The Optimal Design of Wire Rope Tension Detection Based on Series Load Sensor Method

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Abstract: It is one of the main problems in the study of mine hoisting system to improve the tension imbalance and overload of steel wire ropes. In order to ensure the better detection of the tension of the steel wire rope under the premise of production safety, this paper mainly monitors the tension of the steel wire rope on the basis of the serial load sensor method, balances the working principle of the suspension device by lifting the tension of the steel wire rope and a special drawing loop mechanism on the sensor. The type of selection and installation location are optimized. Test results prove the feasibility and practicality of the optimized design.

Keywords: Lifting wire rope; Tension monitoring; Load sensor; Mounting position.

1. Introduction

According to relevant statistics, the deepest depth of mine exploitation at home and abroad has reached more than 1000 kilometers [1]. In order to ensure the improvement of efficiency, multi-rope friction hoists have been widely adopted as lifting devices. Lifting steel wire rope is an important part of mine hoisting equipment and plays an important role in the safety and economical operation of mine hoisting. At the same time, steel wire rope mine is used to upgrade the easy-to-consume and easy-to-failure products. Safety and reliability are of great significance for safe and efficient operation. Therefore, special attention is paid to the production. With the increase in the number of steel wire ropes being used, in order to ensure the safe use of steel wire ropes and prevent the occurrence of broken rope accidents, it is particularly important to accurately and quickly understand the actual changes in the actual tensions that the wire ropes are subjected to in the course of production operations.

With the addition of various sensors and computers and other hardware, the
development of software has led to closer monitoring of wire ropes. Taking into account the specific work environment and specific work requirements for mine improvement, the following major methods for monitoring wire rope load are summarized with reference to Chinese and foreign literature and related books: side pressure monitoring method, motor current method, oil pressure monitoring method, serial load sensor method. Traditional monitoring methods can easily cause the wire rope to wear, or there are problems such as the technology is not mature enough. In view of this, this article is mainly based on the serial load sensor method to optimize the design of the load sensor mounting position for the tension monitoring of the wire rope.

2. Design Principle

The tandem sensor method and the wire rope tension auto-balancing suspension device are analyzed. The detection of the tension of the steel wire rope is to use the tension auto-balancing device to pull the loop structure, and the level signal monitored by the load sensor is installed on the communication port through the communication port. Passed to the host computer to determine the tension of the wire rope. Serial load sensor method, the load sensor has two connection methods, one is shown in the figure 1(a), the sensor is directly connected and then measured between the steel wire rope and lifting bucket [2]. The second is to indirectly measure the tension of the wire rope by detecting the pressure between the piston and the adjusting rope nut as shown in the figure 1(b). In the series load sensor, there is a high risk factor in the method of directly connecting the sensor and lifting the bucket [3]. However, by monitoring the pressure between the piston and the adjusting rope nut, the monitoring method has good performance and does not have obvious defects in the above methods. Based on this method, improvements are made and the pressure value of the monitoring load sensor is used to reflect the tension of the steel wire rope. The size of the value.

![Fig.1 Serial load sensor method](image)

With the widespread use of multi-rope friction hoists, it is difficult to maintain the
tension of the hoisting ropes in the course of work, and to ensure production safety, the auto-balancing suspension device of the steel rope tension is used. The tension auto-balancing suspension device is generally composed of three parts: a wedge-shaped rope loop, a hydraulic balance system and a bearing component [4]. As shown in the figure 2, the main working system of each single device is the pull-pull working system, and the automatic tension balance device applies the principle of closed-loop passive hydraulic communication. During the lifting or working of the lifting system, the tension deviation of the steel wire rope can be adjusted to automatically adjust the tension deviation caused by the difference in physical properties between the wire ropes, installation errors, etc., and solve the tension imbalance problem between the wire ropes. The pull-out loop system of the suspension device is automatically balanced by tension, and the load sensor is mounted thereon.

Fig.2 Tension automatic balance suspension structure

3. Load Sensor Installation Position and Type Selection

3.1 Load Sensor Installation Location Analysis
The main function of the sensor is to perform data detection. The design of the installation location will directly affect the accuracy and reliability of the monitoring data. By installing the load sensor on the basis of the special structure of the tension balance device on the basis of the serial load sensor method, it is required that the normal operation of the tension balance device cannot be influenced and the normal and safe operation of the lifting system is ensured. After the load sensor confirms the installation position, the type selection is performed. The installation position is the primary consideration to ensure accurate and reliable data. The above-mentioned detection of the tension of the steel wire rope is a draw-back
loop structure using a tension automatic balance device, and a load sensor is installed on the wire rope tension automatic balance device.

The installation position of the load cell is optimized on the basis of the serial load sensor method, and the data of the load sensor is monitored on the basis of not affecting the normal operation and safety of the lifting system, so as to detect the tension of the hoisting wire rope. As shown in the figure 3, the main working structure of the tension automatic balance device is to install a load sensor on the pull-back loop structure. According to the working principle of the device, two mounting position conditions are also designed. One is mounted on the cylinder piston and slides. Between blocks, one is installed between the inner plate and the slider. Both mounting positions compress the load cell under static and dynamic conditions to obtain data. This design can avoid structural changes to the lifting system structure, and at the same time does not affect the work of the tension balancing device under normal conditions, nor does it affect the lifting system. The structural strength caused too much influence.

