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Computer-aided strength analysis of the modernized freight wagon

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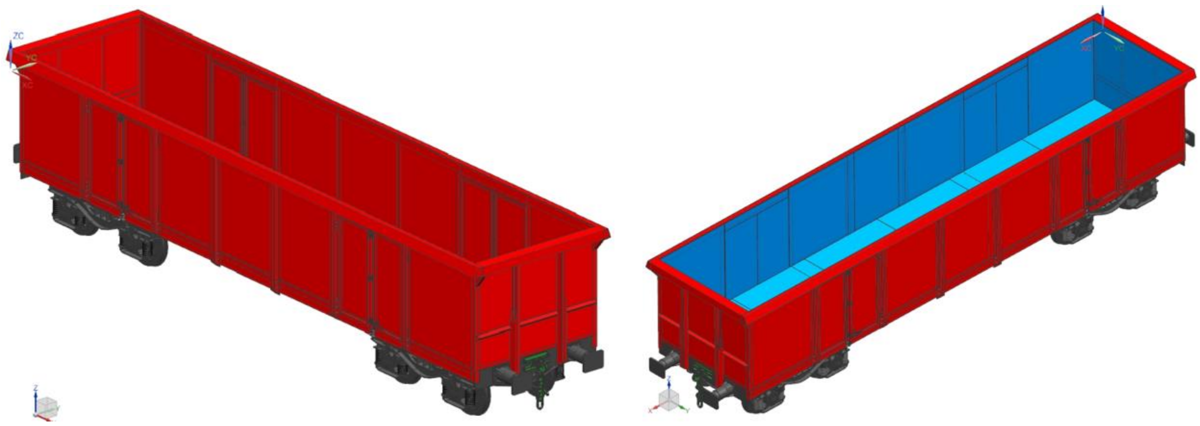
Abstract. In the paper results of computer-aided strength analysis of the modernized freight wagon based on Finite Element Method are presented. CAD model of the considered freight wagon was created and its strength was analysed in agreement with norms described the way of such kind of freight wagons testing. Then, the model of the analysed freight wagon was modernized by adding composite panels covering the inner surface of the vehicle body. Strength analysis was carried out once again and obtained results were juxtaposed. This work was carried out in order to verify the influence of composite panels on the strength of the freight car body and to estimate the possibility of reducing the steel shell thickness of the box in order to reduce weight of the freight wagon.

1. Introduction

Rail transport is a very important part of the modern economy, one of the components determining its dynamic development. Nowadays, numerous studies are conducted, aimed at introducing new technologies and solutions in railway infrastructure, logistics management systems, as well as in the traction vehicles [5, 15-18, 20]. Introduction of modern technology can eliminate or reduce nuisance problems associated with the implementation of any kind of transport or the operation of used technical means [1, 2, 17, 21, 24-26]. This paper contains a report on the part of the research conducted in the research and development project entitled "Analytical and experimental studies and determination of the structural features of components and assemblies in innovative structure of repaired wagons". This project is being implemented under the Programme for Applied Research by Institute of Engineering Processes Automation and Integrated Manufacturing Systems of Silesian University of Technology with consortium partners: DB Schenker Company and Germaz Company. The main objective of the project is to develop technologies to modernize freight wagons for the transport of coal and aggregates, through the use of innovative materials and technologies to repair this type of wagons during periodic repairs [1, 2, 24-26]. Works which have been undertaken within the project are to improve the operating conditions considered types of wagons by increasing their resistance to corrosion and freezes of the freight to the shell of the wagon body in winter, and thus an easier unloading. An additional objective is also to retrofit verification of strength coaches, as well as to estimate the possibility of reducing their weight, while maintaining or increasing the permissible load. Gliwice research centre has a great experience concerning with tasks of modern technical devices [13, 14, 21] as well as analysis and synthesis of mechanical and mechatronic systems [3, 4, 6-12, 19, 22, 23] also supported by computer methods [24].

