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DESIGN REVIEW OF GONDOLA CAR

Purpose. To ensure the constantly growing volume of freight transportations it is necessary to introduce the innovation rolling stock. It should have the best technical and economic parameters in comparison with the existing fleet. Gondola car is the most popular type of railway freight car. Designs of the modern gondolas are based on many years of operating experience and numerous tests carried out by design and research organizations in the field of car building. To improve the body structure of gondolas it is necessary to perform a review of the existing structures and to identify the trends in their improvement. **Methodology**. The works on improvement the designs of produced gondolas are held by many engineering organizations in almost all industrialized countries. Analysis of the existing body designs of gondola cars is possible by analyzing the research in the field of transport engineering, namely patents, scientific articles, producers catalogues and so on. **Findings**. When analyzing it was determined that there are gondolas of different designs, but the most common are the gondolas with a solid floor and unloading hatches, the covers of which form the floor of gondola design. An effective method for reducing the gondola empty weight and increasing the body volume is also the use of aluminum alloy instead of steel. Results of the improvement analysis of the gondola bodies` designs showed that the creation of the modern gondola car requires from designers and scientists the implementation of scientific and technical solutions providing the increase of carrying capacity and the body volume, reduction of the gondolas empty weight, increase in repair intervals while improving the strength and dynamic qualities at the same time. **Originality**. For the first time the gondolas designs were analyzed, their advantages and disadvantages were considered and the trends in improvement of the given structures of gondola cars were determined. **Practical value**. The generalization of theoretical, scientific and methodological, experimental studies aimed at further improving the technical and economic parameters of gondola cars are urgent when improving the body structure of the gondola cars. The above mentioned design features of the bodies of some models of modern gondola cars have practical value and can be used in further developments.

Keywords: gondola; design; body; body volume; carrying capacity

Introduction

Railway transport is still the main mode of transport, carrying out most of the freight transportations of both universal and specialized goods. Thus, the greatest part of the freight car fleet of industrialized countries, such as Ukraine, Russia, the United States, Canada and so on form the universal gondola cars. In Ukraine gondolas occupy 35% of the total freight car fleet [12], the number of gondola cars in Russia is about 535.000 out of total fleet 1 million 200 thousands of cars, the fleet of US gondolas is about 230 thousands units out of the fleet 1 million 400 thousands [16]. This contributes to improvement of the gondola designs by the majority of car building enterprises all over the world. Since in order to reduce the operating costs and improve the economic efficiency of the gondolas use it is necessary to move towards the use of new generation cars, i.e. the cars, whose technical characteristics are considerably superior to existing models.

Purpose

To provide the constantly growing volumes of cargo transportations it is necessary to introduce the innovative rolling stock, having the best technical and economic parameters in comparison with the existing car fleet.

Gondola car is the most popular type of railway freight car. The designs of modern gondolas are

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based on many years of operating experience and numerous tests carried out by the design and research organizations in the field of car building. As a result, the gondola design had been continuously improving to meet the increasing demands of operation. In order to improve the body design of gondola at the design stage it is necessary to analyze the existing designs and to determine the trends for further improvement. Therefore, the subject of this study related to the analysis of design features of gondolas is urgent for the railway transport.

Methodology

The works on improvement the designs of produced gondolas are held by many engineering organizations in almost all industrialized countries.

Analysis of the body designs of gondola cars is performed as a result of the research of technical description and engineering documentation of gondolas models of different producers, as well as using the materials of scientific publications based on the data of the designers about the obtained results during theoretical and experimental research.

Findings

Gondolas represent open cars with high sides, used for the transportation of coal, ore, timber, rolled products, metal and other bulk and piece cargo, which do not require protection from the weather. Gondola car body has no roof. It allows loading and unloading efficiency (including unloading on car dumpers).

Floor of the four-axle universal gondolas is in most cases made of 14 discharging hatch covers, but there are solid floor types. This increases the strength and rigidity of the frame and body components, prevents the loss of small fractions because of the leaks between the frame elements and hatch covers. However, it makes impossible unloading of bulk cargo by the gravity of the cargo itself (the use of grabs is prohibited).

The main construction diagrams of gondolas are shown in the Fig. 1.

The gondola body consists of a number of racks attached to the car frame at the bottom, at the top they are connected with the strapping frame. The gaps between the stands are filled with a metal covering (made of flat steel with longitudinal goffer or periodical trough-shaped profile, or smooth sheets, connected to the frame by resistance spot or arc welding). The shape and height of the body can be different depending on the destination of car and the discharge circuit.

