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Study on Tribology Characteristics of Friction Material Based on Tribo-Systems

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Abstract: The basic principles of tribo-systems and study method based on tribo-systems are introduced in the paper. Based on the viewpoint of tribo-systems, the experiment on tribology characteristics of friction lining material in multi-rope friction hoist is carried out. The research result shows: tribology characteristics of friction material are not its inherent characteristic but system characteristics of the tribo-systems, the "sliding-rope" of multi-rope friction hoist can be divided into "safety sliding-rope" and "fault sliding-rope", study on friction material only based on characteristic of system where friction material exists possesses practical significance.

Keywords: Friction coefficient, friction material, tribo-systems, hoist, lining

Introduction

Friction material is widely used in the brake devices and the friction transmission equipment. Friction coefficient is the one of most important characteristic parameters of friction material. But, in the common design handbook and textbook, friction coefficient is taken as inherent characteristic of friction material and is given only as the constant. It makes the some phenomena taking place in engineering be explained incorrectly, such as braking failure of friction brake in certain working condition, "sliding-rope" phenomenon in multi-rope friction hoist (the "sliding-rope" means that there is relative slip between the hoist wire rope and friction lining of the hoist when the hoisted load is more than the limit load (friction force) transmitted by the hoist) and so on. Based on viewpoint of tribo-systems, the experiment on tribology characteristic (friction coefficient) is carried out, taking the friction lining material of multi-rope friction hoist as the example, so as to get the better results.

Basic principle of tribo-system

H. Czichos is the person who earlier discussed the method of tribo-systems [1]. The theory of tribo-system he studied is based on a simple friction pair sub-system that consists of two rubbing surfaces, lubricating medium and environment. The simple tribo-system is shown in Fig. 1.

The structure feature of the tribo-system can be shown with the set:

$$S = \{A, P, R\} \quad (1)$$

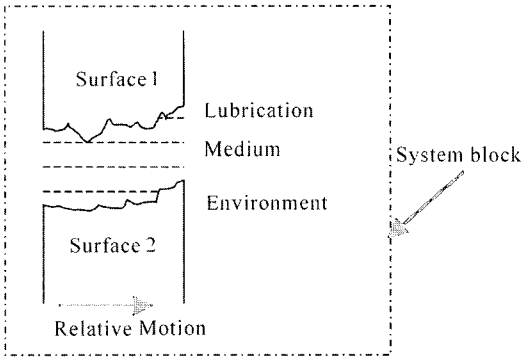

Fig. 1. Simple tribo-systems.

Where, A is material elements in the tribo-system, P is related property of every elements, R is mutual relationship among the elements.

According to the tribology feature, namely, the tribology behavior is system dependent that single surfaces or medium substance can not realize any tribology behavior, the properties of tribo-elements and the systems with tribo-elements are time dependent, tribological behaviors are the results of strong coupling of many behaviors of other disciplines, such as mechanics, chemistry, heat transfer, material science, electronics and theory of control [2], the theory of tribology general system (frame) was put forward [3]. It is suggested that the tribo-system should be drawn from the machine and machine system in more wide range. The system includes all the friction pairs and several support sub-systems. The structure feature of the system can be shown with the set:

$$J = \{S, Z, X\} \quad (2)$$

In formula (2), {S} is structure subset of system friction pairs, {Z} = {H, T, R} is support sub-system subset of system

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where {H} is lubrication sub-system (oil and grease lubrication), {T} is state monitoring and fault diagnoses sub-system and {R} is state compensation and control sub-system, and {X} is relationship subset of every sub-system.

The theory is helpful for understanding general action among the friction pairs, researching into sub-system which support friction pair better action, research on the movement relationship between the every friction pairs and restrictive (coupling) relationship among the loads; is helpful for researching into the other external (environment) condition of every friction pairs. It overcomes the two trends of research facing objects and facing friction pairs in the research of friction, wear, lubrication.

Study method based on tribo-systems

According to the above theory, it is necessary to study tribology characteristics of friction material in the view of the tribo-systems. Take friction lining of multi-rope friction wider as an example.

The Fig. 2 shows the composition of multi-rope friction hoisting system. The system consists mainly of hoisting container, hoisting ropes, friction wheel, balance ropes, guiding wheel and so on. The Fig. 3 and Fig. 4 show the Main shaft device structure and the lining arrangement of multi-rope friction hoist.

The Fig. 5 shows the friction hoist working principle. The hoist transmits power depending on the friction force between the hoisting ropes and the friction linings fixed on the friction wheel. The motor drives the friction wheel turning. Owing to the friction force between ropes and linings, the wire ropes make hoisting containers move up and down.