2. The considered freight wagon and its CAD model

In this paper the freight car type 1415 A3 designed for coal and aggregate transport is analysed. This type of freight car is designed for tipping unloading. Examinations of real objects were performed and photographic documentation of damages of freight cars prepared for repair was created. Also employees of repair facility were interviewed about typical defects and operation problems. Recurring damage and their causes were indicated. In case of all considered types of freight cars the main problems occurring during their exploitation are: corrosion of the freight cars shells of body and floors and freezing of the cargo to the sides and floor of the wagons. In case of the type 1415 A3 there is also a problem with damages of the vehicle body shells that occurs as the result of inappropriate methods of unloading (using scoop, excavator, etc.). For the car type 1415 A3 it can be also noticed that it has a very durable wagon supporting frame and frame of the body – there is almost no damages in repaired cars. It means that there may be a possibility to reduce the weight by the use of smaller cross-sections profiles after modernization. The incomplete documentation of the considered freight wagon supplied by consortium member forced the visual inspection of real object and measurements in order to create its CAD model. The main idea of the research project is to use composite panels mounted to the vehicle body shell in order to increase its resistance to corrosion and freezes the freight to the shell of the wagon body in winter. Created CAD models of the original freight wagon and wagon modernized by adding composite panels are presented in figure 1.



a) b)

Figure 1. The CAD model of the considered freight wagon before (a) and after modernization (b).

The created CAD was verified by juxtaposing the weight of the real object (20600 kg) and the CAD model after the material parameters were applied (19500 kg). The difference in weight is 5.34 %. It should be mentioned that the braking system (air pipes, brake pads, etc.) was not taken into account in the CAD model. It causes the difference in the weight. After this verification it can be assumed that the created CAD model of the real freight car is very precise and can be successfully used in next analysis.

3. Assumptions of the strength analysis and its results

In the first test of the strength analysis the static loading test of the wagon floor was carried out. As a load the maximum permissible mass of freight was assumed, taking into account its uniform distribution on the surface of the floor of the wagon. The analysed model is presented in figure 2.
As the next step of the presented work the strength analysis of the considered freight car type 1415 A3 was carried out. It was realized using Siemens NX 8.5 software and Finite Element Method. In the first step the strength analysis of the freight car's body was carried out. The method of load of the model was assumed 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] [27].

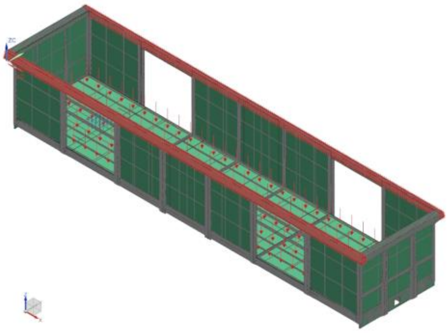


Figure 2. The way of the freight wagon forcing during the static loading test of the wagon floor.

In agreement with this norm the structural design and assessment of freight wagon bodies depend on the loads they are subject to and the characteristics of the materials they are manufactured from. Within the scope of this European Standard, it is intended to provide a uniform basis for the structural design and assessment of the vehicle body. The loading requirements for the vehicle body structural design and assessment are based on proven experience supported by the evaluation of experimental data and published information. 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 [27]. 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 [27]. In Figure 3a the way of the freight wagon forcing is presented. In agreement of requirement of the norm the CAD model was forced by a system of forces presented in figure 3b. Forces are transferred by rigid beams.

