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# Prospects for the Use of Gondola Cars on Bogies of Model ZK1 in the Organization of Heavy Freight Traffic in the Republic of Kazakhstan

**Gulnar IMASHEVA*, Seidulla ABDULLAYEV**, Natalya TOKMURZINA***, Nazdana ADILOVA****, Gabit BAKYT*******

**Academy of civil aviation, Zakarpatskaya 44, 050039 Almaty, Kazakhstan, E-mail: seidulla@mail.ru*

***Kazakh Academy of Transport and Communications named after M. Tynyshpayev, Shevchenko 97, 050012 Almaty, Kazakhstan, E-mail: seidulla@mail.ru (corresponding author)*

****Kazakh Academy of Transport and Communications named after M. Tynyshpayev, Shevchenko 97, 050012 Almaty, Kazakhstan, E-mail: natalytokmur@mail.ru*

*****Kazakh Academy of Transport and Communications named after M. Tynyshpayev, Shevchenko 97, 050012 Almaty, Kazakhstan, E-mail: adilova_n@mail.ru*

******Kazakh Academy of Transport and Communications named after M. Tynyshpayev, Shevchenko 97, 050012 Almaty, Kazakhstan, E-mail: gaba_b@bk.ru*

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## 1. Introduction

The introduction of heavy freight trains is a complex task, associated with the use of more powerful locomotives, higher axle loads, reconstruction of road infrastructure and electricity supply, improvement of technology of transportation process [1-3]. The use of heavy freight trains will reduce the fleet of electric locomotives for a specified turnover and increase throughput plots [4-6].

In several foreign countries, including the USA and Canada the use of heavy freight trains is reduced operating costs due to the reduction of locomotive brigades, which consequently reduced the price of the carriage of goods [1, 6, 7].

Development strategy of JSC "national company "Kazakhstan Temir Zholy" (hereinafter – JSC "NC "KTZ") until 2020 provides for the introduction of innovative systems of planning, organization and implementation of transportations, fundamentally improve the efficiency of use of rolling stock and the capacity of sites of the network.

The most promising to enter the heavy freight traffic in Kazakhstan are the areas of delivery of coal from Ekibastuz routes Ekibastuz - Petropavlovsk; Ekibastuz - Karaganda; Ekibastuz - Zolotaya Sopka (Russian Federation).

In implementing this strategy, the Company seeks to raise the average weight of trains by 30%. Currently, standardized weight norm of freight trains in the Republic of Kazakhstan does not exceed 6000 tons.

On these plots the mass of freight trains is limited by train length by condition free installation on station tracks (the maximum number of wagons - 71 conventional car), which corresponds to the length of receiving-departure tracks is equal to 1050 m.

Increase the weight standards of freight trains without reconstruction of infrastructure possible in the operation of freight cars with axle load of 245 kN, which will increase the weight of freight trains up to 7100 tons [8-10].

Thus, the purpose of this article is the analysis of the construction trucks wagons models 12-9941 produced by LLP "Kazakhstan wagon company".

## 2. Analysis of fleet of freight wagons

Freight car fleet of the Company is 65521 units. The major share of the car fleet are gondolas 49.8 per cent. Other types of cars in car Park are as follows: indoor – 15,2%, the platform – 5,1%, tanks and 9.9%, other – 20,0% [11]. The adopted axial loading of freight cars is not more than 230 kN.

With the 60-ies of XX century in the United States, Canada, Australia and other countries produced four-axle wagons with a capacity of 90 tons (axial load of about 294 kN) and exploiting the car Park with loads of up to 340 kN in trains weighing 12 – 20 thousand tons. Foreign manufacturers widely used aluminum alloys for the manufacture of bodies of freight cars, which allows significantly reducing the tare weight of the car to 17 – 23 tons with load ratings 117 – 120 tons.

