Academic Journal of Engineering and Technology Science
ISSN 2616-5767 Vol.3, Issue 8: 98-104, DOI: 10.25236/AJETS.2020.030811

Design of environmental simulation experimental device for testing insulation evolution law of explosion-proof electrical appliances in coal mines

Hongkui Zhang[1, 2, *], Dejun Tong[1, 2], Tingliang Li[3], Aimin Liu[4], Wenhai Yu[1, 5]

[1] *CCTEG Shenyang Research Institute, Fushun Liaoning 113122, China*
[2] *State Key Laboratory of Coal Mine Safety Technology, Fushun Liaoning 113122, China*
[3] *Taiyuan Huite Science & Technology Co., LTD, Jinzhong Shanxi 030600, China*
[4] *Shenyang University of Technology, Shenyang 110023 China*
[5] *Datong Coal Mine Group Electromechanical Equipment Science and industry Safety Instrument CO., LTD Datong Shanxi 037000 China*
[*] *Corresponding author e-mail: 18940021505@126.com*

ABSTRACT. *In order to study the evolution law of insulation of explosion-proof electrical appliances in coal mines and realize the simulation of underground operation environment in coal mines, the design scheme of simulation experimental device for underground operation environment in coal mines was put forward. On the basis of analyzing the situation of coal mine safety production, the types of coal mine explosion-proof appliances, their functions in safety production and the harm of insulation damage, this paper puts forward the main technical indexes of the environmental simulation experimental device based on the technical requirements in national standards, and designs the overall structure, box body, transportation system and temperature and humidity adjustment system of the environmental simulation experimental device for testing the insulation evolution law of coal mine explosion-proof appliances.*

KEYWORDS: *Explosion-proof electrical appliances, Evolution of insulation, Environmental simulation, Device design.*

1. Introduction

In recent years, under the comprehensive influence of many factors, such as the guidance of national policy, the promotion of safe mining theory, and the progress of comprehensive mechanization technology, the situation of coal mine safety

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production in China has been improving continuously, and the total number of coal mine safety production accidents and the death rate of one million tons have been declining continuously. In 2019, there were 170 fatal accidents and 316 deaths in coal mines nationwide, which decreased by 24.1% and 5.1% respectively. The mortality per million tons was 0.083, down 10.8% year on year. However, the hidden dangers of accidents affecting the safety production of coal mines in China have not been completely eliminated. The number of accidents and deaths in coal mines are still higher than those in other primary energy industries, and the safety production of coal mines is still a focus of future work. With the increasing depth of coal mining and the continuous development of underground comprehensive mechanized coal mining technology, the types and quantity of explosion-proof appliances in coal mines cannot be increased. Mechanical and electrical accidents caused by explosion-proof electrical appliances in coal mines have become one of the major accidents endangering coal mine safety production. At the same time, mechanical and electrical accidents can also cause other accidents such as transportation and gas explosion.

Coal mine explosion-proof electrical equipment mainly refers to the electrical equipment which is used in coal mines and mines with explosive gas outburst, can avoid the explosion of combustible gas such as gas in the use environment caused by internal spark through explosion-proof shell, and has its own explosion-proof capability. Coal mine explosion-proof electrical equipment is the main control equipment of power transmission and distribution and power consumption system in coal mine power grid, which mainly includes mine flameproof high-voltage distribution equipment, mine flameproof low-voltage feed switch, mine flameproof high-voltage and low-voltage vacuum electromagnetic starter, mine flameproof multi-circuit combination switch, mine flameproof electric control box and mine flameproof lighting signal comprehensive protection device, etc. It embodies switching in and out branch power grid, switching on and off power consumption equipment, fault detection and protection of coal mine power grid, etc. Coal mine explosion-proof appliances run in a humid environment with large temperature difference between day and night, and are also affected by other unfavorable factors such as dripping water, condensation and coal dust, which leads to accidents such as insulation breakdown and partial discharge. The environmental simulation experiment device is used to assess the insulation strength and electrical performance stability of coal mine explosion-proof electrical appliances under special temperature and humidity conditions, and can also test the insulation evolution process of coal mine explosion-proof electrical appliances. Therefore, it is of great significance to carry out the research on the control technology of environmental simulation experimental device for improving the insulation strength and safety of explosion-proof electrical appliances in coal mines, avoiding electromechanical faults and accidents, and ensuring the smooth development of underground safety production.

