On potentiality of brake rigging unification for freight cars with separate braking

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Abstract. A possibility of unified rigging use with a brake cylinder (BC) in bogie areas or on a bogie in a freight car is defined. Two ranges of transmission ratios were obtained for freight cars with pressure control in cylinders with the aid of the automated mode. To change transmission ratios, two openings are supposed to be used in rigging.

1. Introduction

One of the ways of brake system updating in domestic freight eight-wheel cars consists in the location of the mechanical unit on a bogie.

This direction is most developed abroad. We should mention such characteristic examples of a brake system used on the bogie as Motion Control manufactured by Amsted Rail Co. Ltd. (USA), a brake system developed by Cardwell Westinghouse (incorporated into Wabtec Co.) for Barber bogie manufactured by Wabtec Co. (USA), and Knorr-Bremse (Germany) for European bogie Y 25.

According to [1-3], systems with the location of an actuator component of a brake on bogies allows simplifying a brake system and with further substitution of existing arrangements. Furthermore, when arranging the system on bogies, an undercar area becomes almost absolutely free from brake equipment.

It becomes particularly important during designing railroad cars for increased axial loads. At present, this drive is used on a closed-bottom gondola car of model 12-9828 with a lowered floor level and the axial load of 27 t manufactured by Roslav 1 Railway-Carriage Repair Works Co. [4]. In comparison with analogs this car has an increased carrying capacity at the expense of floor lowering in the central area ensuring additional body space. Here, the original design of a brake mechanical unit with a separate bogie drive is realized. A rigging structure includes a brake cylinder of model TCR-10-85 (a brake cylinder with an integrated regulator of a rod outlet manufactured by Trans –pneumatics Co.) installed on a carriage under frame close to a bogie. A cylinder conveys an effort to a bogie rigging by means of levers fixed on a horizontal shaft. A shaft is installed on a carriage under frame through bushings with elastomeric spacers.

The experience of this work is significant from the point of view of the particularly compact brake equipment use in a freight car. In this connection, the application of just cylinders TCR in an actuator unit of the brake of freight eight-wheel cars with drives located in bogie areas is promising.
A possibility of such rigging use for a maximum amount of car types is limited to a high extent by a certain scatter of transmission ratios in riggings used in domestic railroad cars.

It is necessary to determine a possibility of a unified rigging (with cylinder TCR) use in railroad cars with pressure control in cylinders with the aid of an automated mode. A similar problem should be solved also for railroad cars having no possibility to adjust pressure in cylinders with the aid of an automated mode.

At the same time, it is necessary to consider a possibility of the location of a brake system with cylinder TCR both in bogie areas and on a bogie for a maximum possible number of railroad types. In addition, we shall define limitations on the correlations of a lightweight and carrying capacity for freight cars operated in the RF, within the limits of which it is possible to use a unified brake system. It is supposed to use a cylinder in a brake system with its location on a bogie, as a system least dependent on design peculiarities of railroad cars. The cylinder of the TCR-10-40 type is chosen as one of the most possible variants of brake cylinders.

In accordance with a routine calculation [5], we will define the ranges of transmission ratios of the rigging with cylinder TCR-10-40 TR 24.05.382, within the limits of which, it is possible to use a brake system, the actuator of which is located on the bogie of type 18-100 or corresponding to it with the axial load of 25 tons (trucks types 2 and 3, GOST 9246-2013).

According to [5], for railroad cars with separate braking and compact cylinders, there is no standard foreseen for a rod outlet to regulate a system on cast-iron shoes. Kinetic friction modeling is considered thoroughly in [6]. In this connection, we will consider a brake system equipped only with composite shoes.

