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The Application Status of Unit Brakes on Metro Vehicles in China

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Abstract: *With the increasing speed of urbanization in China, the demand of urban rail transit construction is growing. Metro vehicle as the mainstay of urban rail transit has been in rapid development. The increasing speed of the vehicle has put forward higher requirements on the braking technology of metro vehicles. Firstly, the main braking methods and their application in metro vehicles are introduced. Secondly, from the two aspects of tread brake and disc brake, combined with typical unit brakes, the characteristics are analyzed. Finally, the problems which existing in the braking technology of the metro vehicle in China, such as too large tread wear, frequent slide failures, and poor interchangeability of the brake, are analyzed and some suggestions are put forward.*

Keyword*- rail transit; unit brakes; tread brake; disc brake*

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I. Introduction

With the acceleration of urbanization process in China, the metro vehicle as the mainstay of reduce the pressure on urban traffic has been in rapid development, its highest speed from the initial 30 km/h, up to 60 km/h and 80 km/h, until the 100 km/h and 120 km/h. The increasing speed of the vehicle has put forward higher requirements on the braking technology of metro vehicles.

The subway is a form of railway transportation, but unlike the railway locomotive, the main operating range of the subway is the city, so it has the following main features: 1) shorter distance between subway stations leads to frequent braking and start-up; 2) in order to improve the speed and efficiency of the vehicle, the braking distance caused by the acceleration and the braking speed reduction is shorter; 3) high positioning parking accuracy due to the shielding door system installed in the station[1]..

Therefore, the subway vehicle must rely on the braking system to adjust its running speed in high speed, so as to ensure that the vehicle can stop at the predetermined location in time and accurately. The brake system is an important device to ensure the safe and normal operation of subway vehicles.

II. Main braking mode

According to the different modes of vehicle kinetic energy transfer, braking mode can be divided into dynamic braking and air braking. Dynamic braking, in which a vehicle transforms its kinetic energy into electric energy through a generator and then moves out of the vehicle. The dynamic braking mode of the urban rail vehicle is mainly based on resistance braking and regenerative braking. The air braking, also known as mechanical braking or friction braking, means that the vehicle's kinetic energy is converted into heat by friction of the friction pair and then dissipated into the atmosphere. The air braking forms used for urban rail vehicles usually include three kinds of brake, disc brake and magnetic rail brake[2].

2.1Tread brake

Tread brake is one of the most commonly used braking methods. When braking, the air pressure enters the brake cylinder through the brake pipe, and pushes the piston in the brake cylinder to make the piston rod generate thrust. After a series of rod transmission, the brake shoe is tightly attached to the wheel tread, as shown in Fig. 1. The friction resistance is generated by the relative sliding between the brake shoe and the wheel tread, and the brake of the vehicle is realized. The tread brake needs small space, light weight and low cost, but it is greatly influenced by braking power and high wear. It is suitable for low and medium and low speed metro vehicles. Most of the metro vehicles, such as Shanghai Metro Line 1 and line 2, use tread braking.

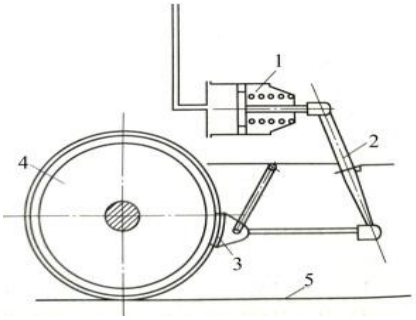

Fig1. Tread braking diagram

1- brake cylinder 2- foundation brake rigging 3- brake shoe 4- wheel 5- track

2.2 Disc brake

Disc brake, by installing the brake disc on the side of the axle or the spoke side of the wheel, push the clamps under the air pressure to tighten the brake disc, transform the kinetic energy of the vehicle into heat energy and dissipate it into the air, so as to realize the braking of the vehicle. According to the different installation methods, it can be divided into axial disk and wheel disk, as shown in Fig. 2. Disc brake does not directly effect on the wheel, can effectively prolong the service life, high brake efficiency, but easy to reduce adhesion coefficient between wheels and rail. It is not easy to make the wheel tread lightly wear self-trimming through friction [3]. The new metro vehicles such as Guangzhou Metro Line 3, 4, 5 and Shanghai Metro Line 11 adopt disc brake.

