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SUBSTANTIATION OF REPLACEMENT OF THE BLOCK BRAKE ON THE DISC BRAKE IN THE BOGIE OF ARTICULATED PLATFORM WAGON FOR INTERMODAL TRANSPORT

This contribution is focused on the presentation of an original freight wagon bogie modification in order to integrate a disc brake into its structure. Such a modified freight wagon bogie will be used for the six-axle articulated flat wagon for intermodal transport, i.e. for transport of containers, trailers, etc. The main advantage of the proposed technical solution is, that the operation of freight wagons braked by means of disc brakes generates significantly less noise and requires lower power than block brakes. In this work there is presented the design of the integration of the disc brake with two discs, attachment of the brake beam on the original bogie frame and also mounting the disc brake unit on the brake beam.

Keywords. Freight wagon, Disc brake, Design modification, Disc brake beam.

Introduction. From the railway operation point of view brake equipment of wagons, belong to the most important part of all railway vehicles. Therefore, the design and function of brakes equipments have to meet strict conditions given by the International union UIC.

The brake equipment of a rail vehicle is composed of the pneumatic pressure system – pressure brake. The pressure brake serves as the safety brake for operation, quick-acting, emergency and automatic brake. A disc brake is nowadays the dominant design version of pressure brake for passenger rail vehicles and train units. In the freight railways transport cast-iron block brakes are currently used [1, 2], but with regard to requirements for increasing the transport speeds and axle loads the integration of the disc brake into the original design of a freight wagon bogie is very up-to-date. The installation of the disc brake will ensure higher brake power and significant noise emissions reduction, which have impairment effects on the environment.

The goal of an article Presentation of the modification of a freight wagon bogie's design in order to implement a disc brake into its original design.

Freight wagons with a disc brake. The Y25 bogie (Fig. 1) is the most widely used type of a freight wagon in the western and middle Europe [3, 4]. Originally, it is French design of a bogie [5]. Generally, this type of bogie uses block brakes [6]. The GG block is most often applied, which acts on a wheel.

However, the current development of this type of bogie is focused on the disc brake implementation with-out radical design modification, mainly for higher brake power, because just the right guarantees constant and safe heat sink without adverse load of wheel surfaces.

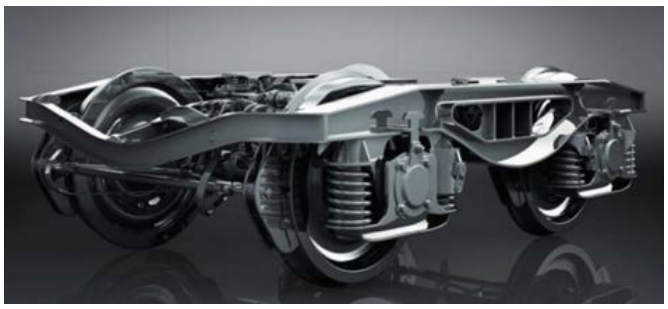

Fig. 1. Y25 freight wagon bogie

Disc brakes already were implemented for freight wagons, e.g. Y25Lss bogie (Fig. 2). However, in this case, the disc brake was combined with the additional block brake. It allows wheel surfaces cleaning, so it ensures appropriate force ratios in the wheel/rail contact. Hereby, the block brake assumes the part of the brake force and it means that the disc brake is lite during braking at high speeds. The disc brake ensures approx. 75 % of the braking power and the block brake remaining 25 %. This ratio results from the necessity of brake blocks, as during the lifetime of one relining of a disc brake blocks have to be changed from 4 to 6 times [3, 6].

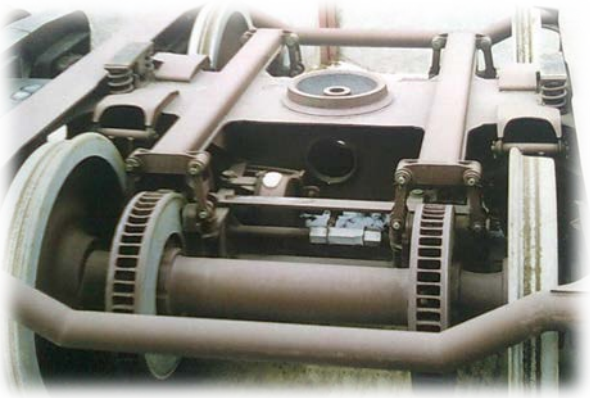

Fig. 2. Y25Lss freight wagon bogie

Another representative of a freight wagon, which is equipped with a disc brake in combination with a block brake, the Y37VR bogie is (Fig. 3). There is version 9-846.0. In the 9-846.1 version of it a handbrake is mounted. This bogie is determined for the freight wagon with axle load of 18 t and the operation at the speed of 140 km/h [5, 6].

