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THE INFLUENCE OF ADDITIONAL DISCHARGE OF THE BRAKE LINE ON THE LONGITUDINAL DYNAMICS OF THE TRAIN DURING BRAKING

Nikolay E. Razinkin*, Nina I. Voronova, Yaroslav D. Podlesnikov, Sergey N. Danilov

Department of Technology of Transport Processes, Institute of Applied Technologies, Russian University of Transport, 14 Kuchin Lane, Moscow, Russian Federation
****Corresponding Author Email: razinkin@mkgt.ru***

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ABSTRACT

The importance of the problem under study is related to the need to solve a number of problems arising with the formation of long-freight trains. The purpose of the article is to analyze various brake systems of wagons of various lengths. The primary method for studying this problem is modeling, which permits to consider this problem. The article presents the results of studies of gas-dynamic processes taking place in the brake line of the train during braking, as well as the results of calculations of the instantaneous values of forces in the automatic coupling devices of rolling stock in the train during braking. The study results can be used to analyze the formation schemes of freight trains, especially long-base ones, and developing a new design of a freight-type air distributor.

KEYWORDS

Air distributors, additional discharge, long-wagons, longitudinal forces in the train.

1. INTRODUCTION

Over the years, much attention has been and is being paid to the research of the brake systems of trains of various formation configurations. Particularly applicable is the research data in relation to heavy cargo traffic. Certain interest from the point of view of the longitudinal dynamics of the train pose the long-range freight trains, formed from long-wagons, as well as freight trains, which include passenger cars.

The purpose of the additional discharge of the brake line by air distributors is widely recognized [1]. It is believed that the air distributors of cargo type, conv. No. 483 have an effective additional discharge in the brake line, they contribute to a decrease in pressure in the brake line by 0.05 MPa with full service braking. Thus, the air distributors can be activated for braking along the entire length of the train, the length of which can be up to 1500 m, even if several air distributors in the train are turned off. If there are long-base cars in the train, with a train length of 1500 m, the number of air distributors will be less than in a train formed of short-base cars. In accordance with the rules for maintenance of brake equipment and brake control for railway rolling stock (2014) in passenger cars, air distributors should be turned off if the number of such cars does not exceed 2 in one group. When forming trains, there can be situations when there are several groups of passenger cars along the train with air distributors turned off. These moments unfavorably affect the controllability of automatic brakes and lead to an increase in longitudinal reactions in the train.

Long wheelbase cars have a greater length of the brake line without additional discharge during braking and a larger volume. When including in a freight train of passenger cars with the air distributors turned off, the speed of the brake wave also decreases. Air distributors of passenger type conv. No. 292 practically do not discharge the brake line during braking, the property of additional discharge of the brake line is better implemented in new passenger-type air distributors, conv. No. 242, but they also ineffectively affect the discharge of the brake line of a freight train.

In the design of the air distributor conv. No. 242 has an additional brake line discharge limiter, a similar device can be used on a cargo type air distributor, representing either a new device or an upgraded standard air distributor. An example would be the new serial main part of the air distributer of a cargo-type conv. No. 483.400.

2. MATERIALS AND METHODS

In the process of research, the following methods were used: theoretical (analysis, synthesis, specification, generalization, analogy method, modeling), empirical (study of normative and technical documentation), experimental, method of graphical representation of results.

The experimental base of the study was the Russian University of Transport (RUT (MIIT)). The study of the problem was carried out in three stages. At the first stage, a theoretical analysis of the existing methodological approaches in the technical scientific literature, as well as the theory and methodology of research was carried out; the problem, purpose and methods of research were highlighted, the plan of experimental research was composed. At the second stage, a mathematical model was developed; Experimental work was carried out, the conclusions obtained in the course of experimental work were analyzed, verified and refined. At the third stage, the experimental work was completed, the theoretical and practical conclusions were refined, and the results were summarized and systematized.

3. RESULTS

The known formula for determining the magnitude of instantaneous effort in the coupler for a homogeneous train is [2]:

$$R = A \cdot \sum_{i=1}^{n} K_p \cdot \varphi_{kr} \cdot \frac{L_p}{v_{tv} \cdot c}, \text{ кН} \quad (1)$$

where A is a coefficient depending on the design of the air distributor, the

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state of the train before braking and wear of automatic couplers (A = 0.65 if the train is stretched; A = 0.4 if the train is compressed);

K_p – the calculated force of compression of the brake pads;

φ_{kr} – the calculated friction coefficient of the brake pads;

L_p – the length of the train, m;

V_{tv} – the speed of the brake wave, m / s;

T_c – the time of filling the brake cylinders, p.

