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Dynamic contact characteristics between hoisting rope and friction lining in the deep coal mine

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ABSTRACT

Dynamic contact characteristics between hoisting rope and friction lining in the deep coal mine were analyzed in the present study. Dynamic rope tension and tension differences were obtained using Simulink simulation models. Evolutions of slip states and stress distributions along the groove bottom of friction lining during hoisting, and the effect of coefficient of friction on those evolutions, were explored employing finite element analyses. The results show that fluctuating rope tensions and tension differences during hoisting exhibit three stages. The wear failure is more likely to occur along contacting surfaces between the rope and friction lining. Contact arcs between the rope and friction lining consist of two frictional arcs with severe damage and a sticking arc with slight damage. Dynamic contact status during hoisting consists of a slip regime and a mixed regime. Larger tension difference results in larger relative slips, contact pressure and equivalent stress. Frictional arcs exhibit more serious wear due to higher stress levels as compared to the sticking arc. An increase of coefficient of friction reduces the possibility of gross slip and wear between the rope and friction lining.

1. Introduction

Multi-rope friction hoist systems, connecting the underground production system and the ground industry square, are widely employed in deep and ultra-deep (>1000 m) mines to lift and lower the coal, gangues, equipment and workers [1–3]. The multi-rope friction hoist system operates by friction between multiple ropes and rope grooves of the friction lining [4–5], and has double containers, i.e. a full loaded container on one side and an empty container on the other side (Fig. 1). Pull forces applied at both ends of the rope over the friction pulley induce the elastic deformation of each rope and the three-dimensional contact between the rope and corresponding groove, which cause the local slip between contacting components and specific local stress distributions throughout the contact region [6–8]. During hoisting in deep and ultra-deep coal mines, the changing vertical rope length and inertial load will result in the system vibration during a hoisting cycle (stages of acceleration, constant speed and deceleration), and thereby induce dynamic rope tensions [3,9,10]. Dynamic rope tensions result in dynamic contact characteristics (stress distributions, local slip states, and et al.) throughout the contact region between the rope and friction lining. Abnormal contact and excessive slip may produce the premature failure of friction lining and the state of gross slip of the rope over the friction lining, which will cause damages of containers and wellbore facilities, and casualties. Meanwhile, in deep and ultra-deep coal mines, the hoisting rope is subjected to the trickling water, high humidity atmospheres and variable temperature [9]. In order to increase the friction transmission and anti-skid capacities, the friction-increasing grease is added between the rope and friction lining. In those cases, the coefficient of friction between the rope and friction lining varies from 0.25 to 0.65, which affects

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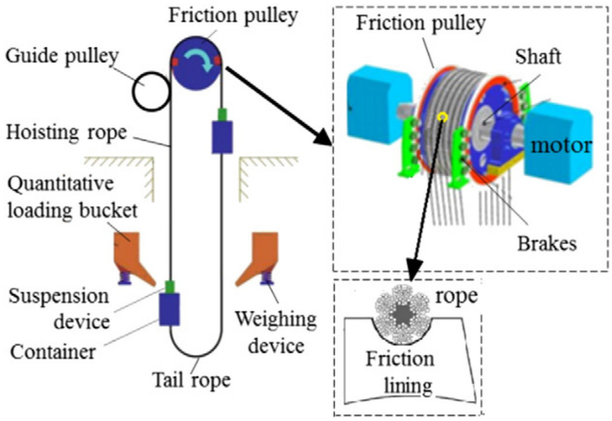

Fig. 1. Schematic of the friction hoist system in coal mine.

their dynamic contact properties. Therefore, it is of great importance to investigate dynamic contact characteristics between the rope and friction lining in deep coal mine hoist systems.

In recent years, many scholars have performed researches on the sliding friction between steel wire rope and friction lining. Ge SR [11,12] explored the effects of sliding velocity and contact pressure on coefficient of friction and the probability distribution between the rope and friction lining, respectively. Peng et al. [13] investigated the effects of the rope tension, and thermo-mechanical properties of GM-3 and K25 polymer linings on the coefficient of friction between the rope and friction lining. Meanwhile, Peng et al. [14] also studied the thermo-stress coupling field of friction lining during serious high-speed sliding friction between the rope and friction lining, and found that the contact zone presented the highest temperature and thermo-stress. Ma et al. [15] discussed influences of friction-promoting greases on anti-wear properties of friction lining during sliding friction between the rope and friction lining.

Considering antiskid characteristics between the rope and friction lining, Chen et al. [16] developed a wireless detection system for the friction hoist system, which could indirectly calculate the difference between velocities of guide pulley and the rope and thereby dynamically detect the rope skid phenomenon. Chen et al. [17] introduced a new depth indicator for a multi-rope friction hoist system which could avoid the deviation between the actual cage location and theoretical location due to the elastic slip between the rope and friction lining during hoisting. Zhao [18] dynamically recorded speeds of the rope and pulley to avoid the rope skid phenomenon. From literature studies mentioned above, one has found that previous efforts have been focused on the sliding friction and antiskid characteristics between the rope and friction lining. However, dynamic contact characteristics between hoisting rope and friction lining in the deep coal mine, and the effect of coefficient of friction on dynamic contact properties, have not been previously reported.

The objective of the present study is to explore dynamic contact characteristics between hoisting rope and friction lining. Section 2 presents theoretical and Simulink simulation models of dynamic tensions of hoisting rope to investigate dynamic tensions and tension differences of the rope during lifting and lowering processes. In Section 3, a three-dimensional contact finite element model is established; stress distributions and slip characteristics in a typical case of tension difference were discussed; the role of coefficient of friction on dynamic contact properties between the rope and friction lining during the entire hoisting was explored.

2. Dynamic tensions of the hoisting rope

2.1. Theoretical models

Ignoring the unbalancing effect of multi-rope tensions, and assuming the same transmission capacity between each rope and the corresponding groove of friction lining, we explore the contact properties between a rope and a groove for convenience. As the friction pulley rotates in the clockwise direction (Fig. 1), the rope lifts a container filled with coal and lowers an empty container on the left and right sides of the friction pulley, respectively, according to the speed curve as shown in Fig. 2. Left

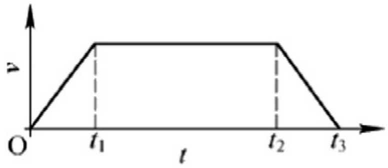

Fig. 2. Speed curve during hoisting.