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2. Requirements of environmental simulation experiment device

The national mandatory standard GB 3836.1-2010 "explosive environment-part 1: general requirements for equipment" stipulates that class I electrical equipment must undergo wet heat test. The severity level of the test shall comply with the provisions of the current hot and humid zone electrical product standard: high voltage electrical equipment, +40℃, 21d; days; Low voltage electrical equipment, +40℃, 12d; Portable electrical equipment, +40℃, 6d, wet heat test method according to GB/T 2423-2008. MT/T 661-2011 "General Technical Conditions for Electrical Equipment Used in Coal Mines" stipulates the technical requirements of environmental parameters and environmental tests for electrical equipment used in coal mines.

Combined with the national standard GB/T 10586-2006 technical conditions of damp-heat test chamber, GB/T 11158-2008 technical conditions of high-temperature test chamber, GB 3836.1-2010 "Explosive Environment Part 1: General Requirements for Equipment", and GB/T 2423.4-2008 "Environmental Testing of Electrical and Electronic Products Part 2: Test Methods Test Db Alternating Damp-heat". The main technical indexes of the environmental simulation experimental device are determined as follows: temperature range: 0℃ ~+80℃, temperature fluctuation: ≤1℃, temperature uniformity: ≤2℃, humidity range: 30 ~ 98% RH (temperature range: +20℃ ~+80℃).

3. Design of environmental simulation experiment device

The environment simulation experimental device for insulation evolution test of explosion-proof electrical equipment in coal mine can simulate the special environment such as high and low temperature cycle and humidity change in coal mine, and is suitable for high and low temperature test, damp heat test and insulation performance evolution rule test of explosion-proof electrical equipment in coal mine. It adopts modular design idea and is composed of box body, transportation system, power supply system, temperature and humidity adjustment system, control system and display system. The structure diagram of simulation experiment device for insulation evolution test environment of coal mine explosion-proof electrical appliances is shown in Figure 1. The box provides a space environment for simulating the special environment in coal mines, and is the place where the explosion-proof appliances in coal mines are placed. The transportation system converts electrical energy into mechanical energy and provides power for coal mine explosion-proof appliances to enter and exit the box. Power supply system is the energy source of the whole system, providing power for transportation system, control system, temperature and humidity adjustment system and display system. Temperature and humidity adjusting system is used to adjust the temperature and humidity in the box, and realize the simulation of the underground operation environment of coal mine. The control system converts the control instructions into digital signals to control the whole system. The display system is used to display

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system temperature, humidity, voltage, current and other information, as well as system running status and fault information.

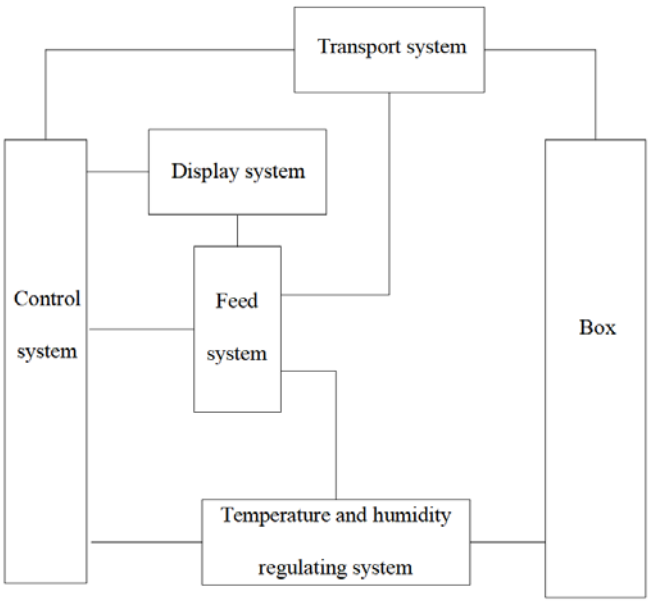

Figure. 1 Structure of simulation experiment device of coal mine explosion-proof electrical insulation evolution test environment