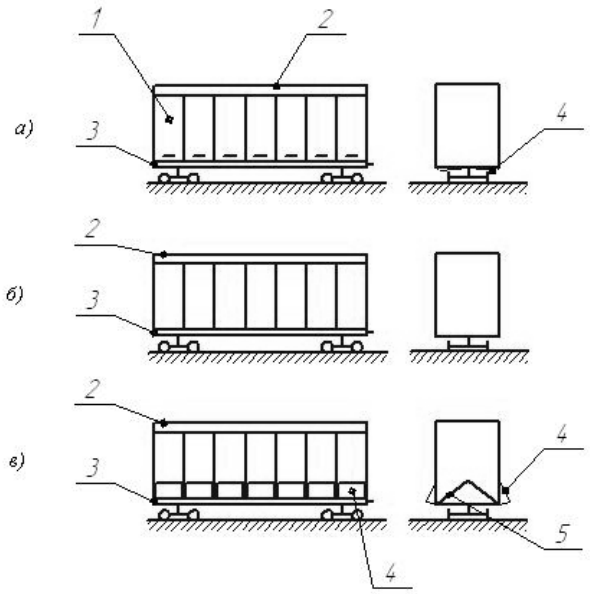

Fig. 1. Construction diagrams of gondolas:
1 – side wall; *2* – upper chord; *3* – car frame;
4 – hatch; *5* – gable floor

Bodies of non self-discharging gondolas do not have hatches in the floor (scheme b, Figure 1) and are designed for unloading them on the car dumpers. Constructions of this type of body are reflected in the patents [5, 6, 9, 11]. In the first designs of these gondolas the doors were located in the side and end walls to make the semi-automated unloading possible. Later, the body began to be manufactured without doors. It was fitted with a device for fixing in a car dumper. Before arriving of gondola at the car dumper the frozen load for better discharge can be subjected to vibration loosening and heating in the special garage defrosters [3]. An example of solid-bottom gondola car is the car model 12-757 EI-2 produced by Kriukov car building carriage works (Fig. 2).

The most frequently for unloading the solid-bottom gondola car dumpers the rotory car dumpers are applied (Fig. 3). On these car dumpers the car is rotated relative to its longitudinal axis by 180°. Such car dumpers, in particular, are also produced in Ukraine by the company «Dneprotyazhmash». This company produces a wide range of rotary car dumpers. VRS-75S and VRS-110S can serve as examples of such devices. The first one is

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intended for unloading the gondolas with carrying capacity up to 75 tons, the second one – up to 110 tons. Both car dumpers are able to provide unloading up to 20 gondola cars per hour [2]. The twinned tipper VRS-2×75 is intended to unload two cars at the same time. At the cost of this its performance is up to 50 cars per hour.

Fig. 2. Gondola car, model 12-757 EI-2, production of Kriukov car building carriage works

When rotated the platform with car moves under the influence of its own weight and bogie springs until the side wall will border on the mounting wall of the car dumper 3. As a result the body deformations (narrowing), bending of racks, damages of the welded joints may take place [4].

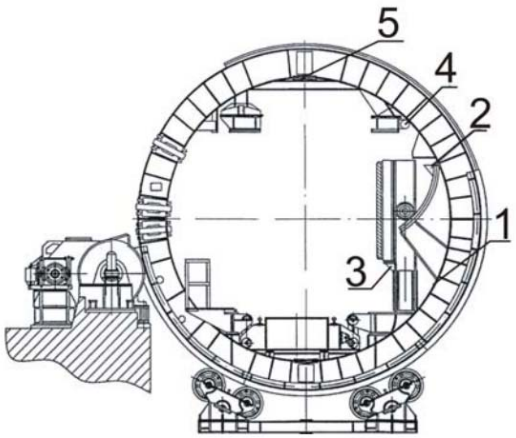

Fig. 3. Rotory car dumper to unload the solid-bottom gondola cars:
1 – rotor; *2* – pressure arrangement; *3* – mounting wall; *4* – small vibrator, which is set at the support foot; *5* – big vibrator mounted on the beam connecting the rotor discs

There are also side car dumpers, the example of which can be VBC-93. It raises the gondola car to the height of 4 meters. The devices of this kind are used in the places, where the high level of ground waters makes it difficult to equip the high cavations.