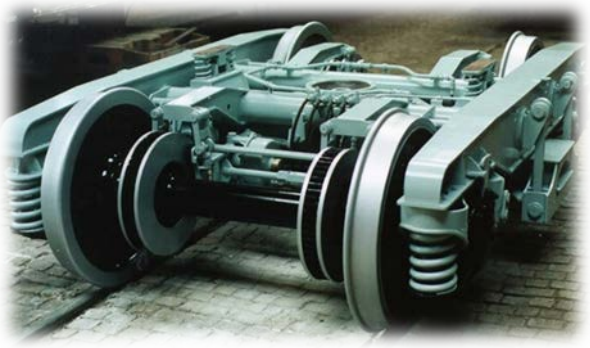

Fig. 3. Y37 VR freight wagon bogie

Brakes of freight wagons. The classic block brake is equipped with cast-iron brake blocks. Current trends direct to composite brake blocks, which represent very advantageous price alter-native for a disc brake. However, in this case the unfa-vourable abrasion of a material occurs.

For block brakes, the friction coefficient depends on the material of brake blocks, speed, temperature and surface compression between the wheel and the brake block. Brake blocks made of composite materials or cemented metal have the similar friction coefficient to the disc brake from the speed and dimension dependency point of view [7, 8]. This is caused by the material similarity of composite blocks and disc brake lining.

In operation of rail vehicles the intention is to decrease of its curb weight and also to decrease unsuspended masses. While individual components of a block brake belong to suspended masses of rail vehicles, classic types of a disc brake with shaft or wheel brake discs are not suspended. Therefore, in comparison with block brake disc brakes increase unsuspended weight of a freight wagon bogie.

Features of brakes of freight wagon bogies. The block brake is the best-known adhesion brake. The braking happens, when brake blocks are pushed against wheel surface [7, 10]. The pressure is during operation caused by pressure of compressed air, which acts on the brake cylinder rod.

The main advantages of block brakes are:

- simple verification of functionality,
- block ability to slick minor irregularities on wheel surface,
- brake verification can be performed visually without other checking system.

The disadvantages of block brake a are:

- large dimension and complexity of a system,
- relatively low efficiency related to wagon weight,
- high level of the operation noise,
- low lifetime of brake blocks.

The disc brake composes of two basic elements:

• brake disc,
• brake lining.

Generally, the brake disc is very often fixed on a axle. A brake disc can be produced either as single or compound.

The number of brake discs used to be various and depends on required brake power. For lower speeds one brake disc suffices. For high speed vehicles there are used higher number of discs – from two up to five.

From the design point of view brake discs may be intended either to be mounted on an axle of a bogie, or to be mounted on a wheel.

Design of a disc brake for a freight wagon bogie. Firstly, there is necessary to determine the brake power, which acts against a freight wagon running on a track [9] and it is generated by the brake accessories of a freight wagon (Fig. 4).

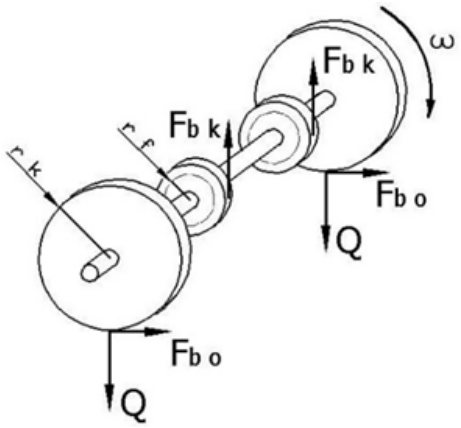

Fig. 4. Wheelset braked by a disc brake

In this contribution the disc brake is designed for the six-axle freight wagon (Sdggmrss), which maximum weight is ml = 135 t, considered equivalent weight is mekv = 141.75 t and calculated vehicle resistance is Ovoz = 7.932 kN.

