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New Design of the Hatch Cover to Increase the Carrying Capacity of the Gondola Car

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ABSTRACT

The paper presents a new design of the gondola car hatch cover to increase the carrying capacity. The results of calculations the CAD model of the gondola car hatch cover showed that the maximum equivalent stresses do not exceed 216.4 MPa, the maximum equivalent displacements are 3.323 mm, and the maximum equivalent strains are 6.834×10^{-4}. A new design of the gondola car hatch cover helps reduce the tare weight of 1.2%, i.e. increase the load capacity of the gondola car of 0.9 tons. The proposed design of the gondola hatch cover allows one to reduce the amount of rolling stock in the train by one unit while maintaining the total mass of the train.

Keywords: rolling stock, railways, gondola car hatch cover, design

INTRODUCTION

The railway transport in the world is a large part of the market of services that are associated with the organization of transportation processes [1]. The main task of the railways is to increase the level of the safety of trains [2, 3], which affects the reliability of the rolling stock, power lines, and the lock status of the communication devices and profile path. Rolling stock, especially gondola cars, the total number of failures of railway transport is on the first position. This is due to the fact that the number of freight traffic is only increasing every year [2].

The failures of the gondola cars in operation are an indicator of the reliability of the design [2, 3]. The design and fabrication of all the components of rolling stock affects reliability. Therefore, in the design phase is necessary to lay sufficient structural strength with the technology of production, as well as to take into account operational factors [4] and experience of the carriage economy. An analysis of traffic safety in the carriage economy of Ukrainian railways indicates the need to modernize obsolete gondola cars, as well as to improve and manufacture more modern gondola cars of all types. That is, it is necessary to develop modern gondola cars, the design of which will ensure high reliability. This will reduce failures of the gondola cars in operation and improve traffic safety. Faults in the bodywork of gondola cars, especially the hatch cover, resulting in the loss of bulk cargo, i.e., bodywork of gondola cars cannot ensure the safety of cargo and this, in turn, affect the safety of trains. In addition, an urgent task is to increase the carrying capacity of gondola cars to meet the growing demand for cargo transportation. Therefore, the work considers the design of the hatch cover to increase the carrying capacity of the gondola car.

CONSTRUCTION ANALYSIS GONDOLA CARS

In Europe, used for transportation of inert goods from gondola cars, mainly coal, by gondola cars. For example, Polish gondola cars [5] series E are called wagons for coal transportation. To distinguish them from the universal gondola cars of a 1520 mm is the lack of hatch cover, but only the side doors. Discharge occurs through the doors and with the conveyor belt. The German campaign «SCHENKER» launches gondola cars with retracted roof model 889 [5, 6], with an inclined end wall. Model 889 gondola cars are designed for the transport of heavy objects.

The German company manufactures and gondola cars to transport bulk cargo carrying capacity of different body volumes [6] that do not have a hatch cover on the floor (as opposed to the gondola car of 1520 mm), but each side car in the side walls is made of two double doors. The industrial sector of China is already in a significant period of time is in a stage of rapid development, requiring ever larger volumes of cargo. This contributes to the uninterrupted development of the transport system in China and, in particular, the development of the gondola car [5, 7]. Because of this, Chinese gondola car manufacturers produce more and more new gondola car models calculated on a track of 1435 mm (track width PRC) and a track of 1520 mm (for export). One of the largest manufacturers of rolling stock is China Jinan Railway Vehicles Equipment Co., Ltd. (JRVEC) – a subsidiary of China CNR Corporation Limited. It produces a large number of different models of gondola cars, including gondolas with a body made of aluminum alloys: models C80 and C80V, allowing open top wagons to increase the carrying capacity by reducing the tare [7–13].