![Diagram of Load Sensor Installation Position](image)

**Fig.3 Load sensor installation position**

Analyze the above two installation methods. The outer beam of the wire rope tension balance device will limit the upward movement of the slider without limit, and at the same time ensure that the device is protected when the device fails or the tension difference is too large. If the sensor is installed between the inner plate and the slider, the hoist stops or accelerates. In the event of an impact, the load sensor will receive a large load shock, and the data will be distorted instantaneously, causing damage to the sensor over time. The sensor is installed between the piston and the slider, because the slider will be limited by the outer plate cross beam, while the buffer effect of the
cylinder is used to effectively protect the sensor. When the slider moves critically, the tension balance device also stretches the inverse limit, the sensor as the squeeze force becomes smaller, the situation can be quickly known through the data and a corresponding adjustment can be made. Therefore, it can be finally determined that the sensor is installed between the piston and the slider.

3.2 Load Sensor Selection
Because this sensor must adapt to the complicated mine environment and meet the safety requirements of coal mines, the choice of sensors is very important. The types of load sensors are varied, and suitable sensors can be selected for different environments and work requirements. Different types of sensors also have their own advantages and disadvantages. Common types of load sensors include piezoelectric, strain, inductive, resistive, potentiometric, capacitive, servo, and fiber optic types. Considering the application environment and working range of the sensor, it is necessary to use a sensor with strong anti-interference ability, a relatively large range, and a certain impact resistance. Among them, piezoelectric and inductive load sensors have high sensitivity, but they have poor anti-interference ability and are easily affected by the environment, which is not conducive to use in complex mine environments. Servo and optical fiber measurement range is small, although other types of sensors are suitable, but due to technical and other reasons cannot be used for this wire rope tension measurement.

After analyzing the relevant data and comparing the advantages and disadvantages of each type of sensor, this paper decided to use a resistive shear strain sensor [5]. After the development in recent years, the application technology of shear strain load sensors is relatively mature, the structure is simple, the application range is wide, and the anti-interference ability is strong. It can be used in outdoor engineering occasions to cope with various environments. Because the working environment of the sensor needs to bear a certain impact load, the spokes in the parallel structure of the elastic original are selected as shown in the figure 4. The tension of the lifting wire rope is converted to pressure on the sensor by the tension balance device, and the resistance strain gauge is set at the maximum deformation of the elastic element. At the same time, strain gauges are attached to the upper surface and side surfaces of the adjacent spokes, and the strain gauges have equal resistance values. When the spoke-type elastic element is deformed by force, the deformation resistance of the strain gauge with the spoke is also correspondingly changed.

Load sensor four resistor strain gauges form the Wheatstone bridge circuit [6], as shown in the figure 5. The strain gauges are arranged symmetrically, and when the strain gauge is pulled or pressed, its resistance value changes. Assume that each strain
gauge has a change in resistance $\Delta R$, and the strain gauge resistance is equal to $R$. Analyze the circuit and calculate the output voltage $U$ for:

$$UR = \Delta RE$$

According to the relationship between the pressure change of the sensor and the change of the resistance of the strain gauge, the relationship between the pressure of the sensor and the output voltage of the circuit is obtained, and the tension of the steel wire rope is reflected by the output voltage.

4. Experimental Testing

In order to verify the reliability, accuracy and practicality of this design, this was tested in the Zhaolou Coal Mine. Firstly, with the help of on-site staff, install the sensor and signal transmission equipment to ensure that the load sensor is stable in installation without large displacement. Finally, it is determined that the signal transmission stability can be monitored by the host computer to monitor sensor signal changes and zero calibration.

The operation of the hoist is shown in the upper computer as shown in the figure 6. As the speed of the hoist changes, as shown in the figure 7, the tension value of the hoisting rope during the heavy-load accelerated rising phase is greater than that during the uniform rising phase, as shown in the figure a, b. In the stage of deceleration and increase of heavy load, the tension value is smaller than the uniform speed stage, as shown in the c and d sections in the figure. No-load acceleration the tension value in the lower stage is smaller than that in the uniform speed stage, as shown in Figure e and f. In the lower stage of no-load deceleration, the tension value is larger than that in the uniform deceleration stage, as shown in the g and h sections in the figure. Due to the reason of the tail rope. It can be seen that the tension of the steel wire rope tends to increase when the heavy load rises, the tension of the steel wire rope
increases when the load is lowered, and the loading and unloading of the steel bucket is performed during the x and y phases. Through the analysis and comparison of data, the upper computer showed that the force curve of the steel wire rope was in line with the stress change curve of the wire rope when the hoist was lifted and lowered. Test results show that the load sensor installation position does not affect the normal operation of the lifting system, the sensor works normally, and accurately reflects the tension change of the lifting steel wire rope.

Fig. 6 Wire rope force curve

Fig. 7 Lift speed map

5. Conclusion

By serially connecting the load cell method and the analysis of the wire rope tension auto-balancing suspension device, the load sensor is optimized to improve the installation position of the load cell, and the load sensor is applied to the special drawing loop system of the tension balance device. The type of the sensor is determined. In the experimental test, the upper computer interface accurately reflects
the tension change of the hoisting wire rope. The experimental test has verified the reliability and accuracy of this design. The monitoring of the tension of the hoisting wire rope was realized.

References