From the freight train equation of motion

$$m_{ekv} \cdot a_b = -O_{voz} - F_B \tag{1}$$

we express the brake force needed for slowing-down of rail vehicle:

$$F_B = -O_{voz} - m_{ekv} \cdot a_b \tag{2}$$

For a rail vehicle stopping within the brake distance there is necessary to produce brake deceleration ab. For the speed higher than 100 km/h the brake distance is L = 1000 m. In the calculation the brake deceleration, we consider for the speed of v = 120 km/h:

$$a_b = \frac{v^2}{2 \cdot L} = \frac{(33.333)^2}{2 \cdot 1000} = 0.55 m/s^2 \tag{3}$$

The calculated brake deceleration (eq. (3)) we sub-stitute in eq. (2) and we can find out the brake force FB:

$$F_B = -7.932 - 141.75 \cdot (-0.55) = 70.03 kN \tag{4}$$

From eq. (4) we have calculated the maximum brake force, which the disc brake of one vehicle has to generate. Further, we have to calculate the brake force for individual brake discs. As we consider six-axle freight wagon, the brake force on one axle will be following:

$$F_{BN} = \frac{F_B}{6} = \frac{70.03}{6} = 11.67 kN \tag{5}$$

For the brake force transmission on the adhe-sion limit there is valid:

$$F_{BN} \le 2 \cdot Q \cdot \mu \Rightarrow 11.67 < 30.9 \tag{6}$$

then

$$F_{BN} \le 2 \cdot \frac{135 \cdot 9.81}{12} \cdot 0.14 \Rightarrow 11.67 N < 30.9 N \tag{7}$$

The vertical wheel force Q is calculated from the total weight of a vehicle and from the number of wheels on a vehicle. The adhesion coefficient μ = 0.14 is the maximal safe during braking.

In the next step, we choose the number of discs on an axle in order to calculate the brake for one brake disc. For the proposed solution, there are chosen two brake discs on an axle. The brake force on one disc is

$$F_{BK} = \frac{F_{BN} \cdot \frac{r_f}{r_k}}{2} = \frac{11.67 \cdot \frac{0.233}{0.46}}{2} = 2.95kN \quad (8)$$

The calculation of the compressive force of a brake lining on one disc is given by following formula

$$F_{BK} = F_P \cdot f \Rightarrow F_P = \frac{F_{BK}}{f} = \frac{2.95}{0.3} = 9.85kN \quad (9)$$

The new solution of the brake system of the Y25 freight wagon bogie with disc brake using there is nec-essary to choose a disc brake unit. There are several producers and several types of such devices. For our purposes, we have chosen the DAKO KB brake unit. The scheme of disc brake is shown in Fig. 5.

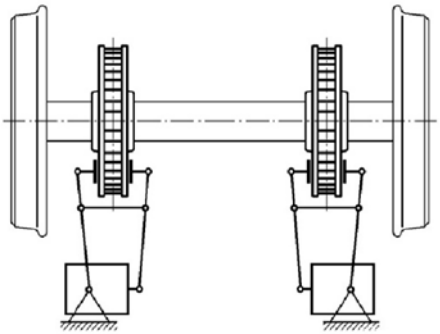

Fig. 5. Scheme of disc brake

This brake unit is used in brake equipment of rail vehicles mainly as the part of a bogie. On a bogie, it is localised in such way to generate the brake force directly on discs.

This brake unit is active device of the rail vehicles brake, which contains in one construction unit always the brake cylinder with the built-in one-side acted a setter of brake shoes, brake rigging with defined brake ratio, holders of brake lining, linkages and swing links. Main parts of the chosen disc brake unit are:

- brake cylinder,
- handbrake mechanism,
- braking indicator,
- brake rigging (parts of transmission of the brake force to brake lining).

Design of a beam and attachment of the disc brake on a fright bogie frame. The bogie frame is the main support part of a bogie. The role of a frame is to ensure the proper position of wheelsets, traction forces transmission between wheelsets and a vehicle frame. At the same time, it car-ries other construction units and parts of a bogie depend on the type of a bogie (brakes, tubes, electric installation, etc.).

The bogie frame holds the position of freight wag-on body on a bogie in all directions and transfers all op-eration loads in all basic directions. For its every func-tionality it has to be designed properly not only form the form point of view (i.e. joints surfaces, mounting condi-tions, etc.), but also from the strength point of view (types of loads, fatigue, etc.).

