Application Research on CHR2 Type EMU Braking System

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ABSTRACT

CRH2 high-speed EMU is the power source of the traction drive system. The whole system is evenly distributed among the four basic units of the whole EMU, forming a complete combination of power sources. Large traction power, start smooth, fast and efficient, effectively inhibit the idle and taxi protection in place and other characteristics, and with a number of system chain control, to achieve smooth operation, multi-level speed and accurate parking.

KEYWORDS: traction system; traction motor; electrical control; pantograph

Introduction

Since we are entering the new century, China's railway truck technology and truck brake technology has developed rapidly. At present, I am trapped in more than 700,000 rail trucks, rail truck technology is moving towards a fast and heavy load direction. In recent years, China's railway brake technology concentrate at truck quickly and overload aspects, and carried out a lot of fruitful work. This paper will have a brief introduction of each of this.

1. Composition of a traction drive system

CRH2 high-speed EMU consists of four moving group, of which 2, 3, 6, 7 car are motor car, 1, 4, 5, 8 car is a trailer, which equipped with two traction system. The first two cars are equipped with the driver room and can travel in two directions. Under normal circumstances, both traction systems are working, when there is a system failure, it can cut off the source of failure automatically and to continue driving.

CRH2 high-speed EMU using dynamic dispersion AC drive mode, mainly pantograph, traction transformer, pulse rectifier, intermediate links, traction converter, traction motor, gear drive and other components.

2. CRH2 brake mode

At present, there are two kinds of brake commonly used in the train: adhesive brake and non-adhesive brake. The braking force generated by the friction between the wheel and the rail is called adhesive brake, or friction brake. When the brake is applied, the braking force is limited by the adhesion between the wheel and the rail, and the maximum braking force does not exceed the adhesive force. Adhesive brake is the main braking method. Brake, disc brake, hydraulic brake, resistance brake, rotary vortex brake and regenerative braking and other braking methods are adhesion brake. Braking force that not through the wheel and the friction between the rails is produced by the braking method is known as non-adhesive brake. Track electromagnetic brake and track eddy current brake are all non-adhesive brake. The braking force is not limited by the adhesion between the wheel and rail. Non-adhesive brakes are currently used primarily as an auxiliary braking method for high-speed passenger trains with insufficient adhesion braking force.

2.1. Adhesive Brakes

2.1.1 Brake of Brake Shoes

Brake of brake shoes is a break method that through the brake shoe pressing wheel on the tread to produce a strong friction, so that most of the train kinetic energy converts into the thermal braking method. Brake of brake shoes is currently the most widely used in domestic train, which has the advantage of simple manufacturing process, low cost, large braking force, easy to use, free from weather conditions. The brake can pass clean the tread to improve the
adhesion of the wheel to the rail. But the brake shoe brake has many shortcomings: the friction coefficient with the speed of rapid decline; cannot make full use of the adhesion coefficient between the wheel and rail to reduce the braking efficiency when high speed, low speed and prone to impulse and scratches wheel tread; So that when the running noise of motorcycle significantly increased; brake shoes in the friction on the wheel will produce a lot of heat, wear fast, lead to large consumption of resources from time to time. Based on the above characteristics, most of the domestic freight trains use brakes of brake shoes method.

2.1.2 Disc Brake

Disc brake is a brake method by clamping the brake disc, so that friction between the brake pads and brake discs play a role in braking. Disc brake release brake energy fast, brake pads have a very stable friction factor and the noise is small. Based on these factors, it is necessary to use disc brakes on high-speed passenger trains. Now the new bus is basically replace the traditional brake shoes brake by disc brake. However, the disc brake has some drawbacks: the total mass is increased by the installation of the brake disc; the adhesion of the wheel to the rail is deteriorated by the lack of cleaning the wheel tread.