A feature of gondola cars USA and Canada is to increase carrying capacity of the wagons are not a result of increasing the number of axles and the application of high loads on the axis on rails that make up the majority of wagons 32.5 ton. This allows you to build a four-axle car that can carry up to 100 tons. For some special wagons axial loads up to 40 ton [9, 14]. The standard US cars are in most cases the ratio of the container is higher than the cars of Ukraine. The Ukrainian campaign PJSC 'Kryukovsky Railway Car Building Works' produces gondola cars of model 12-7039 [6, 9] with a carrying capacity of 75.5 tons. A general view gondola car of model 12-7039 is shown in Fig. 1, a; gondola car hatch cover is shown in Fig. 1b. The material of the gondola car hatch cover is steel 09G2C with yield limit 345 MPa. The weight of the gondola car hatch cover is 175 kg.

The work [15] presents an improved design of the gondola car hatch cover with intermediate S-shaped straps made of polytypic materials. However, this design of the hatch cover does not allow increasing the carrying capacity of the gondola car. In other works, it is not presented according to the results of the study of the gondola car hatch cover.

THEORETICAL BACKGROUND FOR THE CREATION OF A NEW OF THE GONDOLA CAR HATCH COVER DESIGN

According to the authors, in a gondola car has a promising decrease of metal bodywork. This reduction may be achieved using basic engineering principles and surface resistance materials.

The analysis of gondola car structures made it possible to formulate the hypothesis that the gondola car hatch cover should have a different geometric shape and design. Therefore, the proposed gondola car hatch cover with completely different geometric and design parameters. A general view of the proposed design of the gondola car hatch

a)

b)

Fig. 1. A general view gondola car of model 12-7039 (a); gondola car hatch cover (b)

cover is shown in Fig. 2. In this form of construction of the gondola car hatch cover will initially be loaded sheet itself, i.e., the deflection plates will not, and the profile can take heavy loads. In such a case can be made increasing payload gondola cars, and considering different thickness of gondola car hatch cover can reduce metal body. The negative side of the use of the proposed gondola car hatch cover is the reduction in body volume, which can be up to 0.15 m^3 per hatch cover.

It should be noted that the profiles of the gondola car hatch cover sheet can be varied. But in this paper, there is only one kind of sheet.

RESEARCH RESULTS

To confirm the hypothesis put forward for the use of a structurally modified gondola car hatch cover, theoretical studies were carried out based on the finite element method. The proposed design of the gondola hatch cover was calculated

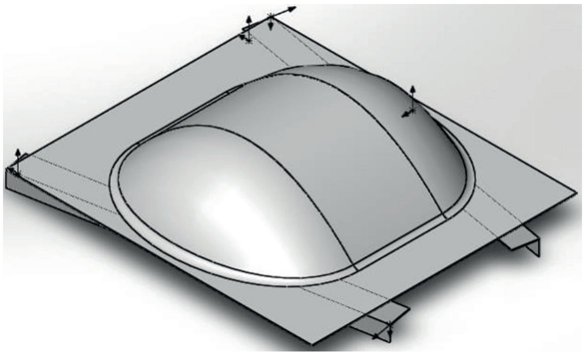

Fig. 2. The proposed model of the gondola car hatch cover

in accordance with [16]. A uniformly distributed load of 80 kN was applied to the gondola car hatch cover. We studied a typical gondola car with a carrying capacity of 75.5 tons with a geometrically and structurally modified 4 mm thick and a total weight of the structure of 110 kg, made of simple carbon steel. Equivalent stresses, displacements and strains calculations were performed for the CAD model of the gondola car hatch cover. The simulation results are shown in Fig. 3–5. The stress analysis of the gondola car hatch cover under load (Fig. 3) showed that the maximum equivalent stress is 216.4 MPa at yield strength of 220.6 MPa. An analysis of the displacements of the gondola car hatch cover under load (Fig. 4) showed that the maximum displacement is 3.323 mm. An analysis of the strains of the gondola car hatch cover under load (Fig. 5) showed that the maximum strain is 6.834×10^{-4}.

