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Study on viscoelastic friction and wear between friction linings and wire rope

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ABSTRACT

The purpose of this paper is to establish the relationship between dynamic viscoelastic friction and wear. Friction and wear mechanisms were analysed by dynamically monitoring the viscoelastic slippage and temperature of the friction interface. The results show that the friction coefficient was positively correlated with the loss factor. Friction and wear both decreased with the increase of the interfacial friction temperature. The wear increased exponentially with the increase of the loss factor. Friction and wear properties of three types of friction linings were compared; the loss factor of K25 lining was the largest (0.21); the sticking time of the K25 lining was the longest (0.27 s), and its friction coefficient was the largest (0.67) in the early stage of the friction experiment. As the friction experiment progressed, the temperature of the interface increased. The loss factor and the friction coefficient decreased noticeably with the increase of temperature. This resulted in less friction, less surface damage and fewer cracks and debris. The wear of the K25 lining was the smallest (0.32 g).

1. Introduction

The working principle of a multi-rope friction hoist is reliance on friction between the friction lining on the friction wheel and the wire rope to overcome the tension difference acting on the wire ropes on both sides of the hoist [1]. Friction is the driving force, as shown in Fig. 1. The source of friction is the viscoelastic contact deformation between the viscoelastic lining material and the flexible steel wire rope. During work, the friction lining first deforms and then creeps when the deformation reaches a certain extreme value. This creep causes energy release. The friction lining then re-adheres to the wire rope. A stick-slip phenomenon occurs with adhesion as the main source of friction. However, energy release during stick-slip also causes wear of the friction lining [2], causing faster wear and tear and increasing the required maintenance and replacement. This causes great economic losses and decreases the safety of the hoist [3]. Therefore, it is important to explore the factors that affect the viscoelastic friction and wear properties of friction lining to increase the safety of multi-rope friction hoists.

In recent years, the viscoelastic friction and wear properties of friction linings have been studied. The main factors affecting the friction and wear of the lining include material properties, contact pressure, sliding speed and surface contact state. (1) Material properties: The friction lining is mostly made by mixing various types of resins, rubber and other high polymers. To improve the friction coefficient of the lining, various reinforcing materials are added, mainly including various metals, metal oxides, high-performance fibres, and/or inorganic particles (such as SiC and Al_2O_3). However, the addition of too much reinforcement will result in a loose material structure, decreasing viscoelasticity and wear resistance [4,5]. (2) Contact pressure [6,7]: wear of the friction lining is proportional to the contact pressure. As the contact pressure increases, the viscoelasticity decreases, and thus the wear rate of the lining material increases. However, to prevent the rope slipping on the friction wheel in a hoist, it is necessary to increase the contact pressure between the wire rope and the lining to ensure sufficient friction. Therefore, both friction and wear should be considered simultaneously. To ensure the safety of the hoist, a smaller contact pressure is sometimes chosen to extend the service life of the friction lining. (3) Sliding speed: the wire rope sometimes slides on the friction lining during lifting. Peng et al. [8,9] analysed temperature, stress, and coupling behaviour of the friction lining when sliding at high speed. It was found that the temperature, strain and friction coefficient changed drastically under this condition, and the sliding caused serious abrasive and adhesive wear between the friction lining and the wire rope. The wear rate and the frequency of alternating stress on the friction lining increased with the increase of the sliding speed. This accelerated the wear and tear, reducing the service life of the lining. (4) Surface contact [10–12]: as the wire rope is a spiral structure, the rope and the lining are not in full contact at the arc surface. The pressure distribution is not uniform. The peristalsis, torsion

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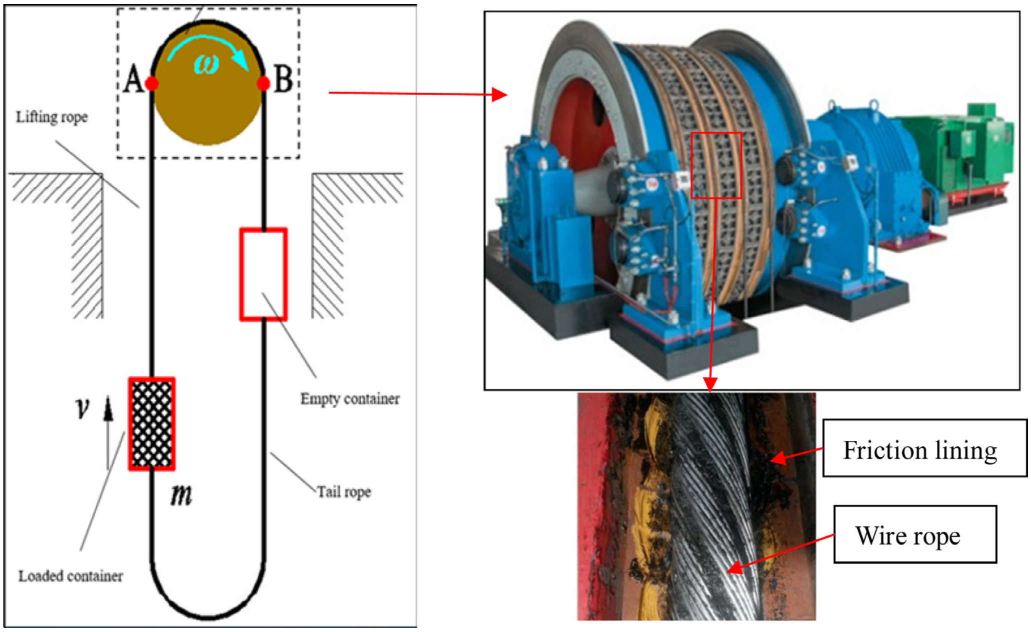