2.1.3 Power Brake

Power brake is the way of breaking after the appropriate control and conversion of train traction power device. Power brake composed of two parts which are regenerative braking and resistance brake. Regenerative brake convert kinetic energy into electricity and feedback to the grid in the brake when the traction motor performing break action, it can only be used in electric locomotives and electric vehicles. Resistive braking is a regenerative braking method which transpired by the heat that generated by the power added to the braking resistor. The use of regenerative braking is a priority when brake, it will only converted to resistance braking automatically when the catenary fail to absorb the regenerative braking energy. Power brake mode does not need to consume energy, it is environmental protection, energy saving and braking stability as the auxiliary braking method is widely used in friction brake-based train. The study shows that the use of dynamic braking device make the brake shoe wear speed reduced by 50%, wheel cramping wear speed reduced by 30%.

2.1.4 Hydraulic Brake

Oil is supplied to the hydraulic brake when brake, the turbine is fixed, the pump wheel driven by inertial force and with the motor rotation, the working oil in the rotor was accelerated in the stator and was slowed down, and finally form a circulation in the pump wheel and turbine, resulting in braking torque, and converted into work oil to dissipate the heat. It is mainly used in the locomotive on the hydraulic drive.

2.1.5 Rotating Vortex Brake

Rotating vortex brake is the traction motor shaft or axle that is equipped with the electromagnetic induction body of the metal vortex disk. When brake, the disk in the electromagnetic field formed by the magnetic field rotation and the disk surface induced by eddy current, so that increase the heat of vortex plate and the train kinetic energy will be converted into heat.

2.2. Non-Adhesive Brake

2.2.1 Track Brake

The rail brake is energizing by attaching the electromagnets above the rails mounted on the two wheel sets of the train bogie, so that the electromagnets with the wear plate are attracted to the rails with a certain suction force and can glide. Kinetic energy is converted into heat and distributed by friction between the plates. The rail brake is a non-adhesive brake, which is a very effective way to increase the braking force and can significantly reduce the braking distance. The use with a rail brake shows that the braking distance can be reduced by 20% to 25%. At present it is mainly used as an auxiliary brake for high-speed train emergency braking.

2.2.2 Track vortex brake rails

Road vortex brake is the electromagnet hanging in the rail just above the rail bogie, through the relative movement between the electromagnet and the rail, eddy current is inducted in the rails, produce resistance, and make the rail heat, so the kinetic energy of the train converted to heat. The orbital eddy current brake has the following advantages: the magnet does not come into contact with the rail, does not produce friction, the noise is small; the braking force is not restricted by the sticking condition; the braking force is big and stable, can reduce the braking distance, comfort. Disadvantages: high cost, large power consumption; moving time will make the rail temperature rise, affecting stability.
3. Improvement of the Brake Device

At present, friction brake is the commonly used brake method for domestic and international train. It mainly consists of brake shoes and brake disc brake. And other braking methods such as resistance braking, regenerative braking, orbital electromagnetic brake is still only as auxiliary braking, so the focus of the study is the performance improvement of brake shoe brake and disc brake.

3.1. Brake Shoe Brake Mode

The braking capacity of the brake shoe is mainly determined by the friction between the brake shoe and the wheel. In order to improve the brake shoe brake performance, the commonly used method is to change the friction between the brake shoe and the adhesion through the use of new materials. At present, the main research is mainly in the phosphorus gate, high phosphorus brake shoe, synthetic brake shoe and rubber brake.

3.1.1 The High-Phosphorus Brake Shoes

Since 1920s, the phosphorus cast iron of brake shoes used in China's quasi-rail trains is in range 0.7% - 1.0%. Practice has proved that the use of phosphorus gate has more shortcomings, especially with poor wear resistance and short service life. The high-phosphorus brake shoe in the wear resistance, high temperature, friction coefficient stability and efficiency are better than the phosphorus gate, wear resistance for the phosphorus gate is 2.5 to 3.0 times better [3]. However, due to material brittle, low strength in high temperature, and poor thermal conductivity, it is easy to produce cracks in the brake.