3.1 Box

The box of the environmental simulation experiment device for insulation evolution test of explosion-proof electrical appliances in coal mines adopts a sunken structure, the plane of the inner container is flush with the ground outside the box, the inner and outer tracks of the box have the same gauge and the upper surface is flush with the ground, and the inner and outer tracks are disconnected to prevent heat transfer. In order to reduce the deformation of the box body caused by thermal deformation and expansion, the welding area of the inner wall of the box body is designed to be telescopic, and stainless steel decorative plates are installed outside the expansion joints. The insulation material of the box body has the characteristics of low heat transfer coefficient, high strength and no water absorption. After the equipment is insulated at 0℃ for 24 hours without load, no frost or condensation shall appear on the outer surface, door crack, joint and lead hole of the box body. The door of the box body adopts a split structure, with reinforced profiles embedded inside and stainless steel edging around to ensure that the door panel and the door frame are closely attached. The gate is sealed by rotating reinforced hinge and double-layer high and low temperature resistant soft silicone rubber sealing strip, which is embedded and shielded by conductive sealing cloth pad sealing strip.

ISSN 2616-5767 Vol.3, Issue 8: 98-104, DOI: 10.25236/AJETS.2020.030811

3.2 Transport system

Coal mine explosion-proof electrical insulation evolution test environment simulation experimental device transport system supporting 30 tons of load-bearing car, using electric pin teeth in and out of the way. The trolley is composed of an electric pin tooth tractor and a flat load-bearing vehicle, and gears are installed on the tractor. A pin tooth is installed on the ground in the middle of the track outside the box, and the tractor moves back and forth on the track through the pin tooth transmission. The front end of the tractor has a traction rod, which is connected with the traction frame on the load-bearing car in the box manually, driving the load-bearing car in and out of the box. The load-bearing car is designed with all stainless steel. The structure of the trolley is shown in Figure 2.

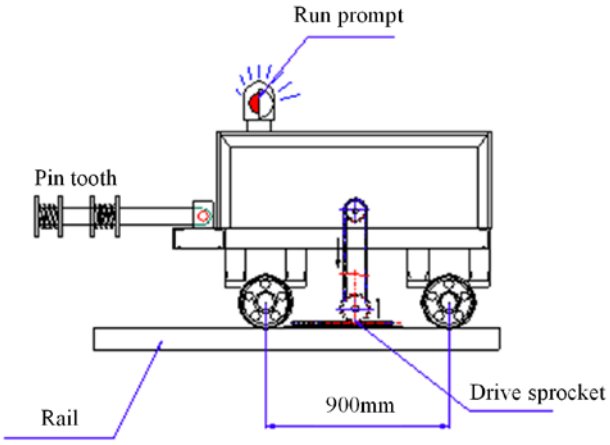

Figure. 2 Schematic diagram of the structure of the transport trolley

3.3 Temperature and humidity regulating system

The temperature control of temperature and humidity control system of the environmental simulation experiment device for insulation evolution test of coal mine explosion-proof electrical appliances is compared with the set value by collecting the signal of temperature sensor, and the temperature in the equipment box is dynamically balanced by the closed-loop control mode of automatically adjusting the heating power or refrigerant flow. Pt 100 is selected as the temperature monitoring sensor of temperature and humidity control system. The sensor can directly output RS 485 signal or 4-20mA analog signal, and has the advantages of strong anti-interference ability, stable signal, wide output range, high precision, etc. The physical object is shown in Figure 3. The heater made of Ni-Cr alloy electric heating wire, insulated electrical ceramics and mica plate bracket has the characteristics of small surface load, sensitive temperature control and small temperature lag.

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Figure. 3 Temperature sensor

Environmental Simulation Experiment Device for Insulation Evolution Test of Explosion-proof Electrical Appliances in Coal Mine The humidity control of temperature and humidity control system compares the signal of humidity sensor with the set value. The system automatically adjusts humidification power or refrigerant flow rate, so that the relative humidity of air in the equipment box can reach dynamic balance. The water vapor condensation on the surface of the dehumidifying evaporator is realized by the cold energy generated by the previous compressor (mechanical vapor compression refrigeration), and the dehumidifying evaporator and the cooling evaporator are independent of each other. When the dew point temperature of the air in the cabinet is lower than the surface temperature of the dehumidifying evaporator, the water vapor in the air will condense on the surface of the evaporating coil.

4. Conclusions

In this paper, combined with the requirements of national standards, industry standards and the characteristics of underground production environment, a coal mine operating environment simulation experimental device is designed. It has the functions of temperature and humidity automatic adjustment, fault alarm and protection, real-time data display, etc. It provides a test platform for the study of insulation evolution law of explosion-proof electrical appliances in coal mines.

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