance with norm EN 12663-2:2010: Railway applications - Structural requirements of railway vehicle bodies - Part 2: Freight wagons [Required by Directive 2008/57/EC] the load of the model was assumed [10]. The structural design and assessment of freight wagon bodies depend on the loads that they are subject to and the characteristics of the materials they are manufactured from, in agreement with this norm. It is intended to provide a uniform basis for the structural design and assessment of the vehicle body within the scope of this European Standard. Based on proven experience supported by the evaluation of experimental data and published information the loading requirements for the vehicle body structural design and assessment are described [10]. The aim of this European Standard is to allow the supplier freedom to optimize his design whilst maintaining requisite levels of safety considered for the assessment.

The way of verification described by the norm is that the following tests are to be carried out: Forcing outwards in the horizontal direction at a level of 1,5 m above the floor:

1) force of 100 kN applied at four centre posts of each side wall;

2) force of 40 kN applied at the corner posts of wagons equipped with drop ends.

The significant permanent deformation at the point where the force is applied shall not exceed 1 mm. In addition, the elastic deformation observed during the test shall not result in any encroachment of the loading gauge. In Figure 2 the forces applied to the freight car CAD model are presented.

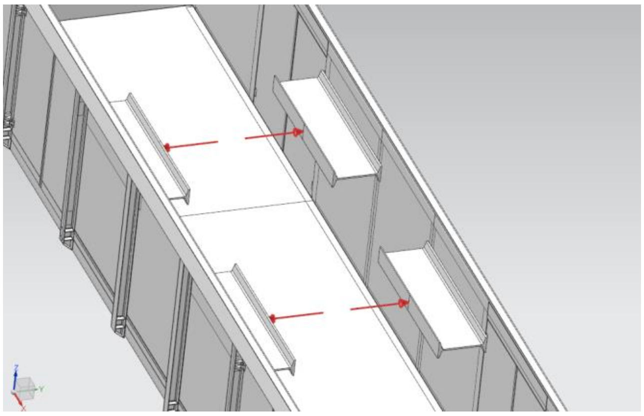

Figure 2. The way of the CAD model forcing

Results obtained using the Finite Element Method for the freight car's displacements and stress are presented in Figures 3 and 4 respectively.

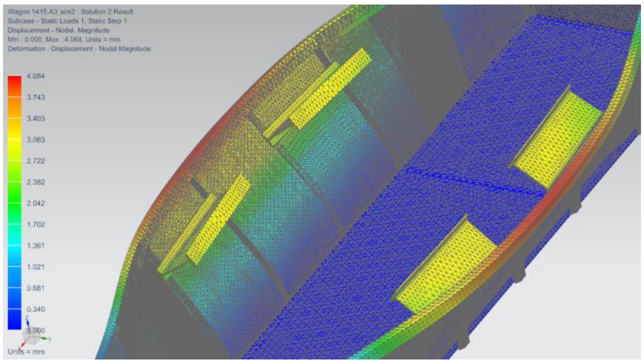

Figure 3. Displacements of the freight car's body

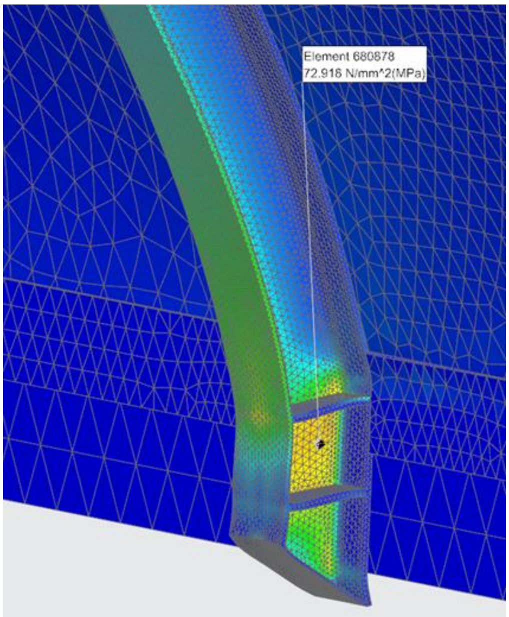

Figure 4. Stress of the considered freight car's body

Maximum value of the displacement was equal to 4,084 mm and occurred on the upper side beam. Average stress obtained in strength analysis is 50-65 MPa while the yield strength is 235 MPa. The maximum value is 72 MPa.

