3503 貨物列車の空気ブレーキ管の圧力変動に関する研究

A Study on the Pressure Variation of Pneumatic Brake Pipe-line for Freight Train

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We have performed experimental studies for the improvements of pneumatic brake systems of freight trains. Currently, most of the freight trains operated by the Korean National Railroad have either empty-load or diaphragm type brake systems. In this study, appropriate methods that the air pressure characteristics in both type of brake systems are in accordance with each other have been investigated. Also, we have performed running tests using a 30 car - train set in order to design optimum capacity of a quick release valve. The test results show that the quick release valve is considerably effective in shortening the release time of the diaphragm type brake system. In the case of a normal brake application, the diaphragm type brake system with the quick release valve reduces the release time to 34% of that of the system without the quick release valve. This release time is almost equivalent to that of the empty-load type brake system. Accordance of braking performance in different types of brake systems in a train set is expected to prevent wheel flats and to reduce maintenance costs.

Key Words :　Pressure Loss, Pneumatics, Air Brake system, Freight Train, Empty-Load Brake, Diaphragm Valve, Triple Valve

1. Introduction

In case of a freight train set consisted of various kinds of cars, there is disharmony of pressure variations in brake cylinders between freight cars in front and the ones in rear. The discord of air pressures in the brake cylinders between front cars and rear cars results in difference of idle running time among freight cars. The troubles related to the brake system, for example, wheel flat or bad release application, cause the delay of train operation as well as unnecessary maintenances.

Because each country around TKR(Trans-Korean Railway), TCR(Trans-China Railway) and TSR(Trans-Siberian Railway) has its own brake systems for freight cars, some country may experience these phenomena when, what is called, the iron silk-road between Europe and Asia is opened to traffic.

Computational studies have been conducted to solve the characteristics of pneumatic brake system for the brake pipe and the simple model[1,2]. But, there is no study to analyze the entire pneumatic brake system with various control valve, brake pipe, and brake cylinder due to the complexity of modelling. The running test using freight cars and a locomotive was conducted to measure the pressure characteristics of brake pipe and brake cylinder[3].

In this study, experimental studies using the running tests with freight cars have been conducted for the improvements of pneumatic brake systems of freight trains. Also, we modulate the pneumatic characteristics of brake and release applications using a quick release valve incorporated in diaphragm valve to attain coincident pressure variation of each brake system and to shorten the release time of the gradual release brake system.

2. Pneumatic brake system of freight train

Figure 1 shows the schematic sketch of a pneumatic brake system for freight trains. The brake valve supplies the compressed air in the main reservoir of a locomotive to the auxiliary reservoir of each freight car via brake pipes. To stop the train set, driver needs to control the brake valve to exhaust the compressed air in the brake pipe. Those movements of compressed air result in the frictional force between a brake shoe and a wheel. To release the brake shoe from the wheel, driver needs to control the brake valve to pass the compressed air to the auxiliary reservoir and the brake pipe. Pressure increase in these parts makes the control valve to exhaust the compressed air in the brake cylinder to the atmosphere. The pneumatic brake systems of freight cars are controlled by the brake valve to increase and decrease the brake pipe pressure that plays the signal of brake-release applications[4].

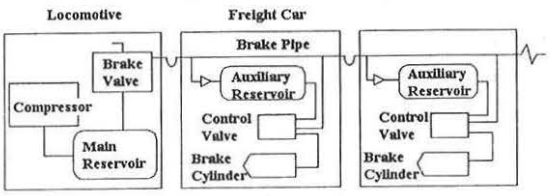


Fig. 1 Schematic Sketch of Brake System for Freight Train

3. The details of experiment

Figure 2 shows an experimental freight train set that is composed of a diesel locomotive, twenty-nine freight cars, and a test car equipped with various measuring instruments. Through the experiment using freight cars installed with the empty-load brake systems and the diaphragm ones, respectively, the pressure variation and release characteristics of the brake cylinder have been investigated. To attain the similar braking behavior between the systems, the quick release valve was additionally incorporated in the diaphragm brake system.