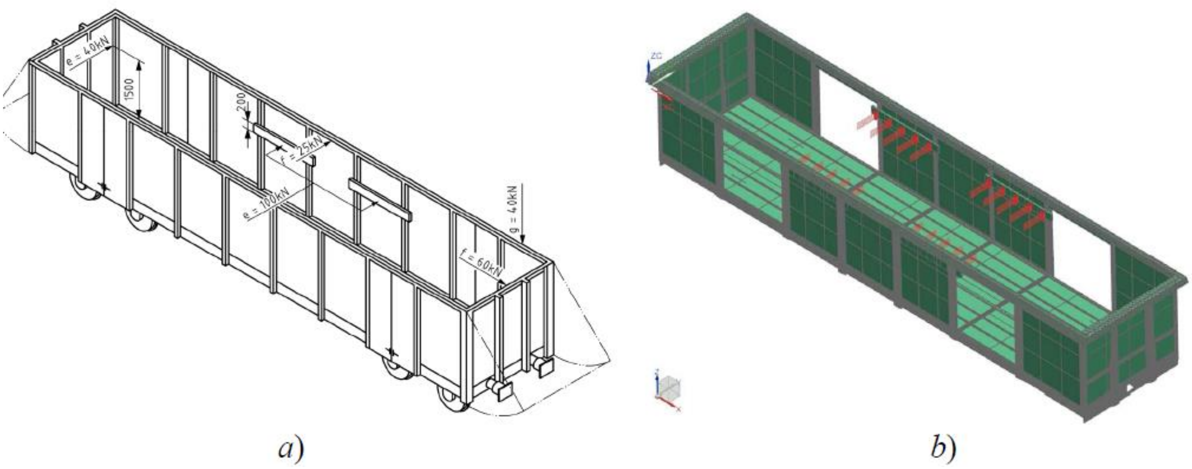


Figure 3. The way of the freight wagon forcing (EN 12663-2:2010) (a) and its implementation on the CAD model (b)

Results of the carried out analysis are presented in figure 4 and 5. Displacements and strains of the model before and after modernization (model with laminate plates) obtained during the static loading test of the wagon floor are presented in figure 4. It can be noticed that for the modernized model of the considered freight wagon values of the maximum strain and displacement are much lower than for the model without laminate plates. The same results were obtained during the static loading test on the four central columns of each wall of the wagon. Those results are presented in figure 5. Result of the

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carried out analysis is also the possibility to identify elements of the model with maximum or minimum strenuous and identify those which in the future can be upgraded by the thinning of the used steel sections or modernize their structural form. Such modernization can reduce the mass of the wagon and balance the mass growth caused by the adding of composite panels.

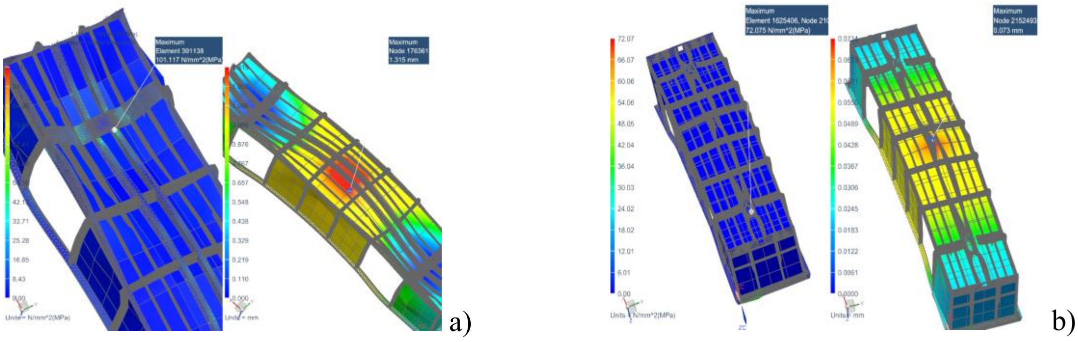

Figure 4. Results (displacements and strains) obtained for the CAD model before (*a*) and after modernization (*b*) obtained during the static loading test of the wagon floor.

