Research on process improvement and optimization design of a certain type of mine explosion-proof electric control box

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Abstract-In order to reduce the cost of electric control box and improve its beauty and universality, the design structure of a mine explosion-proof electric control box is improved in view of the disadvantages existing in the use of a certain type of mine explosion-proof electric control box; At the same time, for the problems of heavy self-reliance, high processing cost and poor heat dissipation of the existing electric control box, by changing the material, plate thickness, stiffener treatment at the appropriate position, or changing the plate structure of the box, the stress analysis is carried out under the pressure conditions, and the box with two schemes meeting the service conditions is designed and improved. At the same time, the manufacturing cost and heat dissipation of the box before and after the improvement are compared, which can be used as a reference for the design of electric control box in the future.

1. Introduction
Mining explosion-proof electric control box is widely used in vehicles, excavation, short arm equipment, etc. As the core control unit of the electrical part of coal mine equipment, its importance is self-evident. In addition to meeting the special explosion-proof requirements and use functions of the electric control box shell, the design also needs to meet the aesthetics of the box and the universality of the electric control box. In other words, similar devices use the same housing as much as possible, or the same box can be placed in different positions and directions of the same device without affecting the connection of its cable output, etc. At the same time, under the condition of pressure, the weight of the box is reduced as much as possible, the cost is reduced, the heat dissipation of the box is increased, the service life of the electrical components in the electric control box is prolonged, and the purpose of reducing cost and increasing efficiency is achieved. However, there is very little research on this aspect in the design of the electric control box in China. This paper makes a corresponding improvement design for these drawbacks of the electric control box in actual use. At the same time, under the condition of satisfying the test conditions, the electric control box is optimized for weight reduction, and two optimal design schemes are proposed, and then the heat dissipation and respective characteristics of the two optimized electric control boxes are analyzed.

2. Process improvement of box structure
Usually when designing the electric control box body, in order to take into account the use...
requirements of different users, or to be able to use a single shell for different equipment, and control boxes with different internal control methods, the box body is designed to meet the needs of different equipment. control of multiple inlet interfaces, As shown in Figure 1: In this way, when the electric control box is working, due to its special explosion-proof use requirements, the unused inlet device interface can only be blocked with a bell mouth and a gasket (for imported equipment, a gland is used), resulting in unnecessary cost increase. Aiming at this problem, the universal structure design of the cable entry device interface on the box is carried out, as shown in Figure 2:

![Figure 1 Improved front cable entry interface](image1)

**Figure 1 Improved front cable entry interface**

1- Unicom Section

![Figure 2 Improved cable entry interface](image2)

**Figure 2 Improved cable entry interface**

1- Interface blocking board    2- Tag assembly with connecting section

With this improved method, it is not necessary to use a high-cost bell mouth to block the cable entry device interface that is not needed in a piece of equipment, and only needs to process a small explosion-proof surface and add a small blocking plate. This design method can be flexibly extended and applied to the same equipment in different placement positions and directions of the box, which improves the flexibility of the use of the electric control box.

3. Optimal design of electric control box

The explosion-proof electric control box used in this department generally has a large safety margin during the pressure test, the box is heavy, and the cost is high. Especially for the box used for explosion-proof vehicles, it directly leads to high vehicle fuel consumption. Or because the selected board is too thick, resulting in problems such as poor heat dissipation of the box. Based on the principle of reducing cost and increasing efficiency, and improving the heat dissipation of the box, it is urgent to carry out an optimized design of the electric control box to lighten the weight and improve the heat dissipation of the box [1]. In this paper, a kind of thin coal seam explosion-proof electric control box is taken as an example, and the lightweight design research of upgrading and improving heat dissipation is carried out.

Taking into account the comprehensive mechanical properties of the material and the cost of the plate, the weight reduction of the box, the cost performance and other factors, the optimized shell was changed from the Q235A before the optimization to the Q345.
3.1 Optimization scheme

3.1.1 Introduction of the original box design

The box body is welded by rectangular steel plates of different sizes and thicknesses. It is divided into two chambers, large and small. It needs to meet the explosion-proof and hydraulic test, the pressure is 1 MPa, and the pressure is maintained for 10-12 s. visibly deformed. Since the periphery of the rectangular plate is fixed, its maximum force point is at the center of the plate, thus:

Center stress in x direction
\[ \delta_x = C_1 q \left( \frac{b}{h} \right)^2 \] (1)

Center stress in y direction
\[ \delta_y = C_2 q \left( \frac{b}{h} \right)^2 \] (2)

In the formula
- \( C_1, C_2 \)——corresponding rectangular plate coefficient;
- \( q \)——the pressure on the rectangular plate;
- \( b \)——the length of the short side of the rectangular plate;
- \( h \)——Thickness of rectangular plate

According to the overall size of the box, the yield strength of the selected material and the theoretically calculated plate thickness, the thickness of each plate of the box is finally determined. The main plate and other small cavity plates are respectively 22 mm and 16 mm thick steel plates.