For freight cars having a gross weight of 100 t and a light weight in accordance with table 2.2 [5] (corresponding table 10 [7] has a lower upper limit of pressure taking into account skid), let us determine transmission ratios. At the same time, we find an inferior limit with the lightweight of up to 27 t in accordance with the formulae of the standard computation [5]. Now, we will define a minimum possible transmission ratio (during computation of brake effectiveness) for a fright car with a gross weight of 100 t (25 tons per axle). This transmission ratio will be a maximum during computation taking into account the skidding for a fright car with a minimum possible lightweight. In the same way, we will define transmission ratios for freight cars with a minimum possible light weight having a gross weight of 94 t (23.5tnfper axle) and a lightweight in accordance with Table 2.2 [5].

2. Results and discussions

We will determine a minimum possible light weight.

Let us determine $K_{r_{min}}$ under the complete freight car load reasoning from the relation of:

$$\delta_r = \frac{mK_{r_{min}}}{Q}, \quad (1)$$

where $Q$ – the gross weight of a freight car (100 t); $\delta_r = 0.14.$

$K_{r_{min}} = 1.75tf.$

Let us determine $K_{D_{min}}$ – the minimum possible force on a shoe in the system with composition brake shoes under the maximum load of a freight car. For that, we will solve the following equation:

$$K_{r_{min}} = \frac{1.22K_D(K_D + 20)}{4K_D + 20}; \quad (2)$$

$K_{D_{min}} = 1.79tf.$

Let us determine $n$ taking into account the pressure for the computation of effectiveness under maximum load. In addition, we will take into account the absence of spring compression force of an automatic regulator, which leads to the rod ($F_2$) in the system with TCR (BC).
For an empty car, taking into account the obtained \( n \) and pressure in cylinders for an empty car during the computation for a skid through formulae (3) and (2), we will find \( K_{D\text{min skid}} = 0.854 \text{tf} \) and \( K_{r\text{min skid}} = 0.928 \text{tf} \).

At the same time,

\[
\delta_r = \frac{mK_{r\text{min skid}}}{T}.
\]

In accordance with formula \( \delta_r \Phi_{kr} \leq [\psi_r] \), we will obtain the equations set:

\[
[\psi_r] = \frac{mK_{r\text{min}} \Phi_{kr}}{T}; \\
[\psi_r] = \psi(q_0)(V),
\]

where \( \psi(q_0) = 0.17 - 0.0015(q_0 - 5) \); \( q_0 = T/4 \) – load on a wheel pair (axle). At that, it should be taken into account that \( q_0 \geq 5 \text{tf} \), that is, a car cannot have lightweight less than 20 t.

For its solution, we find:

\[
\Phi_{kr20} = 0.322; \quad \Phi_{kr100} = 0.257; \quad \Phi_{kr120} = 0.249; \\
\psi(20) = 0.7829; \quad \psi(100) = 0.5638; \quad \psi(120) = 0.5447
\]

Let us solve the equations set (4) and choose the highest values:

\[
[\psi_r]_{20} = 0.0947; \quad \tilde{T}_{120} = 19.519.
\]

In accordance with GOST 9246-2013, the minimum lightweight is 21 tons for trucks types 2 and 3. Let us accept minimum packaging as 21 t.

According to Table 1, the transmission ratios of 5.7/6.3 in the light weight range of 21-27 t are within the limits of 22.5-27 t. Thus, we obtain the transmission ratio of 5.7/5.9 under the light weight of 21-22.5 t. For the rest of cars with the light weight from 22.5 t, the range of transmission ratios is 5.7/6.3.

The inferior limit with the lightweight of up to 27 t of freight cars with composition shoes and gross weight of 94 t, determined according to the mentioned method, will also make 21 t (Table 2).

**Table 1.** The ranges of transmission ratios for the rigging with cylinder TCR-10-40, under standard pressure control in cylinders for cars with a gross weight of 100 t.

| Lightweight, 21-27 t; P=0.13/0.16 MPa | Lightweight, 27-32 t; P=0.15/0.19 MPa | Lightweight, 32-36 t; P=0.18/0.22 MPa | Lightweight, 36-45 t; P=0.21/0.24 MPa |
|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|
| Lower limit                          | Upper limit                          | Lower limit                          | Upper limit                          |
| 5.7/5.9                              | 5.8/7.8                              | 5.7/6.3                              | 5.8/7.6                              |
| 5.7/6.4                              | 5.7/7.3                              | 5.7/6.55                             | 5.7/8.45                             |

In the numerator there is a value for brake effectiveness, in the denominator – for skidding.

