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Dynamic simulation and optimization of clamping mechanism of online tension testing machine for wire ropes

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ABSTRACT

This study analyzes the slipping and crushing behaviors of a steel wire rope during a tensile test using a curve-type clamping mechanism to realize safe and reliable clamping during safety testing. Then the dynamic simulation analysis of the clamping and stretching processes is performed using the finite element method. The reasons for the damage caused to the wire rope by clamping force are investigated. The clamping mechanism of the tensile testing machine is improved using a force amplifier and the optimization design of its jaws. The experimental results show that the improved clamping mechanism can effectively clamp the wire rope for tensile testing and meet test requirements.

1. Introduction

Tensile testing machines are used for testing the tensile mechanical properties of various wire ropes, strands, connectors, and other relevant rigging. They are widely used in electrical engineering, machinery manufacturing, metal materials, and other industries. The clamping mechanism, which is an important part of such machines, helps in conducting tests smoothly and determining the reliability of test results. Steel wire ropes are widely used in engineering practice as a type of flexible member. They are reused in tensile tests to determine safety as per industry standards. Currently, enterprises frequently cut off a section of a wire rope close to the rope end for testing. This method has evident limitations and cannot reflect the condition of the entire wire rope. Therefore, the mechanical properties of the entire rope are randomly determined during its reeling using an online tensile testing machine. To continue using the qualified rope after the test, the clamping mechanism must reliably clamp the steel wire rope, and prevent any secondary damage to the rope. Therefore, there is an urgent requirement to design a clamping mechanism for rope tensile test machine to meet actual project requirements.

Tensile tests and computer simulation methods are generally used to investigate the mechanical properties of flexible members, such as steel wire ropes. Davies et al. [1] considered a marine braided rope as the research subject and studied the effects of torsion on its tensile properties by manually varying the torsional moment during a tensile test. Onur [2] compared tensile test results with theoretical calculation to determine the mechanical response of a strand to axial tensile loads. Piskoty et al. [3] performed a tensile test on a cableway wire rope using a universal testing machine, and provided a basis for wire rope failure analysis. With the development of computer technology, the analysis of the complex structures of a wire rope through numerical simulation has become an important research subject. Stanova et al. [4] simulated the mechanical responses of circular, triangular, and oval-shaped strand ropes subjected to axial tensile loads using ABAQUS simulation software and obtained the laws of stress and deformation. Fontanari et al. [5] analyzed the tensile behavior of Warrington–Seale wire ropes by conducting a tensile test, determined their elastic moduli,

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(a)

(b)

Fig. 1. a) Horizontal online tensile testing machine and b) crushed surface of a steel wire rope.

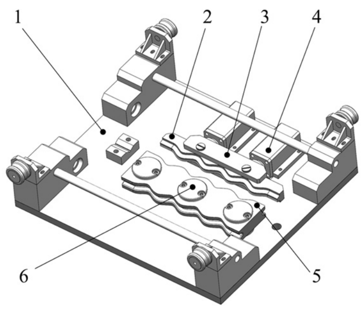
and provided a basis for finite element analysis. Wang and Wang [6] and Wang et al. [7] studied the effects of lifting parameters on the dynamic contact characteristics between a deep coal mine rope and friction lining. This dynamic contact was also simulated using the contact method in ABAQUS. Finally, the relationship between the friction coefficient and contact pressure was obtained. The structure and force of the steel wire rope were simplified using numerical simulation to facilitate the solution. Therefore, the wire rope must be tested for verification. Wang et al. [8] conducted numerical simulation on the stress and strain of braided wire ropes for the tensile stringing of transmission lines. They verified their effectiveness by conducting a tensile test. Xiang et al. [9] established an analytical model for the elastoplastic behavior of steel wire ropes, and provided a theoretical basis for the prediction of the stress and strain acting on steel wire ropes and for experimental verification.

A reasonable and effective clamping method is essential for ensuring the reliability and authenticity of tensile tests. The existing clamping methods employed for wire rope tension tests include casting, winding, pressing sleeve, and direct clamping methods. Suh and Chang [10] casted pure zinc to fix the end of a steel wire rope sample and performed a tensile test using a horizontal tensile testing machine. They evaluated the axial fatigue behavior of the wire ropes used in suspension bridges. Prawoto and Mazlan [11] used 6 × 7 and 6 × 19 wire ropes as test subjects and fixed the ropes to a tensile testing machine using a winding method. The mechanical properties of the ropes under tensile loads were validated by performing a tensile test. Zhang et al. [12] employed a pressing sleeve method to fix wire rope samples and measured the dynamic torque of the ropes under a tensile load. Then, the dynamic torsional characteristics of the hoisting ropes were analyzed.

In summary, the abovementioned experimental studies focused on the tensile testing of only a particular section of a rope to study its behavior. However, accurately evaluating the mechanical properties of an entire rope is still difficult. To this end, our research group cooperated with a certain enterprise to develop a horizontal online tensile testing machine for a steel wire rope in the early stage (Fig. 1(a)). A combination of direct clamping and winding methods was employed in the clamping mechanism of the wire rope. The equipment can be used for the online testing of steel wire ropes under rated loads. However, the rope was partially crushed and broken at the jaws when subjected to a rated load of 2.0 times (Fig. 1(b)). In addition, slipping occurred occasionally during the tensile test, this affected the analysis of tensile deformation. Therefore, the dynamic simulation analysis of the clamping process of a wire rope must be conducted using an online tensile testing machine. Moreover, the design of the clamping mechanism must be optimized. Studies on the stress and strain of steel wire ropes subjected to tensile loads and their contact simulation analysis can provide a useful reference for the dynamic simulation of the clamping process.

2. Clamping mechanism for the original online tensile test and its dynamic simulation analysis

Fig. 2 shows the original clamping mechanism of the horizontal online tensile testing machine and its installation. Fixed jaw 5 is fixed to pulley floor 1 through pin 6, and moving jaw 2 and hydraulic cylinder 4 are connected via connecting plate 3. The clamping process of the wire rope was achieved using hydraulic cylinders that helped push the moving jaw to extrude the fixed jaw. The



1 — pulley floor; 2 — moving jaw; 3 — connecting plate; 4 — hydraulic cylinder; 5 — fixed jaw; 6 — pin

Fig. 2. Installation of the original clamping mechanism.