Intelligent Equipment and Special Robots
Q. Zhang (Ed.)

doi:10.3233/ATDE240269

Study on Automatic Locking System of Explosion-Proof Cover of Fan in Coal Mine

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Abstract. Explosion-proof cover locking system is an important part of explosion-proof cover work. The existing platen type air back locking system has some problems, such as manual operation, complicated steps and long time. In this paper, the mechanical structure of the automatic locking system of explosion-proof cover is studied by analyzing the requirement of the system. Through the finite element analysis of the box, it is proved that the designed box structure and strength meet the requirements. The system control program is designed to realize the function of automatic locking of explosion-proof cover, improve efficiency and reduce the probability of workers being injured.

Keywords. explosion-proof cover, locking system, PLC, finite element analysis

1. Introduction

As an important part of ventilation system, explosion-proof cover is very important to improve the safety of mine [1-6]. When there is a fire or toxic gas in the underground air inlet roadway, anti-wind fire must be carried out in time to prevent the flame and toxic gas from entering the mining area and endangering the lives of miners, which requires timely compression of the explosion-proof cover and positive pressure to enforce anti-wind in the underground. At present, the pressure plate type anti-air lock system needs to manually complete the clamping operation of explosion-proof cover, which is cumbersome and cannot be completed quickly, so it is necessary to study the automatic locking device to improve efficiency and ensure the safety of workers.

Aiming at the automatic locking of explosion-proof cover, Zhang Chi [7] et al. designed an intelligent anti-wind system by using hydraulic equipment. Xun Hongfei [8] et al proposed self-compound explosion-proof cover and applied stroke switch to solve the problem of automatic control of explosion-proof cover. Yu Jianting [9] et al. designed an electric pneumatic locking device for explosion-proof cover to realize one-key air reversal; Mikhail A. Semin [10] et al. The optimization of automatic ventilation system is realized by studying the optimal control algorithm. The automatic locking system of explosion-proof cover of ventilator studied in this paper is driven by servo motor and driven by gear. It has reliable structure and can automatically, quickly and efficiently lock the explosion-proof cover within a specified time.

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2. Modeling of mechanical structure of reverse wind locking device

The mechanical structure of the anti-wind locking device used in the explosion-proof cover automatic locking system is composed of four parts: box base, electric locking device, belt drive and motor. The three-dimensional model is shown in Figure 1.

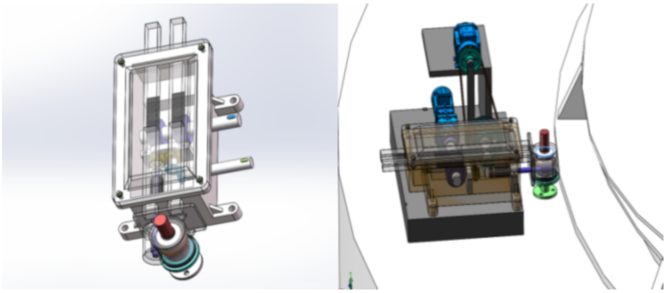


Figure 1. Mechanical structure of anti-wind locking device

The anti-wind locking device applies decelerating motor and three-phase asynchronous motor to meet the needs of use; The locking device is mechanically locked. When working, the reducer motor controls the gear drive rack through the coupling to extend the locking connecting rod horizontally. After reaching the limit, the three-phase asynchronous motor drives the bevel gear to reverse through the V-belt, realizes the worm rotation through the cylindrical gear, and then drives the worm gear to rotate, and realizes the vertical movement through the thread rotation.

3. Case finite element analysis

Through the finite element simulation of the box of the anti-wind locking device, the structure of the box and the selection of materials are analyzed.

The box material of the anti-wind locking device is made of steel 20MnCr5, with an elastic modulus of 209GPa, a Poisson ratio of 0.280, a density of 7810kg/m^3, and a yield strength of 1230MPa. Take the up and down direction of the anti-wind lock device in normal operation as the Z axis, and impose a fixed constraint on the box. Because the box is subjected to the vertical upward force C transmitted by the wellhead during operation, a load of the same size as force C is applied. The calculation process of force C is as follows:

It is known that the positive pressure of the fan back wind is 2700Pa, the radius of the explosion-proof cover is 5000mm, and the vertical upward force on the wellhead can be calculated from formula (1)

$$F = P \times A = 2700 \times \pi \times 5^2 = 211950N \tag{1}$$

The automatic anti-wind locking system designed in this paper adopts 4 anti-wind locking devices, and the force of one locking device is C=52987N.