There are several conception arrangements of bo-gie frames, on which we can use the disc brake. The most often we can meet the rigid attachment of the disc brake beam on a bogie frame. In this case, the disc brake beam is welded to the frame or to another beam, which hangs on a bogie frame.

In our modification of the original bogie with the block brake, we have chosen the conception with hung beam of disc brake beam on a bogie frame. This con-ception solution is in our considered case more suitable. There is for more reasons (Fig. 6).

The hung beam requires indeed the frame modifi-cation, which consists in the complement of beam hold-ers, but these construction components do not affect the frame structure such significantly as in the case of welded beam. Another advantage is the simplifier modi-fication of the original frame. Such a technical solution is suitable also in respect of space layout. Screw con-nections ensure detachable of the beam. It makes easier the bogie maintenance and also potential repairs.

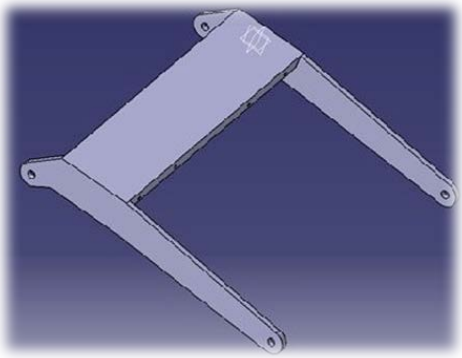

Fig. 6. Design of the disc brake beam

In our supposed modification of the Y25 freight wagon bogie, which the disc brake will be used on, the beam will be mounted on the frame by means of screw connection (mentioned above), which allow the easier and more flexible modification of the existing original frame design for the new conception with the disc brake (Fig. 7.). As the beam will be hung on the frame, forces transmission will be significantly lower in comparison with a welded beam.

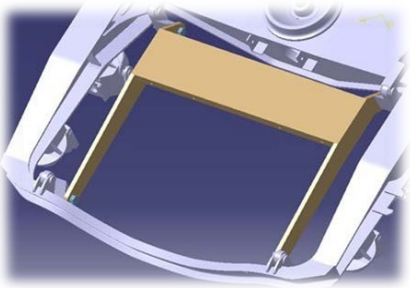

Fig. 7. Attachment of the designed beam of a disc brake on a bogie frame

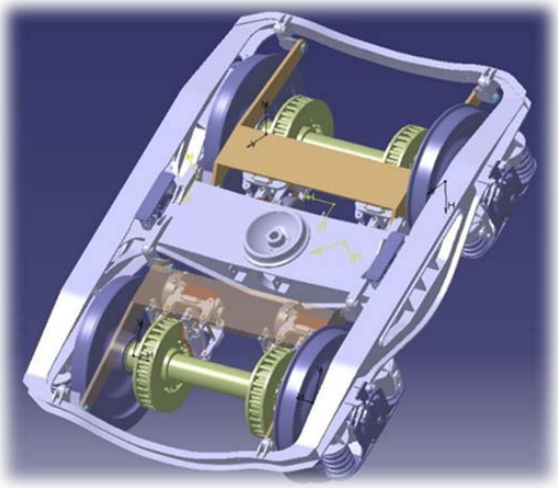

Fig. 8. Y25 bogie with the disc brake

Results of the designed technical solution. For proposed technical solution of the freight wag-on bogie modification two brake discs for one axle are chosen. Thus, four brake discs for one bogie are used (Fig. 8). The bogie will use four individual brake units with brake lining (Jurid) made of the special alloyed material. These lining will ensure significantly noise de-creasing and also they have convenient brake properties even in bad weather conditions. The brake unit will be mounted on the beam by means of screws and it will hang on the original bogie frame.

Conclusion. In this contribution, the propose of the original Y25 freight wagon bogie modification is presented. The design consists in the disc brake integration into the original freight wagon bogie without significant modification of the original bogie frame structure. The goal of the technical solution is increasing

the brake power and increasing the negative effects of noise to environment. Such a modified bogie is intended for using in a six-axle jointed wagon for intermodal transport (Sdggmrss serie). The brake system is proposed for axle load of 22.5 t with four discs in one bogie. This technical solution does not require significant modification of the original bogie frame and it ensures sufficient brake power within the acceptable heat load.

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1. Loulovб, M. Konљtrukčnб ъprava brzdovйho systйmu podvozka železničnйho nбkladnйho vagyna / M. Loulovб, J. Gerlici, T. Lack, J. Haruљinec // Dynamika tuhэch a de-formovatelnэch těles 2013, Sbornнk přednбљek, 9.-11. řnjna, 2013, Ъstн nad Labem, 8 pages, ISBN 978-80-7414-607-7.