As shown in the Fig.2, when the locomotive is located in the left side, the test freight cars, A(#24), B(#27) and C(#29) are in the rear condition. Reversely in the right side, A(#7), B(#4) and C(#2) are in the front condition. Therefore, various conditions can be conducted with only changing the locomotive's position. The brake pipe pressure and brake cylinder pressure are simultaneously measured in the case of minimum, normal, emergency, and repeat brake applications, respectively. If the overall length of each freight car is taken as 15 meters and the locomotive as 20 meters, the length of the train of 30 cars becomes 470 meters. Pressure sensors are installed in the brake cylinder of each car and the signal of pressure variation are transferred to the test car equipped with the measuring instruments. The nominal capacity and nominal output of the pressure sensor are 1 MPa and 1.0mV, respectively. The 16 bits data acquisition and analysis instrument which has a performance of 100kS/s sampling rate is used.

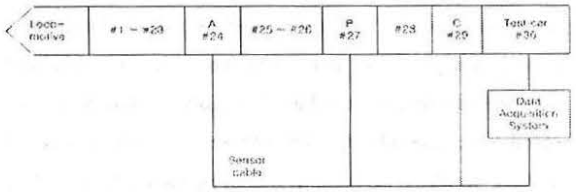


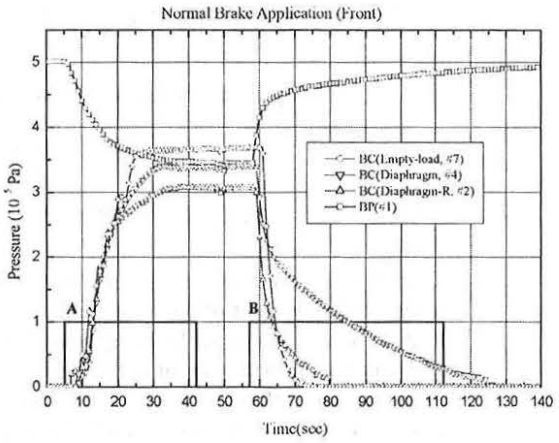
Fig. 2 Experimental Freight Train

4. Results and review

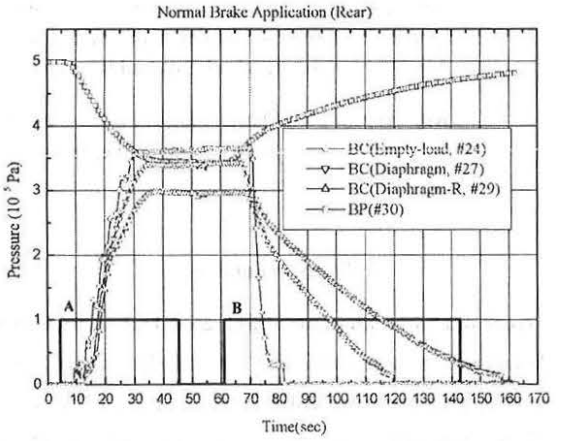
Figure 3 shows the pressure variation of the brake pipe and the cylinder in case of a normal brake application. Brake pipe pressure varies from 500kPa to 350kPa.

The sections A and B corresponds to brake command and release one, respectively. In graph, lines with ○, ▽ and △ symbols represent the pressure variances in the brake cylinder of the empty-load type brake, diaphragm type brake without the quick release valve and diaphragm type brake with the quick release valve, respectively.

The normal brake application would be frequently used in operation to stop a train. Because the pressure variation of the brake pipe is larger than that of the minimum brake application, the friction force doesn't play a role to stop the piston of the triple valve.



(a) Front Side

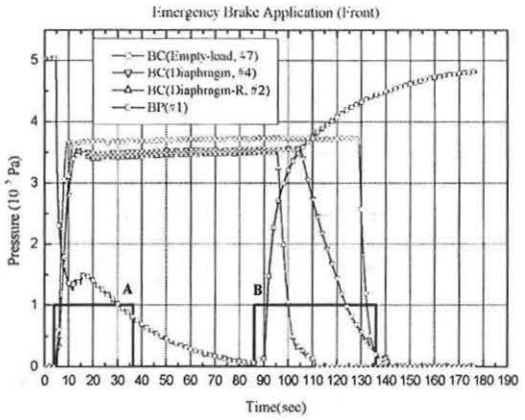


(b) Rear Side

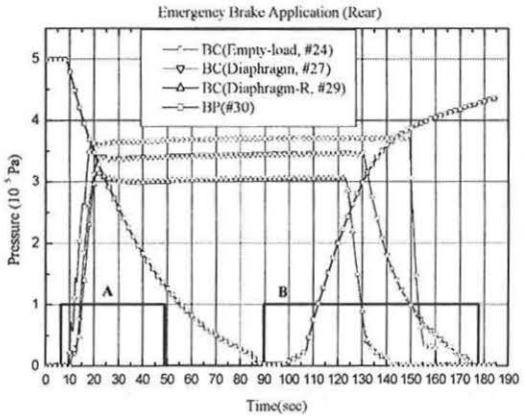
Fig.3 Pressure Variation of Brake Pipe and Cylinder in case of Normal Brake