According to the famous Eulers formula, on the sliding condition:

$$F_s = F_x e^{\mu\alpha} \tag{3}$$

Where: F_s is general wire rope tension of rising side, F_x is general wire rope tension of declining side, μ is friction coefficient between lining and rope and α is the contact angle between ropes and friction wheel.

Friction force (power) transmitted by the hoist is

$$F_s - F_x,$$

and

$$F_s - F_x \le F_x(e^{\mu\alpha} - 1) \tag{4}$$

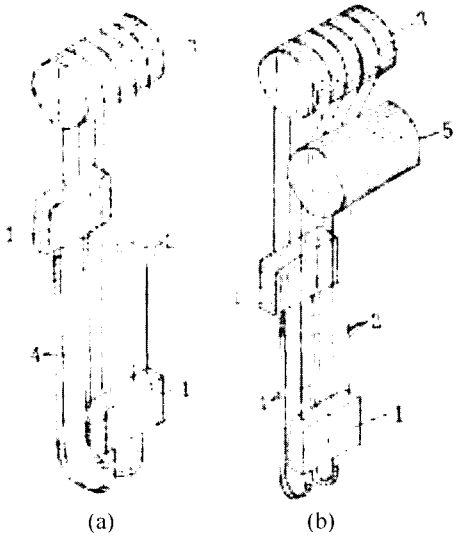

Fig. 2. Composition of multi-rope friction hoisting system. (a) the contact angle between ropes and friction wheel $\alpha = 180^0$ system, (b) the contact angle between ropes and friction wheel $\alpha = 190^0$~195^0 system. 1-hoisting container, 2-hoisting ropes, 3-friction wheel, 4-balance ropes, 5-guiding wheel.

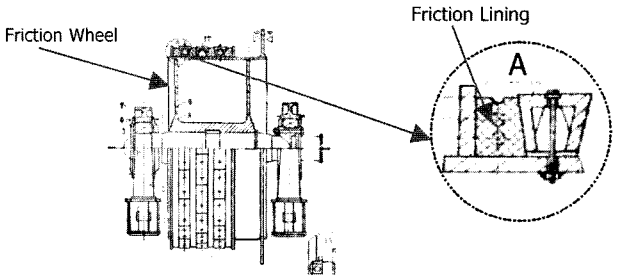

Fig. 3. Main shaft device structure of multi-rope friction hoist.

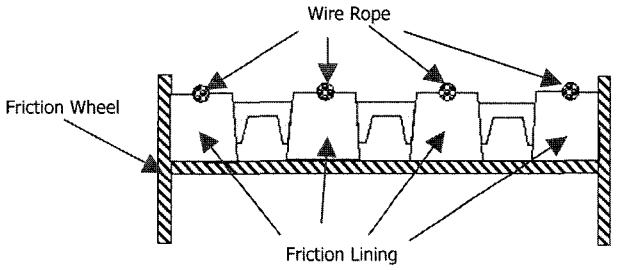

Fig. 4. The lining arrangement diagram of multi-rope friction hoist.

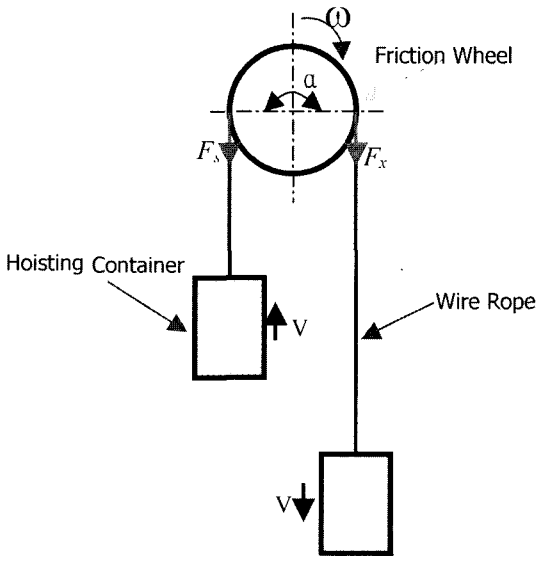

Fig. 5. Friction hoist working principle diagram.

