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# АНАЛИЗ ВЛИЯНИЯ КОНСТРУКЦИОННЫХ ПАРАМЕТРОВ ГЛАВНОГО ТОРМОЗНОГО КЛАПАНА НА РАБОТУ ПНЕВМАТИЧЕСКОЙ ТОРМОЗНОЙ СИСТЕМЫ ТЯЖЕЛЫХ ГРУЗОВИКОВ

# ANALYSING THE IMPACT OF STRUCTURAL PARAMETERS OF THE DUAL BRAKE VALVE ON PNEUMATIC BRAKE SYSTEMS IN HEAVY TRUCKS

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*Пневматические тормоза до сих пор широко используются в тяжелых грузовых автомобилях благодарю их плавного управления. Однако одним из самых больших недостатков пневматических тормозов является медленная реакция системы и сложность контроля изменения давления в тормозных камерах. Главной тормозной клапан является наиболее сложным узлом в клапанных системах, и он также сильно влияет на время срабатывания системы. В данном исследовании описывается оценка влияния конструктивных параметров главного тормозного клапана на изменение давления в тормозных камерах. Анализируется связь между диаметром поршня и времени повышения давления в тормозных камерах в пневматическом приводе без релейного клапана. Рассматривается влияние расстояния между поршнем и воздушным клапаном на время повышения давления и выпуска воздуха в тормозных камерах.*

*Pneumatic brakes are still widely used in heavy-duty trucks due to their smooth control force. However, one of the biggest disadvantages of pneumatic brakes is the slow response of the system and the difficulty in controlling the pressure changes in the brake chambers. The dual brake* *valve is the most complex valve assembly in the system, and it also greatly influences the system's response time. In this study, we evaluated the influence of the structural parameters of the dual brake valve on pressure changes in the brake chambers. The relationship between the piston diameter and the rising time of pressure in the brake chambers in a pneumatic drive without a relay valve is analyzed. The influence of the distance between the piston and the air valve on the time of pressure increase and air release in the brake chambers is considered.*

***Ключевые слова***: *пневматические тормоза, главный пневматический тормозной клапан, время срабатывания, релейный клапан.*

***Keywords***: *pneumatic brakes, pneumatic dual brake valve, response time, relay valve.*

INTRODUCTION

Pneumatic brakes are still of particular interest and research [1–7], as they have the advantages of smooth control force and low cost. This is why they are still widely used in large trucks today, although this system has a major disadvantage of long response time due to the slow response of the airflow through the valves and pipes. This issue is also regulated in the ECE R13 standard. Current research on pneumatic brakes often focuses on addressing this issue [1, 6, 8, 9]. Research can be divided into groups such as optimizing the system structure and optimizing control methods in the pneumatic ABS brake system [1–9].

Previous studies often considered valves as flow holes accompanied by a volume [10]. This reduces the accuracy of the model and does not investigate the influence of valve opening and closing time. With the development of technology, simulating valves more accurately with computer support has been possible. Therefore, many studies have used specialized simulation software to investigate and optimize the system. The dual brake valve and pipeline are the two main factors affecting the reaction time, as pointed out in the study by Zhe Wang and colleagues published in 2017. The authors concluded that the dual brake valve and pipeline accounted for 80 % of the total delay of the entire system. Among them, the delay caused by the pipeline and connectors can be up to 30 % [1, 8]. From the authors' study, it can be seen that reducing the delay of the system, the process of reducing the delay on the dual brake valve, valves, and pipeline is one of the important solutions [1, 8, 10].