The support frame analysis was carried out twice. In the first case only the uniformly distributed load of 58 tons (the maximum weight of cargo) has been taken into consideration, while in the second case also compressive force of 2 MN in the axis of bumpers was applied. In the first case the maximum value of displacement was 4,32 mm, and maximum stress 170 MPa, while its average values were about 40 to 60 MPa. In the second case the maximum displacement was 4,49 mm in the vertical axis and 0,74 mm in the axis of the bumpers. Maximum value of stress was 180 MPa and its average value was also about 60 MPa.

4 COMPOSITE PANELS APPLICATION

Using virtual models of the considered types of freight cars, an application of composite panels was simulated and further analyses were performed. Two models of freight cars were considered: EAOS and a hopper freight car type 418V (Fig. 5.). In Figures 6 and 7 CAD models of both types of freight cars with applied composite panels are presented.

Figure 5. The type 418V of the freight car

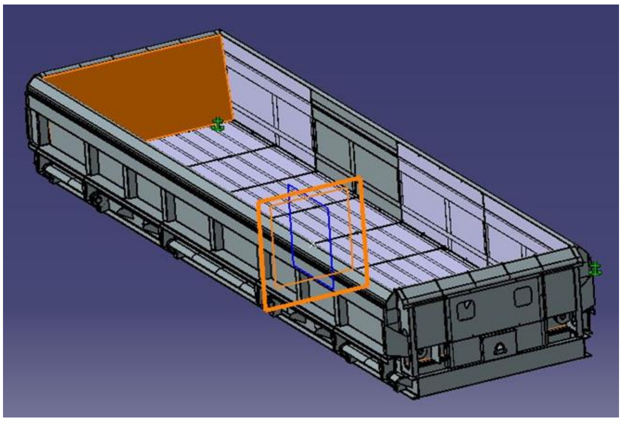

Figure 6. Application of composite panels in the model of the type 418V of freight car

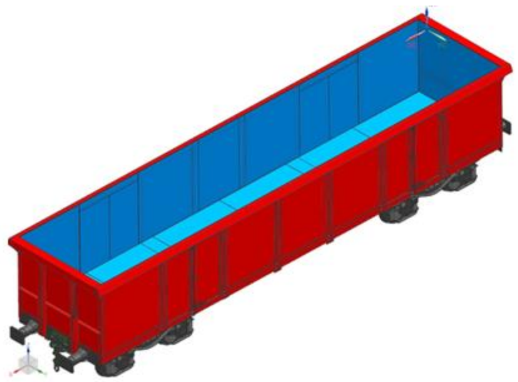

Figure 7. The CAD model of the EAOS freight car with composite panels

The design process of the composite panels started by determining the dimensions of the interior of the wagons and the preliminary estimate of the amount of plates, taking into account the criterion of their width and thickness. An additional criterion to limit the number of types of manufactured items and to ensure the easiest mass production was also assumed. A contextual modelling has enabled the creation of references to the existing geometry of the freight car, which excluded the necessity of positioning the panels at a later stage of the design. The geometry of the freight car, the location of adjacent panels and the maintenance of dilation between panels with the width value of 3 mm was taken into account. Wholes of diameter 11 mm were introduced in order to use rivet nuts to fix composite panels to the shell of the wagon. In the case of identical composite panels an auto copy and positioning of components within an assembly were used, taking into account the expansion joints between the panels. The 2D documentation of composite panels was prepared after verification of their dimensions.

CAD systems facilitate and greatly accelerate the process of new elements construction. Additionally, making changes and creating revisions of new objects do not constitute any problem. In Figure 8 the distribution of composite panels on the shell of the 418V freight car body is presented.

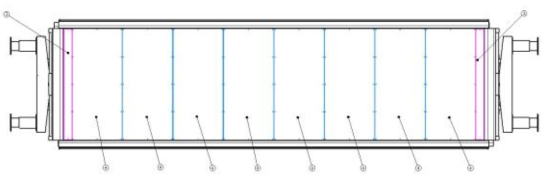

Figure 8a. The distribution of composite panels to the shell of the 418V freight car body

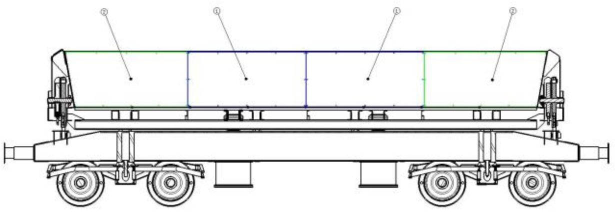

Figure 8b. The distribution of composite panels to the shell of the 418V freight car body

Fulfilling all the objectives the following configuration of covering of the freight car's body was achieved. In order to cover the interior of the EAOS freight car 18 composite panels with 4 different sizes were used:

- 8 plates covering the bottom of the wagon;
- 2 plates covering the front and back of the wagon;
- plates covering the edges of the sides (two per side);
- 4 plates covering the central part of the side (two per side).

