Finite Element Analysis and Structure Optimization of the Middle Groove of Scraper Conveyor

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Abstract. The middle groove is the most used and consumed component of the scraper conveyor. Its strength, rigid and wear resistance play an important role in the normal operation of the scraper conveyor. In this paper, the finite element analysis of the 1350 scraper conveyor is carried out of nonlinear finite element method, and the plastic deformation of the concave and convex ends of the groove is obtained during the tension and compression process. In order to prevent the phenomenon of the concave end of the groove, the paper proposes three methods to improve the performance of the middle groove. Through analysis and comparison, an optimization method is proposed to reduce the stress value during the tension and compression process by increasing the length of dumbbell rod concave end section and the diameter of the bell mouth, thus improving the reliability of the scraper conveyor.

1. Introduction

China is the world's largest coal-producing country and a major consumer of coal. Coal accounts for about 70% of China's energy industry and consumption structure, and is China's leading strategic energy source. The coal industry has become an important foundation for the rapid development of the national economy. The coal mine machinery and equipment that serves coal production will become the key to promoting China's coal technology advancement and industrial modernization [1]. The scraper conveyor is one of the most critical equipment in coal mining machinery. The middle groove is the main part of the scraper conveyor, and as a consumable part of the scraper conveyor, its reliability has an important influence on the life and reliability of the scraper conveyor [2].

The middle groove acts as a conveyor unit for the conveyor and its number determines the working length of the scraper conveyor. As the bearing part of the material, the middle groove is subjected to the intense friction of coal, scraper and chain during transportation, and is the component with the largest amount of consumption and consumption. The weight of the middle groove accounts for more than 70% of the total weight of the scraper conveyor. In the process of coal transportation, it not only has to bear the running load of the shearer, pushes and pulls the hydraulic support under the conditions of pushing and pulling, and also bears coal, but also the impact of the rock on the central trough, the pressing force, etc. Under the above conditions, the middle groove failure rate is extremely high, and the failure of the central trough directly leads to the failure of the scraper conveyor [3].

The finite element analysis of the middle groove with the dumbbell socket, the groove head and the shearer passing through the middle groove to study the reliability of the structure. On the basis of fully grasping the theory of structural optimization, we will further explore the application of structural
optimization in practice to achieve the purpose of improving its reliability, and thus improve the reliability of the scraper conveyor [4].

2. Finite element model establishment

2.1 Establishment of finite element model
In this paper, the finite element analysis of the structure of the middle groove of the 1350 scraper conveyor is carried out. Modeling with Pro/E, using ANSYS software's powerful structural optimization function, optimizes the strength calculation size of the middle groove to reduce the stress level of the device. Homogenize the stress and improve the service life of the product to enhance the inheritance of the design, reduce the cost of the company's technical transformation and shorten the cycle of technological transformation [5].

The material properties of middle groove as shown in Table 1.

| Components   | Material name | Young's modulus | Poisson's ratio | Yield strength | Tensile strength |
|--------------|---------------|-----------------|-----------------|---------------|-----------------|
| Groove       | 30MnSiMo      | 2.02E5          | 0.3             | 766.07        | 862.03          |
| Middle plate | NM360         | 2.02E5          | 0.3             | 950           | 1080            |
| Bottom plate | NM360         | 2.02E5          | 0.3             | 950           | 1080            |
| Concave end  | 20MnVB        | 2.02E5          | 0.3             | 885           | 1080            |
| Convex end   | 20MnVB        | 2.02E5          | 0.3             | 885           | 1080            |
| Others       | Q345B         | 2.02E5          | 0.3             | 345           | 550             |

2.2 Finite element analysis of the groove in middle groove
The stress distribution diagram of the shovel groove is shown in Figure 1. The stress sipe of the groove is shown in Figure 2. The stress sipe of the groove is shown in Figure 3. The equivalent surface stress cloud is shown in Figure 4 The groove body is fully constrained on one side and the other side loads 720t at the dumbbell socket. In the stress cloud diagram, numerical specifications are made for the allowable stress of the material of 680 MPa and the allowable compressive stress of 1156 MPa. It can be seen from the figure that emerges to the action of 720t force, the dumbbell socket is only surface crushed, and the strength meets the requirements.
2.3 Finite element analysis of the middle groove

