Time-Varying Characteristics of the Longitudinal Vibration of a High-Speed Traction Elevator Lifting System

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Hoisting rope in a high-speed traction elevator lifting system exhibits strong time-varying characteristics, which, to a large extent, affect the comfort and safety of high-speed elevators. In order to analyse the influence of the time-varying characteristics on the vibration of elevators during the whole operation process, the longitudinal vibration of the hoisting rope of a lifting elevator is introduced to study the effect of the time varying characteristics of a lifting system on the time-varying characteristics of longitudinal vibration. The nonlinear time-varying model of the longitudinal vibration of the hoisting rope is established using the Hamilton principle and energy method. The Galerkin method is used to discretize the partial differential equations of vibration. The quintic polynomial is used to fit the ideal operating state of the elevator. Following this, the quintic polynomial is input as the motion parameter. The precise integration for the time-varying model of longitudinal vibration of the lift system is put forward. The time variant of elevator hoisting system is solved and vibration analysis is carried out with elevator case. It is observed that, during operation, as the length of the hoist rope increases, the acceleration of the longitudinal vibration of the elevator increases too. As the tensile force, provided by the tensioning device, increases, the acceleration decreases.

1. INTRODUCTION

The continuous emergence of high-rise and super high-rise buildings prompted the development of high-trip, high-speed elevators. In the course of operation, elevators inevitably experience a variety of vibration phenomena, with a large part of vibration being related to the elevator lifting system.

An elevator lift system is mainly composed of hoisting ropes with a certain axial movement length, a counterweight at one end, and a car at the other end. Hoisting ropes exhibit certain time-varying characteristics. As the lifting part of the elevator, hoisting ropes are elongated and shortened during elevator operation. Thus, parameters, such as stiffness and hoisting rope damping, constantly change. Furthermore, time-varying characteristics are apparent at high speed, thereby seriously affecting the comfort and safety of elevators. With the change in rope length, natural frequencies and vibration energy also change. When the rope is shortened, free vibration energy increases exponentially, and dynamic instability easily occurs, thereby seriously affecting the safety of passengers. The effect of longitudinal vibration on the lifting system is markedly stronger than that of lateral vibration under consistent initial conditions. Therefore, the effect of the time-varying characteristics of hoisting ropes, in the longitudinal vibration of the elevator lifting system, should be studied.

Numerous studies on the longitudinal vibration of traction elevator hoisting systems have been conducted. The basis of these studies is to establish discrete models based on distributed parameters, in which the wire rope in the hoisting system is separated into a number of time-varying characteristics of quality-spring-damping systems. Parameters vary with changes of the elevator operating state. The advantage of this type of model is that the established ordinary differential equations are easy to understand and solve. However, this type of model disregards the continuity of wire rope flexibility and thus cannot effectively reflect the dynamics of elevator lifting systems. Therefore, the continuous model based on a distributed parameter, which can describe the flexible characteristics of traction ropes better, is gradually applied.

The distributed parameter continuous system model generally simplifies the lifting system to an axially moving chord with a certain mass attached at one end, and the kinetic behavior of the system is described by establishing either a functional differential control or a partial differential control equation. The parameters of the model are continuously distributed in time and space; thus, the model possesses infinite degrees of freedom and can satisfactorily describe the flexible continuous characteristics of the elevator lifting system. Zhang established differential equation of motion and energy equations representing the longitudinal vibration of an arbitrary variable-length flexible lifting system by using the Hamilton principle and validated the accuracy of continuous system modeling and energy methods. Bao established the equations governing flexible lifting wire ropes by using the Hamilton principle, studied the nonlinear vibration of a flexible lifting wire rope with time-varying length, and verified the theoretical model by experiment. In addition, considering the interaction between the rigid and the deformation motions of the hoisting rope, Bao established a differential equation that represented the longitudinal vibration of the hoisting rope of a variable-length lifting system, and a numerical example is given to analyse the model. These studies considered the high-speed elevator lifting system as the research object. However, the weight of the