Improvement of solid-bottom gondola cars resulted in the creation of car, which has rounded surfaces at the joints of the frame with side and end walls, ensuring the car unloading with minimal possible residues of the cargo using the car dumper. An example of this gondola can be the gondola car model 12-791 produced by Kriukov car building carriage works. Its general view is shown in the Fig. 4.

Fig. 4. Gondola car model 12-791

Except the advantages (unloading the car at the lowest possible cargo residues), this design also has its drawbacks, namely under-utilization of the body useful volume due to rounding in its lower part.

Dumper capsules (universal gondola cars) have markedly different design schemes. They differ in both the body equipment, and the equipment of discharging devices. It should be noted that the gondola cars with unloading hatches currently are the most common, since they do not require special devices for unloading, such as car dumpers.

Unloading of these gondola cars is carried out through the hatches in the floor (the scheme a, Fig. 1) or in the side walls (the scheme *b*, Fig. 1) under the influence of gravity of the goods themselves. Gondola design equipped by unloading hatches in the floor, is reflected, for example, in the patent [7]. A gondola car model 12-7039 (Kriukov car building carriage works construction) can serve as example of this. Metal construction is made of steel of strength class 450, which have anti-corrosion properties with an axle load of 25 tf (Fig. 5). The use of steel with a high level of strength not only reduces the overall weight of the car, but also contributes to the safety of its operation [1].

The use of steels with a high level of strength not only reduces the overall weight of the car, but also contributes to the safety increase of its opera-

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tion [1]. Also, this gondola car has a number of other improved indicators, including an increased for 10 years standard service life, and increased time between repairs – up to 500 thousand km. According to the assessment of Ukrzaliznytsia the new car will reduce the annual maintenance costs in 3.5 times, as well as reduce the costs for locomotive traction on 10% [12].

Fig. 5. Universal gondola car with unloading hatches in the floor of the model 12-7039

Hatch covers, forming the bogie floor together with the frame, are used for unloading of bulk cargo from the car in the open position. The weight of every hatch cover is about 200 kg (depending on the design). That is why, to facilitate the closing they are equipped by torsion devices.

Further improvement of universal gondolas has led to the creation of cars with gable floor (Scheme *b* in the Fig. 1), as they provide the best unloading of bulk cargo without any additional equipment. One of these structures of gondola is patented [8] (Fig. 6).

Body of the considered gondola includes frame, gable floor 1, end 2 and side 3 vertical walls and lateral unloading hatches with 4 drives. Lateral vertical walls and lateral unloading hatches are made of flat sheets of exterior paneling on the inner side of which the frames are located. The bottom 1 is inclined to the butts of lateral unloading hatches from the center sill 5, which are placed vertically in the lower part of the side walls.

The car frame is formed by the gable floor and beams, when in the cross-section in the installation places of the transverse horizontal and inclined beams to the center sill it is made of triangular shape.

The bottom form 1 with a slope to the lower ends of vertically placed unloading hatches and triangular shape of the frame cross-section provide:

– unloading without formation of stagnant zones in gondola body and without dirt inclusion of assembled rails and sleepers;

– weight reduction of the frame and bottom and increase in their strength and hardness;

– increase in the utilized useful volume of the body in the existing dimensions;

– improvement of the dynamic qualities of the gondola at the expense of by means of lowering the body center of gravity;

– decrease of the time required to unload the gondola.