3.1.2 Synthetic Brake Shoes

In view of the shortcomings of high and medium-phosphorus cast iron brakes, foreign countries have already carried out research on high friction coefficient synthetic brake shoes. Some developed countries in Europe and America such as the United States have adopted synthetic brake shoes instead of cast iron brakes. Braking force of friction coefficient synthetic brake shoe is high, less wear, and has long service life. Besides, the noise is small when brake, no spark dust, and low manufacturing costs. The main features of synthetic brake shoes are as follows:

(1) Has a smooth coefficient of friction and can make full use of adhesion to improve the braking force, shorten the braking distance.
(2) Wear, long life, less wear on the wheel. Synthetic brake shoe life is generally 3 to 10 times longer than cast iron gates. This can greatly reduce the replacement of the brake shoe workload, reduce railway operating costs.
(3) Light weight. Synthetic brake shoe weight is only 1/4 - 1/3 of cast iron brake shoe, it is easy to replace the brake shoe, and reduce labor intensity.
(4) No spark when braking, to avoid fire accidents, favorable and safe operation.

Synthetic brake shoes also have their shortcomings:

(1) The middle is faster wear than both ends and easy to produce rupture, drop block in the practical application.
(2) The use of high-wear synthetic brakes than cast iron brake shoes is more prone to dynamic relaxation.

3.1.3 Rubber Rock Wool Brakes

Rubber masonry brake shoe wear resistance is higher than the synthetic brake shoe and the brake shoe, wear resistance 2 times higher than the synthetic brake shoe, and 5 times higher than the phosphorus brake shoe. It has low manufacturing costs, wear resistance, long service life, easy to replace and so on.

3.1.4 Cermet Brake Shoe

Compared with the cast iron brake shoe, the metal ceramic brake shoe has a high friction coefficient, good relationship between the friction factor and the brake force, and long service life. Although the cermet has successfully applied to the structure of a highly efficient disc brake for a long time, but it is expensive due to its complicated manufacturing. High hardness and high difficulty to run the material is the reason that caused metal ceramic brakes cannot be evenly attached to the wheel, so the installation of new brake shoes will inevitably appear when the high contact stress area. The thermal conductivity of the cermet is worse than that of the gray cast iron, so the braking energy of the transmission wheel is 15% larger than that of the gray cast iron brake shoe.
Use a small metal sheet or even a carbon fiber sheet. Germany company Knoor Br em. Se developed a carbon fiber composite disc brake device, which maintain good quality even the operation speed is up to 254 km / h. France developed ‘Sepcar b SAW’ carbon-carbon composite disc brake, can absorb the brake power up to 90 MJ, and has been in the TGV-A and TGV-PSE train trial. Japan’s Shinkansen operating speed of 270 km / h electric car brake system also uses carbon fiber reinforced materials.

3.2. Disc Brake Mode

The improvement of the disc brake mode is mainly achieved by changing the performance of the brake disc brake. At present, the research is more on the metal brake pads, the ceramic brake discs and the carbon fiber brake pads. Foreign operated high-speed train disc brakes are still using forged steel and iron-copper powder metallurgy. In order to further improve the energy of the brake disc and reduce the weight, the research focused on the high energy brake disc and the energy brake disc. The results show that the carbon fiber composite material has low density and high braking energy, but there is still a lot of work to be done in terms of friction coefficient stability and manufacturing cost. Ceramic materials have excellent high temperature friction and wear properties, but still did not solve the brittle nature of large parts. Material surface strengthening technology can greatly improve the friction and wear properties of the surface of the brake disc. The problem to be solved is the reliability of the combination between the coating and the substrate. Aluminum-based reinforced composites can reduce the weight more than 50%, but use relatively low temperature, limiting its use in a larger range to promote the use of f 6]. Foreign carbon fiber brake pads applied research significantly accelerated, and moving brake has begun to use semi-metallic brake from the main turn.

4. Traction drive system with the main equipment

4.1. Roof Equipment Configuration

The main circuit between the vehicles is connected with high-voltage cable and high-voltage cable connector. High-voltage cable connector is divided into linear, 5-degree tilt, and T-type several. Connector connected to high-voltage cable through these high-voltage cables. Power supply equipment in the 4,6 car front roof, mainly are pantograph and grounding protection switch.

4.2. Vehicle Equipment Configuration

EMU traction drive system chassis equipment consists of high-voltage electrical equipment, traction transformer, traction converter, traction motor and other equipment components. Total is two traction transformers, four traction converter, 16 traction motor. Traction transformer is located at the bottom of the 2,6, traction converter and traction motor are arranged in the 2,3,6,7 bottom of the car.

