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# Concepts of modern bogies for railway freight wagon

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Summary. The article provides the analysis of current situation in freight wagon bogies and provides concepts of modern freight car bogies, namely increasing the strength of bogie side frames, lowering dynamic loads, reducing force impact on the railway, increasing the permissible speed, lowering resistance to motion, developing bogies with rolled steel in construction.

The following results. The max. equivalent stress in the side frame with axle-box line 35% below the classic 18-100 and 50% below with using pre-stress. The authors created safety element of bogie side, bogies type 18-100 with the first stage spring suspension in order to improve safety and reduce the dynamics. Are used the method of applying circuit and picked up a profile based on the rails. Preliminary calculations show a reduction in weight. Are reviewed all the major perspective methods of perfection the bogies for reducing force impact on the railway and increase strength. Prepared stand tests of new freight car bogies.

Key words. Bogie, side frame, primary suspension, stress-strain state.

## INTRODUCTION

Three element bogies are the main type of bogies for railway freight wagons in Ukraine and in the world (In Ukraine the main model of freight bogies is 18-100). According to the research of many scientists, this type of bogies is morally obsolete, does not meet the requirements of speed and force impact on the railway. The situation is aggravated by the fact that there are more than 20 failure a year of bogie side frame on the railways of Ukraine and Russia. Therefore, insufficient strength is also a disadvantage of bogie [1-3].

Modernizations of bogies in our country is mainly due to the increase overhaul life. The issue of increasing the strength and speed, reducing of force impact on the railway is not considered.

Also, in many countries are developing a radically new freight wagon bogie [8-10].

## OBJECTIVES AND PROBLEMS

The aim of the article is to develop recommendations and constructive solutions to create the concepts of modern freight car bogies, namely to increase the strength of bogie side frames, to reduce force impact on the railway, to increase the permissible speed by closing the axle-box slots on the bogie side frame, using the pre-stressed state of the frame, safety designs, introduction the first stage of suspension [26].

## METHODS AND TECHNICAL SOLUTIONS FOR CONCEPTS OF MODERN BOGIES

According to the analysis of breakdowns bogie side frames 18-100, the most dangerous zone is transition Radius R55. It should be noted, that 60% of broken frames contained casting defects. Therefore improving the quality control will partially solve the problem of breakages. And this diagnosis is a very expensive process. Reduced quality of railways (especially the hump yards) exacerbates the problem [8, 24].

Typical breakdown of bogie side frames 18-100 [5, 7] in transition Radius R55 on the railways of Ukraine and Russia is shown in Fig. 1.

**Fig. 1**. Typical breakdown of bogie side frames

According to the authors, the reason for the accelerated destruction of the side frames is pouring defects [19] and high values of forces on the hump yards. Max. longitudinal force acting on the outer jaw of side frame is 100 kN [24, 25].

Axle-box lines have been using on the locomotives (for axample TEM3 – Fig. 2) The scheme with axle-box lines on the side frames of 18-100 (Fig. 3) [14, 23, 27].

The authors calculated static (Fig. 4) and dynamic (Fig. 5) stress-strain state of the side frames 18-100. The max. equivalent stress in the side frame with axle-box line (Fig. 6) 35% below the classic 18-100. Cross-sectional area of axle-box line is 20 $cm^2$.