From the formula (1) it is seen that with an increase in the speed of the braking wave, the forces in the coupler devices decrease. Typical air distributors of freight wagons, when triggered by braking, perform additional discharge of the brake line quite effectively as compared with the previous versions of the cargo-type air distributor conv. No. 270-002 and 270-00 5. Air distributors conv. No. 483 allow to drive freight trains with a length of up to 1.5 km, if they are formed from short-base cars. But now for the transport of specific goods, such as containers, cars, large-diameter pipes, timber, long-base cars with a length of 24-25 m along the clutch axes are used more.

The filling time of the brake cylinders of freight wagons depends on the position of the deceleration mode switch. Provided freight cars are equipped with composite brake pads, the switch of the braking modes of the air distributors is set either to the “empty” mode or to the “middle” mode. The greatest values of instantaneous effort in coupled devices appear between empty and loaded wagons or between groups of empty and loaded wagons. Although it has no effect on the study of the pneumatic brake system.

Various techniques have been developed to study the longitudinal dynamics of a train, for example, a researcher taking into account various additional parameters, and requiring the input of a large amount of data [3]. Such techniques allow you to accurately assess the level of instantaneous forces that occur in the automatic coupling devices of the rolling stock during braking. To analyze the longitudinal dynamics of a train formed from long-wheel cars, it is necessary to consider the process of additional discharge of the brake line by air distributors during braking. Discharge of the brake line in the train is performed primarily through the driver's valve, additional discharge of the brake line is performed by each working air distributor and, in addition, can be performed through the tail car unit. This article deals with all these cases. Having determined the speed of the brake wave in the section of the brake line where the air distributor is located, it is possible to calculate the instantaneous forces in the automatic coupling devices of the cars.

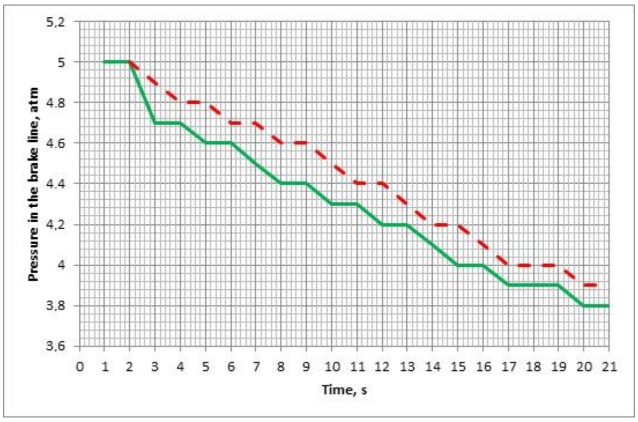

Figure 1: The change in pressure in the brake line of the train

An experiment was carried out to study the work of the brake system of a train formed from long-base cars with cargo-type air distributors. The process of pressure changes in the brake line of the 20th car is shown in Figure 1. The solid line is typical for a train with 20 included air distributors, a dashed line is for a train with 10 included air distributors (10 long-base cars with a length of 25 m along the axes of the coupling).

From Figure 1 it can be seen that the discharge of the brake line in a train formed from long-base cars is slower than in a train formed from short-base cars, which corresponds to a slower brake wave speed.

Figure 2 shows the results of calculating the values of the instantaneous forces in the coupling devices in the train at the initial moment of braking, i.e. when the air distributors act on the additional discharge of the brake line. The solid line is typical for a train formed from short base cars, a dashed line is for a train formed from long base cars.

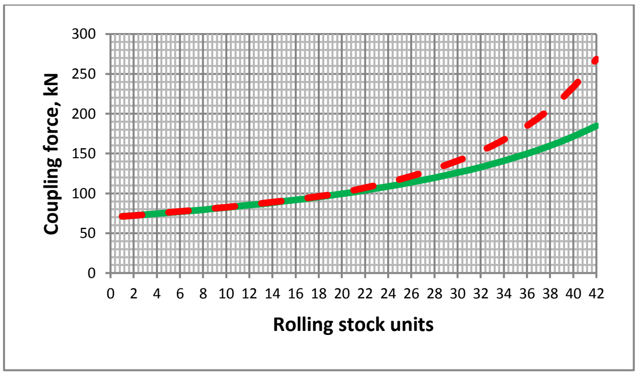

Figure 2: The values of the instantaneous forces in the automatic coupler cars at the initial moment of braking

During the additional discharge of the brake line by a freight-type air distributor, conv. No. 483 compressed air enters the brake cylinder at the initial braking moment. At the same time, part of the compressed air from the brake cylinder enters the atmosphere through the hollow rod of the balancing piston.