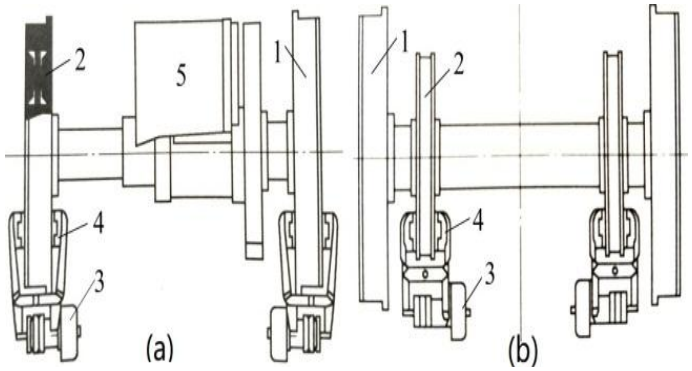

Fig2. Disc braking diagram

(a) wheel disk (b) axial disc

1- wheel pair 2- brake disc 3- brake cylinder 4- brake pad 5- traction motor

2.3 Magnetic rail brake

The magnetic rail brake puts the electromagnet and wear plate together under the bogie of the vehicle. During braking, by putting the electromagnet down, and making use of the attraction between the rail and the rail, the friction plate between the plate and the rail will cause friction, so that the vehicle's kinetic energy can be converted to heat energy, and the braking of the vehicle can be realized, as shown in Fig. 3. The magnetic rail brake will not damage the wheel tread, but this brake mode has great wear on rail, and the braking force is not controllable. Therefore, it is regarded as a supplementary braking method for emergency braking. The Beijing Metro Airport Line, Changchun light rail line 3, line 4 and other high-speed rail vehicles use magnetic rail brake.

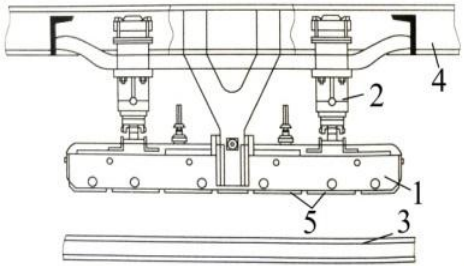

Fig3. Magnetic track braking diagram

1-electromagnet 2-wind cylinder 3-rail 4-bogie 5-wear plate

III. Foundation brake rigging

During braking, regenerative braking, resistance braking and air braking are the first, second and third priority brakes. The electric brake system is preferentially selected under the common brake. Air brake system is a basic guarantee for safe and reliable operation of metro vehicles. It is usually composed of gas supply system, antiskid, foundation brake rigging and brake control unit. The foundation brake rigging is the last guarantee for safe and reliable braking of metro vehicles. According to the different production modes of the braking force, the foundation brake rigging can be divided into tread brake and disc brake. In addition, the parking brake device is installed in some brake devices according to the needs of the vehicle anti running measures[4]..

3.1Tread brake unit

3.1.1 Wedge type

The Chengdu Metro Line 2 adopts the XFD-1H type tread brake unit and the XFD-2HS type tread brake unit with the spring parking device. The XFD-1H type tread brake unit is composed of the brake shoe holder and the cylinder block, as shown in fig. 4.

The XFD type tread brake unit is a wedge type tread brake unit, which changes the braking ratio by changing the angle of the wedge.The unit brake has the characteristics of light weight, small volume, easy adjustment of braking ratio and high transmission efficiency.The XFD-2 type tread brake unit is based on the XFD-1 type. The parking brake is added to the upper part of the brake cylinder, as shown in Figure 5.

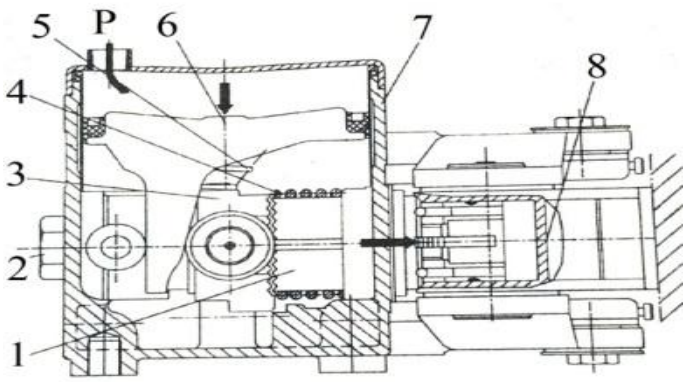

Fig4. XFD-1H type tread brake unit

1-brake slack adjuster 2-adjust rear cover 3- bearing bracket4-recovery spring
5-piston recovery spring 6-piston7-brake cylinder 8- brake shoe holder