Therefore, the brake cylinder pressure instantly comes to be constant level. The release time of revised diaphragm brake system incorporated with the quick release valve is shortened by 45 sec. in case of front condition and 37 sec. in rear condition. The discord of the brake cylinder pressure between freight cars results in various troubles like wheel flat, poor release action, and etc.

Because pressure difference becomes severe in proportion to the length of a freight train, it is necessary to remove the pressure loss elements in the brake pipe line. These improvements may result in the equalization of brake performance in the train set. According to the kind of brake control valves, it is recommended to arrange for the freight cars installed with diaphragm brake valves at front side of the freight train, and for the cars with empty-load brake valves at rear side in order to reduce pressure difference and wear. When the accidents happen or urgent stop is needed during train operation, emergency brake application is operated. In the emergency brake application, brake pipe pressure is decreased from 500kPa to 0kPa and a cut-off valve in



(a) Front Side



(b) Rear Side

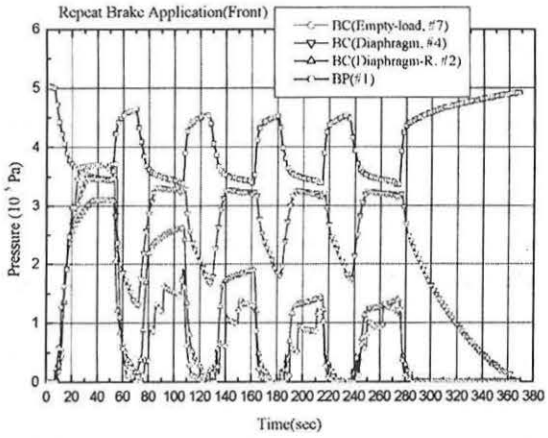
Fig.4 Pressure Variation of Brake Pipe and Cylinder in case of Emergency Brake

a locomotive prevents air flow from main reservoir. In addition, emergency parts help the control valve to quickly flow from the auxiliary reservoir to brake cylinder.

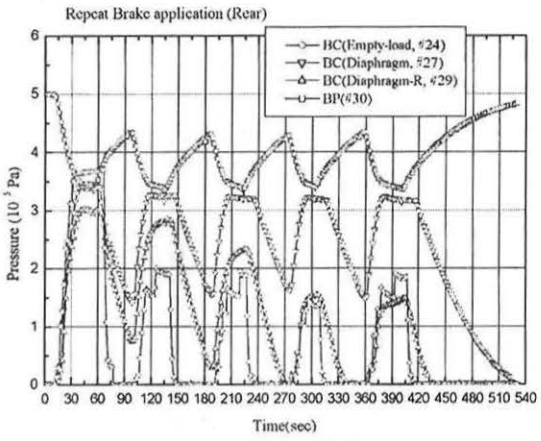
The pressure variation of brake pipe and cylinder in case of emergency brake are shown in Fig. 4. Due to the expansion wave induced by sudden pressure decrease, there is a discontinuous part on the line of the variation of the brake pipe pressure. These phenomena can't be found in the freight cars in rear side. It is considered that the brake pipe pressure of the freight car in rear side varies relatively slowly due to the various pressure loss elements such as tee, valve, coupling and bend in the brake pipe line. Because the exhaust air velocity is proportioned to the pressure reduction for the brake application, the pressure variation among cars also differ greatly.

Figure 5 shows the pressure variation in case of a repeat brake application. The repeat brake is used for decelerating railroad vehicles when they are being operated on the lines placed in sharply inclined mountainous areas. This needs quick release of brake with the supply of constant air pressure to the brake cylinder under the condition of repeat brake and release applications.