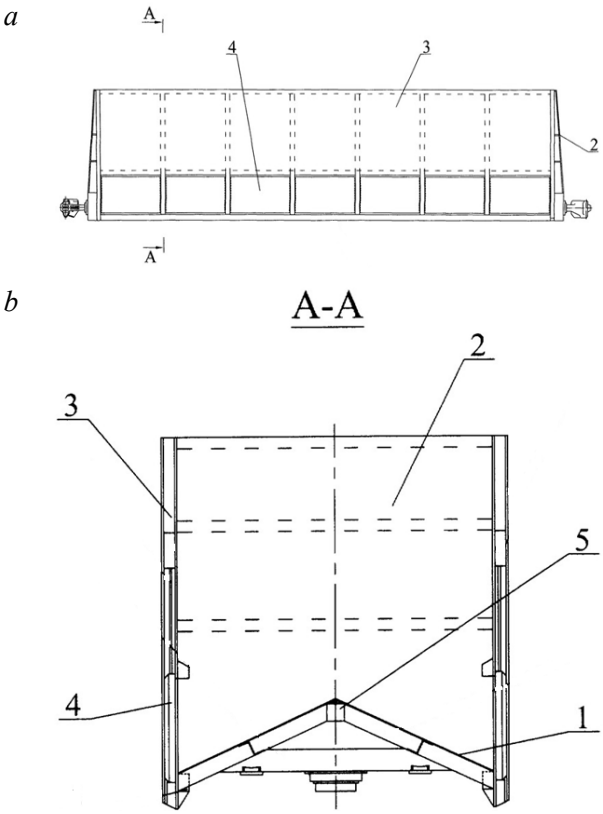

Fig. 6. Gondola with gable floor:
a – side wall (3) with unloading hatches (4);
b – cross-section of the body

On most of cars with the gable floor the crank mechanisms of the hatch locker drivers with pneumatic or hydraulic control are used. In recent years, preference is given to the locker construction with hydraulic control.

One of the most effective ways to improve the efficiency of freight transportations is the most complete use of overall capabilities of railways in CIS.

In 2008 the gondola car, model 12-9828 was built with an axial load of 27 tf, dimension Tpr, which in comparison with 1-T dimension permits

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an increasing the width in a body on 150 mm, edge height on 500 mm and decreasing the car length on 2 000 mm. This permits to take on 11 gondola cars more under the station tracks mileage of 1 050 meters, namely in addition to transport from 850 (axle load of 23.5 tons) up to 1 350 (axle load of 25 tons) of coal in one train. It does not require strengthening the existing station tracks. The car has increased loading capacity of 83 tons; herewith its length on coupling axles is only 12.1 m (at the standard serial gondola cars 13.92 m). This car is designed for coal transportation, which is important for the industrial enterprises and other inert cargo in closed routes on track roads of 1 520 mm. The payback period of a gondola car is 4.6 years against 7 years for a serial car. Body construction without central center sill in the middle part is related to features of the gondola car. It let maximum use interbogie space in the form of cargo niches for increase net volume of the body. Advantages of the gondola model 12-9828:

– load from the axis on the rail is 27 tf;
– loading capacity is 83 tons;
– increase in useful linear load is 37.4%;
– operating costs reduction on 8-10%;
– annual increase in productivity on 15%;
– increase the number of cars in the train up to 11 gondola cars;
– weight cargo (coal) in the train 6 806 tons;
– mass of additional coal transported by a train from the gondola cars, model 12-9828 in comparison with a train from cars - analogs is 1 871.5 tons.

General view of the gondola car, model 12-9 828 is shown in the Fig. 7.

Fig. 7. Gondola car, model 12-9828

Company Johnstown America has proposed a new manufacturing method of a center sill, one of the main type's frames of cars majority. Usually it is welded from two hot-rolled profiles. The replacement of welded structure by the profile from cold-rolled steel with a yield point 4 920 instead of 3 515 kg/cm^2 was the result of conducted work. The new frame is strong enough, but the empty weight of the car for coal transportation is reduced by 450 kg [14].

When designing the gondola car one should take into account such an important parameter as the ratio of loading capacity. The higher it is, the more efficiently a car is operated. In this connection it should be noted that increase of this rate, in particular, is provided by the use of aluminum alloys in car building. Economic calculations, made by foreign experts, suggest that although the cost of cars from aluminum alloys by 25-35% higher than steel one, their operation is more effective economically by reducing the weight of the car up to 15%, reduction in energy consumption for haulage of train on 10%, cost reduction for routine and major repair of cars up to 18%. And, in general, by reducing the number of cars and locomotives required for the transportation of a certain load quantity. Also cars, manufactured with use of aluminum alloy, have improved corrosion resistance and operational reliability, the possibility of structures manufacturing without staining and protective coatings. The payback period of aluminum cars is 3-4 years [13].

About 80% of the fleet of coal carriers in USA and Canada are made of steel and about 20% of aluminum alloy (only in USA their number is greater than 100.000 of units). In Europe, the rolling stock with bodies of light alloys has been used since with the 80-ies of the last century, however it was not widespread.

Although in the 60s in SUE "PA "Uralvagonzavod" the universal gondola models 12-505 (four-axle) and 12-504 (six-axle) with bodies of combined structure (covers of unloading hatches and side walls are made of aluminum alloys) were designed, but these projects did not have further development.