There have been some studies to reduce the slow response time of the compressed air brake system, especially the compressed air ABS system. The relay valve is an important component in reducing the response time of the compressed air brake system. Palanivelu and colleagues [11] showed that the type of valve and the number of relay valves significantly affect the pressure increase and decrease time in the brake chambers in the system, especially in the rear axle. The difference in response time can be about 0,23 s. In addition, Ren He and Zhecheng Jing used the energy storage brake chamber of the parking brake system as a support measure for the main brake chamber to reduce the slow response time. The results showed that the new method could reduce the response time of the system by 0,19 s [12]. In addition, the control algorithm will also affect the response time. The author Devika concluded that a good PID controller can reduce the delay time in the compressed air ABS brake system by 40 % [6, 11, 12, 13, 14].

Our study focuses on simulating the dual brake valve of the compressed air brake system to investigate the influence of parameters such as piston diameter and distance between valves to the pressure increase and decrease in the brake chamber, thereby proposing solutions and recommendations to limit these effects.

## METHODS

To study the influence of the parameters of the total valve, this study uses a compressed air brake system diagram as shown in fig. 1. This diagram is the most common and basic type in the compressed air brake system. From this diagram, when developed into other systems, only need to add valves behind the relay valve. Therefore, the system like the diagram in fig. 1 can partially represent different compressed air brake systems on large trucks.

When the driver operates the dual brake valve through the pedal, compressed air will go from the tank to the dual brake valve and then to the two front brake chambers along the orange line for the front axle and from the tank to the dual brake valve and then through the relay valve to the rear brake chambers along the blue line for the rear axle. The diagram of the dual brake valve and relay valve is presented in fig. 2. The entire system is modeled as shown in fig. 3. The simulation method has been presented in a previous paper at this conference «Developing A Simulation Model Of The Air Actuation System For Pneumatic

Brakes In Heavy-Duty Trucks». The throttles within the valves will have varying cross-sections depending on the position of the pistons.

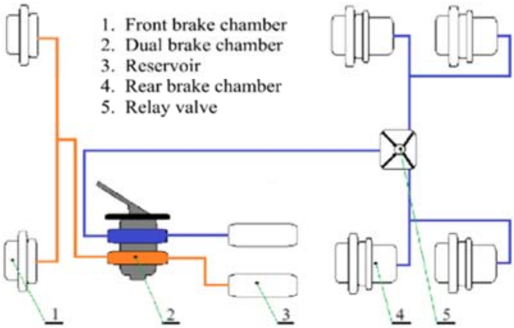


Figure 1 – Diagram of the compressed air brake system used in the study

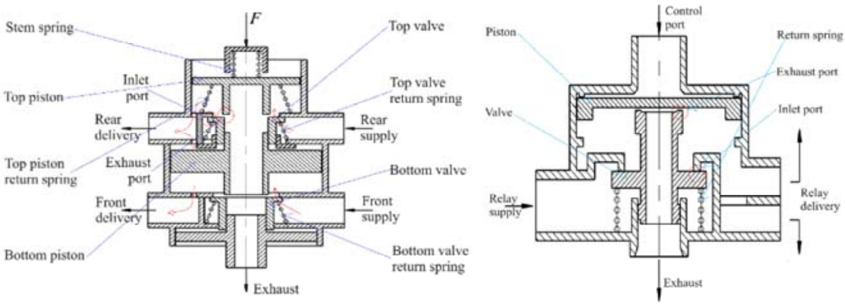


Figure 2 – Diagram of Dual brake valve and relay valve

SURVEY SCENARIOS

Previous studies have shown that the two factors that most affect the delay time of the total valve are the flow rate into and out of the dual brake valve and its volume, and they often simulate the dual brake valve with a flow control valve combined with a volume. Therefore, in this study, we will investigate the influence of parameters that cause changes in the two factors of flow rate and volume placed in a 3-axle brake system as shown in fig. 3. In this brake system, the compressed air pipes from the dual brake valve to the front and rear axles has a diameter of 7 mm, a length to the front axle of 3 m and a length to the rear axle of 15 m, the rest of compressed air pipes from the relay valve to the brake chamber and from the reservoir to the valves have a diameter of 10 mm and a length of 1m. Specifically in this paper, we will study the influence of 2 factors: the distance between the piston and the valve, and the diameter of the lower piston.