**Fig. 2**. Axle-box lines (locomotive TEM3)

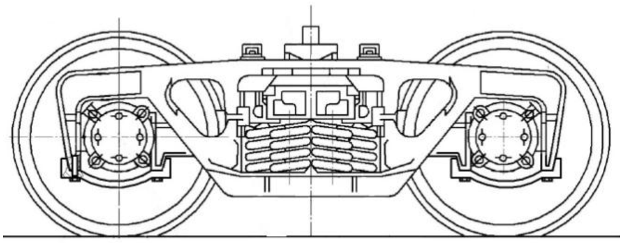

**Fig. 3**. Axle-box lines on the side frames of 18-100

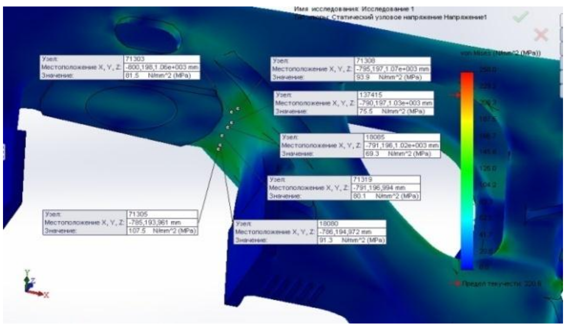

**Fig. 4**. Calculation of stress-strain state

Researchof stress and strain state bogies frames for calculated and experimental method [6, 12, 13] made using SolidWorks Simulation software.

Dynamic response bearing structure caused by its own forms of vibrations.Of all the natural frequencies of the array, which has a design process vibrations occurs mainly at certain frequencies. These frequencies are called the principal, and areas in which they operate - main lines. In calculating the bogies frame is considered a limited number of modes defined so that sum Percent in the fate of the masses was the main line of at least 60%. Modal results are presented in Table 1 [4, 11, 17, 18].

**Table 1.** Results of modal calculation

| № | frequency Hz | longitudinal | vertical | transverse |
|---|---|---|---|---|
| 1 | 1.33 | 3.09e-006 | 6.95e-006 | 0.62 |
| 2 | 1.79 | 0.56 | 0.08 | 6.76e-006 |
| 3 | 2.10 | 0.11 | 0.84 | 2.23e-006 |
| 4 | 2.71 | 0.27 | 0.02 | 2.50e-008 |
| 5 | 21.95 | 2.22e-008 | 1.72e-012 | 0.001 |
| 6 | 34.07 | 1.99e-007 | 9.72e-011 | 0.32 |

Statistical characteristics of random energy excitatory forceshave the power spectral density of acceleration measuredin the testson the axle-box of bogies frame.

According to the results of dynamic calculations have received rms stress in dangerous points (Fig 5) and power spectral density of stress in dangerous points (Fig 7).

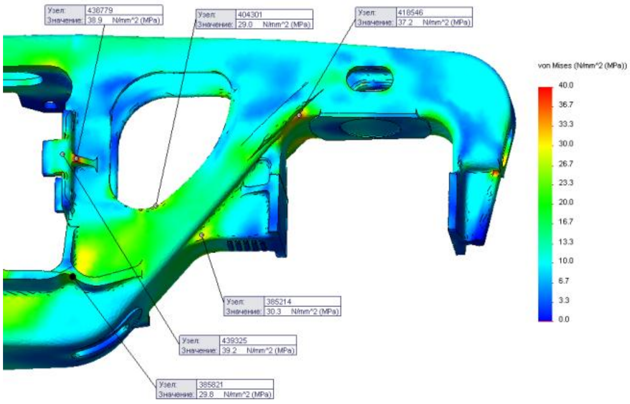

**Fig. 5**. Plotting RMS stress

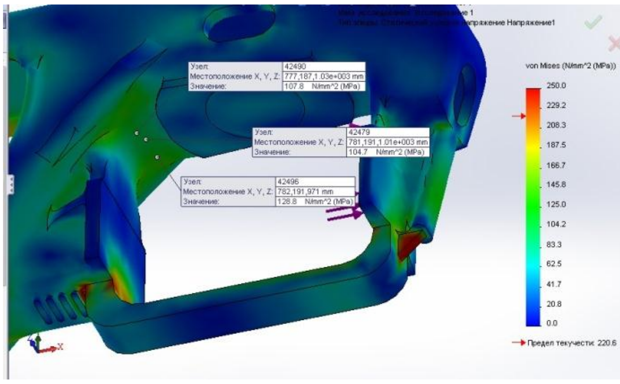

**Fig. 6**. Calculation of stress-strain state

The next step is to create a pre-stress in bogie side frame (Fig. 8). If axle-box line pulls together jaws with the force F, general stress in the stress-strain frame reduces.