The company "SUAL-Holding" has built a gondola from extruded aluminum profile. Increased structural strength of the car was provided by the use of the body as the solid cover. The car has a useful volume of body 99.5 m^3, the empty weight 18 tons and load capacity 82 tons (Fig. 8). Gondola car has a body made of hollow-core panels. The car was successfully tested in the TestLoop in Scherbinka and speed range Belorechenskaya – Maykop [15].

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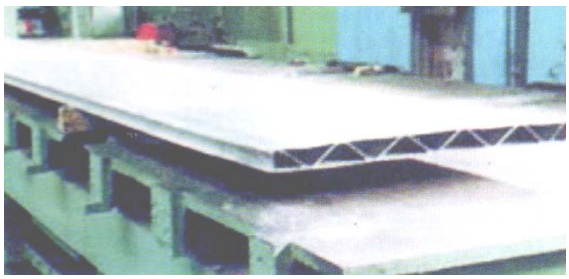
a



b

Fig. 8. Gondola of new generation of aluminum alloy: *a* – hollow aluminum panel for the construction of freight gondolas; *b* – gondola of aluminum alloy AMg6

Design of the similar gondola is patented [10]. The feature of this gondola is that its side and end walls are hot-pressed hollow panels of alloy 6005A. Hollow extruded panels have high stiffness, bear the concentrated loads well and have high resistance to deformations during welding. One of the main advantages of car design with the extruded panels is the reduction of manufacturing costs by reducing the number of structural elements. Car floor is made of sheet functioning as the bearing component. The upper flanges of the channel bars of cantilever beam and center bearer, beam knees and intermediate transverse beams are welded to this sheet. The sheet thickness is 10-12 mm.

In order to increase the carrying capacity of gondolas it is also possible to increase their axle number. The gondola car model 22-4024 is a specialized eight-axle gondola car to transport the lumpy copper ore from the places of its production to metallurgical enterprises.

The car has a small body volume (83 m³) at a sufficiently high load capacity (115 tons), as well as it was designed for transportation of the certain cargo classification with high density.

Ore loading in to the gondola car is made by excavators with buckets, volume of 8.6 m³ and unloading is via car dumpers. Body frame of the gondola car consists of two reinforced Z, two end beams, two bolster beams from rolled metal sheets with thickness of 10, 12, 14 mm and intermediate transverse beams from curved profile of 200×120×10 mm. Flooring is made of steel sheets, thickness 10 mm, framed side wall of the body from the racks of curved profile, section 160×80×7 mm, bottom rail of a special curved profile. Frame end wall consists of two corner posts from the corner of 125×125×10 mm, two uprights trough-shaped profile with a wall thickness of 8 mm, the upper tying closed profile 160×80×7 mm and the end frame rail gondola, which is also the bottom plate. Body frame is covered in a shell of metal sheets with thickness of 10 mm.

Originality and practical value

Creation of the modern gondola car requires the implementation of scientific and technical solutions that could provide increase in carrying capacity, useful volume of the body, cargo unloading without residues in the body, increase repair intervals, high cargo safety during transportations, while improving the strength and dynamic qualities, including the dynamic interaction of the gondola and the railway line [17], improved aerodynamic performance of gondola, which is also important [18]. This will reduce the costs for maintenance and repair, operating costs associated with the reduction of energy consumption for traction of trains and rolling stock maintenance, and, in general, by reducing the number of cars and locomotives required to transport a certain amount of cargo.

Conducted by the author's research concerning the improvement of the gondola cars bodies are of vital importance. They have practical value and can be used in further developments.

Conclusions

Generalization of theoretical and experimental research directed on further improvment the gondola cars bodies of promising constructions is a necessary condition at improvment the design of the rolling stock. The basic trends of some types of gondola cars embodiment were considered in the paper. The authors place special emphasis on the gondola cars bodies improvement.

Thus, design features of innovative gondola cars bodies that provide meeting requirements for modern railway rolling stock were reviewed.