3.2 Optimal design scheme

3.2.1 Optimal design scheme I

Based on the formed electric control box shell, the weight reduction optimization of the box body is carried out. Due to the small size of the wiring cavity, under the condition of constant pressure, the external force of each board in the small wiring cavity is small, which causes the deformation of the board to be relatively small. The steel plate with a thickness of 10mm is temporarily selected, and the reinforcement in the board is not considered; The cavity is large and the pressure is large. The main steel plate with a thickness of 12 is selected and the internal reinforcement is evenly arranged. Considering the internal space of the box, the width of the ribs is tentatively 20 mm and the thickness is 18 mm; first, build a three-dimensional model of the box to simulate the cavity pressure. In the test, apply pressure in all directions, pressurize 1Mpa, hold the pressure for 10-12 seconds, and find out the maximum stress point of the box. Under the conditions of changing the thickness and material of the box body, adding ribs, changing the position of the ribs, and the thickness of the ribs, etc., continue to analyze to find the best box design structure that meets the strength requirements and facilitates production.

The stress of the box under the condition of fully satisfying the yield strength of the selected material is analyzed, and the stress is shown in Figure 3 and Figure 4:

![Figure 3 The internal force of the box](image)
The maximum stress of the box shown in the figure is within the maximum yield stress allowed by the material. After the box meets the pressurization conditions and pressurization time, it can be restored to its original state to meet the requirements of use.

3.2.2 Optimal design scheme II
The main board is changed to a wave-shaped bending plate, and the plate thickness and corrugation height are continuously changed to meet the pressure test conditions of the explosion-proof box as shown in Figure 5 and Figure 6:

4. Comparison of three schemes

4.1 Comparison of weight loss optimization
The box structure is shown in Figure 7, and the three schemes are compared in Table 1:
Table 1 Comparison of the three schemes of the cabinet

| name                              | Original plan plate thickness (mm) | Optimization plan I thickness (mm) | Optimization plan II thickness (mm) |
|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|
| The main boards of the upper board| 22                                | 12                                | 6                                 |
| main cavity flange                | 30                                | 22                                | 22                                |
| door panel                        | 20                                | 18                                | 18                                |
| Ribs                              |                                    | 18                                |                                    |
| lower board                       | 22                                | 12                                | 12                                |
| other boards                      | 16                                | 12                                | 12                                |

The weight of the original box is 495 kg, the optimized scheme I is 91 kg lighter than the original box, and the optimized scheme II is 130 kg lighter than the original box. The cost of a single unit of the optimized scheme I is 1500 ¥ lower than the original one, and the cost of a single unit of the scheme II is 2340 ¥ lower than the original one.

4.2 Comparison of theoretical calculation of heat dissipation

The electric control box of this design relies on the natural heat dissipation of the box body and is cooled by the outside air, so the heat conduction of the electric control box body is stable heat conduction[4]. In the analysis, the temperature difference inside the box is ignored, and the thermal conductivity of the box is determined only according to the temperature difference between the inside and outside of the box and the thermal resistance of the box material. The thermal conductivity of the box under stable conditions[5]:

\[
Q = \frac{t_1 - t_2}{R_t}
\]

(3)

In the formula

\( t_1 \) —— The internal temperature of the box °C;

\( t_2 \) —— The temperature outside the box °C;

\( R_t \) —— Thermal resistance of the box material °Cꞏh/kcal

\[
R_t = \frac{\delta}{\lambda b} = \frac{\delta}{\lambda l}
\]

(4)

In the formula

\( \delta \) —— The thickness of the single-layer box;

\( b \) —— The thickness of the single-layer box;

\( l \) —— The length of the single-layer box;

\( \lambda \) —— Data for Select Matters in Thermal Conductivity

Select \( \lambda = 31.3 \), set the internal temperature \( t_1 \) of the box to 60 °C, the ambient temperature of explosion-proof electrical equipment to be -20 to 40 °C, and set the external temperature \( t_2 \) to be 25 °C, so the thermal conductivity of the original box is calculated as \( 2.8 \times 10^6 \) kcal/h, the thermal conductivity of optimization scheme I is \( 5.4 \times 10^6 \) kcal/h, and the thermal conductivity of
optimization scheme II is $14.57 \times 10^6$ kcal/h.

5. Conclusion
The two optimization schemes have their own characteristics. In the actual design, the requirements for the use of the cabinet, the batch size of the cabinet, and the required heat dissipation effect are comprehensively considered. Two schemes have been applied to the design of electric control boxes with different requirements. The use shows that after the improved structure and the optimized design of weight reduction, the aesthetics of the electric control box is improved, the manufacturing cost of the electric control box is reduced, the heat dissipation of the electric control box is increased, and the service life of the electrical components is prolonged. The cabinets of these two structural forms have been fully verified in practice, and the use effect is good.

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