**Table 2.** The ranges of transmission ratios for the rigging with cylinder TCR-10-40 under standard pressure control in cylinders for cars with a gross weight of 94 t.

| Lightweight, 21-27 t; P=0.13/0.16 MPa | Lightweight, 27-32 t; P=0.15/0.19 MPa | Lightweight, 32-36 t; P=0.18/0.22 MPa | Lightweight, 36-45 t; P=0.21/0.24 MPa |
|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|
| Lower limit                          | Upper limit                          | Lower limit                          | Upper limit                          |
| 5.25/5.95                            | 5.8/7.8                              | 5.25/6.3                             | 5.8/7.6                              |
| 5.25/6.4                             | 5.3/7.3                              | 5.25/6.6                             | 5.65/8.45                            |
According to Table 2, the transmission ratios of 5.8/6.3 in the range of the light weight of 21-27 t are within the limits of 22.5-27 t. Therefore, we will obtain the range of transmission ratios of 5.25/5.95 under the light weight of 21-22.5 t. For the rest of cars with a light weight from 22.5 t, the range of transmission ratios is 5.8/6.3.

In the numerator, there is a value for brake effectiveness, in the denominator – for a skidding. In the general case, for cars having a maximum lightweight within the range of 21-45 t and a gross weight of 94 or 100 t, we obtain two ranges of transmission ratios: 5.7/5.9 for cars with the light weight of 21-22.5 t and 5.8/6.3 for the rest with the light weight of 22.5-45 t.

**Table 3.** The ranges of transmission ratios for the rigging with cylinder TCR-10-40, under the standard control of pressure in cylinders for cars with the gross weight of 94-100 t

| Lightweight, 21-27 t; P=0.13/0.16 MPa | Lightweight, 27-32 t; P=0.15/0.19 MPa | Lightweight, 32-36 t; P=0.18/0.22 MPa | Lightweight, 36-45 t; P=0.21/0.24 MPa |
|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|
| Lower limit                           | Upper limit                           | Lower limit                           | Upper limit                           |
| 21-22.5                               | 22.5-27                               | 5.7/5.9                               | 5.8/6.3                               |
| 5.8/6.3                               | 5.8/6.3                               | 5.8/6.3                               | 5.8/6.3                               |

In the numerator, there is a value of brake effectiveness, in the denominator – for a skid. Now, we will determine the limits of possible use of pressure automatic control in cylinders. The possibility of the automatic mode use in cars could be determined in accordance with the diagram [8] taking into account standard adjustments of pressure [7]. In Figure 1, there are values of minimum possible deflections of a car suspension under a paying load, that is, at lesser deflections, the value of pressure will be less than 0.3 MPa. It should be emphasized that on the basis of the diagram mentioned above under the pressure lower than 0.3 MPa, we will obtain sufficient brake effectiveness without the skid. But at present, this problem in the regulation documentation is not shown. This circumstance may be one of the reasons for the use of a single-mode brake (along with the necessity of an automatic mode (automatic modes) installation and supporting beams and their maintenance).

Cars having lightweight up to 27 t must have the deflection of the spring suspension not less than 35mm. Those cars having light weight from 27 to 32 t – not less than 27.3 mm. And the cars having lightweight from 32 to 36 t – not less than 21.6 mm, and those having lightweight from 36 to 45 t – not less than 17.5 mm.