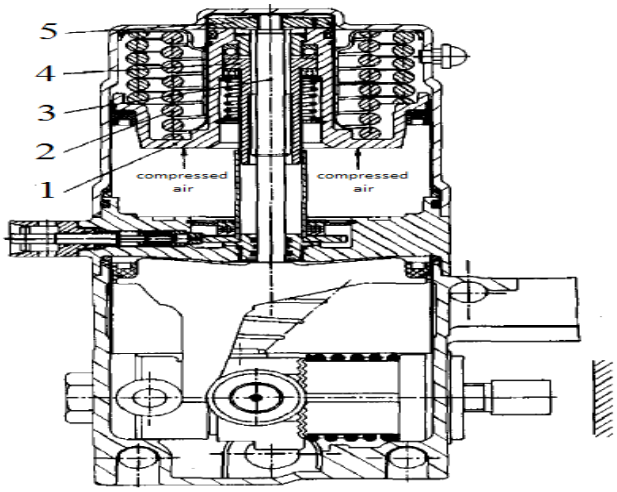

Fig5. XFD-2HS type tread brake unit

1-spring piston 2-main spring 3-adjustment screw 4-adjustment nut 5-small adjustment piston

3.1.2 Lever type

The Shanghai Metro Line 1 adopts the PC7Y type tread brake unit and the PC7YF type tread brake unit with the spring parking device. The PC7Y type tread brake unit consists of the brake cylinder body, the drive lever, the brake slack adjuster, the brake shoe and so on, as shown in Fig. 6.

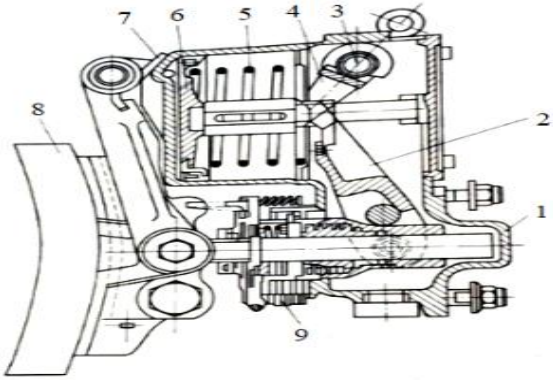

Fig6. PC7Y type tread brake unit

1-brake cylinder block 2-drive lever 3-pivot 4-hand brake lever 5-release spring
6-piston 7-torsion spring 8-brake shoe 9-brake slack adjuster

The PC7Y type tread brake unit is a typical lever type tread brake unit. When braking, the working principle of the PC7Y tread brake unit is to enter the brake cylinder by air pressure, push the piston forward, and the piston lever drives the brake lever to rotate the pin shaft. The other end of the brake lever drives the brake slack adjuster to move in the direction of the wheel, pushing the brake shoe holder and brake shoe so that the brake shoe is attached to the wheel tread and the brake is realized [5].This unit brake has the advantages of flexible operation, rapid reaction and compact structure. After replacing the brake shoe, it usually does not have to adjust the stroke again, and it can be used for the next braking.However, the slack adjuster is a one-way structure with more springs, resulting in increased resistance, thus increasing the loss of output force.

The PC7YF type tread brake unit with the spring parking device is shown in Fig. 7.

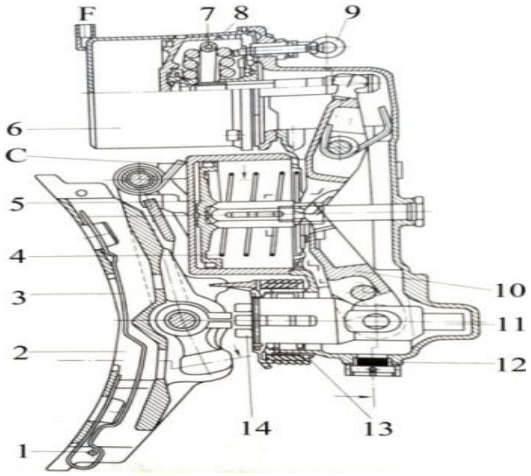

Fig7. PC7YF type tread brake unit

1-opening pin 2-brake shoe 3-lock spring 4-relieve spring 5-brake cylinder piston 6-brake cylinder
7-spring of spring parking device 8-piston spring parking device 9-emergency relief pull ring
10-drive lever 11-lever of brake slack adjuster12-filter 13-leather cavity 14-adjusting nut

3.2 Disc brake unit

Disc brake unit can be divided into two parts : brake disc and the brake clamp. The friction pair is composed of the brake clamp on the brake disc and the brake disc in different installation forms. The kinetic energy of the vehicle is converted into thermal energy by the braking force produced by the friction between the brake clamp and the brake disc, so that the vehicle stops forward.