In addition, CAD model studies were carried out in static analysis for different thicknesses of the extruded sheet (3–6 mm) of the gondola car hatch cover. The results of equivalent stresses (according to Mises), displacements, and strains of the CAD models of the gondola car hatch cover under loading are shown in Fig. 6. Data presented (Fig. 6a) revealed that the new gondola car hatch cover made from plain carbon steel with a sheet thickness of 3 mm maximum equivalent stresses exceed the yield strength of more than 1.4 times, i.e., coachwork use gondola car hatch cover sheet with a thickness of less than 4 mm is only possible when using steel alloys which have higher strength characteristics. The optimal sheet thickness of the structurally modified gondola car hatch cover, which will ensure

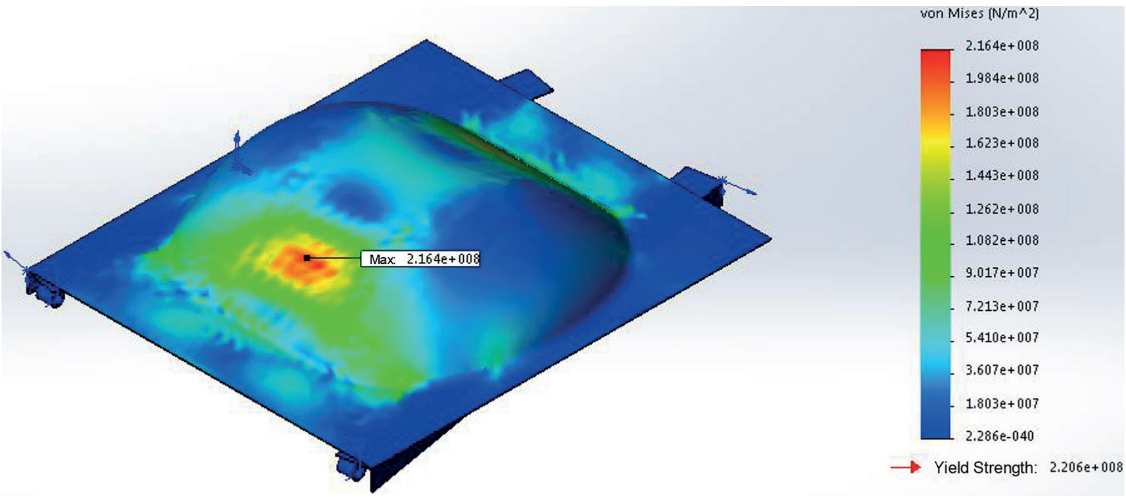

Fig. 3. Equivalent stresses of the gondola car hatch cover

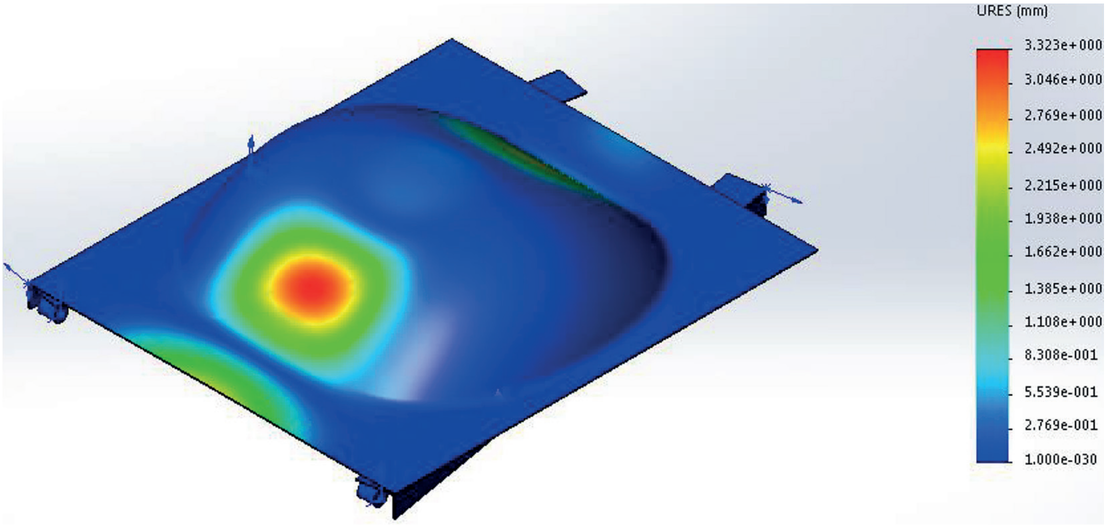

Fig. 4. Displacements of the gondola car hatch cover under loading

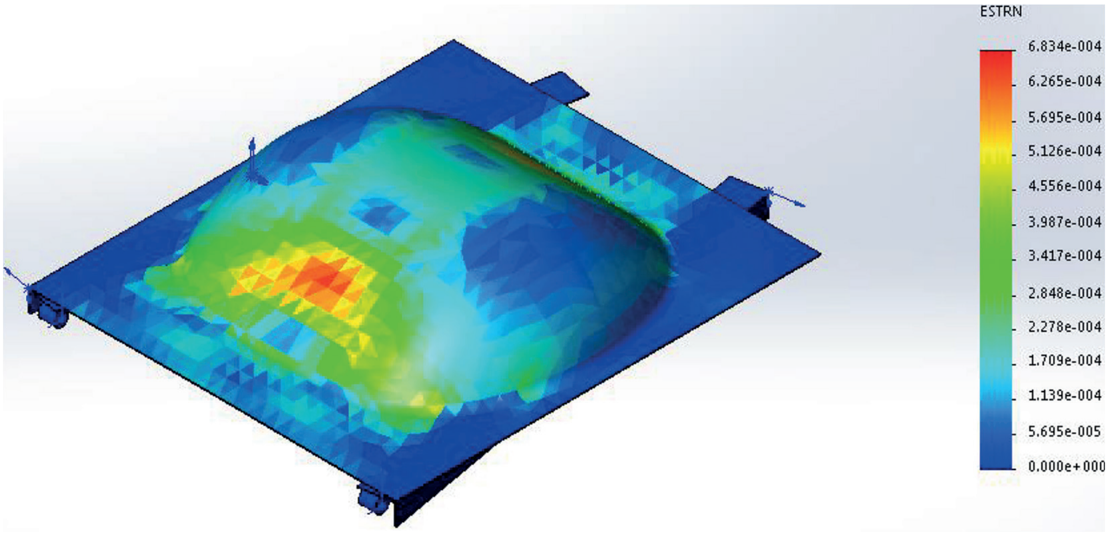

Fig. 5. Strains of the gondola car hatch cover under loading

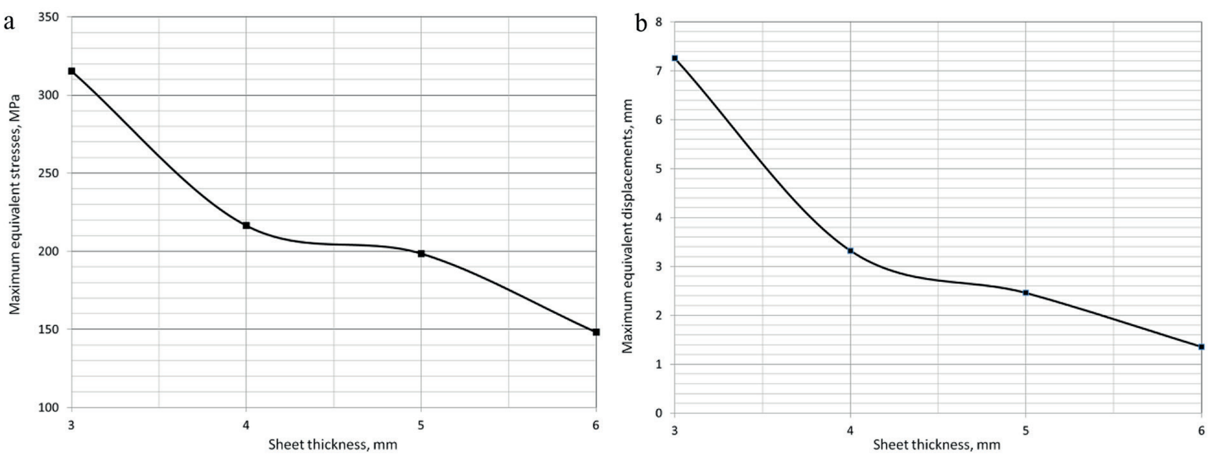