Accordingly, the minimum carrying capacity of cars on the bogies of type 18-100 with the flexibility of a spring set equal to $\lambda = 1.13 \text{ mm/t funder light weight of up to 27 t should be not less than 61.9 t. Under the light weight from 27 to 32 t – not less than 48.3 t. With the lightweight from 32 up to 36 t – not less than 38.2 t. Under the light weight from 36 to 45 t – not less than 31 t.}$

Practice shows that these cars are operated both with an automatic mode and without one [9]. Under the complete load, the pressure of an automatic mode may be less than 0.3 MPa. In particular, freight cars for the motor car transportation possess this property. It is assumed, according to an agreement with a customer “RRW” Co. to be limited with modes switched manually for cars loading, the complete rated loading of which does not exceed 70% of light weight [5]. The computations of a brake for some types of cars in this case show a possibility of skid under a loaded state of a car under a complete rated load. In this connection, the advantages of a single-mode brake are evident.

The use of a single-mode brake has also limitations. According to the computations carried out, one limitation is a ratio of a light weight to a carrying capacity equal to $\sim 0.8$ (carrying capacity should not exceed 125% of a light weight). With the carrying capacity less or equal to this ratio, it is possible to obtain a stable transmission ratio meeting the normative requirements. With larger carrying capacity, at the minimum possible transmission ratio of rigging, we obtain skid possibility.
Figure 1. The dependence of the output pressure of automatic mode 265A-4 upon a deflection of a car spring unit [8] and the value of minimum possible deflections at pressure adjustment depending on the lightweight.

Now, we will determine ranges of transmission ratios for a single-mode brake. According to [10], air distributors must be switched on in a medium mode in cars having a board ‘single-mode’ on a car body supplied with composite shoes.

The minimum carrying capacity may be equal to zero. The maximum carrying capacity of such cars, according to the dependences obtained within the limits of adjustable pressures for such cars on the bogies of type 18-100 under the light weight, is up to 27 t – 61.9 t (229 % of the light weight). Under the lightweight from 27 to 32 t – the maximum carrying capacity is 48.3 t (151 % of the light weight). Under the lightweight from 32 to 36 t – the maximum carrying capacity is 38.2 t. Under the lightweight from 36 to 45 t – the maximum carrying capacity is 31 t (69 % of the lightweight).

The analysis of transmission ratios for the maximum ranges of the paying load spread under the pressure corresponding to the average mode of an air distributor shows the following: under the light weight of 36-45 t (carrying capacity is within limits from 0 up to 31 t), we can obtain transmission ratios of 4.25/4.35, under the light weight of 32-36 t, (carrying capacity is within the limits from 0 up
to 38.2 t), we obtain two ranges of transmission ratios — 3.75/3.8, within the limits of the lightweight of 32-33 t, and 3.9/3.95 — within the limits of the lightweight of 33-36 t.

Under the lightweight of 27-36 t (carrying capacity is within the limits from 0 up to 48.3 t), and also under the light weight from 21 up to 27 t (carrying capacity is within the limits from 0 up to 61.2 t) of a stable transmission ratio in the range from minimum to maximum carrying capacity, a stable transmission ratio is impossible to obtain. In this connection, for these cars, a level of carrying capacity must be considerably lower. Besides, in this case, a considerable number of transmission ratios depending on individual peculiarities of every car will be obtained.

3. Conclusion
Thus, we have obtained a possibility of using a unified rigging (with cylinder TCR) for cars with pressure adjustment in cylinders with the aid of an automatic mode. At the same time, two openings will be used for the changes of transmission ratios in the rigging.

It should be pointed out that cylinder TCR-10-40 at the obtained transmission ratios will not allow using standard gaps between shoes and wheels to a sufficient extent. In this connection, they can be used when coupled for one bogie, or a cylinder with a large rod travel has to be used.

For cars without a possibility of pressure adjustment in cylinders with the aid of an automatic mode, we have a considerable number of transmission ratios depending upon individual characteristics (a lightweight and carrying capacity) of cars. This circumstance does not allow using a unified rigging (including that with cylinder TCR).

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