

Research on Inspection Technology of Limited-rotation Explosion-proof Electric Actuators for Coal Mines

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Abstract. Based on the analysis of the status of the coal resource industry and the intelligent construction of coal mines, this paper introduces the application scenarios, design basis, and composition structure of the explosion-proof limited-angle electric actuator in coal mines. It establishes an inspection platform for the explosion-proof limited-angle electric actuator in coal mines and achieves the testing of rated travel time error of the explosion-proof limited-angle electric actuator in coal mines.

Keywords: Mine, limited-rotation, actuator, inspection.

1. Introduction

In recent years, driven by the continuous development of the Chinese economy and the improvement of people's living standards, the demand for energy in various industries has been increasing. The current energy situation of "rich coal, deficient oil, and scarce gas" determines that coal will maintain its predominant position and play a vital role in the energy system of China, serving as a stabilizer. The coal industry is a crucial foundation industry that is vital to the national economic lifeline and energy security. In the context where large-scale low-cost carbon reduction and large-scale low-cost energy storage have not made breakthroughs, coal is facing challenges to breaking through the bottleneck of carbon emissions, and renewable energy is struggling to achieve high proportion integration into the existing energy system. Therefore, for a considerable period, coal will continue to be the "stabilizer" for ensuring stable and secure energy supply, supporting the adjustment of the energy structure and the transformation and development of the energy sector.

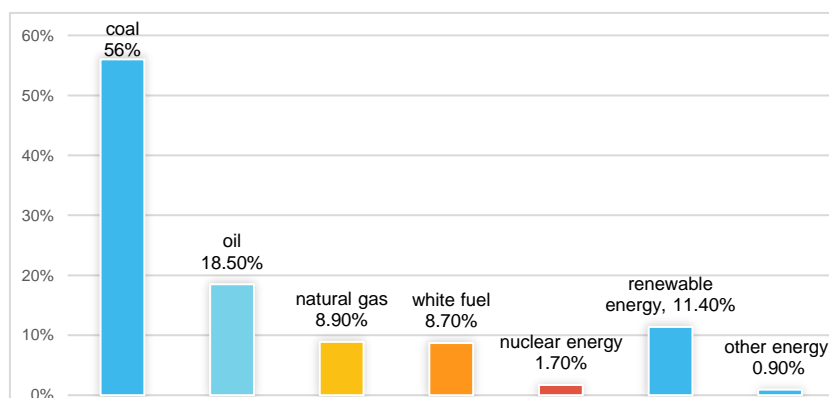


Figure 1. Proportion of energy consumption in a given year

In order to promote the integration and development of intelligent technology and the coal industry, and to enhance the level of intelligence in coal mines, in March 2020, the National Development and Reform Commission, the National Energy Administration, the Ministry of Emergency Management, the State Administration of Coal Mine Safety, the Ministry of Industry and Information Technology, the Ministry of Finance, the Ministry of Science and Technology, and the Ministry of Education jointly formulated the "Guiding Opinions on Accelerating the Development of Intelligent Coal Mines". It proposed strengthening the theoretical research of intelligent coal mines and the

construction of national key laboratories and engineering (research) centers. It also called for support in establishing platforms for technological innovation in intelligent coal mines. Furthermore, it emphasized the development of common key technologies such as core basic components, advanced basic processes, and key basic materials. The opinions also highlighted the key breakthroughs in precise geological exploration, accurate positioning and efficient continuous data transmission, intelligent rapid excavation, intelligent fully mechanized mining under complex conditions, continuous auxiliary transportation, unmanned continuous operation in open-pit mining, intelligent perception and early warning of major hazardous sources, coal mine robots, and digital electronic detonators in underground mines and other technologies and equipment. It further urged the acceleration of the construction of intelligent factories and digitized workshops, the promotion of the research and industrial application of large-scale coal mining equipment and coal mine robots, and the implementation of special measures for mechanization and automation to reduce human labor, with the aim of increasing the modularization and domestication level of intelligent equipment. Coal mine robots, trackless rubber-tyred vehicles, inspection robots, and other equipment are the key directions for the intelligent development of coal mines, and they are expected to lead the mechanization, automation, informatization, and intelligent construction of coal mines, offering broad market prospects and development space.