For comparison, the freight wagons of 1520 mm have a relatively low capacity (60-70 tons), require additional costs associated with loading-unloading and securing of cargo have a small turnaround and a low level of specialization, the axial load is 230 kN tare weight is 240 kN.

Due to the frequent failures of components and parts of freight cars, the most massive of which are the fractures of cast parts of bogies of the model 18-100, widely used on the Railways of 1520 mm of the States-participants of the Commonwealth of Independent States, is steadily increasing cases of derailment of trains, resulting in significant financial losses.

Design and manufacturing technology of the model developed in 40-50-ies of the last century. Recently, the fractures are more often seen on the side frames of the trucks that were in operation three years or less, which indicates poor quality of their manufacture, do not provide guaranteed lifetime [12].

## 3. Design features of the trucks of model ZK1

In 2012, LLP "Kazakhstan car-building company" has mastered the production of gondola cars of model 12-9941 with improved technical and economic characteristics.

Gondola cars of model 12-9941 are made by the project of Qiqihar railway company (PRC) with the use of trucks of model ZK1.

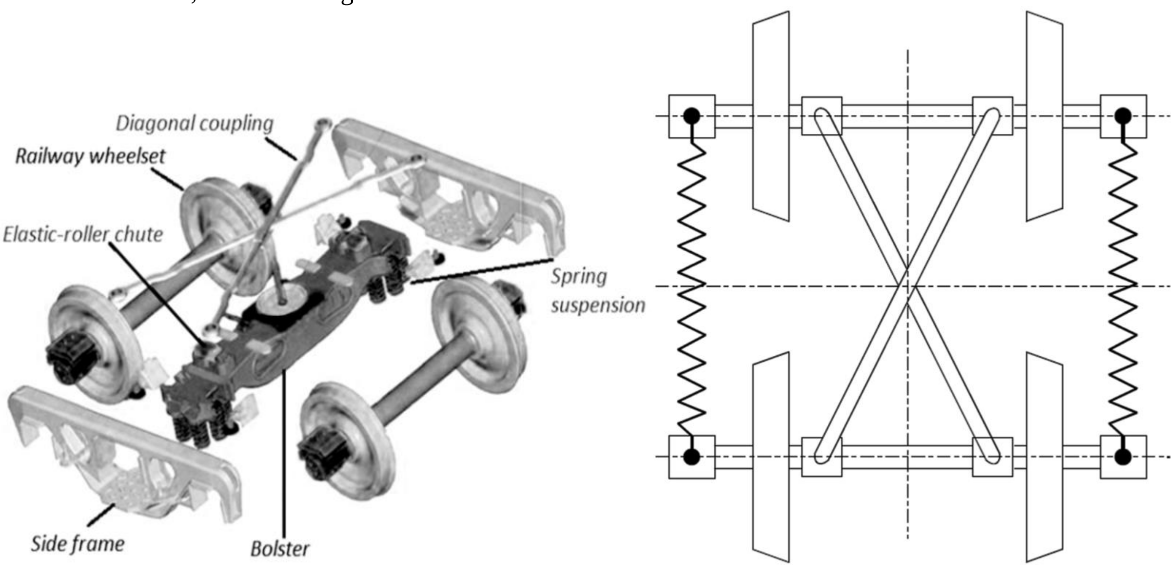
Trucks of model ZK1 compared with conventional three-piece freight trucks have a number of design features. Truck model ZK1 is designed for an axial load of 245 kN and a speed of 120 km/h.

Freight two-axle three-piece truck ZK1 produced in China is made by the standards of TB/T2942 (Fig. 1) [13]. It consists of a cast truck bolster of a closed box section with four technological openings and cast side frames with process windows.

For a more rigid connection between the side frames, bolster beam and spring sets, the side frames are diagonally interconnected by means of two cross-bonded elastic elements (anchor). They go through technological openings of the truck bolster, the technological window of the side frames and are fixed in technological boxes of side frames using four control arms.