In Figure 9 the distribution of composite panels on the shell of the EAOS freight car body is presented.

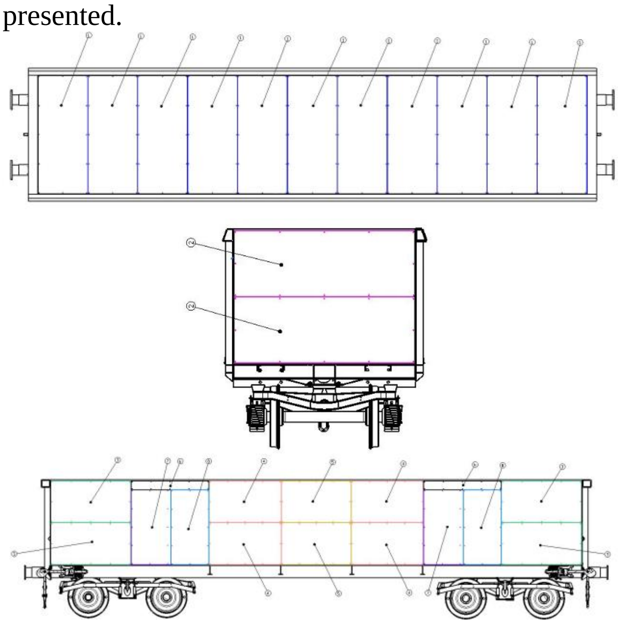

Figure 9. The distribution of composite panels to the shell of the EAOS freight car body

In order to cover the interior of the 418V type of the freight car 43 composite panels with 8 different sizes were used:

- 11 plates covering the bottom of the wagon;
- 4 plates covering the front and back of the wagon (two per side);
- 8 plates covering the edges of the side (four per side);
- 8 plates covering the central part of the sides (four per side);

- 4 plate covering the central part of the side (two per side);
- 4 plates covering the space over the door (two per side);
- 4 plates covering the left hand side of the door (two per side);
- 4 plates covering the right hand side of the door (two per side).

Tests on real objects during their standard exploitation were also conducted. Composite panels were mounted on walls and doors of modernized freight cars. An example of composite panels mounted on the modernized freight car walls are presented in Figure 10. Panels presented in Figure 11 were exploited during standard operating conditions of the freight car for approximately 14 months.

Figure 10. Composite panels mounted on the freight car's doors

Figure 11. The composite panel after exploitation

5 CONCLUDING REMARKS

This paper deals with the possibilities of freight wagons modernization during their periodic repairs. The possibility of composite materials application in the construction of the freight wagon body is considered as well as reduction of the weight of the wagon while its payload increases. In order to achieve that, a series of analysis of the real objects and their models was carried out, especially the strength analysis. The incomplete documentation of the considered freight wagons supplied by consortium member forced the visual inspection of real objects and measurements. However, after the verification of the created CAD models it can be assumed that they are very precise and can be successfully used in such kind of analysis. The carried out analysis proved that there is a possibility to use smaller cross-sections profiles and thickness of the wagon body sheets in the modernized wagons. Furthermore, the additional composite panels mounted to the wagon's body shell will also bring an additional stiffness to the structure Therefore, it will not be necessary to replace the corroded panels during repairs of the wagons while composite panels will be applied. The presented concept of technology for freight wagons modernization should solve mentioned problems that occur during exploitation of freight wagons. The proposed technology of mounting composite panels to the wagon's body shell during its renovation is easy to apply and will extend the period of time between necessary repairs of freight wagons, thus reducing the costs of their exploitation.

Carried out tests proved that the proposed solution of the main problems that occur during exploitation of a standard freight car can be successfully solves by applying composite panels to the walls and doors of the freight car's body. This protection of the freight car's body shell increases a period between freight cars renovations because a standard body made of steel has better protection against corrosion. In standard condition steel sheets installed during freight cars renovations are not painted using any kind of anti-corrosion layer because it would be destroyed by a transported cargo very soon. Modernized freight cars are protected mechanically and by the anti-corrosion agent.

Furthermore, the proposed solution with composite panels application can be easily introduced to the standard technology of freight cars renovation. Composite panels with the required dimensions for the selected types of wagons can be easily installed using rivet-nuts. They can also be installed without replacing some of the corroded elements because they will increase their mechanical strength.

After more than one year of exploitation some damages of the installed composite panels could be observed. The most probable causes of this damage are mechanical loads. Such kind of damages are very often the result of improper unloading of the transported cargo, for example by using excavators.

6 ACKNOWLEDGEMENTS

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