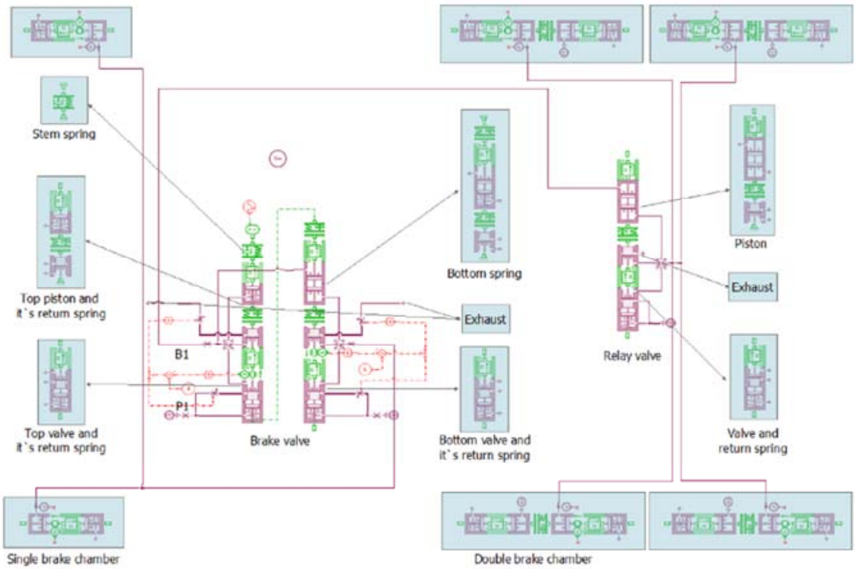


Figure 3 – Brake system diagram constructed in Simcenter

Our survey scenario is as follows: with a distance between the piston and the valve of 1 mm, we will change the diameter of the lower piston with values of 60 mm, 80 mm, 100 mm, and 120 mm. These changes can alter the volume of air in the dual brake valve, thereby slowing down the pressure increase process in the system. Similarly, we will keep the piston diameter at 100 mm and change the distance between the piston and the valve with values of 0,5 mm, 1 mm, 1,5 mm, 2 mm. These changes in distance will increase the delay time and affect the flow rate in the exhaust process. In this study, we will investigate both scenarios with and without relay valves.

RESULTS AND DISCUSSION

The results of fig. 4 and 5 show that changing the diameter of the lower piston can alter the delay when increasing the front axle pressure by about 0,15 s, equivalent to about 25 % of the delay time, and 0,1 s, equivalent to about 20 % of the delay time when decreasing the pressure in the system without a relay valve. The slow response on the rear axle will affect the increase in front axle pressure due to the special structure of the brake system using the rear axle pressure to create balance on the front axle. However, for systems with a relay valve, this influence is significantly reduced because the amount of air passing through the brake system is greatly reduced.