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АНАЛІЗ КОНСТРУКЦІЙ НАПІВВАГОНІВ

Мета. Для забезпечення постійно зростаючих об'ємів перевезень вантажів необхідно впровадження інноваційного рухомого складу, який володіє кращими техніко-економічними параметрами в порівнянні з існуючим парком. Піввагон є найбільш поширеним видом залізничного вантажного вагона. Конструкції сучасних піввагонів створюються на основі багаторічного досвіду експлуатації та численних випробувань, проведених проектними та дослідницькими організаціями в галузі вагонобудування. Для поліпшення конструкції кузова піввагонів необхідно виконати огляд існуючих конструкцій і визначити тенденції у їх удосконаленні. **Методика**. Роботи з удосконалення конструкції піввагонів, що випускаються, проводяться багатьма конструкторськими організаціями практично у всіх промислово розвинених країнах. Аналіз існуючих конструкцій кузовів піввагонів можливий шляхом огляду досліджень у цій області транспортного машинобудування, а саме: патентів, наукових статей, каталогів виробників та ін. **Результати**. При виконанні аналізу було визначено, що існують піввагони різних конструкцій, але найбільш поширеними є піввагони з глухою підлогою і з розвантажувальними люками, кришки яких утворюють підлогу піввагона. Також ефективним методом зниження маси тари піввагона та збільшення об'єму кузова є застосування в конструкції алюмінієвих сплавів замість сталі. Результати аналізу вдосконалення конструкцій кузовів піввагонів показали, що створення сучасного піввагона вимагає від конструкторів і вчених реалізації наукових і технічних рішень, котрі забезпечують збільшення вантажопідйомності та об'єму кузова, зниження тари піввагонів, збільшення міжремонтних інтервалів із одночасним поліпшенням характеристик міцності та динамічних якостей. **Наукова новизна**. Вперше проведено аналіз конструкцій піввагонів, розглянуті переваги й недоліки конструкцій, визначено тенденції із удосконалення конструкцій піввагонів. **Практична значимість**. Актуальним при вдосконаленні конструкції кузова піввагона є узагальнення теоретичних, науково-методичних, експериментальних досліджень, спрямованих на подальше поліпшення техніко-економічних параметрів піввагонів. Розглянуті конструктивні особливості кузовів деяких моделей сучасних піввагонів мають практичну цінність і можуть бути використані в подальших розробках.

Ключові слова: піввагон; конструкція; кузов; об'єм кузова; вантажопідйомність

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АНАЛИЗ КОНСТРУКЦИЙ ПОЛУВАГОНОВ

Цель. Для обеспечения постоянно растущих объёмов перевозок грузов необходимо внедрение инновационного подвижного состава, обладающего лучшими технико-экономическими параметрами в сравнении с существующим парком. Полувагон является наиболее востребованным видом железнодорожного грузово-

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го вагона. Конструкции современных полувагонов создаются на основе многолетнего опыта эксплуатации и многочисленных испытаний, проведенных проектными и исследовательскими организациями в области вагоностроения. Для улучшения конструкции кузова полувагонов необходимо выполнить обзор существующих конструкций и определить тенденции в их усовершенствовании. **Методика.** Работы по совершенствованию конструкции выпускаемых полувагонов проводятся многими конструкторскими организациями практически во всех промышленно развитых странах. Анализ существующих конструкций кузовов полувагонов возможен путем обзора исследований в этой области транспортного машиностроения, а именно: патентов, научных статей, каталогов производителей и т.д. **Результаты.** При выполнении анализа было определено, что существуют полувагоны различных конструкций, но наиболее распространенными являются полувагоны с глухим полом и с разгрузочными люками, крышки которых образуют пол конструкции полувагона. Также эффективным методом снижения массы тары полувагона и увеличения объёма кузова является применение в конструкции алюминиевых сплавов вместо стали. Результаты анализа совершенствования конструкций кузовов полувагонов показали, что создание современного полувагона требует от конструкторов и ученых реализации научных и технических решений, обеспечивающих увеличение грузоподъёмности и объёма кузова, снижение тары полувагонов, увеличение межремонтных интервалов с одновременным улучшением прочностных и динамических качеств. **Научная новизна.** Впервые проведен анализ конструкций полувагонов, рассмотрены их преимущества и недостатки, определены тенденции в совершенствовании данных конструкций полувагонов. **Практическая значимость.** Актуальным при совершенствовании конструкции кузова полувагона является обобщение теоретических, научно-методических, экспериментальных исследований, направленных на дальнейшее улучшение технико-экономических параметров полувагонов. Рассмотренные конструктивные особенности кузовов некоторых моделей современных полувагонов имеют практическую ценность и могут быть использованы в дальнейших разработках.

Ключевые слова: полувагон; конструкция; кузов; объём кузова; грузоподъёмность

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