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ТРАНСПОРТНЕ БУДІВНИЦТВО

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Modernization of Platform Schnabel Car with a Carrying Capacity of 220 Tons

Purpose. The article is aimed to calculate the strength of the element of the special design of the Schnabel car to increase the carrying capacity up to 250 tons, as well as consider the possibility of using special cars to transport the oversized cargo according to the strength calculation results of the span bolster of the Schnabel car. **Methodology.** A special design of the span bolster of the Schnabel car was developed, which allowed increasing the carrying capacity of the platform Schnabel car to 250 tons. SolidWorks CAD allowed testing the span bolster strength of the modernized Schnabel car. **Findings**. A review analysis of railway Schnabel cars has been performed. The possibility of testing the strength of the Schnabel car design details using modern SolidWorks CAD is considered. When loading the span bolster of the modernized Schnabel car with a compressive force of 2.5 MN, the stresses do not exceed the allowable, and the design has no weaknesses. The specialists of Design and Development Technological Bureau for the Design and Modernization of Rolling Stock, Track and Artificial Structures performed research and development for the production of a sixteen-axle platform Schnabel car with a capacity of up to 250 tons. **Originality.** The mathematical model of the modernized sixteen-axle platform Schnabel car with a loading capacity up to 250 t was further developed. The implementation of the mathematical model in SolidWorks CAD allowed testing the design for the strength of the Schnabel car. **Practical value**. The results of the work can be useful for the design departments for rolling stock design and relevant specialists. Modern CAD in some way simplifies the process of designing parts and assemblies of mechanisms, allowing one to test certain system parameters with high accuracy.

Keywords: freight transportations; oversized cargo; railway Schnabel car; international transportations; car modernization; finite element method

Introduction

Rail transport is one of the cheapest, most reliable, fast, universal and safe types of land transport. Transportation by rail is divided into two types: passenger and freight ones. Freight transportation is carried out by different types of rolling stock.

There are several types of cars, depending on the cargo characteristics, the methods of loading – unloading, the need to protect the cargo.

The railway network is quite developed, so transportation is carried out in different directions in the minimum time. Rail freight transportation simplifies logistical planning, is convenient for transporting raw materials to industrial enterprises, deliveries to large cities, supplying more goods to remote locations.

The rolling stock variety today allows transporting almost any type of cargo.

Ukrzaliznytsia JSC provides transportation in four main directions: across Ukraine, to the CIS countries, Europe and Asia. A significant share is accounted for by transportation to the CIS countries and Europe. The main issue is the possibility of coordinating traffic according to the track gauge (in Ukraine and the CIS – 1520 mm, in the vast majority of European countries – 1435 mm). In general,

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the share of the track 1435 mm is approximately 60% of the total length of the rails [13]. Therefore, the problem of rearranging cars in the international direction from the track gauge of 1435 and 1520 mm and vice versa is relevant for Ukraine's export-import.

As a result of multiple coupling-uncoupling of cars and the use of changeable bogies, international trains at the station may require up to 3 hours of additional travel time. At the beginning of the twentieth century, attempts began to develop technology for the transition of cars from one track gauge to another. The bogie rearrangement of passenger and freight cars for different track gauge in specially organized track-gauge changeover points at border junctions has become more progressive [8].

One of the important tasks regularly facing industrialists is the transportation of oversized and heavy loads, its solution is always a technical problem that can be overcome with the help of specialized Schnabel cars.

Today there is a problem: the fleet of specialized Schnabel cars and other cars for oversized cargo is not updated, its technical condition is critical. The need for Schnabel cars is constantly growing, as many of them have already been decommissioned, and the number of running Schnabel cars is decreasing every year. Thus, the car fleet is not replenished, and the service life of the existing Schnabel cars is coming to an end.

The constant need to transport heavy cargoes by rail with minimal investment, on the one hand, and limiting the axle loading, on the other, created the preconditions for the development of a new generation of Schnabel cars as the cheapest transport mode for heavy, large and long equipment.

The condition of load-bearing metal structures of the special cars for the transportation of special cargoes is not close to the limit after long operation [14].

According to design and purpose, Schnabel cars include the following main types: platform, well, coupling, articulated. Each type of Schnabel car is distinguished by the number of axles, capacity and other technical characteristics [7].