To increase the speed of propagation of the brake wave can be more effective by further discharging of the brake line. If in types of air distributors conv. No. 483, we can increase the flow areas of the calibrated openings in the body of the three valves; when braking, a larger volume of compressed air will flow out of the brake line, i.e. additional discharge of the brake line will be more efficient. But in this case, the main diaphragm will quickly move to the brake position, the discharge of the spool chamber will start earlier, respectively, the filling of the brake cylinders will begin faster in the head of the train, which will cause large longitudinal forces in the train. In addition, a more intense additional discharge in the air distributor conv. No483 will lead to a deterioration in the control of train brakes.

Figure 3 shows the results of calculating the values of the instantaneous forces in automatic couplings in a train formed of combined cars at the initial moment of deceleration (when the air distributors trigger an additional discharge of the brake line). The solid line is typical for a train with improved air distributors (with more intensive additional discharge), a dashed line is for a train with typical air distributors.

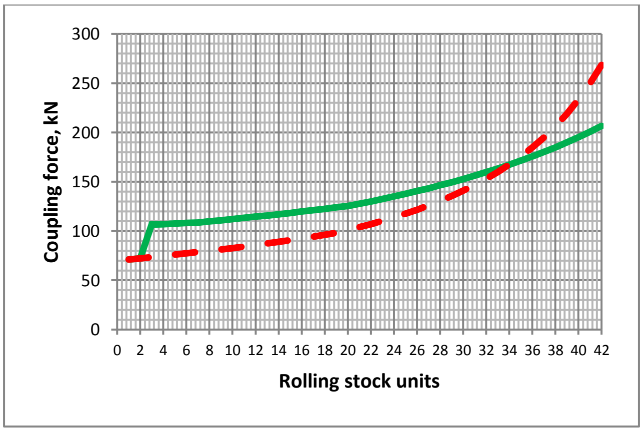

Figure 3: The values of the instantaneous forces in the automatic coupler cars at the initial moment of braking

From Figure 3 it is seen that the use of air distributors with more intensive additional discharge contributes to the reduction of longitudinal forces in the train during braking by maintaining the speed of the braking wave, which is especially important for long base cars.

To determine the longitudinal dynamic forces in the train during braking, a train was modeled, which consists of a two-section locomotive and 40 cars. The total length of the train is 1000 m. All cars are 4-axle, except for one, and each one has a different load. The eight – axle tank wagon is located in position 12 from the locomotive. The train has 2 passenger cars located in a row after 19 cars, which means 8 non-brake axles in the middle of the train. Passenger cars are included with the air distributors turned off. At a speed of 100 km / h, the driver applied full service braking until the train stopped, the train was moving in a stretched state. The values of the calculated depression of the brake pads for each unit of rolling stock were determined. The magnitude of the instantaneous effort in coupler devices are presented in Figure 4.

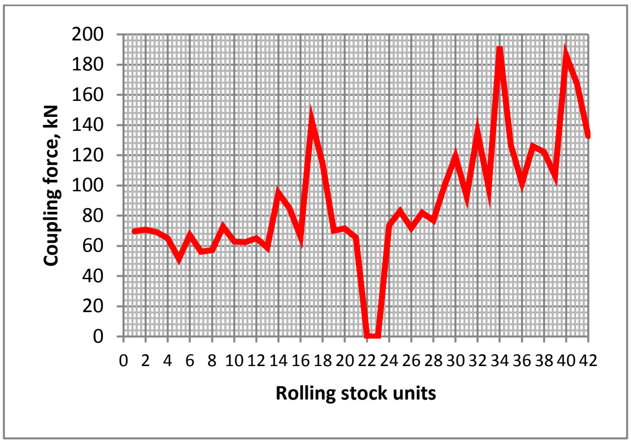

Figure 4: Instantaneous values in automatic couplings with full service braking

Figure 4 shows an increase in the longitudinal forces in the couplings of cars in the tail section of the train. This is due to the decrease in the speed of the brake wave, which is especially evident after two passenger cars with air distributors turned off (without additional discharge of the brake line). The ramp view of the graph indicates the different load on the wagons in the train. It should be noted that with the inclusion in this case of passenger-type air distributors, conv. No. 292 additional discharge of the brake line practically does not increase, since in this case, the chamber is filled with an additional discharge of 1-liter air distributors from the brake line of the car, which has a volume of about 25 liters. Figure 5 presents the results of calculations of instantaneous forces in automatic coupling devices when braking using the tail carriage unit (BTU) of the Distributed Train Brake Control System (TBCS). In this case, the discharge of the brake line is carried out not only from the head of the train through the driver's valve, but also from the tail through the BTU.