The hydraulic support of the middle groove of the 1350 scraper conveyor is about 100t and the pulling force is about 150t. Theoretical analysis shows that when the frame is pulled, the concave head of the groove is the maximum force. Figure 5 shows the force of the middle groove when the frame is pulled: the horizontal pulling force acting on the ear is 150t, and the concave head of the groove and the concave head of the shovel groove are completely restrained. Figure 6 is a graph of stress distribution at The maximum stress in Figure 4 is 485.8 MPa, which is less than the allowable stress of material ZG30MnSi of 680 MPa. The under the action of 150t pull force, the strength of the concave head of the groove and the ear can Meet the demand.
2.4 Finite element analysis of the middle groove when the shearer passes

Take the worst working conditions for analysis: the middle groove is in a suspended state, the single sliding shoe of the shearer has a force of 100t on the shovel and the working area is 635mm × 135mm. Figure 7 is a force diagram of the shearer Figure 8 is a stress distribution diagram at this time. Figure 9 is a graph showing the stress distribution when the sliding shoe is moved to the middle of the blade.

![Force diagram of the sliding shoe just entering the middle groove.](image)

**Figure 7.** Force diagram of the sliding shoe just entering the middle groove.
3. Structural optimization

3.1 Stress analysis of the concave and convex ends of the middle groove

The groove break is mainly the fracture of the shovel groove, and the fracture mode of the shovel groove is as shown in Figure 10: 1. occurs at the convex end; 2. occurs at the concave end. First, to reduce the stress value of the concave end, only the stress value of the concave end can be reduced to avoid the fracture of the concave end. After repeated trials, it was determined that the two methods can reduce the stress value of the concave end: one is to increase the length of the dumbbell rod concave end; the other is to increase the diameter of the bell mouth.

After experimental comparison, the method of increasing the diameter of the bell mouth in the two methods is more effective than increasing the length of the dumbbell rod. If both methods are used simultaneously, the effect is better than using any single method. Figure 11 is a stress distribution diagram of the dumbbell rod section under the force of 720t in the middle groove of the 1350 scraper conveyor, and the maximum stress value is 950 MPa.
3.2 Structural optimization analysis

According to the method of increasing the length of the dumbbell rod concave end, the length is increased from 146 to 156. At this time, the stress condition of the dumbbell rod concave end is as shown in Figure 12, and the maximum stress value of the action rod section is 910 MPa. According to the method of increasing the diameter of the bell mouth, the diameter is increased from 84 to 114. At this time, the stress of the dumbbell rod concave end is as shown in Figure 13, and the maximum stress value of the dumbbell rod section is 710 MPa. Finally, the first and second methods are applied simultaneously, that is, the length of the concave end dumbbell rod is increased from 146 to 156, and the diameter of the bell mouth is increased from 84 to 114. At this time, the stress condition of the concave end dumbbell rod section is as shown in Figure 14, and the maximum stress value of the dumbbell rod section at this time is 695 MPa.
It can be seen from the above analysis that the area exceeded 680 MPa is gradually reduced until it disappears. Table 2 shows the comparison between the original design and the three optimization schemes.

It can be seen from Table 2 that the percentage of stress reduction is the largest when the length of the dumbbell rod concave end and the diameter of the bell mouth are increased at the same time, and the optimization effect is the best.

**Table 2.** Comparison of analysis results of three optimization methods.

|                              | Length of the dumbbell rod (mm) | Diameter of the bell mouth (mm) | Maximum stress value (MPa) | Percentage of stress reduction |
|------------------------------|---------------------------------|---------------------------------|---------------------------|-------------------------------|
| The original design          | 146                             | 84                              | 950                       | 0                            |
| Increase the length of the   | 156                             | 84                              | 910                       | 4.21%                        |
| dumbbell rod concave end     |                                 |                                 |                           |                               |
| Increase the diameter of the | 146                             | 114                             | 710                       | 25.26%                       |
| the bell mouth               |                                 |                                 |                           |                               |
| Two methods                  | 156                             | 114                             | 695                       | 26.84%                       |
| superimposed optimization    |                                 |                                 |                           |                               |

4. Conclusion
In this paper, the nonlinear finite element method is used to model the middle groove. During the finite element analysis, it was found that the concave and convex ends of the groove had plastic deformation during the tension and compression process. In order to prevent the rupture of the concave end of the shovel groove, this paper proposes an optimization method to enhance the strength of the concave end of the shovel groove. According to the analysis, the length of the dumbbell rod and the diameter of the bell mouth are increased at the same time, and the optimization effect is best. The optimization improves the strength of the middle groove, effectively reduces the maximum stress value during the tension and compression process, maximizes the safety factor, and further improves the reliability of the scraper conveyor.

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