5. EMU traction drive system main equipment

5.1. Pantograph

EMU pantograph is the main equipment from the catenary to obtain electricity, but also EMU main circuit of one of the high-voltage equipment. The pantograph is compressed by air when the train is running. The pantograph is brought into contact with the contact line by the pantograph slide and the compressed air is discharged from the airbag.

5.2. Ground Protection Switch

The pantograph and grounding protection switch is mounted on the same vehicle. Ground protection switch is grounding the UHV power supply to prevent the application of special high voltage on the body. The main circuit current abnormalities or catenary voltage abnormalities and other accidents happened, in order to protect the EMU from damage, the mandatory operation of the protective grounding switch, the grounding grid, the ground current flow to the catenary, substation power supply system isolation switch trip, and the contact network in a non-voltage state. In addition, the maintenance personnel use the high-pressure equipment to check the maintenance of the equipment to ensure the safety of personnel, grounding protection switch and high-voltage equipment box to take linkage locking measures, the pantograph pre-ground, even if the pantons rise, but also to prevent electric shock.

5.3. High Pressure Equipment Box

High-voltage equipment box installed in the 2,6-car low-shelf, built-in: vacuum circuit breakers, arrester, under the cable connector box and other major devices. The components installed in the high-pressure equipment box can be
handled separately. High voltage equipment box is equipped with lightning arrester. The side is equipped with vacuum circuit breakers, under the floor cable box and indicator light. To prevent the operation of maintenance personnel get high voltage electric shock in the equipment inspection, high voltage equipment box and grounding protection switch linkage is locked.

5.4. Vacuum Circuit Breaker (VCB)

Vacuum circuit breaker configuration use to disconnect and turn on the 25KV circuit in the high-voltage equipment box, and it act as a fault state of the protection device, perform both circuit breaker and switch action. It can cut off the circuit quickly, safely, and accurately when there is failure in traction transformer traction side of the circuit. Vacuum circuit breakers and traction transformer are supporting the use of each other. Each EMU has 2 sets of vacuum circuit breakers and each vacuum circuit breaker control a traction transformer.

5.5. Traction Transformer

Traction transformer is an important part of the EMU, 25KV high voltage used to transform the traction converter and other electrical equipment for the work of the appropriate voltage. Traction transformer has a solid mechanical structure and small size, low quality, large electromagnetic wire, use of small advantages, and also has a traction winding reactance equal to ensure that the traction winding side load equal. Traction transformer of two separate traction winding, each traction winding connected to a traction converter, and the interference is small, so that the EMU can have stable operation.

5.6. Traction Converter

Traction converter consists of single-phase three-level pulse rectifier, intermediate DC circuit, three-level inverter, vacuum AC contactor, other main circuit equipment, traction control device, control power and other components. Each trolley is equipped with a traction converter and each traction converter drives four parallel traction motors.

5.7. Traction Motor

The traction motor is the power source of the EMU. A total of 16 sets of three-phase asynchronous motor are evenly distributed in the EMU group 2, 3, 6, 7 car bottom. Each vehicle has 4 traction motor, each rated power 300KW, the maximum speed is 6120r / min, the maximum experimental speed is 7040r / min. The traction motor adopts the bogie suspension type, the mechanical ventilation cooling. The parallel gear bending shaft universal joint direction drive has the good traction performance, big power and small interference.

6. Main Performance and Characteristics of the Traction Drive System

6.1. Traction Drive System Energy Conversion and Transmission

The energy and mechanical energy conversion and transmission process is called as EMU traction operation. Regenerative braking is the process of converting mechanical energy into electrical energy. Thereby, it forms a closed energy conversion chain. Traction operation: pantograph will be connected to the AC 25KV single frequency AC power, through the relevant high-voltage electrical equipment to the traction transformer, traction transformer step-down output 1500V single-phase AC power supply to traction converter. The pulse rectifier converts the single-phase alternating current into direct current, output direct current of DC 2600DC----3000V through the middle of the DC circuit to traction inverter. Traction inverter output voltage / frequency adjustable three-phase AC power supply (voltage: 0 ---- 2300V; Frequency: 0-220HZ) drive traction motor, traction motor torque and speed up through the gearbox transmission to the wheel drive to run the train. This achieves the conversion of electrical energy to mechanical energy. In the regenerative braking, the traction inverter is controlled so that the traction motor is in the power generation state. The traction inverter is operated in the rectified state. The three-phase alternating current emitted by the traction motor is rectified to DC and the intermediate DC link is charged to make the intermediate DC link voltage rise. Pulse rectifier working in the inverter state, the middle DC circuit is reversed into single-phase alternating current, the AC contact network through the traction transformer, vacuum circuit breaker (VCB), pantograph and other high-pressure equipment, in order to achieve mechanical energy Conversion.

