Design of wire receiving device for wire rope maintenance line and simulation analysis and improvement of key components

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Abstract. According to the maintenance requirements of engineering steel wire ropes, the function of wire rope maintenance line was analyzed, and the detailed structural design of the wire receiving device as an important part was implemented. The finite element analysis of the key components of the wire receiving device shows that the design strength was insufficient. On this basis, the drive shaft structure was improved, and further simulation analysis verified the reliability of the improved structure.

1. Introduction

As an important lifting and traction tool, wire ropes are widely used in lifting machines, cableways, power grid construction and other engineering fields. As a power transmission stringing construction project, it is mostly field work. During the construction process, the wire rope is inevitably exposed to the sediment, rocks and other debris, which often causes pollution, wear and broken wires of the wire ropes. In order to ensure the safe use of the wire rope and extend its life, it is necessary to develop an automatic wire rope maintenance line that integrates functions such as cleaning, safety testing and maintenance.

The data retrieval showed that some scholars have studied the cleaning and maintenance of steel wire ropes. Chen JJ et al designed an automatic cleaning, testing and maintenance integrated system and achieved comprehensive cleaning and testing of steel wire ropes[1]. Michael V. Liebing et al. designed a cleaning device for the surface of the steel wire rope for the elevator. The cleaning position of the device is limited, and the surface of the wire rope can not be completely cleaned, so the cleaning effect is not good[2]. Fu C et al. improved a wire rope cleaning device for different diameter wire rope designs and achieved good results in practice[3]. Farris Charles J. et al. also designed a rotary wire rope cleaning device to achieve a circumferential sweep of the wire rope, and more sets of rotating brushes can be arranged as needed to achieve better cleaning results[4].

The above researches mainly focus on the cleaning of steel wire ropes. The discussion on the integrated equipment for cleaning, testing and maintenance of wire ropes is not deep enough. At the same time, in view of the urgent need of the project, it is necessary to develop the wire rope maintenance line. This paper focuses on the design of the wire rope maintenance line receiving device. The finite element simulation analysis and improvement of its key components are carried out.
2. Design of wire drawing device for wire rope maintenance line

In order to realize the integration of the wire rope cleaning, testing and maintenance, the maintenance line must have a clean module, test module, maintenance module and the feeding module. The case of each mode of the maintenance line is shown in figure 1.

In the wire rope maintenance line, the wire receiving device is used as a power source to complete the wire rope traction and receiving work of the entire line, which is an important component. The analysis believes that the device should have the functions of clamping, lifting, driving and receiving of the wire rope reel.

According to the needs of the enterprise and calculating, the maximum torque of the receiving device is 1050N·m and the 5.5kw AC motor is used as the drive motor of the wire receiving device. The design of the drive mechanism is shown in figure 2. The drive shaft 2 is connected by a motor and a reducer, and the sheave is rotated by the shift fork 10 to realize the traction operation of the wire rope in the maintenance line.

The wire receiving device clamping mechanism must achieve reliable clamping of the wire rope reel to facilitate stable lifting and passive driving of the rope reel. Thus, the clamping mechanism is designed as shown in figure 3, and the screw 10 is driven to rotate by the clamping motor 13, and the nut 9, the sliding sleeve 7, and the tip 3 are moved to realize the clamping of the rope.
Figure 3. Clamping mechanism
1-press plate; 2-bearing; 3-active top; 4-bearing cover; 5-tip shaft; 6-tip slide; 7-sliding sleeve; 8-locking handle; 9-transmission nut; 10-screw; 11-bearing seat; 12-motor base; 13-gearmotor; 14-track

The function of the lifting mechanism is to achieve the lifting and lowering of the wire rope reel and to hover at a fixed height during the operation of the maintenance line. The lifting mechanism of the design wire receiving device is shown in Figure 4. The clamping mechanism and the rope reel are moved up and down together by screw nut which is driven by motor.

Figure 4. Lifting mechanism
1-frame; 2-lifting geared motor; 3-screw; 4-rail

The cable arranging mechanism ensures that the wire ropes are arranged neatly and can be adjusted according to the size of the rope diameter. Thus, the mechanism is driven by a separate motor, as shown in Figure 5. The screw 2 is driven by the motor 1 with the reducer to realize the movement of the nut, and the wire guide frame with the guide roller is connected with the nut, and the right and left rotation of the motor realizes the left and right movement of the wire frame to achieve uniform arrangement of the wire rope on the rope wheel.

Figure 5. Wiring arrangement
1-motor; 2-screw; 3-moving cable rack
Through the structural design of the above components, the 3D effect diagram of the wire receiving device is shown in Figure 6.

![Figure 6. Three-dimensional diagram of the line-removing device](image)

3. Finite element simulation analysis and improvement of key parts of wire receiving device

The drive mechanism is the main mechanism for powering the take-up device. And the drive shaft is a key component of the drive mechanism. The original design of the drive shaft as shown in Figure 7, the driving torque is transmitted from the front end of the key to the shift fork, and then the rotating sheave rotates. So the connection key is very stressed and it is a weak link of the key components. It is necessary to perform a finite element analysis of the part.

![Figure 7. Original design drive shaft structure](image)

![Figure 8. Original design drive mechanism Safety factor cloud map](image)

The finite element analysis of the components consisting of the drive shaft and the shift fork gives the safety factor cloud diagram of the drive shaft as shown in Figure 8. It is found that the minimum safety factor at the key joint is only 0.02. According to the design experience, the shaft member is subjected to bending and twisting combination. When acting, the minimum safety factor of the shaft of the 45 steel material should be 1.5, so the design has certain defects here.

Therefore, the structural improvement of the drive shaft key joint is carried out, as shown in Figure 9, the front end is changed to a round shaft cut flat structure. In order to ensure the reliability of the improved structure, a finite element analysis was further carried out. Figure 10 shows the improved safety factor cloud diagram of the finite element analysis of the drive shaft. It can be seen from the figure that the safety factor of the drive shaft is 1.808, which is greater than 1.5, indicating that the design improvement of the drive shaft of the receiving device is reasonable and reliable.
4. Conclusion
(1) According to the requirements of the wire rope maintenance line, the detailed structural design of the wire-receiving device of its important components was carried out. 
(2) The finite element simulation analysis of the drive shaft and the fork of the key components of the wire receiving device was carried out, and the problem of insufficient design strength at the bond joint was found. 
(3) Structural improvement was made for design defects, and further finite element analysis was carried out to verify the reliability of the improved structure.

Acknowledgments
The research reported here was supported by the Science and Technology Development Plan Project of Shandong Province (2014GGX103016).

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