The design articulation of a truck bolster with the side frames ensures the squareness of the shape of the bogie. The benefit is the alignment of wheelset axles when the truck traffic.

For ease of fit in the curves of the track sections, these carts have 11 mm transverse stroke of the wheel pair relative to the sidewall. To reduce the yaw of the truck slipping in the nodes of the applied rubber adapters. The center of rigidity shear is achieved the diagonals of the axlebox housing with the help of anchor links. In addition, the bogie of model ZK1 is equipped with wear-resistant liner between the center plate and thrust bearing, elastic-roller bearers of constant contact, a wedge in the central absorber suspension [8, 14, 15].




a b

Fig. 1 ZK1 model bogie: general structure (a), scheme (b)

Analysis and design of the truck revealed that the design of the cargo trucks of model ZK1 excludes:

- rushing longitudinal side frames relative to each other (truck 18-100 they reach 15 - 20 mm), resulting in a decrease in the intensity of the wagging of the truck, improves the smoothness of the car;

- pendulum oscillation of the frames about their own longitudinal axes, the result is uniform transfer of loads on the elements of the axle unit, which eliminates the distortions of the bearings.

In addition, the comparison of cars with 18-100 bogies of freight cars on bogies model ZK1 have a higher design speed, less wear of wheels and more time between repairs [13].

## 4. The dynamic characteristics of gondola cars on bogies of the model ZK1 and indicators of their impact on railway track

By order of JSC "NC "KTZ" Testing laboratory of rolling stock, Dnipropetrovsk national University of railway transport in 2011, conducted the certification testing of the batch of gondola cars model 12-9941. During the certification testing of these gondolas were the main dynamic characteristics, given in Table 1 [16].

Analysis of the data table.1 shows that the dynamic characteristics of the cars meet the requirements of the international standard [17].

The effects of ZK1 bogies on the path determined by calculation.

Calculation of stresses in structural elements of the path produced by the formulas given in [10, 18].

The maximum stresses in the elements of track structure under the action of the truck ZK1 was calculated by the formulas:

- bending stresses of vertical load in the rail flange:

$$\sigma_p = f\,\frac{P^{max} + \sum \mu_i P_i}{4kW} \le \left[\sigma_p\right], \text{MPa} \tag{1}$$

- stresses in ballast under each sleeper:

$$\sigma_b = \frac{kl_{pm}}{2\Omega_\alpha}\left(P^{\max} + \sum \eta_i P_i\right) \le \left[\sigma_b\right], \text{MPa} \tag{2}$$

here: $M$ is bending moment, Nm; $W$ is strength moment of rail cross section in respect of flange, m$^3$; $P_i$ is vertical dynamic load on rail from rated wheel, N; $\mu_i$ and $\eta_i$ are coefficients, evaluating influence of contiguous (not rated) axes (bending moment is proportional to the influence line μ and load to sleeper; elastic deflection will influence line $\eta$); $P^{max}$ is vertical dynamic load on rail from rated wheel, N; $k$ is coefficient of rail and rail flange relative stiffness, calculated according to formula, m$^{-1}$; $f$ is coefficient, evaluating eccentricity of acting forces; $l_{p.m.}$ is distance between axes of sleepers, m; $\omega$ - is fish plate area, m$^2$; $\Omega_\alpha$ area of supporting half-sleeper, m$^2$; $[\sigma_p]$, $[\sigma_{p.m.}]$, $[\sigma_b]$ are permissible values of corresponding stresses. Permissible values differ in various sources [9, 19, 20].