The value of maximum stress as a function of force F is shown on Fig. 9.

Another technical solution is safety element (fig. 10). There is a redistribution of stresses because of safety element. This element partially retains the jaw after fracture in R55 of side frame.

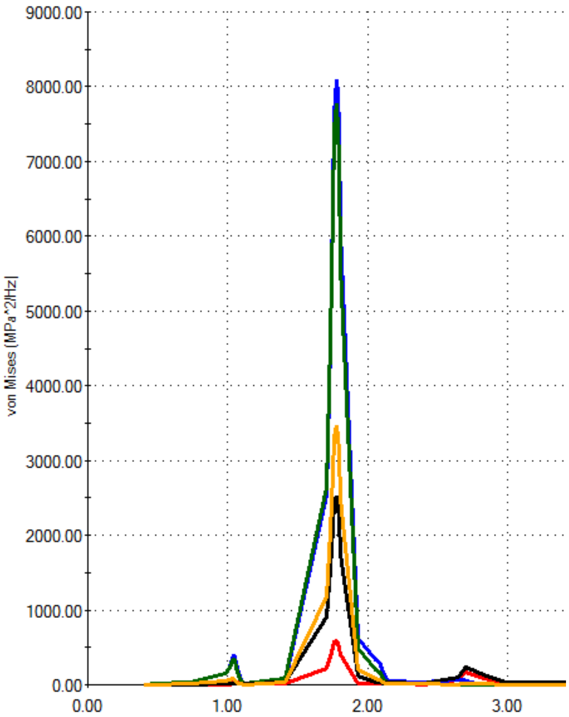


**Fig. 7**. The PSD vonMisesstress

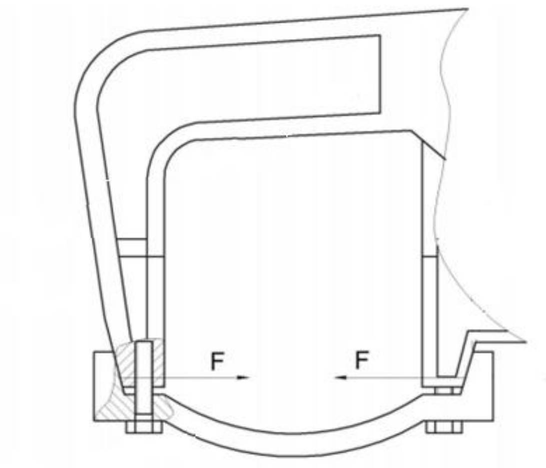


**Fig. 8**. A method of pre-stressing

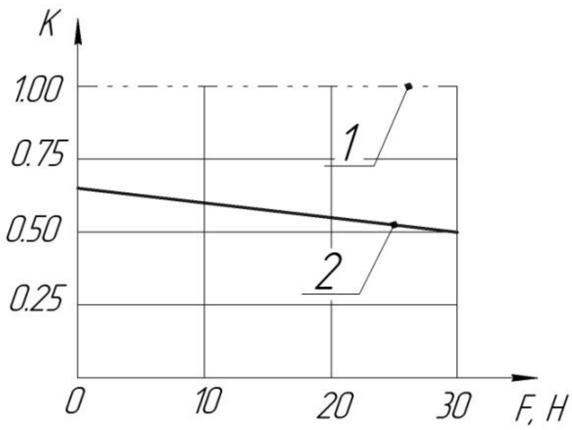


**Fig. 9**. The value of maximum stress as a function of the force F ($K=\sigma_{MAX2}/\sigma_{MAX1}$): 1 – max. stress in side frame 18-100, 2 – max. stress in side frame with axle-box line and pre-stressing force F