Platform conveyors are designed for transporting the oversized cargo. As the cargo dimensions are limited [3], its transportation is complicated, the transportation cost is higher or transportation by rail is not possible at all. Therefore, such Schnabel cars have a lower loading platform due to the curved shape of the main beam, which reduces the cargo oversize index and, accordingly, the transportation cost by rail [13]. Platform Schnabel cars have 4, 8, 12 or 16 axles and a capacity of 55 to 225 tons. Modern upgraded Schnabel cars can have a capacity of up to 250 tons, due to the use of modern materials, the introduction of new design and technological solutions. But platform Schnabel cars also have a significant disadvantage: the platform length is limited, which does not allow transporting long cargoes.

Platform Schnabel cars are a relevant solution when transporting military equipment, as well as oversized and heavy cargo by rail.

In general, the advantages of using rail transport compared to other transport modes are as follows:

– the price in case of long routes, railway transportation will always be cheaper, than air and sea transportation;

– safety, because the transportation of goods by rail – is almost absolute guarantee of its preservation. During the rail transportation of goods, such factors as the quality of the road surface (compared to road transport), weather conditions, human factor, do not affect the conditions of its preservation. It is also possible to protect a certain type of cargo from harmful environment factors;

– speed, as rail transport is one of the fastest and most punctual transport services. Minimal breakage probability, absence of risk factors, etc. less often result in delivery delays;

– versatility – there are different types of cars for different cargoes, which allows rail transportation of oversized cargo, hazardous substances, and the goods requiring special storage conditions;

– the structure reliability of cars is tested using modern calculation methods, in particular, during the design, as well as experimentally.

Purpose

The main purpose of the article is to characterize the existing Schnabel cars, consider the possibility of using them for the transportation of oversized cargo, as well as the development of a modern method to calculate the strength of the Schnabel cars' structural element.

Methodology

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Quite often, the question about the modernization of special types of high-capacity cars arises. The Design and Construction Technological Bureau for Design and Modernization of Rolling Stock, Tracks and Artificial Structures of Dnipro National University of Railway Transport named after Academician V. Lazaryan has developed a project of a sixteen-axle platform Schnabel car (Fig. 1) with a capacity of up to 250 tons.

Fig. 1. General view of the sixteen-axle platform Schnabel car

The sixteen-axle platform Schnabel car with a capacity of up to 250 tons is designed for the transportation of heavy and oversized cargoes that do not require protection against precipitation. In order to support international transportation, the operation on both 1520 mm and 1435 mm tracks is provided due to the fact that the design of this special car can use bogies for different track gauge.

Modernization of the above Schnabel car was performed, for which the products and components of metallurgical, press-forging, handling, power, electrical, chemical processing equipment, backhoe frames, bridge span structures, etc. were used.

The Schnabel car is assembled in the placement category 1 according to GOST 15150-69 [2]. It has 16 axles, which make up the railway carriage, where the load-bearing frame rests on spherical center plates through two end beams, each of which connects two four-axle bogies.

Auto-coupling and braking equipment are placed on the end beams. The supporting frame is curved in a vertical plane, with a lowered middle part – the platform on which the cargo is transported. The frame consists of four longitudinal components of unequilateral I-beams, the lower and upper flanges of which are 30 and 60 mm thick, and the walls – 14 mm, interconnected by diaphragms, ribs and top covering 14 mm thick.

Brackets and clamps for fastening the cargo are welded to the outer side surfaces of the side I-beams, and a number of holes are provided in the top covering for the same purpose.

The material of the load-bearing structures of the Schnabel car is 09G2SD steel in accordance with GOST 19281–2014 [4].

End beams are welded from the longitudinal I-beam elements covered with sheets; 14-, 30- and 60-mm thick sheet steel is used for metal structures.

The center plates are attached to the lower sheets and the middle end I-beams using insert bolts. The center plates rest on the span bolsters of four-axle bogies. To the upper sheets, center pads are attached (rotary-support nodes of the supporting beam).

Braking of each four-axle bogie is carried out by a separate automatic brake consisting of its standard 483M air distributor, brake cylinder no. 519A and a lever transmission system with autoregulator of brake cylinder rod output no. 574B. The brake is designed for the use of composite brake pads, but also does not preclude the use of cast iron ones.

The lever transmission of the four-axle bogies from each end of the Schnabel car is connected to the hand drive of the parking brake. The Schnabel car is equipped with standard automatic coupling device and absorber, footboards, handrails and brackets for signal lamps. Four-axle bogies that rolled under the car consist of typical two-axle bogies of the 18-100 model and span bolsters.

The Schnabel car is represented by a multilevel structure (Fig. 1). The main load-bearing frame rests on two intermediate beams through spherical center plates, each of which, in turn, rests on two four-axle bogies by means of flat center plates.