Table 1

The main characteristics of
Gondola cars on bogies of the model ZK1

| Indicator | Value |
|---|---|
| Carrying capacity, tons | 75 |
| The maximum design load from wheel pair on rails, kN | 245 |
| Design speed, km/h | 120 |
| Carriage base, mm | 1900 |
| The mass of one cart assembly is not more than, kg | 5300 |
| Static deflection of spring suspension truck with a maximum load from wheelset on rail, mm | 65 |
| Frame strength is not more than, kN | 93 |
| The coefficient of structural margin of deflection for suspension at the maximum load from wheel set on rail | 1,8 |
| The coefficient of stability from the wheels derailment | 1,6 |
| The coefficient of lateral stability of the carriage from tipping over while moving in the curved track | 2,0 |
| The coefficient of vertical dynamics of the body at maximum load from wheel set on rail | 0,48 |
| The coefficient of vertical dynamics of a bogie frame at maximum load from wheel set on rail | 0,68 |
| The vertical acceleration of the body | 0,39g |
| The horizontal acceleration of the body | 0,22g |

Calculation of stresses in the elements of track structure under the action of the truck ZK1в straight parts of the road were produced for rails of type R65, wooden and concrete sleepers by the number 2000 and 1840 units per 1 km, crushed stone ballast.

In Figs. 2 – 4 shows the stresses in the elements of track structure for type R65 rails, concrete sleepers quantity of 2000 units per 1 km, crushed stone ballast. The modulus of elasticity of rails base was taken equal to $U$=150 MPa and $U$=100 MPa.

In Figs. 5 – 7 shows the stresses in the elements of track structure for type R65 rails, on wooden ties by the number 2000 and 1840 units per 1 km of crushed stone ballast.

The analysis of Figs. 2 – 7 have shown that the stresses in the design of the track structure under the action of the truck ZK1 does not exceed the permissible limits in both straight and curve track sections.

As can be seen from Figs. 2-7, the stress-strain state of structural elements of the path is influenced by the modulus of elasticity of rails base, the speed and the radius of the curve sections of track.

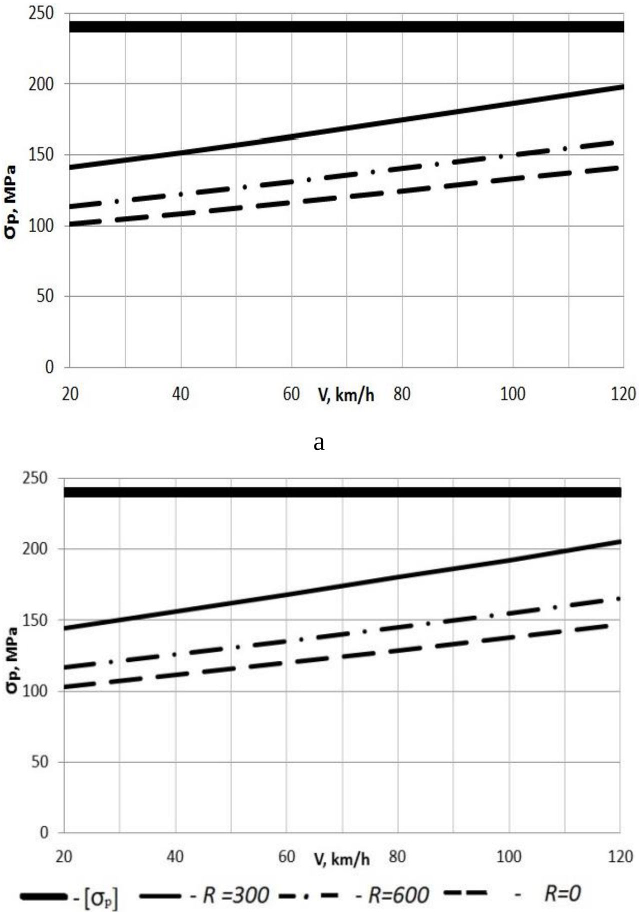



Fig. 2 Stress in the edges of rail foot in tangent ($R$=0 m) and curved track ($R$=600 m, $R$= 300 m) for rails R65, ballast - crushed stone, concrete sleepers - 2000 pieces per 1 km, the modulus of elasticity of rails base: $U$=150 MPa (a), $U$=100 MPa (b)