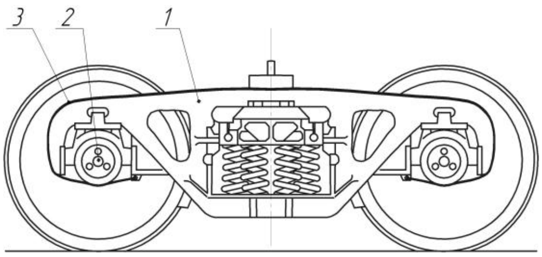


**Fig. 10**. Safety element of bogie side frame: 1- side frame, 2 - axle-box, 3 - safety element

The authors have developed and patented more than 10 designs of bogies type 18-100 with the first stage spring suspension (Fig. 11 for example). Positive results of this solutions [20, 21, 22]:

- reducing force impact on the railway
- increasing the permissible speed
- lowering dynamic loads
- lowering resistance to motion [16].

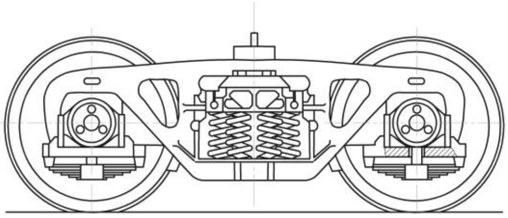

**Fig. 11**. Bogies 18-100 with the first stage spring suspension

Rolled steel is the best material for load-bearing structures. Many companies are developing bogies with rolled steel in construction. For example «Tatravagonka» has developed 18-100 bogie side frame. It is harder than casting, the difference is 50 kg (Fig. 12).

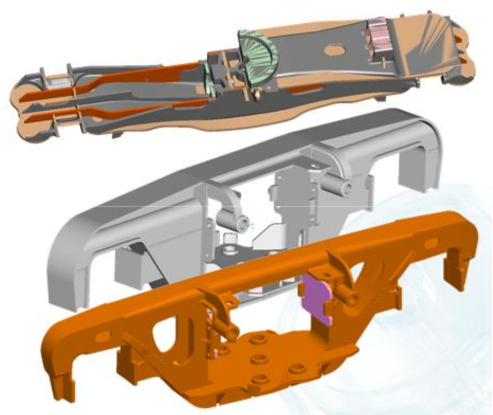

**Fig. 12**. Rolled steel in construction of side frame (Tatravagonka)

We used the method of applying circuit and picked up a profile based on the rails (Fig. 13). Preliminary calculations show a reduction in weight. Therefore the selection of a profile for the freight bogie is an urgent task [11, 12].

Perspective methods of perfection the bogies are shown in Table 2.