2. Coal mine explosion-proof limited angle electric actuator

With the development of intelligent technology in coal mines, mining robots, mine inspection instruments, and trackless rubber-tyred vehicles are increasingly being used as carriers for intelligent mining in underground coal mines. Mining robots are machines that can rely on self-power and autonomous control to perform specific mining functions. They can assist or replace human mining operations or operate in hazardous positions through command, pre-programming, and artificial intelligence planning. Broadly, the connotation of coal mine robots is rich, and according to different underground operation areas and functional positioning, coal mine robots can be divided into five categories, including excavation, coal mining, transportation, safety control, and rescue. Trackless rubber-tyred vehicles are suitable for auxiliary transportation operations in underground coal mines, mainly used to transport general auxiliary materials, small equipment, and for engineering construction in mine galleries and underground road surfaces. Trackless rubber-tyred vehicles are composed of explosion-proof engine devices, exhaust explosion-proof systems, mechanical transmission systems, hydraulic systems, electric start (or air start), electric protection systems, and explosion-proof electrical systems.



Figure 2. Mining tracked firefighting reconnaissance robot



Figure 3. Explosion-proof diesel engine trackless rubber wheel vehicle

The design of coal mine explosion-proof limited-rotation electric actuator products complies with the requirements of the national standard GB/T 3836.1-2021 “Explosive atmospheres Part 1: Equipment - General requirements” and GB/T 3836.2-2021 “Explosive atmospheres Part 2: Protection by constructional safety d” and is widely used in coal mines under gas and dust explosive environments. The coal mine explosion-proof limited angle electric actuator is composed of explosion-proof housing, power mechanism, and conversion mechanism. It is the power source for intelligent mining equipment in coal mines such as mining robots, mine inspection instruments, and trackless rubber-tyred vehicles, playing the role of converting electrical energy to mechanical energy. It is a core component of intelligent mining equipment in coal mines, and its reliability and safety directly impact the safety of intelligent coal mining equipment.

3. Inspection platform design

The type test of the coal mine explosion-proof limited-angle electric actuator mainly includes the test of the shell’s pressure resistance, the non-propagation of internal ignition, the highest surface temperature, dielectric performance, rated stroke time error, and hysteresis, among other inspection items. The product is considered qualified if it passes all type test inspection items. The inspection platform for the rated stroke time error of the coal mine explosion-proof limited-angle electric actuator is composed of a test platform, power supply, load device, steel ruler, oscilloscope, and other components. The test platform is used to secure the coal mine explosion-proof limited-angle electric actuator product in place. The power supply provides operating power for the coal mine explosion-proof limited-angle electric actuator. The steel ruler is used to test the linear stroke of the coal mine explosion-proof limited-angle electric actuator. The oscilloscope is used to collect the rated stroke time of the coal mine explosion-proof limited-angle electric actuator. The structure of the inspection platform for the coal mine explosion-proof limited-angle electric actuator is shown in Figure 4.

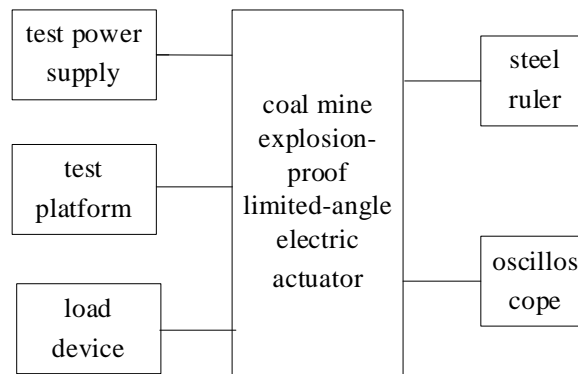


Figure 4. Inspection platform structure diagram

The test for the rated stroke time error of the coal mine explosion-proof limited-angle electric actuator involves adding a step signal sufficient to move the output shaft (rod) of the electromagnetic mechanism by the rated stroke, and recording the time it takes for the output shaft to move the rated stroke. The rated stroke time error is calculated according to formula (1):

$$\delta_1 = \frac{t_1 - t}{t} \times 100\% \tag{1}$$

Where:

- Rated stroke time error, %;
- The actual time it takes for the output shaft to move the rated stroke, in seconds (s);
- The theoretical time it should take for the output shaft to move the rated stroke, in seconds (s).

4. Conclusion

The explosion-proof limited-angle electric actuator for coal mines is a key component of mine robots, mine inspection instruments, and mine trackless rubber-tired vehicles, providing power for the intelligent equipment in coal mines. The establishment of the test platform for the rated angle (travel) time error of explosion-proof limited-angle electric actuators in coal mines has enabled the testing of rated linear travel and action time, providing an inspection platform to enhance the quality of explosion-proof limited-angle electric actuators in coal mines.

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