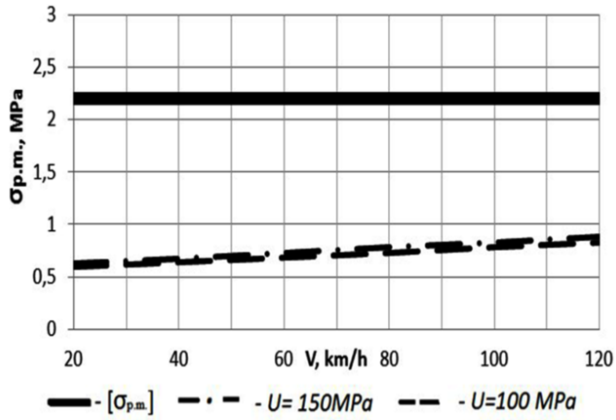



Fig. 3 Stress under rail bearing plates for rails R65, ballast - crushed stone, concrete sleepers - 2000 pieces per 1 km

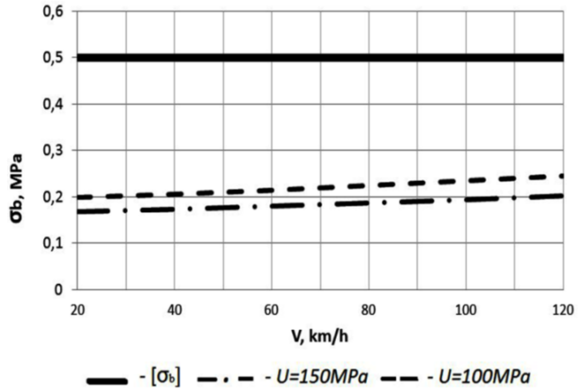
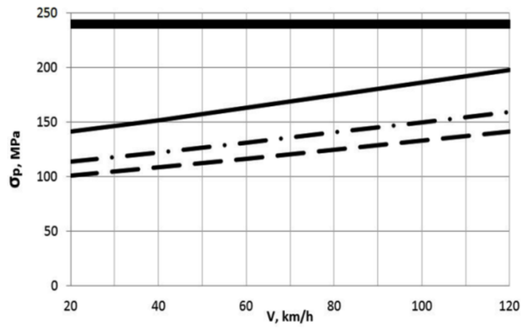
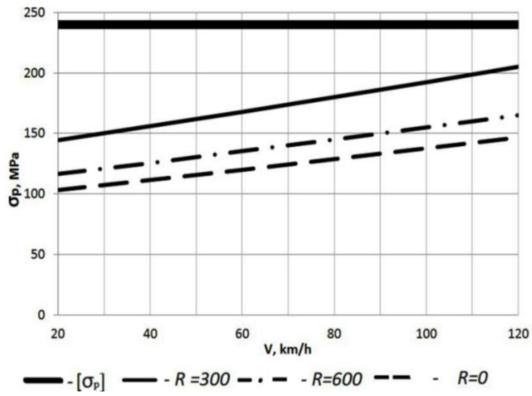



Fig. 4 Stress in ballast layer under cross-tiles for rails R65, ballast - crushed stone, concrete sleepers - 2000 pieces per 1 km




a




b

Fig. 5 Stress in the edges of rail foot in tangent (*R*=0 m) and curved sections of track (*R*=600 m, *R*= 300 m) for rails R65, ballast - crushed stone, the modulus of elasticity of rails base *U*=29 MPa, wooden sleepers: 2000 pieces per 1 km (a), 1840 pieces per 1 km (b)

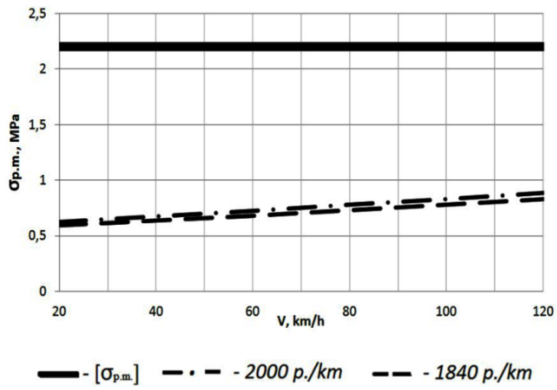



Fig. 6 Stress under rail bearing plates for rails R65, ballast - crushed stone, wooden sleepers