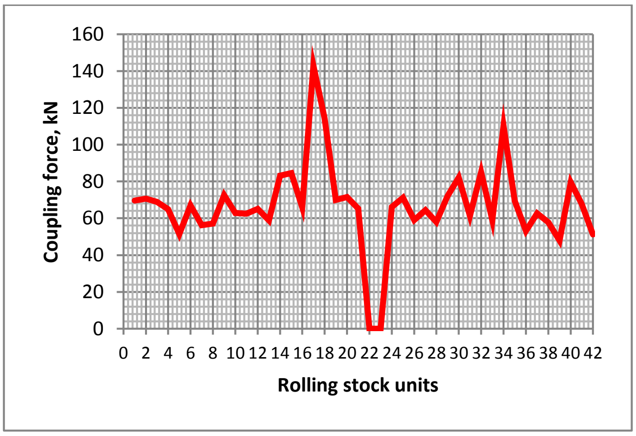

Figure 5: Values of instantaneous forces in automatic couplers when braking using BTU

From figure 5 it can be seen that the use of the tail car unit reduces the effort in the automatic coupling devices of the cars in the tail section of the train due to the high speed of the brake wave that propagates from the tail car to the middle of the train. The calculation results hve shown that in the simulated train the values of the instantaneous forces in the automatic coupling devices of the cars do not exceed the limit values according to the conditions of the cars derailing (500 kN) and the automatic coupling strength (2000-2500 kN).

4. DISCUSSIONS

The issue of increasing the efficiency of additional discharging has been under consideration for decades; it affects both air-distribution and passenger-type air distributors. The use of an electro-pneumatic brake (EPB) removes this question, but only under the condition of the proper operation of such a brake. In the event of an EPB failure, pneumatic brake control necessitates maintaining the speed of propagation of the brake wave. For freight cars, the electro-pneumatic brake was implemented in 1963-1964. in an experimental batch of diffusers conv. №270-004 electrical parts conv. No. 353.Testing operation showed the specific disadvantages of this design.

In this work, the authors proposed an electro-pneumatic brake option for a typical air distributor of a cargo type of the 483 series [4]. In the proposed scheme, the control of an electro-pneumatic device, which is available on each air distributor, is done by a special digital decoder, which converts the signal from the control unit, and which is also installed on each freight car. In addition, the authors recommend introducing an emergency braking accelerator into the design of a standard cargo-type air distributor, which was abandoned after operation of air distributors conv. No. 270-002. However, the process of re-equipment of freight cars with new braking devices has an extended application and is often left without support; therefore, the formation of a freight train from cars with typical air distributors and modified ones leads to significant longitudinal forces in automatic couplings when braking.

The use of emergency braking accelerators on air distributors contributes to the effective additional discharge of the brake line and guarantees operation of all serviceable instruments, but only when the brake line is discharged by the rate of emergency braking. The design of the accelerator of emergency braking, implemented in the air distributor of the cargo-type conv. No. 270-002 turned out to be unfinished, proved to be ineffective in operation, therefore this device was abandoned and in subsequent modifications of this air distributor emergency braking accelerators were not used, which led to the same operation of the devices when the brake line was discharged at full service and emergency braking.

Improving the efficiency of additional discharge of the brake line in freight trains was implemented in the transition from the main part of the conv. №270-1000 to the main part of the conv. No. 483. Various versions of the refinement of this design are reflected in a number of patents of the Russian Federation [5; 6]. Such devices are proposed to be placed either in the linear part of the air distributor, or in the main part. With this design, additional discharge of the brake line is carried out either into the atmosphere or into the brake cylinder.

It should be noted that all proposals to improve the efficiency of additional discharge of the brake line of a freight train relate to a typical air distributor conv. No. 483 suggest its refinement. The transition to a fundamentally new design of a cargo type air distributor is not being considered, although, according to the authors, it is promising, since A typical cargo type air distributor has been in operation since 1959 (conv. no. 270-002), since 1968 the main part of this device has been replaced (conv. no. 270-005), later the main part was replaced again, and the device was designated as conv. №483 (conv. No. 270-008).The main part of the air distributor all this years remained unchanged (conv. No. 270-023), as did the two-chamber reservoir conv. No. 295-001.In 2008, work was completed on the creation of a new main part conv.№ 483.400, which is installed on the diffusers conv. No. 483A-04, 483A-05, 483A-07, and 483A-09.