6.2. Main Circuit Structure Principle of Traction Drive System

EMU from the pantograph accept 25KV, 50HZ single-phase AC from the contact network, connected to the traction transformer primary winding through the vacuum circuit breaker (VCB). Traction transformer traction winding output AC1500V, 50HZ power input into pulse rectifier. Pulse rectifier consists of single-phase three-level
PWM converter, and AC contactor K composition. Achieve the output DC voltage 2600-3000V constant voltage control by using non-contact control device, to traction transformer primary unit power factor control and fault protection. The regenerative brake traction converter passes the traction transformer to feedback the power.

Traction inverter using VF control mode, the rectifier input DC voltage to support the capacitor, according to the contactless control device control signal, the output frequency conversion of the three-phase alternating current control the four parallel traction motor. Regenerative brake traction motor issued three-phase AC power, to support the capacitor output DC voltage after rectification.

6.3. Main Features of Traction Drive System

CRH2 EMU has significant characteristics in traction transformers, traction converters, traction motors, and control strategies.

(1): Traction transformer shell structure, the car under the hanging installation, oil circulation forced cooling the air. There are two independent windings in traction winding to ensure high reactivity and weak coupling of the traction windings.

(2): Main circuit of traction converter use two switching power devices in series with the midpoint with a clamp diode program. Power switching devices using IPM intelligent power module or IG BT module, which IPM is the IGBT power device circuit, the protection circuit boarded in a module of the new electronic devices, IGBT is integrated, to make it more intelligent. With the small drive power, the absorption circuit is simple, the device itself has detection and protection functions, you can use multiple parallel to increase the current capacity.

(3): Single-phase three-level PWM pulse rectifier, DC bus voltage and capacity doubled. Reduce the harmonic distortion, to ensure that the converter input side of the current waveform of a certain degree of sine, thereby reducing the interference of the communication system interference.

(4): Not install second harmonic filter device in traction converter intermediate DC link, reducing the traction converter and traction transformer quality.

(5): The inverter uses a three-level topology compared with other inverters. The terminal voltage waveform contains less harmonic components. In the same cycle, the three-level inverter has 27 kinds of working state, reduce the adjacent circuit state transition caused by the voltage and current fluctuations, thereby reducing the loss, improve traction motor efficiency, and reduce torque ripple.

(6): Traction motor has a good traction performance, can achieve a wide range of smooth speed and make a larger starting torque when the locomotive start; traction motor reliability,

There is no electrical loss and mechanical loss due to commutation if compared with the DC motor, no ring fire, running reliability to further improve; resistance to vibration, snow, in dusty, humid and operate normally in harsh environments; motor overload capacity; high speed, power / mass ratio, Motor suspension; torque - speed characteristics better, can inhibit the air to improve the adhesion rate.

(7): Traction motor using vector control strategy, the control method is simple, so that the entire traction drive system has good dynamic performance and control accuracy.

7. Traction Control of CRH2 Type Emu

Traction control is the EMU traction operation process of the main control relay operation effective control, running direction control, constant speed operation control, and traction equipment control.

7.1. Main Control Relay Operation Effective Control

The main control relay determines whether the driver is operating effectively and has a main control relay in each side of the driver, which is only valid when the main control relay is closed. When one of the EMU in the driver room performs master control operation, the other side of the driver's room operation is invalid through the chain control, so that only one side of the driver room is allowed to drive.