The load-bearing frame is made in the form of a curved beam with a lowered loading platform and has a beam structure welded from sheet metal [9]. The load-bearing frame is formed by longitudinal I-beams connected by diaphragms along their entire length. The intermediate frame has a box-shaped section made of sheet metal [10–12].

One of the important design criteria is strength. It can be checked using field experiments or CAD. In this case, under certain loads, the stress values should not exceed the allowable.

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Due to computer modeling, it is possible to calculate the strength of the structural elements of transport systems. The paper considers the possibility of testing geometric models for allowable stresses in SolidWorks CAD without field experiments.

Modern conditions for the transportation of multi-ton and oversized cargo require renewal of the Schnabel cars fleet. Therefore, there is a need to modernize existing types of Schnabel cars through the introduction of modern technologies, new design and technological solutions. At the same time, the mechanical properties of the system are tested [5].

Let us consider the calculation of the intermediate beam loading of the upgraded Schnabel car in SolidWorks CAD.

The calculation of material stresses is possible using different CAD. In this case, the yield strength is determined at a given load [15].

According to OST 24.050.37-84 [1], car frames shall provide strength according to allowable stresses. First, a geometric model in SolidWorks CAD is constructed (Fig. 2). Then the material is set. Then the loads affecting the structure are set.

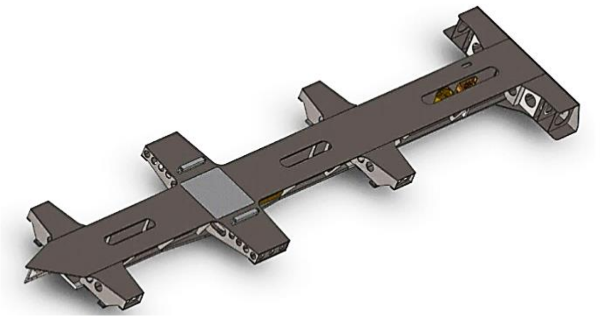

Fig. 2. Geometric model of the intermediate frame of the sixteen-axle Schnabel car

CAD automatically recognizes the model and determines the calculation accuracy: the smaller the grid step of the geometric model, the more reliable is the calculation result (Fig. 3).

SolidWorks CAD calculations show the stress distribution in the structure under the influence of design loads [16].

Then, according to the collection of loads, as well as the elements equal in strength, CAD calculates the allowable stresses using the finite element method (Fig. 4). For example, in the case of a load in the intermediate beam of 2.5 MN [6] stresses do not exceed the strength of the model material.

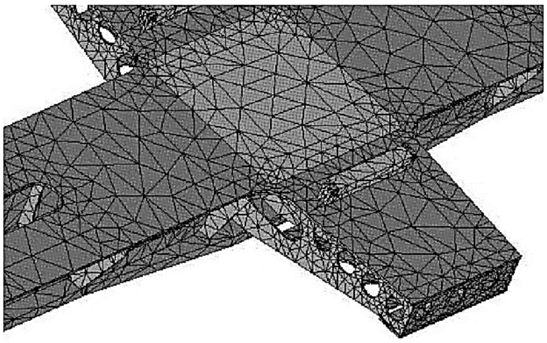

Fig. 3. Dividing the geometric model of the intermediate beam of the Schnabel car into equally strong elements

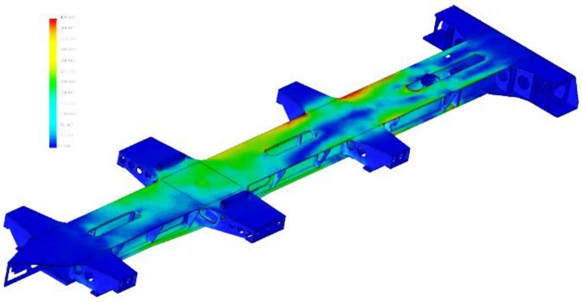

Fig. 4. Stresses in the intermediate beam, MPa (design mode, compressive force 2.5 MN)

Findings

According to the calculation of the intermediate beam loading of the modernized Schnabel car, the stresses do not exceed the allowable ones, so the design has no weaknesses.

Modern logistics capabilities allow organizing the transportation of goods of any complexity by different transport modes, including combination of different transport modes. Rail transport is most often used in cases when the cargo is delivered over long distances, the consignment weighs several tons, to transport oversized or heavy or fragile cargo that cannot be delivered by truck, or in cases where the owner has his own sidings for railway cars.