In this way, finite element analysis is carried out on the box of the anti-wind locking device, and its stress analysis diagram is shown in Figure 2. It can be seen from the figure that under the condition of anti-wind force, the maximum stress and minimum stress of the box are 159.9MPa and 0.098MPa respectively, and the yield stress is 750MPa.

Take the safety factor as 2 to carry out the stress analysis. The stress analysis diagram of the safety factor is shown in Figure 3.

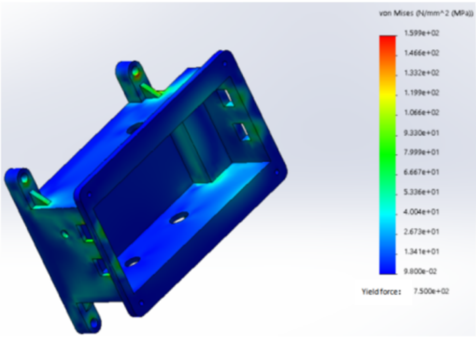


Figure 2. Stress analysis diagram of box

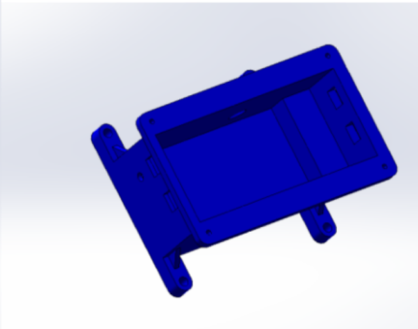


Figure 3. Box safety factor stress analysis diagram

In Figure 3, all the boxes are shown in blue, that is, all the positions of the box do not exceed the bearing limit of the material, so the box can meet the strength requirements and the design is reasonable.

4. Control system design

In this paper, SMART 200PLC is used as the control unit, and it can be integrated into the centralized control system of the fan by means of communication. The simple movement structure of the explosion-proof cover automatic locking system is shown in Figure 4. M1 is the motor that controls the horizontal left and right movement of the locking device, M2 is the motor that controls the vertical up and down movement of the locking device, SQ1 is the left position detection switch, SQ2 is the right position detection switch, SQ3 is the upper position detection switch, and SQ4 is the lower position detection switch. When the system receives the reverse air instruction and the fan change instruction, the explosion-proof cover locking device works successively according to the horizontal right to right limit position, delay 1s, and move vertically down to the lower limit position; When the system receives the stop instruction, the explosion-proof cover locking device resets, and then moves vertically up to the upper limit position, delay 1s, and horizontally move from left to left limit position.

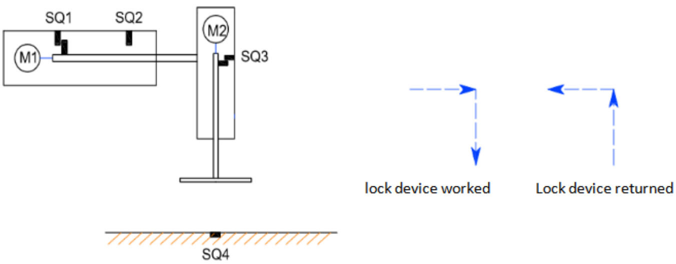


Figure 4. Simple structure and working cycle of the anti-wind locking device

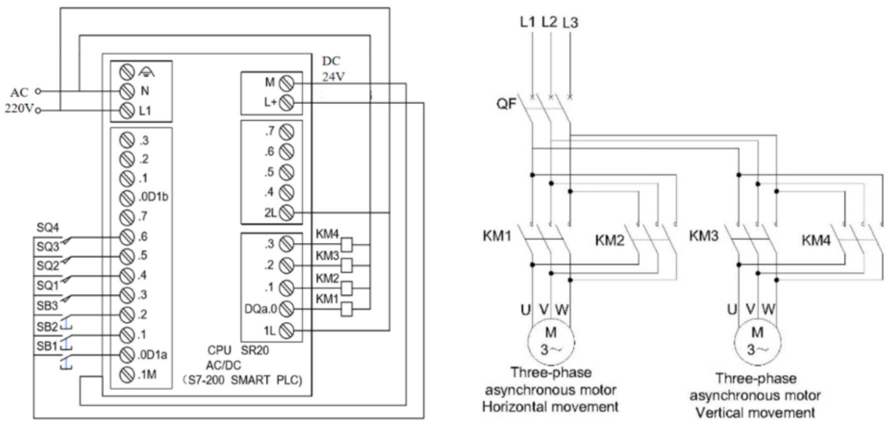
The input/output devices determined according to the above control requirements and their assigned I/O terminals are shown below.