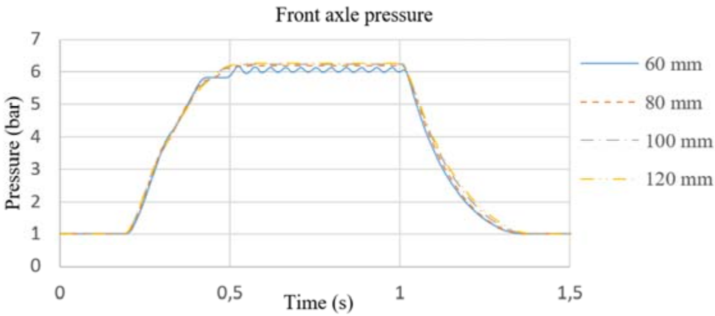


Figure 4 – Influence of piston diameter on systems with relay valve

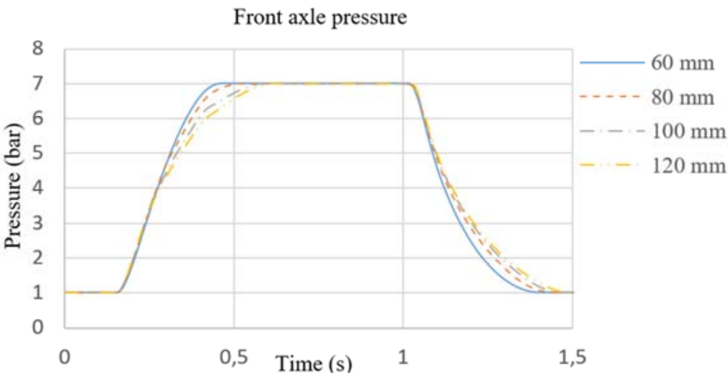


Figure 5 – Influence of piston diameter on systems without relay valve

The results in fig. 6 and 7 show the influence of changing the distance between the piston and the valve, especially during the exhaust process. Increasing this distance increases the delay when increasing the pressure by a few tens of ms for each additional 0,5 mm (about 50 ms when increasing this distance from 0,5 to 2 mm), but greatly reduces the pressure release time. However, when the distance between the piston and the valve reaches 1 mm, the efficiency of air exhaust decreases significantly: increasing from 0,5 mm to 1 mm reduces 0,3 s, but increasing from 1mm to 1,5 mm only increases by a few ms. Therefore, it can be seen that a distance of 1 mm is the optimal distance for both the pressure increase and decrease processes.

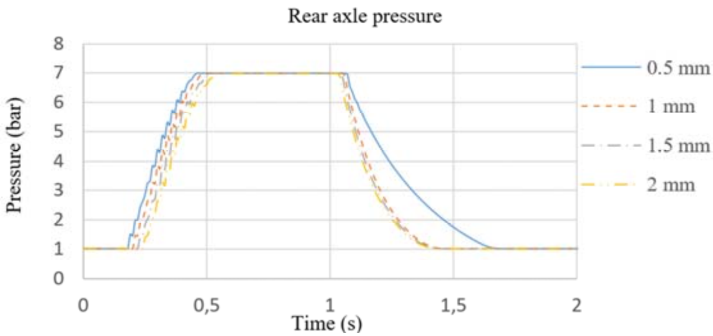

Figure 6 – Influence of piston-to-valve distance on systems with relay valve

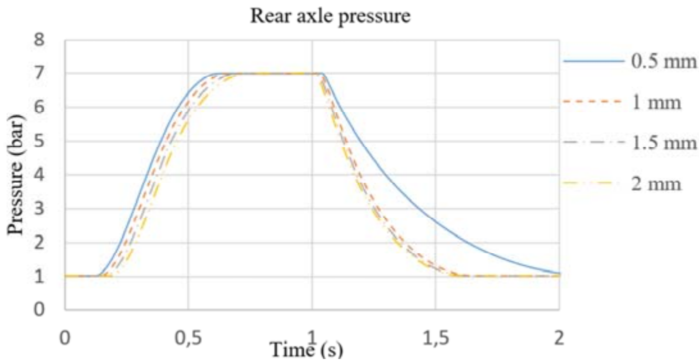

Figure 7. Influence of piston-to-valve distance on systems without relay valve

CONCLUSION

Through the results of the study, it can be seen that the brake system structure can significantly affect the pressure increase and decrease operations of the system. The piston diameter will have a greater impact on systems that do not use relay valves, with an impact of up to 25 % in the pressure increase process and 20 % in the pressure decrease process. While the impact is negligible in systems with relay valves. The distance between the piston and the valve is also a factor affecting the system in both cases with and without relay valves. Decreasing this distance can reduce the response time as the piston quickly contacts the valve. However, it also reduces the flow area during air exhaust. The study shows that a distance of about 1mm is optimal for both the pressure increase and decrease processes.

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