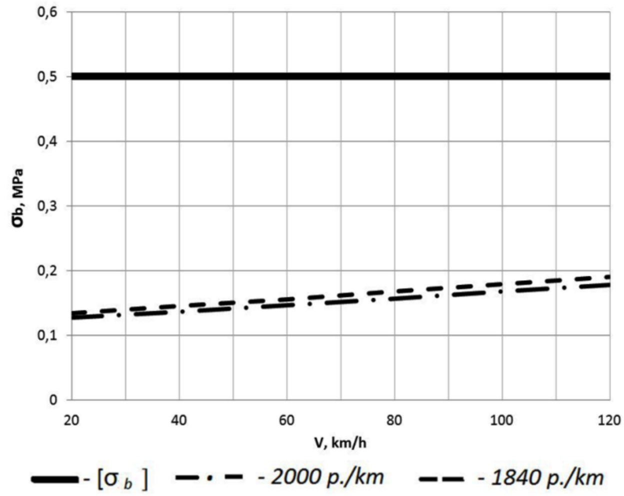



Fig. 7 Stress in ballast layer under rails for rails R65, ballast - crushed stone, wooden sleepers

## 5. Conclusions

1. Application in areas Ekibastuz - Petropavlovsk; Ekibastuz - Karaganda; Ekibastuz - Golden Hill of gondola wagons of model 12-9941 with axle load of 245 kN will increase the weight norm of freight trains by 16 percent without the reconstruction of the rail track and increasing the length of station tracks.

2. For the considered structures of track structure:

- the maximum stress in the edge of the foot rail from the impact of truck ZK1 does not exceed 150 MPa in the straight parts of the road and 210 MPa in the curved track;

- maximum voltage under the linings of the sleepers is less than 1 MPa;

- the maximum stress in the ballast layer under the sleeper does not exceed 0.25 MPa.

3. Analysis of the stress state of the standard design path showed that the estimated parameters of stresses in the structural elements of the route are not exceeded in straight and curved track, when exposed to the path of the truck ZK1, moving at speeds up to 120 km/h inclusive.

Thus, the considered designs of gondola wagons of models 12-9941 can be used for cargo transportation without the necessity of modernization of the railway, which will give an opportunity to increase traffic without significant financial costs.

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G. Imasheva, S. Abdullayev, N. Tokmurzina, N. Adilova, G. Bakyt

PROSPECTS FOR THE USE OF GONDOLA CARS ON BOGIES OF MODEL ZK1 IN THE ORGANIZATION OF HEAVY FREIGHT TRAFFIC IN THE REPUBLIC OF KAZAKHSTAN

S u m m a r y

The increase in heavy freight traffic in recent years is fueled by an increase in demand for coal as an alternative energy resource of oil, and also steel, in the manufacture of which large quantities of iron ore are required. However, in the former Soviet Union, the use of heavy freight trains was complicated due to insufficient quality of the railway. In this regard, the article considers the features of construction truck wagons of models 12-9941 produced by LLP "Kazakhstan car-building company" according to the project of Qiqihar railway company (PRC). The laboratory testing of rolling stock conducted in Dnipropetrovsk national University of railway transport has identified the main dynamic characteristics that meet the requirements of the international standard. The use of gondola wagons of model 12-9941 in the organization of the heavy traffic creates tensions in the construction of the permanent way, which do not exceed the permissible limits in both straight and curve track sections.

**Keywords:** dynamic characteristics of truck wagons, freight wagons, heavy freight trains, railway, truck wagons.

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