In order to guarantee the rope not to slide in the hoisting process, antiskid safety coefficient should be decided as

$$\sigma = \frac{F_x(e^{\mu\alpha} - 1)}{F_s - F_x} \geq 1 \tag{5}$$

From the formulas (4) and (5), it is concluded that friction coefficient is the key parameter to the safe and reliable operation of hoisting device. It mainly depends on hoisting condition (hoisting, declining, accelerating, decelerating, constant speed, load and unload), rope-unbalanced condition, the load value of hoisting, structure size of hoist, material characteristic of friction lining, material characteristic and structure of wire rope, antiseptic friction-increased agent, the temperature (environment temperature, friction temperature) between lining and rope, specific pressure, slip velocity (creep and sliding speed) and single or mutual actions of surface status, environment elements and so on [4,5,6]. So the experiment of friction coefficient should be decided according to the system characteristic of multi-rope friction hoist. In this paper, practical specific lining pressure, temperature, slip velocity range and surface condition of friction lining are considered in the normal hoisting working condition and sliding-rope" condition. Under this circumstance, the research on the variable law of lining friction coefficient possesses practical significance.

Experiment

The experiment is carried out in model friction hoist. Testing condition: The experiment of lining friction coefficient is in "sliding-rope" condition, the diameter D of friction wheel is 480mm, rope diameter d is 3.6 mm, the 6 × 7 strands rope is cleaned, friction lining material is PVC (polyvinyl chloride) plastics, lining specific pressure P is 70~150 kPa, temperature T is 10~140°C relative sliding speed V is 200~800 mm/s.

The relationship curves of friction coefficient μ and temperature T, speed V is shown in Fig. 6 (the pressure P = 140 kPa). Under this experiment condition, coefficient μ is increased with the speed increasing and reach peak value, but is gradually decreased with temperature increasing. The relationship curves of coefficient μ and temperature T, speed V and pressure P is shown respectively in Fig. 7. Under this testing condition, coefficient μ is decreased below 0.3 after reaching peak value with the speed increasing. Temperature continuously increasing makes the lining adhere to the wire rope, seriously wear, and meanwhile, lining pressure is decreased rapidly and coefficient μ is gradually increased above 0.45 again.

An important conclusion can be obtained from the experiment results, namely, "sliding-rope" of multi-rope friction hoist can be divided into "safety sliding-rope" and "fault sliding-rope". "Safety sliding-rope" means the increase of friction coefficient makes "sliding-rope" convergent during the "sliding-rope" processes; "fault sliding-rope" means the rapid decrease of coefficient makes "sliding-rope" divergent or vicious. The conclusion is important to settle the "sliding-rope" accident of multi-rope friction hoist.

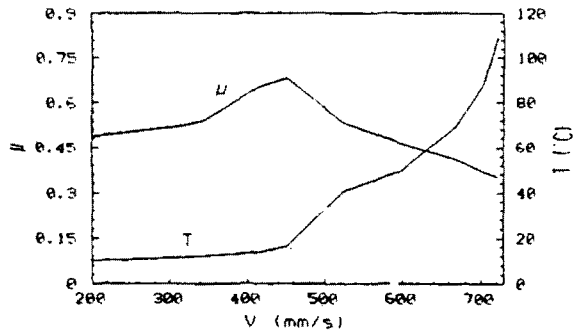

Fig. 6. Relationship curves of friction coefficient μ and temperature T, speed V (the pressure P=140 kPa).

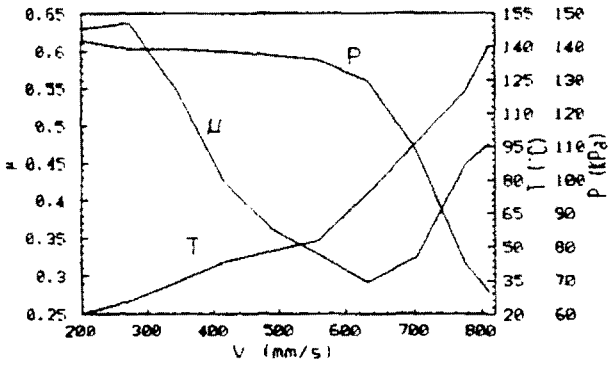

Fig. 7. Relationship curves of friction coefficient μ and temperature T, speed V and pressure P.

Summary

From the above research, it is concluded, i.e. tribology characteristic of friction material is not its inherent characteristic but tribo-system characteristics of the system where friction material works. Study on friction material only based on tribo-system characteristics of system where friction material works possesses practical significance. "Sliding-rope" of multi-rope friction hoist (or elevator) can be divided into" safety sliding-rope" and "fault sliding-rope" in order to settle the "sliding-rope" accident of multi-rope friction hoist (or elevator)

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