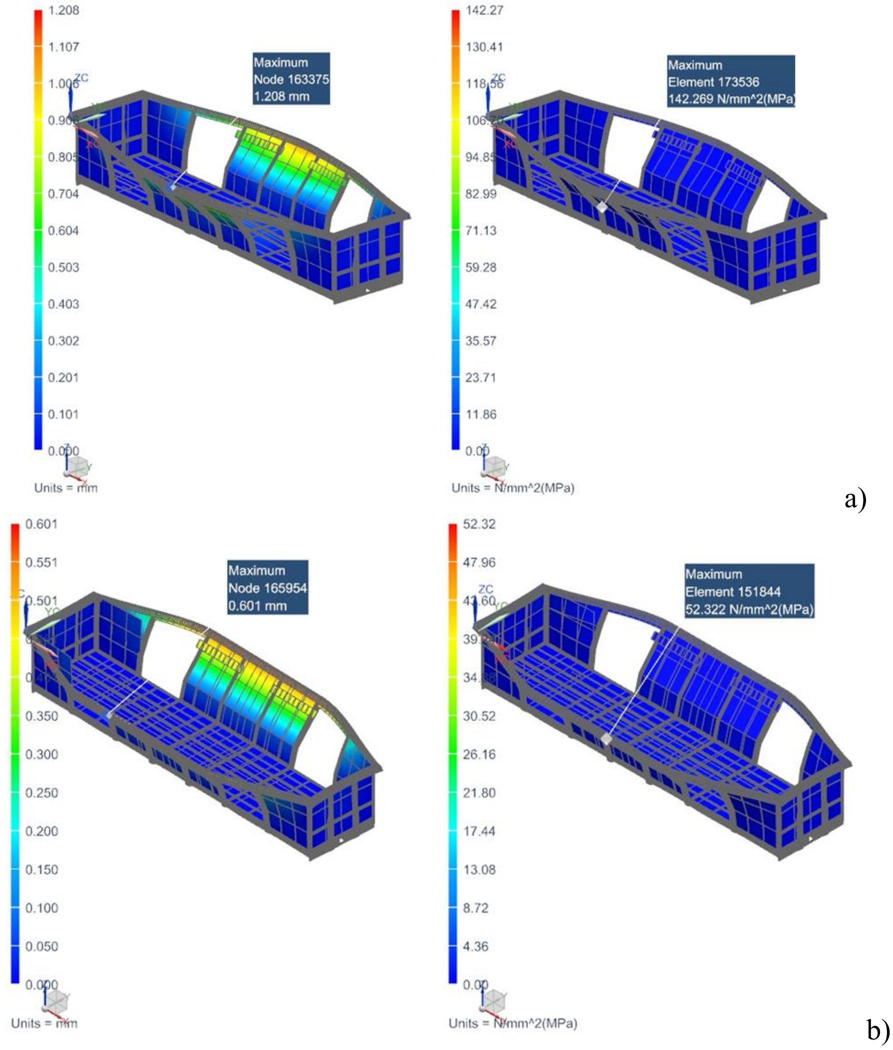

Figure 5. Results (displacements and strains) obtained for the CAD model before (*a*) and after modernization (*b*) during the static loading test on the four central columns of each wall of the wagon.

4. Conclusions

The aim of carried out works that are a part of the research project is to introduce new technologies and solutions in railway traction vehicles. Introduction of modern technology can eliminate or reduce nuisance problems associated with the implementation of this kind of transport. The main nuisance problems that occur during exploitation of the considered freight wagon are corrosion and freezes of the freight to the shell of the wagon body. Those problems should be reduced by adding composite panels mounted to the surface of the wagon's body. The mass of the wagon will increase while adding those new elements. This is why it is necessary to verify the strenuous of wagon's elements and decide if some of them can be replaced by thinner elements or their structural form can be changed. In the paper results of first analysis carried out in order to verify this possibility are presented. It was proved that some elements, for example car body sheet metal plating could be thinner, especially taking into account that laminate panels will be added.

In the future works laboratory stands for testing elements of considered freight wagons will be created and analysis of real objects will be carried out. Results will be juxtaposed with results of strength analysis of virtual models. An attempt will be made to modernize the superstructure of the wagon in order to reduce its weight and balance the additional weight of the composite elements. In the next step the possibility of further reduction of the freight wagon mass will be verify in order to increase permissible load mass of the wagon while maintaining the necessary strength.

Acknowledgments

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