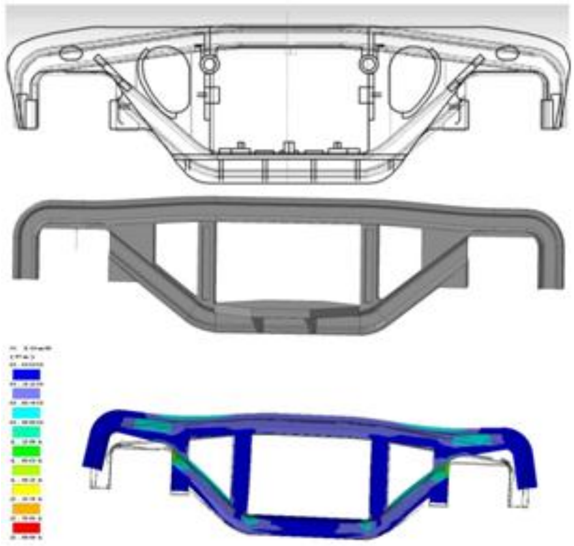

**Fig. 13**. Bogie with profiles based on the rails

**Table 2.** Perspective methods of perfection the bogies

| Technical solutions | Reducing force impact on the railway | Increase strength |
|---|---|---|
| Use of spoke wheels | ● | |
| Reducing the diameter of the wheels | ● | |
| Using a rolling steel frame construction | ● | ● |
| The use of composite materials | ● | ● |
| Pre-stressing in frames | ● | ● |
| Closing the axle opening with axle-box lines | | ● |
| Implementation the first stage spring suspension | ● | |
| Using variable friction pads in areas of friction | ● | ● |
| The use of elastic frame of bogie | ● | |
| Adding lateral stiffness and damping | ● | |
| Displacement of the center of rotation of the center of mass | ● | |
| Introduction diagonal rods in the bogie | ● | ● |
| The use of three or more biaxial bogies in the wagon | ● | |
| Using uniaxial bogies | ● | ● |
| The use of safety element | | ● |
| Improving Quality Control | | ● |
| Using wheels with rubber gaskets | ● | |
| The use of airsprings | ● | |
| Filling the voids of bogie frames by damping material | | ● |
| Using wheels with movable crests | ● | |
| Lowering the center of gravity of the bogie | ● | |
| Lowering the center of gravity of the wagon | ● | |
| Using interbogie space | ● | |
| Using the freely rotating wheels | ● | |

Now there is a preparation for bench tests with axle-box line (fig. 14) at State Economic and Technological University of Transport, Kyiv, Ukraine. And there is a preparation for computer tests of bogies with the first stage of suspension in software complex «UM».

**Fig. 14.** Static bogie stand

We are glad to cooperate in this sphere (Kara_SV@i.ua).

## CONCLUSIONS

1. The article provides the analysis of current situation in freight wagon bogies, generally 18-100 model.

According to the research of many scientists, this type of bogies is morally obsolete, does not meet the requirements of speed, force impact on the railway and strength.

2. The authors have developed next solutions:

- axle-box lines on the side frames of 18-100 (max. equivalent stress in the side frame with axle-box line 35% below the classic 18-100),

- axle-box lines with pre-stressing (max. equivalent stress in the side frame with axle-box line and pre-stressing 50% below the classic 18-100),

- safety element (this element partially retains the jaw after fracture in R55 of side frame),

- bogies 18-100 with the first stage spring suspension (reducing force impact on the railway, increasing the permissible speed, lowering dynamic loads, lowering resistance to motion),

- Bogie with rolled steel in construction of side frames (rolled steel has better mechanical properties).

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## КОНЦЕПЦИИ СОВРЕМЕННЫХ ТЕЛЕЖЕК ДЛЯ ЖЕЛЕЗНОДОРОЖНЫХ ГРУЗОВЫХ ВАГОНОВ

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Аннотация. В статье приведен анализ текущей ситуации в области тележек грузовых вагонов и предоставлены концепции современных тележек грузовых вагонов, а именно увеличение прочности боковых рам тележек, снижение динамических нагрузок, снижение действующей силы на железнодорожное полотно, увеличение допустимой скорости движения, снижение сопротивления движению, разработка тележки из прокатной стали.

Получены следующие результаты. Макс. эквивалентное напряжение в боковой раме с буксовой стрункой на 35% ниже классической 18-100 и на 50% ниже при использовании предварительного напряжения. Авторами созданны элемент безопасности боковины тележки, тележка типа 18-100 с первой ступенью рессорного подвешивания в целях повышения безопасности движения и снижения динамики. При этом используется метод наложения контуров для создания боковины тележки на основе рельсов. Предварительные расчеты показывают снижение веса. Рассматриваются все основные перспективные методы совершенствования тележек для уменьшения силового воздействия на железнодорожный путь и повышения прочности. Идет подготовка стендовых испытаний новых тележек грузовых вагонов.

Ключевые слова. Тележка, боковая рама, первичное рессорное подвешивание, напряженно-деформированное состояние.