Fig. 6. Maximum equivalent stresses (according to Mises) (a), maximum equivalent displacements (b), maximum equivalent strains (c) in the static analysis of the proposed gondola car hatch cover depending on the thickness of the sheet

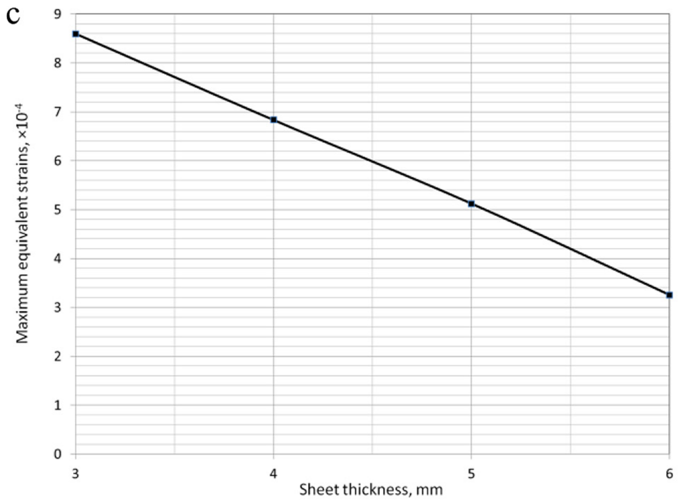

Fig. 6. Cont. Maximum equivalent stresses (according to Mises) (a), maximum equivalent displacements (b), maximum equivalent strains (c) in the static analysis of the proposed gondola car hatch cover depending on the thickness of the sheet

reduction of the metal gondola car body and the required level of strength characteristics, is 4–5 mm. The highest displacement is typical for the gondola car hatch cover with a sheet thickness of 3 mm, which exceeds 7 mm. The most optimal displacement values have gondola car hatch covers with a sheet thickness of 4 to 6 mm. Of course, the lowest values of maximum displacement in the modeling observed in the gondola car hatch cover with a sheet of 6mm thick, which is 1.38 mm (Fig. 6b). The maximum equivalent strains at the surface of the gondola car hatch cover (Fig. 5c) are linear, depending on the thickness of the sheet. The amount of strain is in the range 3.252–8.615×10^{-4}.

CONCLUSIONS

In this work, the principles of engineering surfaces were used to increase the carrying capacity of the gondola car. As a result, a new design of the gondola car hatch cover was proposed. The proposed design of the gondola car hatch cover, made of simple carbon steel, has a mass of 110 kg, which is 37.1% less than the base model. The calculations of the proposed gondola car hatch cover showed the following results. The maximum equivalent stresses are 216.4 MPa at yield limit 220 MPa;The maximum displacement is 3.323 mm. The maximum strain is 6.834×10^{-4}. Using the basics of surface engineering, suggested a new design of the gondola car hatch cover, which helps reduce the tare weight of 1.2%, i.e., increase the load capacity of 0.91 tons. Therefore, the thickness of the simple carbon steel metal sheet of the gondola car hatch cover is 4 mm. Also worth mentioning is the fact that changing the surface of the lids and appearing negative point, which is associated with a decrease in volume of the body gondola car. However, this decrease is not greater than 0.15 m^3 per hatch cover. The proposed design of the gondola hatch cover allows one to reduce the amount of rolling stock in the train by one unit while maintaining the total mass of the train.

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