3.2.1Brake disc

According to the different installation method, the brake disc can be divided into two types: wheel mounted brake disc and axle mounted brake disc. According to the different configuration of the friction surface, the brake disc can be divided into single friction surface and double friction surface. According to the different structure of the brake, the brake disc can be divided into the integral-type and the symmetrical half-type. According to the different materials, the brake disc can also be divided into cast iron type, cast steel type, forged steel type etc.

The Guangzhou Metro Line 3 adopts the WMD 640 wheel mounted brake disc, as shown in Fig. 8.

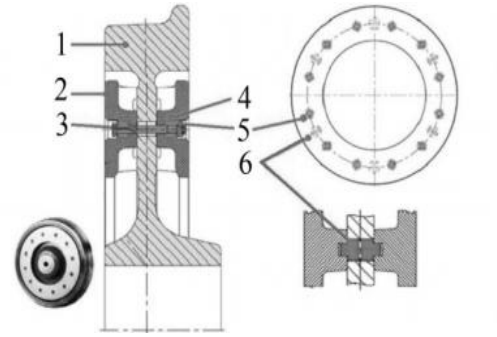

Fig8. wheel mounted brake disc

1-wheel 2-friction disc 3-bolt 4-sleeve 5-locking nut 6-positioning pin

The Guangzhou Metro Line 4 and 5 adopted the AMD 530 type axle mounted brake disc, as shown in Fig. 9.

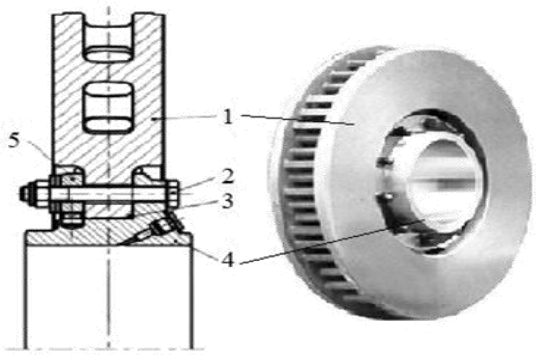

Fig9. axel mounted brake disc

1-friction disc 2-connection bolt 3-positioning ring 4-disc hub 5-ring

The wheel mounted brake disc is easily installed on the axle usually brake by the tread brake unit, which can be a continuous or assembled ring. Wheel mounted brake disc is suitable for vehicles equipped with small diameter wheels, but also for vehicles with large diameter wheels with common bogies. The installation space of wheel load brake disc is small, which can reduce the load on the wheel, but the single side is heated, which can easily deform the friction surface, and the energy dissipation is low.

While the axle mounted brake disc is installed on the inside of the axle, which can be heated symmetrically from two aspects. The air flow passes through the radialpassage formed by the heat dissipation bar between the friction discs, and then carries away the heat. The axle mounted brake disc needs larger installation space and faster heat dissipation, but the requirements for the thermal cracking resistance are higher, and the heat and wear on both sides are larger [6].

3.2.2Brake clamp

According to the different suspension ways, the brake clamps can sometimes be divided into one point hoisting, two point hoisting and three hoisting. They depend on the structural size and layout space of the bogie.

The Guangzhou Metro Line 3 adopts the RZS type brake clamp and the wheel brake disc, as shown in Fig. 10.

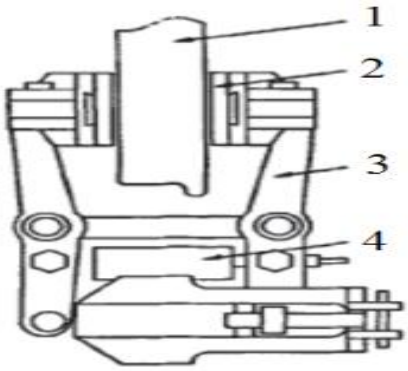

Fig10. wheel mounted brake clamp

1-brake disc and wheel 2-brake pad 3-brake rod 4-hydraulic cylinder
In Guangzhou Metro Line 4 and 5 adopts the WZK type brake clamp and the axle mounted brake disc, as shown in Fig. 11.

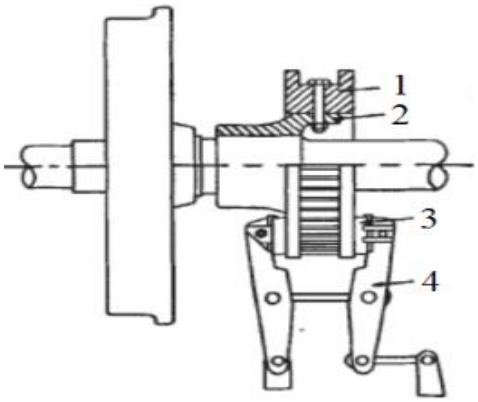

Fig11. axle mounted brake clamp

1-brake disc 2-hub 3-brake pad 4-drive rod

The brake clamp unit is composed of the brake cylinder, the clamp device and the brake pad, and the brake cylinder includes the brake shoe clearance regulator. The brake clamps on the Guangzhou metro are mounted on the outer end of the end beam by using hangers of two brake shoe holders as a suspension point and a three point hoisting suspension with a fulcrum plate as a third suspension point.