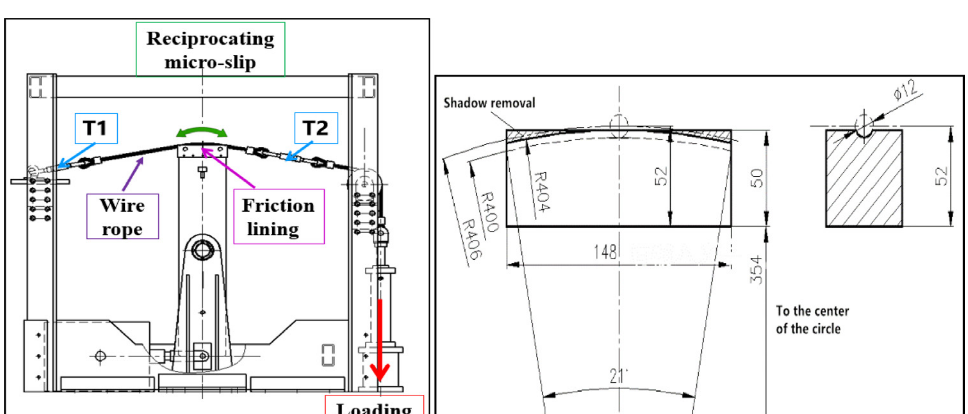
Fig. 1. Work principle of friction hoist.

and tension of the wire rope leads to changes in contact points, tearing and shearing, all of which can cause lining wear.

On the wear mechanism of linings, Feng [13] and Ye and Huang [14] analysed the surface states of the wire rope and friction lining after wear via microscopic topography. It was established that the wear mechanism of the friction lining includes fatigue wear, abrasive wear, and adhesive wear. It was also found that the surface material of the friction lining was transferred to the surface of the steel wire rope. Feng et al. [15] found that the viscoelastic lining material easily produced reel-like debris during wear, based on the real-time in situ observations from a white box test. The wear mechanism model for the lining was divided into four stages.

As to the stick-slip friction mechanism of polymers, Viswanathan et al. [16–18] determined, using interface force measurements and high-speed imaging, that the stick-slip of soft adhesive interfaces is mediated by slow frictional waves. The relationship between stick-slip and slow-wave phenomena was discussed, and a general linear elastic framework was used to describe the propagation of the slow surface waves. Park et al. [19] studied the stick-slip properties of PMMA, PC, PTFE and PVC, and found that the modulus of the polymer determines the slope of the stick portion of a stick-slip profile, while the stick-slip frequency and amplitude were more dependent on the polar contribution of surface energy. Hamdi et al. [20] and Hossain et al. [21] studied the stick-slip problem in the rubbing of polymer coating materials. It was found that increasing the thickness of the soft matrix delayed the formation of cracks in the stick-slip process. At the same time, this also increased plastic deformation and friction.

However, the above studies on the viscoelastic friction and wear of friction linings do not simulate the contact and friction of the arc surface under actual working conditions and ignore the bending action of the wire rope. At the same time, research on the stick-slip behaviour of polymer materials does not consider the contact problem of a friction mating pair, and does not analyse the stick-slip state during the friction process. The relationship between material viscoelasticity and wear is not explained theoretically. There is little analysis of the changes in temperature, morphology and composition during wear. In this paper, experiments were carried out on as self-developed friction lining and wire rope dynamic micro-sliding friction test platform based on the arc method (The arc method is closer to the actual working condition of the hoist than the plane method. The arc method is a reciprocating



(a) Dynamic micro-slip friction test platform (b)Sample size

Fig. 2. Dynamic micro-slip friction experiment.