Input devices: reverse air command start control SB1 corresponds to I0.0, fan change command start control SB2 corresponds to I0.1, stop control SB3 corresponds to I0.2, left position detection SQ1 corresponds to I0.3, right position detection SQ2 corresponds to I0.4, up position detection SQ3 corresponds to I0.5, and down position detection SQ4 corresponds to I0.6.

Output device: The control lock device moves KM1 coil right corresponding to Q0.0, the control lock device moves KM2 coil left corresponding to Q0.1, the control lock device moves KM3 coil down corresponding to Q0.2, and the control lock device moves KM4 coil up corresponding to Q0.3.

The PLC control circuit diagram of the explosion-proof cover locking device is shown in Figure 5. The control process of the explosion-proof cover automatic locking system is as follows:

(1) When the explosion-proof cover locking system receives the reverse air instruction and fan change instruction, the locking device should be located at the upper left limit position, and SQ1 and SQ3 are closed (origin 1); After the wind is reversed and the fan is changed, the locking device should be located at the lower limit position on the right, and SQ2 and SQ4 are closed (origin 2). If the origin condition is not met, the origin detection program returns the locking device to the origin before it starts working.



(a) Control circuit section (b) Main circuit section

Figure 5. PLC control circuit diagram of anti-wind locking device

(2) Motion process control

Startup process: When receiving the reverse air instruction or the fan change instruction, press the start button SB1 or SB2, the contactor KM1 coil is powered, and the locking device is moved to the right through the motor M1. When the right shift is in place, the timer is timed for 1s, the contactor KM3 coil is powered, and the locking device is moved down through the motor M2. When the downward shift is in place, the downward shift switch SQ4 is closed and the start is complete.

Stop the process: After receiving the stop command, press the stop button SB3, the contactor KM4 coil gets power, and the motor M2 drives the locking device to move up; when the upward movement is in place, the upshift switch SQ3 closes; after the timer is timed for 1s, the contactor KM2 coil gets power, and the motor M1 drives the locking device to move left; when the left movement is in place, the left shift switch SQ1 closes. The reset succeeded.

5. Conclusion

This paper analyzes the functions and existing defects of the explosion-proof cover locking system of coal mine ventilator, and improves the functional requirements and scheme design of the automatic locking system.

(1) Through three-dimensional modeling of the locking device and finite element analysis of the box, it is found that the maximum stress and minimum stress of the box are 159.9MPa and 0.098MPa respectively; The safety factor stress analysis diagram of the box is all blue, which proves that the design is reasonable.

(2) Design the system control program based on PLC to realize automatic locking of the locking device, improve efficiency and ensure worker safety.

References

[1] B.C. Yu, L.S. Shao. An optimization method of mine ventilation system based on R2 index hybrid multi-objective equilibrium optimization algorithm. *Energy Reports* **8** (2022), 11003-11021.
[2] Y.Y. Gao. Research on Optimization of ventilation System in Coal Mine. *Jiangxi Chemical Industry* (2019), 218-219.
[3] L. Liu, J. Liu, Q.C. Zhou, et al. Machine learning algorithm selection for windage alteration fault diagnosis of mine ventilation system. *Advanced Engineering Informatics* **53** (2022).
[4] M. Bascompta, L. Sanmiquel, et al. Airflow Stability and Diagonal Mine Ventilation System Optimization: A Case Study. *Journal of Mining Science* **54** (2018), 813-820.
[5] Z.G. He. Improvement of Explosion-proof cover of Return air Shaft in Coal Mine. *Machinery Management Development* **33** (2018), 208-209+284.
[6] S. Yin, S.Q. Yang, et al. Discussion on automatic open/close control of flameproof cover applied to mine emergency rescue. *Coal Science and Technology* **46** (2018), 198-202.
[7] C. Zhang, J.P. Wan, G.L. Luan. Development and application of intelligent anti-wind system in complex ventilation mine. *Coal Science and Technology* **48** (2020), 107-110.
[8] H.F. Xun, H.F. Bai, et al. Design of coal mine self-entry explosion proof cover. *Coal* **12** (2011), 59-60.
[9] J.T. Yu, H.W. Dong, et al. One-key air reverse system of main fan in Tianzhuang Coal Mine. *Safety in Coal Mine* **49** (2018), 90-91+95.
[10] M.A. Semin, L.Y. Levin, et al. Development of automated mine ventilation control systems for belarusian potash Mines. *Archives of Mining Sciences* **65** (2020), 803-820.