In the construction of the main part of the conv. No. 483.400, an additional brake discharge limiter is applied, which is controlled by the pressure in the brake cylinder, and not by the pressure in the spool chamber, as in the main part of the conv. No. 270-023. The time of release of compressed air into the atmosphere from the main chamber through a channel of large cross section (channel of additional discharge) depends essentially on the parameters of the springs used in the limiter of additional discharge, changing the stiffness of the springs, you can adjust the time of additional discharge of the brake line. For more precise control of this process, an atmospheric valve of the body of three valves of the main part of the air distributor and an atmospheric calibrated orifice of 0.9 mm in the valve cover are used.

Currently, the issue of changing the design of a typical cargo type air distributor remains unaddressed, and to perform more efficient additional discharge of the brake line during braking, it is recommended to use the tail carriage unit (BTU), which is part of the distributed train braking control system (DBCS). In this case, in addition to discharging the brake line through the driver's valve and air distributors, the brake line is discharged from the tail of the train through a calibrated opening in the BTU, which is triggered simultaneously with the driver's valve. Such devices are advisable to use on long-base freight trains but equipping each freight train with such blocks is problematic.

For the operation of the DBCS it is necessary to have a valve at the driver locomotive conv. № 130 or conv. No. 230D, or a special supplement for the driver valve conv. No. 395, which are installed on new locomotives; existing freight locomotives in operation, as a rule, are equipped with standard driver's valves conv. No. 394 or conv. No. 395 of various modifications.

When freight trains are formed from long-base freight wagons (80-foot container platforms, pipe carriages, wood cars, carriages for cars, lightweight carriages, refrigerated cars), about 38 carriages can be placed per km of station tracks, which corresponds to 38 air distributors in the train (provided that all devices are in good condition) with a brake line length of about 1000 m. As shown by the test results described in paragraph 3 of this study, such a train can be compared to a long train, according to the nature of the gas-dynamic processes occurring in the brake line, to ensure the controllability of the automatic brakes, which it is advisable to use the BDCS. In reality, for the trains, the length of which does not exceed 1000 m, this system is not used.

The works of a several researchers present the results of calculating the filling time of brake cylinders in a train using the BDCS system and several tail car blocks; In this case, an imitation of the operation of an electro-pneumatic brake on a freight train is obtained [5-9]. A similar figure can be obtained if two air distributors are used on long-base cars. When using the BDCS system with several blocks of a tail car in a train, it becomes necessary to determine the volume of investments and to compare them with other options, for example, with the system described in the work. However, the use of the BDCS system with several blocks of a tail car is implied for a particular long – base train at a specific operating range or closed route. In this case, there is no need to equip all freight cars with air distributors with an electro pneumatic attachment and digital decoders.

In work of a researcher, it is recommended that every fifth air distributor be switched off to prevent “squeezing” of empty cars by longitudinal forces and to improve the controllability of automatic brakes in long-base freight trains, taking into account ensuring brake pressure of at least 43 tf per 100 tons of train weight [10]. Accordingly, every fifth air distributor in the train will not perform an additional discharge in the brake line, which will lead to a decrease in the speed of propagation of the brake wave and may cause a failure of the air distributors of tail cars [11]. The presence of passenger cars with such brakes off in such trains leads to an even greater aggravation of the process of discharging the brake line when braking along the length of the train [12-15]. To substantiate such a proposal, in our opinion, it is necessary to carefully consider the issue of guaranteed operation of all serviceable air distributors during braking [16].

5. CONCLUSION AND RECOMMENDATIONS

It has been established that in order to achieve a more effective additional discharge of the brake line during braking, it is necessary to develop a new design of the air distributor; on long-base freight cars, it is advisable to use at least two air distributors to sustain the speed of propagation of the brake wave. The materials of this article can be used in the educational process, for the training of specialists in the field of railway transport, for the preparation of dissertations, for further research on the longitudinal dynamics of long-base trains.

In the process of research, new issues and problems have arisen that need to be solved. It is necessary to continue the research on the development of methods for studying gas-dynamic processes taking place in the brake line of the train and solving the problem of the effectiveness of additional discharge of the brake line during braking.

In order to improve the controllability of the brakes in the train, especially slong-length ones, without using the BDCS system, to reduce longitudinal forces in the train during braking, it is necessary to increase the efficiency of cargo-type air distributors, which can be implemented without a significant design change, or to develop a fundamentally new air distributor, in which all necessary functions will be accomplished with greater efficiency. In order to improve the longitudinal dynamics in long freight trains, it is necessary to use a distributed train brake control system or an electro pneumatic brake system with remote control over the radio channel (in conjunction with conventional air distributors). In any case, to reduce the longitudinal forces in the train during braking and to improve the controllability of the automatic brakes, investments are needed to implement one of the systems described above, and therefore it is necessary to evaluate the volume of investments and the effectiveness of each proposed system.

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