The brake clamp unit is divided into the brake clamp unit and the brake clamp unit with spring parking device. Each axle is equipped with a brake clamp unit and a brake clamp unit with a spring parking device. The structural difference between them is only whether there is a spring parking brake.

IV. The existing problems and solutions for the braking technology of the metro vehicles in China

At present, there are several problems in the application of the unit brake in the metro vehicles in China.

First, the wheel tread is badly damaged. The braking process of metro vehicle, the brake unit will be converted into heat energy of the vehicle movement, if the wheel and brake or brake disc and brake pad input energy is greater than the braking heat load capacity, it will cause damage to components, thus affecting the driving safety of Metro vehicle. With the operation of the metro vehicle maximum speed to 120km/h after the tread brake from traditional mechanical wear and thermal stress influence the two wheel tread, the former increased the wheel tread wear caused by the loss of life, which make the wheels in the braking process of absorption of more than 90% high temperature heat caused by tread peeling or hot crack. Therefore, the choice of unit brake for metro vehicle must be cautious. The tread brake unit is suitable for medium and low speed metro vehicles. When the vehicle speed exceeds 100km/h, disc brake unit should be adopted. In addition, combined braking mode can be used to share brake tasks effectively with the combination of dynamic brake, non-stick brake and mechanical brake. This can not only reduce the loss, the maintenance and operation costs, but also improve the braking performance and driving safety of the vehicle. The unit brake can also be allocated according to the configuration and deceleration speed of metro vehicles. The motor car can adopt the tread braking unit, the trailer adopts disc brake unit or magnetic rail brake, which can improve the braking efficiency

and guarantee the braking distance by combining the characteristics of different braking modes. The combined braking mode should be the researchdirection of the braking mode of urban rail transit vehicles in the future.

Second, the sliding failure is frequent. Vehicle sliding refers to the relative slip that occurs when the traction force is less than the maximum static friction force between the rails and the wheel speed is lower than the speed of the vehicle. If it cannot be released in time, the wheel tread will become soft, melting and so on, causing the wheel accident; At the same time, it will reduce the braking force and prolong the braking distance, causing serious safety hazard [7]. As the speed of the vehicle increases, the maximum adhesion coefficient between the wheels decreases. The difference of velocity directly affects the transverse force and longitudinal force, contact point and contact area between the wheel and rail. As a result, the adhesive can be used as auxiliary braking, or to redistribute the braking force to make full use of adhesion, or according to the abrasion rail considering tread shape and other methods to reduce the possibility of sliding of metro vehicle.

Third, the interchangeability of unit brakes is poor. The selection of the unit brakes is related to the vehicle type, speed and bogie of the metro vehicle. The metro vehicles in China can be divided into A, B and C type according to the different lines and passenger transport scale. The design parameters of different types of vehicles lead to the different selection of the corresponding bogies, and then affect the selection of the unit brakes. In addition, due to the fact that many production units in China have devoted themselves to the localization of the unit brakes in the past ten years, there are various types of unit brakes used in the current Chinese metro vehicles. Its structure and technical parameters are different, and the same locomotive depot also has multiple unit brakes [8]. With the increasing demand for metro vehicles, this contradiction is more prominent. The unit brake is easy to wear and has a large amount ofmaintenance, and its low interchangeability causes inconvenience of installation, disassembly and maintenance. Therefore, China should set up unified technical standard for metro vehicle unit brakes, increase its interchangeability, so as to reduce maintenance costs, install and disassemble easily, and improve the safety of metro vehicles.

V. Conclusion

Urban rail transit in China is in a period of rapid development. With the improvement of the speed of metro vehicles, the requirements for braking technology have become more stringent. Based on the analysis of the application status of the braking technologyof Chinese metro vehicles, this paper starts with air braking, compares the characteristics of some typical unit brakes, such as XFD type, PC7Y type, and RZS type.At last, the existing problems in the braking technology of metro cars in China are analyzed, and it also puts forward some suggestions on the use of composite braking and the formulation of unified technical standards, hoping to contribute to the research and development of the unit brakes.

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