7.2. Direction of Operation Control

The main means of EMU operation direction control is to use the driver installed in the direction of the driver room. Each directional controller (also known as the direction of the handle) in the T1 car and T4 car has one set. The direction handle has 3 positions: 'front', 'off' and 'after'. 'Front' bit, forward the relay power; 'after' bit, relay the relay power; 'off' when the two relays are not action. The direction controller controls the traction direction
(forward or backward) command condition and the traction command relay condition. Direction (forward or backward) command condition; main control relay MRC excitation, the direction of the handle in the 'front' bit, line 4 pressure, to the monitor to pass forward instructions. When the direction handle is in the 'rear' position, the line 5 is pressurized and the backward instruction is passed to the monitor.

The direction of the handle is not in the 'off' bit, but in the 'front' or 'after' bit, before the switch R or R after the power, the corresponding normally open contact closed, traction command relay R was electric. After the traction command relay R is energized, the traction command can be issued.

### 7.3. Traction Controller and Direction Controller Chain Control

Traction controller, also known as the main controller (MC), the main function is to generate traction instructions level instructions, while generating traction command conditions and constant speed operation command conditions. When the traction controller is interlocked with the direction controller and the traction direction handle is in the 'front' or 'rear' position, the traction command controller R is energized. When traction controller is operated, depending on the position of the traction controller handle, different lines are pressed to form a 10-stage traction instruction input to the monitoring central unit, and the traction instruction is transmitted to the traction converter through the network.

### 7.4. Constant Speed Operation

When there is above 2 main controller handle or more, the constant speed relay CSR is energized if the other conditions are satisfied, and the normally open contact in parallel with the fixed speed switch is closed and it will be in the self-insurance state. The traction direction handle is not in the neutral position. The brake handle is in the 'run' position. ATP Common Brake Invalid: NBR Excitation; ATC Common Brake Invalid: Fixed Speed Off Switch No Press: Fixed Speed Off SW is OFF. It can be seen that the brake is more advanced than traction, thus ensuring traffic safety.

When the above conditions are met, when the CSR moves, the normally open contact is closed, the line 23 is electrically pressurized, and the constant speed control signal is transmitted to the monitoring central unit.

### 7.5. Main Equipment Control and Management of EMU Traction System

#### 7.5.1 Pantograph Chain Control and Management

Pantograph power is only supply in the normal circumstances and the train is not linked to the case in pantograph device in the EMU 4,6 car. When a pantograph is raised, another pantograph lift command cannot be issued through the bow Lock relay (PANIR). The pantograph lifting operation is controlled by the up / down switch provided on the operator's console and on the driver's switchboard or by the information display touch screen key. EMU of the 4,6 cars are set up the bow interlock relay PANIR. When the pantons of No. 4 car rise, the car's rose arch interlock relay excitation. The sixth car's bow circuit opens through the chain circuit, so that the pantograph of the No. 4 car rises even if the pantograph on the 6 car bow operation will not raise the pantograph of No. 6 car.

#### 7.5.2 Traction Transformer Control and Management

There are 1, 2, 3 side protection and other protection in EMU traction transformer control. It provides protection and control of the corresponding protection switch action, and breaking the main circuit breaker, sends information into the terminal device.

#### 7.5.3 Chain Control and Management of Traction Converter and Main Circuit (VCB)

In addition to complete traction control, traction converter also control with the main circuit breaker VCB interface. In order to prevent the VCB closing when the traction converter current shock, primary side power contactor is not putting in the traction converter only. Power loss state from the contactor into the relay KRR, the corresponding normally closed contact closed, the other VCB can be closed when conditions are met. For VCB input state, when the traction converter failure, the traction converter fault relay power failure, or when the traction converter ground fault occurs, the ground relay power, VCB closing relay VCB-M power failure, and VCB is broken. Traction transformer 1 side access to the traction catenary only after the VCB input, VCB input status signal into the traction converter, start the ready to charge middle filter capacitor, and input the traction converter 1 side power contactor.
8. Concluding remarks

200EMU - CHR2 high-speed EMU traction drive system designed and manufactured by CSR has reasonable design concept, unique, practical, a variety of control instructions which fast and unified, and the entire system is secure and tightness with other high efficiency control chain systems. This is one of the most basic protections for the whole row of EMU to have a safe, fast and smooth operation.

References: