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## Design and Development of Experimental Platform for Anti-Skid Device of Friction Hoist

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# Design and Development of Experimental Platform for Anti-Skid Device of Friction Hoist

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**Abstract.** There is no effective special equipment to avoid or stop friction hoist sliding accidents. Study on friction property of braking mechanism for anti-skid device of friction hoist is required. Principle of designing and course of developing were given in this paper, including the principle of anti-skid device friction test, the whole structure of the platform design, mechanical transmission and wire rope brake mechanism procession, hydraulic loading system develop, control system development, experiment data acquisition system development and sensors installation. This experimental platform can be used to study the braking performance of braking mechanism for anti-skid device.

## 1. Introduction

Friction hoists at modern coal mines are running with large quantity and high speed [1, 2]. They have become computer controlled automatic heavy-duty mining machinery. Hoisting system is mainly composed of hoisting wire rope, balancing wire rope, hoisting container, derrick, wheel, shaft equipment (including cage guide, cage guide beam) and so on. Hoisting force is transmitted by the friction force between the wire rope and friction liner, so there is risk of sliding accident [3, 4].

Theoretical studies on anti-skid problems [5, 6] can be summarized as: Studies on sliding mechanism, anti-skid design, anti-skid check, sliding warning and anti-skid braking. The former three cannot totally solve and prevent hoist sliding malfunction, so that the fourth study is very important for the safety in mine production. Brake mechanism of the anti-skid device for braking wire rope should meet two conditions: First, non-damage to the wire rope and hoisting system while the device is running. Second, the friction coefficient of brake mechanism must be higher and stable.

Specifically studies on tribological properties of the brake mechanism of the anti-skid device have not been reported. So far, studies are mainly about the design of braking device, while little literature is available on detailed experimental data for the braking performance and effect [7-9]. Therefore, this paper will establish a hydraulic [10, 11] power source of the anti-skid device experimental system, the following will be from the structure of the principle, installation and experimental program to carry out research.



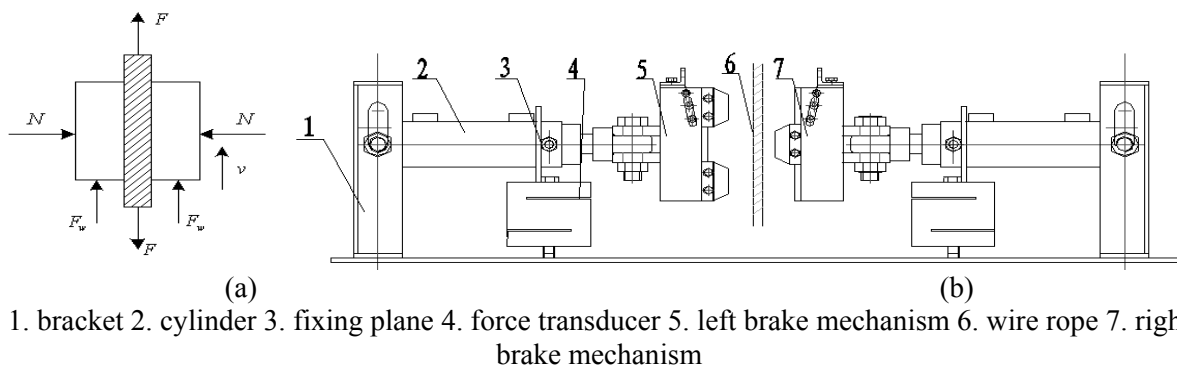
## 2. Principle of the experimental platform

Based on the actual situation, the plane testing method was used to measure the friction force. Its principle is shown in Fig. 1(a). The wire rope is clamped by two breaking blocks under the oil pressure  $N$  and it is moving in a speed of  $v$  under a force of  $F$ , therefore, the friction force of  $F_w$  is forming between the contact surface of wire rope and breaking blocks.

The normal pressure  $N$  is calculated by oil pressure which is measured by sensor as Eq. 1.

$$N = P \times \pi \times d^2 / 4 \quad (1)$$

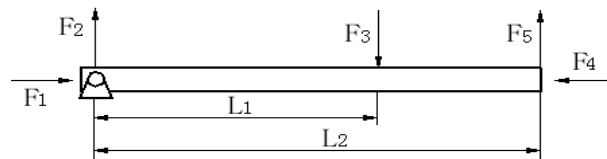
Where,  $P$  is the oil pressure of breaking cylinder,  $d$  is the diameter of breaking cylinder piston. The force transducers are settled as Fig. 1(b), which is used to measure the friction force.



**Figure 1.** Test principle diagram of friction force

The force transducer is settled under the cylinder and the simplified diagram of force analysis is shown in Fig. 2.  $L_1$  is the distance between force transducer and fix hinge,  $L_2$  is the distance between contact surface and fix hinge while the cylinder piston protrude, the initial value of force transducer is  $F_0$  and the working value is  $F_3$ . Therefore, the friction force can be calculated as following Eq. 2.

$$f = F_5 = (F_3 - F_0) \times L_1 / L_2 \quad (2)$$



**Figure 2.** Simplified diagram of friction force analysis

## 3. Whole structure of the experimental platform design

Anti-skid testing system consists of mechanical transmission and wire rope brake mechanism, hydraulic loading system, test data acquisition system and a system controller. Principle of the testing system is shown in Fig. 3 (a). The testing equipment are shown in Fig. 3 (b).

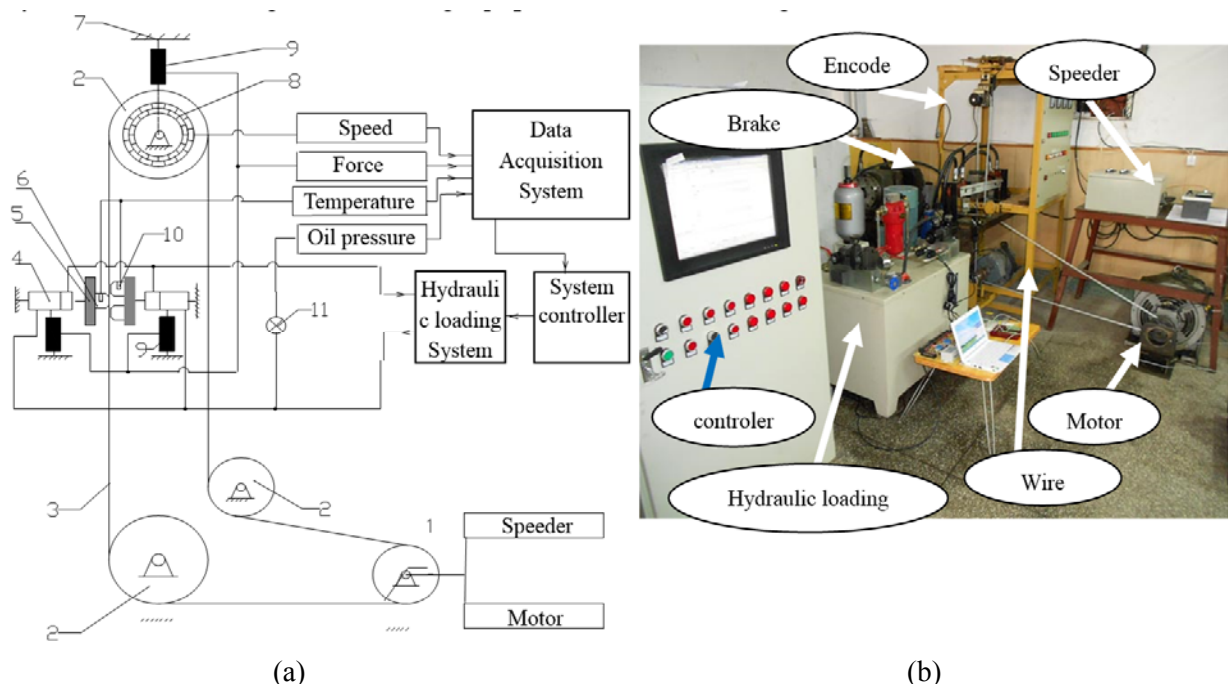
### 3.1. Mechanical Transmission and Wire Rope Brake Mechanism Design

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This part comprises three-phase AC motor, motor speeder, transmission wire rope and wire rope brake device. Motor speeder includes electromagnetic slip clutch occurring, tachometer generator and speed controller.

Wire rope wraps around a mechanism which consists of pulleys and bearings. It is turning with the pulleys which are driven by the three-phase AC motor to simulate hoist container lifting and down. There is an electromagnetic slip clutch installed on the motor output shaft to control the motor speed by controlling its magnetic field strength. Obviously, the magnetic field strength is easily adjusted by changing the electric current.

Brake mechanism comprises brake cylinder and brake block. The tooth brake block is moved with the extending of cylinder shaft to clamp the wire rope. It forms a sliding friction couples to simulate the working condition of anti-skid device when sliding accident occurs in a mine hoist.



1. Friction wheel 2. guide wheel 3. wire rope 4. hydraulic cylinder 5. brake mechanism 6. brake block  
7. rack 8. encoder 9. force transducer 10. temperature sensor 11. oil pressure sensor

**Figure 3.** Schematic diagram of Experimental Platform and Experiment system of anti-skid device.

### 3.2. Hydraulic Loading System Development

This system includes power source, hydraulic cylinder, hydraulic valves, filters, oil tubing, level gauge, differential pressure sender and pressure gauge.

The power source is comprised of motor, gear pump and accumulator. It is emphasized that not only does the accumulator buffer and compensate for oil leaking, but it is more important that the accumulator will be a hydraulic power in power failures which may in result from sliding accidents. Hydraulic valves include relief valve which is used to set system pressure, selector valve which is used to control the brake blocks clamping the wire rope, electro-hydraulic proportional valve which is used to adjust the breaking force and other valves.

### 3.3. Test Data Acquisition System Development

The system includes a computer, data collector and several kinds of sensors such as oil pressure transducer, force transducer, temperature sensor and encoder, and so on. The force transducers are installed on the top wheel and under the hydraulic cylinder to obtain signal of the friction force. The temperature sensor is settled in the brake blocks to measure the friction heat transfer during sliding

braking. The oil pressure transducer is connected before the selector valve to measure the working pressure. The encoder is settled on the shaft of the top wheel to measure the moving speed of rope.

### 3.4. Controller System Development

The system controller includes control cabinet, upper computer and PLC controller. The upper computer is an industrial microcomputer with touching screen. The PLC controller is S7-300PLC made by Siemens that includes power supply module, CPU module and signal module, etc. In addition, there is a power supply circuit including UPS, switch power supply and air switch, and a control circuit composed of relay, AC contactor and overheat protector, etc.

### 3.5. Testing Program Design

Changes of specific pressure and sliding speed between brake blocks and wire rope are obtained by adjusting the oil pressure of hydraulic loading system and the motor speed. Transducers are used to measure the system pressure and friction force.

Since it is difficult to measure the heat transfer caused by friction braking process using non-contact measurement in the contact surface, thermocouple is settled inside the brake block near the surface to measure the braking temperature rise. The U.S. OMEGA TT-K-30SLE PTFE temperature line, graduation number K, was used. Its temperature side is nude. The temperature measuring range is  $-200^{\circ}\text{C}\sim 260^{\circ}\text{C}$  with accuracy of  $\pm 0.1^{\circ}\text{C}/100^{\circ}\text{C}$ . The wire core is made of nickel-chromium alloy with diameter  $2\times 0.255\text{mm}$ . Signals will be converted by the temperature transmitter to 1-5V DC voltage for acquisition and storage.

The control factors in the experiments are sliding speed and specific pressure. Adjustment of sliding time and control factors will result in a different friction force and temperature rise. The control factors and levels are designed as shown in Table. 1 based on the testing apparatus.

**Table 1.** Control factors and levels for friction coefficient test.

Control factor	level
Sliding speed $v(\text{m/s})$	0.2, 0.8, 1.4, 2
Brake specific pressure $p(\text{MPa})$	0.4, 0.8, 1.2, 2.8

Test process:

- (1) Measure the distance between the testing points and contact surface.
- (2) Start the hydraulic motor and adjust the oil pressure, then the cylinder will protrude to make the brake blocks clamp the wire rope.
- (3) Start the three-phase AC motor and change the moving speed of wire rope.
- (4) Store test data of oil pressure, force and temperature, etc. in real time.

## 4. Conclusion

An experimental platform for anti-skid device of friction hoist developed in this paper. Firstly, the paper presents the principle of testing friction. Secondly, it gives the whole structure of the experimental platform. And then develops the mechanical transmission and wire rope brake mechanism, hydraulic loading system, test data acquisition system and controller system. At last it designed the testing program. It is useful for studying the braking performance of braking mechanism for anti-skid device.

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