As you can see in the figure, the main difference between empty-load brakes and diaphragm brake valves is the amount of compressed air exhaust. As the brake is released, the pressure in the brake cylinder of the empty-load system drops to 0 Pa. However, the pressure in the brake cylinder of the original diaphragm system under the same condition applied to the empty-load system maintains 180kPa. Therefore, in the case of a train set that uses both brake systems, excessive frictional forces are applied to the contact areas of wheels and brake shoes of the vehicles with diaphragm systems. Consequently, this causes some kinds of hindrances such as wheel flats and brake shoe fractures. For the case of the repeat brake application with the empty-load system, the pressures generated from 2nd to 5th braking decrease compared with the pressure generated from the first braking.



(a) Front Side



(b) Rear Side

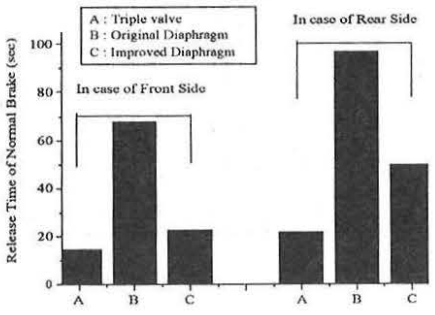
Fig.5 Pressure Variation of Brake Pipe and Cylinder in case of Repeat Brake

However, under the same conditions, the pressure of the diaphragm system remains constant. In this system, the compressed air of 500kPa in a control chamber shifts main diaphragm to open the passage from the auxiliary air reservoir to the brake cylinder. Therefore, constant braking pressure can be obtained if the auxiliary air reservoir contains compressed air. On the contrary, in the empty-load braking system that is direct releasing type, most of the compressed air in the brake cylinder is exhausted to the air in short time. This makes the empty-load braking system have quick releasing time. In order to compensate relatively longer releasing time of diaphragm brake system, quick release valve is additionally adopted to the diaphragm system.

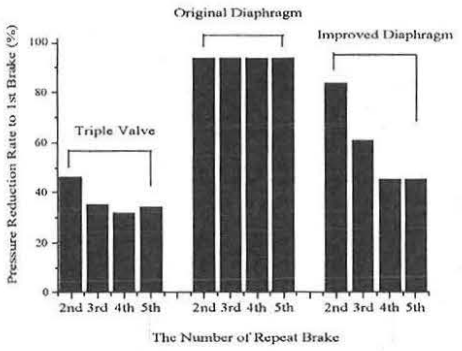
The quick release valve makes the air in the brake cylinder be exhausted to the air at relatively low brake pipe pressure by delivering compressed air in the control chamber to the auxiliary reservoir, and consequently by reducing the air pressure in the control chamber. Once we have improved the diaphragm brake system like the one mentioned above, the releasing time for the brake system has been reduced significantly.

Releasing time is only 34% and 60% of those for the system with no improvement for the cases of vehicles in the front and in the rear of a train set, respectively.

Fig. 6 shows the effects of the quick release valve incorporated in the diaphragm valve. In case of front side, the release time of the normal brake application of the improved diaphragm valve is almost the same with that of the triple valve. And, in contrast to the original diaphragm valve that has constant brake cylinder pressure in the repeat brake application, the patterns of pressure reduction rate resemble to that of the triple valve. For the improved diaphragm brake system, the measured values of releasing time in the case of minimum, normal and emergency breaking have been shortened up to 48%, 34% and 46% for a car positioned in front and 83%, 60% and 59% for a car positioned in rear, respectively. In addition, pressure reduction after the first braking in the repeat brake test has been observed. Especially, great reduction of releasing time has been obtained for a car placed in front.



(a) Comparison of Release Time



(b) Comparison of Pressure Reduction Rate

Fig.6 The Effects of Quick Release Valve

5. Conclusions

Experimental study has been conducted to clarify pressure characteristics of various pneumatic brake system for freight cars. Thirty freight cars installed with empty-load brake system and diaphragm one are used to assess the pressure variation in case of minimum, normal, emergency and repeat brake applications. And, to adjust release time, the quick release valve is incorporated in the diaphragm valve. The pressure characteristics of the brake pipe and cylinder are clarified in quantitatively and qualitatively and the summarized results are as follows

(1) With the help of the quick release valve, the release time of the diaphragm valve is shortened to the level of the empty-load valve.

(2) In normal brake application, release time of revised diaphragm system are reduced to 34% of old one in front case and 60% in rear case, respectively

(3) The pressure difference between freight cars is small when the freight car incorporated with the diaphragm valve is located in front side.

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