2. Suchбnek, A. Zisťovanie љtrukturбlnych vlastnostн brzden-йho železničnйho kolesa nбkladnйho vagyna / A. Suchбnek, J. Haruљinec, P. Љťastniak // Inovбcie v koncepcii, konљtrukcii, vэrobe a skъљanн nбkladnэch vagynov II, Zbornнk prednбљok, 29.-30. janubra, 2015, pp. 81-86, ISSN 978-80-554-0980-1.

3. Kalinčбk, D. Vzбjomnй vzťahy medzi niektorэmi par-ametrami vybranэch nбkladnэch vagynov / D. Kalinčбk // Technolyg, Vol. 5, Iss. 3, 2013, pp. 135-158, ISSN 1337-8996.

4. Lack, T. Analэza vlastnostн železničnйho nбkladnйho podvozka pomocou simulačnэch vэpočtov / T. Lack, J. Gerlici // PRORAIL 2015, zbornнk z konferencie Sъčasnй problйmy v koľajovэch vozidlбch, Diel I., Žilina, 16.-18. septembera, 2015, pp. 345-354, ISBN 978-80-89276-48-6.

5. Hauser, V. Konљtrukčnй rieљenie mechanizmu klanнc zab-ezpečujъcich Tovar pri preprave vozňom Shimmns / V. Hauser, P. Љťastniak, J. Gerlici, T. Lack // Inovбcie v kon-cepcii, konљtrukcii, vэrobe a skъљanн nбkladnэch vagynov I, Zbornнk prednбљok, 27.-28. novembra, 2014, pp. 47-53, ISSN 978-80-554-0955-9.

6. Dižo, J. Design of freight wagon bogie with disc brake / J. Dižo, M. Blatnickэ, P. Љťastniak, M. Moravčнk // Tech-nolog, Vol. 7, Iss. 2, 2015, pp. 20-24. ISSN: 1337-8996.

7. Gerlici, J. Aktuбlne konљtrukčnй rieљenie skъљobnйho stavu brzdnэch komponentov koľajovэch vozidiel RAILBCOT / J. Gerlici, T. Lack, J. Haruљinec // Dynamika tuhэch a deformovatelnэch těles 2013, Proceedings of conference, 7.-9. řnjna, 2015, Ъstн nad Labem, 12 pages, ISBN 978-80-7414-914-6.

8. Gorbunov, M. Assessment and improvement of interaction of locomotive wheelsets on rails / M. Gorbunov, J. Gerlici, K. Kravchenko, T. Lack // Railway transport of Ukraine, Iss. 5-6, 2016, pp. 29-35. ISSN: 2311-4061.

9. Labuda, R. Efektнvne využitie brzdnйho ъčinku pohonu vozidla pri decelerбcin / R. Labuda, D. Barta, A. Kovalčнk // Transport 2011, zbornнk z konferencie, pp. 65-70, 2011, ISBN 978-80-554-0439-4.

10. Gorgunov M. Assessment and improvement of interaction of locomotive wheelsets on rails / M. Gorgunov, J. Gerlici, K. Kravchenko, T. Lack / Науково-практичний журнал Залізничний транспорт України, №5-6 (120-121), 2016, Київ, - С. 29 - 35..

REFERENCES

1. Loulova, M., Gerlici, J., Lack, T., Harusinec, J. (2013). Bogie brake system design modification of railway goods wagon. Dynamics of rigid and deformable bodies 2013, Proceedings of conference, October 9-11, 2013, Usti nad Labem, 8 pages, ISBN 978-80-7414-607-7 [in Slovak].

2. Suchanek, A. J., Harusinec, P., Stastniak (2015). Investigation of structural properties of the braked railway wheel of a freight wagon. Innovations in con-ception, design, production and testing of freight wagons II, Proceedings of Conference, January 29-30, 2015, pp. 81-86, ISSN 978-80-554-0980-1. [in Slovak].

3. Kalincak, D. (2013). Correlation between some parameters of se-lected freight wagons. Technolog, Vol. 5, Iss. 3, 2013, pp. 135-158, ISSN 1337-8996. [in Slovak].