Originality and practical value

Modernization of a sixteen-axle platform Schnabel car with a capacity of up to 250 tons was further developed. The structure is loaded with a compressive force equivalent to the real load. The imple-

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mentation of the car model in SolidWorks CAD allowed testing the allowable stresses of the loaded material of the structural elements.

The SolidWorks CAD strength calculation can be applied to other parts in transport construction. The results of the work can be useful for the Design Bureau for the Design of Rolling Stock and relevant specialists.

It has become possible to calculate real geometric models of parts or elements of transport systems for the allowable stresses that occur, taking into account the accuracy and external loads acting on the system.

Conclusions

Modern transport engineering is not standing still. The introduction of new CAD allows one to clearly see the weaknesses in the structures without the field experiments.

The wear of railway rolling stock in Ukraine is over 80%. At the same time, the number of services offered by international railways is growing, and the variety of rolling stock allows transporting almost any type of cargo, including oversized one.

The car fleet needs to be updated and modernized through the introduction of new design and technological solutions. Modern CAD can significantly reduce the cost of research experiments.

The conveyor car, modernized by the Design and Development Technological Bureau of DNURT, has a number of advantages in comparison with other existing platform Schnabel cars:

1) load capacity up to 250 tons with a tare weight of 123.5 tons. The maximum load capacity of the platform Schnabel car, which is currently used on the general-purpose main lines, is 225 tons with the same weight of 123.5 tons.

2) the height of the upper sheet of the loading platform from the top of the rail heads in the empty state is 1000 mm. The same parameter for the analogue Schnabel car is, 1146 mm. Lowered loading platform allows reducing the cargo oversize index and, accordingly, the rail transportation cost;

3) when placing the cargo on the loading platform of the Schnabel car, the cargo can rest both along its entire length in the form of evenly distributed load, and through the base sheets in the form of concentrated loads;

4) the conveyor has the size 1-VM according to GOST 9238-83, which makes it possible to operate it on the entire railway network with a track gauge of 1520 (1524) mm, and on the main and a number of other railway lines, the members of the Organization for Cooperation between Rails with a track of 1435 mm, which are used for international transportations.

5) the Schnabel car can be used for transportation on international lines. For this purpose, during the design, it is possible to install buffers, traction coupling, and the brake system is adapted for operation on 1435 mm track gauge. The design of the car meets the requirements of international rules and agreements, the rules of the Organization for Cooperation between Rails (OSJD), the regulations of the International Union of Railways (UIC).

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Модернізація площадкового транспортера вантажопідйомністю до 250 т

Мета. У роботі передбачено провести розрахунок на міцність елемента спеціальної конструкції вагона-транспортера для збільшення вантажопідйомності до 250 т, а також розглянути можливості використання спеціальних вагонів для перевезень негабаритних вантажів за результатами розрахунку на міцність проміжної рами транспортера. **Методика.** Розроблена спеціальна конструкція проміжної рами, що дозволило збільшити вантажопідйомність транспортера площадкового типу до 250 т. За допомогою САПР SolidWorks перевірено на міцність проміжну балку модернізованого транспортера. **Результати.** Виконано оглядовий аналіз залізничних вагонів-транспортерів. Розглянуто можливість перевірки на міцність деталей конструкції вагона-транспортера за допомогою сучасної САПР SolidWorks. У разі навантаження проміжної балки модернізованого транспортера стискною силою у 2,5 МН напруження не виходять за допустимі, тому запропонована конструкція не має слабких місць. Фахівці Проектно-конструкторського технологічного бюро з проектування і модернізації рухомого складу, колії та штучних споруд виконали дослідно-конструкторську розробку на виробництво шістнадцятивісного транспортера площадкового типу вантажопідйомністю до 250 т. **Наукова новизна.** Отримала подальший розвиток модернізація шістнадцятивісного вагона-транспортера площадкового типу вантажопідйомністю до 250 т. Реалізація моделі у САПР SolidWorks дозволила перевірити

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конструкцію вагона-транспортера на міцність. **Практична значимість.** Результати роботи можуть бути корисні конструкторським бюро з проєктування рухомого складу та відповідним спеціалістам. Використання запропонованої методики певним чином спрощує процес проєктування деталей та вузлів механізмів і дозволяє з високою точністю перевірити певні параметри системи.

Ключові слова: вантажні перевезення; негабаритні вантажі; залізничний транспортер; міжнародні перевезення; модернізація вагонів; метод кінцевих елементів

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