4. Lack, T., Gerlici, J. (2014). Analysis of the freight wagon bogie properties by means of simulation computations / T. Lack, // PRORAIL 2015, Proceedings of the conference Current problems v rail vehicles, Part I., Zilina, September 16-18, 2015, pp. 345-354, ISBN 978-80-89276-48-6.

5. Hauser, V., Stastniak, P., Gerlici, J., Lack, T. (2014). Design solution of timber mechanism ensuring goods during transportation by the Shimmns wagon. Innovations in conception, design, production and testing of freight wag-ons I, Proceedings of Conference, November 27-28, 2014, pp. 47-53, ISSN 978-80-554-0955-9.

6. Dizo, J., Blatnicky M., Stastniak P., Moravcik M. (2015). Design of freight wagon bogie with disc brake. Technologist, Vol. 7, Iss. 2, 2015, pp. 20-24. ISSN: 1337-8996.

7. Gerlici, J., Lack, T. Harusinec, J. (2013). Rail vehicles brake components test stand RAILBCOT current constructional solution / J. Gerlici, // Dynamics of rigid and deformable bodies 2013, Proceedings of conference, October 7-9, 2015, Usti nad Labem, 12 pages, ISBN 978-80-7414-914-6.

8. Gorbunov, M., Gerlici, J., Kravchenko, K., Lack, T. (2016). Assessment and improvement of interaction of locomotive wheelsets on rails. [Railway transport of Ukraine], *Naukovo-praktichnij zhurnal Zaliznichnij transport Ukraïni* Iss. 5-6, 2016, pp. 29-35. ISSN: 2311-4061..

9. Labuda, R., Barta, D., Kovalcik A. (2011). Effective using the brake effect of a vehicle drivetrain during deceleration. Transport 2011, Proceedings of the conference, pp. 65-70, 2011, ISBN 978-80-554-0439-4.

10. Gerlici, J., Gorbunov, M., Kravchenko, K., Prosvirova, O., Lack, T., Hauser, V. (2018). Assessment of Innovative Methods of the Rolling Stock Brake System Efficiency Increasing. «Manufacturing Technology». February 2018, Vol. 18, No. 1, p. 35-38. ISSN 1213-2489.

Діжо Я., Блатницький М., Кравченко О.П. **Обгрунтування заміни колодкового гальма на дисковий в візках зчленованих вагонів-платформ для інтермодальних перевезень**

У статті представлена модифікація оригінальної конструкції візка вантажного вагона. Основа модифікації полягає в заміні колодкового гальма, яке вста-новлено в оригінальній конструкції візки, дисковим галь-мом, без значної зміни структури оригінальної рами візка. Мета цього технічного рішення - значно зменшити шум і збільшити силу гальмування. Запропонована конструкція візків вантажних вагонів, за рахунок установки дискових гальм дозволяє значно зменшити рівень шуму при гальмуванні і знизу необхідну гальмівну силу. У цій роботі представлена конструкція запропонованої схеми дискового гальма з двома дисками, кріплення гальмівної балки на оригінальній рамі візка, а також установка дискового гальмівного пристрою на гальмівний балці.

Ключові слова: вантажний вагон, дискові гальма, модифікація конструкції, гальмівна колодка дискового гальма.

Дижо Я., Блатницкий М., Кравченко А.П. **Обоснование замены колодочного тормоза на дисковый в тележках сочлененных вагонов-платформ для интермодальных перевозок**

В статье представлена модификация оригинальной конструкции тележки грузового вагона. Основа модифи-кации заключается в замене колодочного тормоза, кото-рый установлен в оригинальной конструкции тележки, дисковым без значительного изменения структуры ори-гинальной рамы тележки. Такая модифицированная те-лежка грузового вагона будет использоваться для шести-осных сочлененных вагонов-платформ для интермодальных перевозок контейнеров, прицепов и т.д. Цель этого технического решения - значительно уменьшить генерирование шума и увеличить силу торможения. Предложенная конструкция тележек грузовых вагонов, за счёт установки дисковых тормозов позволяет значительно уменьшить уровень шума при торможении и снизить необходимую тормозную силу. В этой работе представлена конструкция предложенной схемы дискового тормоза с двумя дисками, крепления тормозной балки на оригинальной раме тележки, а также установка дискового тормозного устройства на тормозной балке.

Ключевые слова: грузовой вагон, дисковый тормоз, модификация конструкции, тормозная колодка дискового тормоза.

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