Structure and Simulation of Roadway Disaster Simulation Control System for High Temperature Smoke Drill

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Abstract: In view of the outstanding problems of the training environment in the high-temperature smoke environment, such as failing to meet the actual combat requirements, poor effect and low efficiency, an integrated simulation exercise system of high-temperature smoke for coal mine emergency rescue is established, which mainly includes the high-temperature smoke control system and the smoke control system. The high temperature drill control system adopts PLC control temperature algorithm and introduces PID fuzzy control rule. The simulation results show that high accuracy of temperature and flue gas concentration can be achieved through PLC fuzzy PID control. The system can simulate the hot smoke environment and achieve the purpose of the actual exercise.

1. Introduction
At present, the main disasters in China's coal mines are the explosion disaster caused by coal and gas outburst and the fire smoke caused by spontaneous combustion of coal seams [1]. In order to adapt to the harsh environment of high temperature and heavy smoke in coal mines during the catastrophic period, high temperature must be carried out regularly. Dense smoke exercise training, but the current high temperature, thick smoke environment is the original means of construction, the effect is poor, and can not be effectively controlled according to needs. The survey found that the current disaster environment simulation control system generally has backward modeling methods [2], and the problem that smoke is difficult to control and cannot achieve rapid automation compensation. In order to improve the quality of emergency rescue training and improve the ability of ambulance personnel to adapt to high temperature and smoke environment, it is urgent to conduct in-depth research on the automatic control system of temperature and smoke in high temperature exercise smoke.

2. High temperature smoke drill roadway control system
The high-temperature smoke drill roadway control system consists of three parts: the roadway monitoring system, the data processing system and the roadway control system [3]. The data processing system mainly processes the data collected and provides data support for system management. The function of the roadway monitoring acquisition system is to send the detected parameters of the collected high-temperature exercise roadway to the central control system; the main function of the high-temperature exercise roadway control system is to control Equipment and equipment in the roadway guide the entire system.

The high-temperature smoke drill roadway shall have the conditions for implementing high-temperature exercises and smoke exercises, and shall also have a quick smoke exhausting device after the exercise, as follows:
(1) High temperature disaster drills. During the high temperature disaster exercise, the temperature should be controlled at 60 °C, the insulation performance in the roadway should be intact, and the fan power should be controlled to control the temperature of the high temperature exercise lane.

(2) Smoke disaster drills. During the smoke disaster drill, the smoke machine is used as the smoke generating device in the roadway. The smoke emitted is smoke. It should be non-toxic, harmless, non-polluting, and slightly smaller than the air. It is controlled by the configuration software of the console. The concentration of smoke is controlled by the length of continuous smoking. Visibility in the training room is generally close to zero within 10 minutes. The smoke emitted by the smoke generating device is non-corrosive, non-toxic and free of residual gas. At the same time, the smoke generating device should have a multi-point timing smoke generating function.

(3) Ventilation and exhaust. After the exercise, the system quickly controlled the smoke by controlling the ventilation fan, and the smoke was discharged from the roadway through the exhaust port.

3. Disaster Simulation Control System

3.1. High temperature exercise control system

3.1.1 Heating method

Assume that the high temperature exercise roadway is 25 m long, 2 m wide and 3 m high. The total volume in the high temperature zone is 150 m³. According to the design requirements, the indoor temperature should be raised from 20 °C to 60 °C within 30 min. The temperature in the roadway is 20 °C, and the heat required to heat up to 60 °C is

\[ E = p v c = 1.29 \times 150 \times 1000 \times 313 = 60565500 \text{ J} = 16.82 \text{ KW} / \text{h} \]

Where: 

- \( v \) —— the volume of air;
- \( c \) —— the specific heat capacity of the air;
- \( p \) —— air density;
- \( \Delta T \) —— Temperature difference.

Since the roadway is long and underground, the dissipation factor is 50% \[^4\], the heating equipment efficiency is 90%, the heating time requirement is 30 min, and the total power required is 74.8 KW/h. According to the existing heating equipment, in order to meet the requirements of high efficiency and environmental protection, four 20 kw heating devices are selected to be placed in the four corners of the high temperature exercise roadway.

Temperature control adopts PLC-based solid state relay PID discrete control mode, as shown in Figure 1. The temperature in the high temperature zone is controlled at about 60 °C, and the control accuracy is within 1 °C \[^5\]. Due to the PID discrete control method, the heating fan is always started. The setting parameters can be changed according to actual needs. When the temperature is maintained, the electric fan operates at half power, and the temperature is automatically kept within the required range. At the same time, the temperature of the monitoring point in the roadway and the temperature outside the high temperature zone are displayed on the display outside the high temperature zone.
3.1.2 Temperature adjustment algorithm

When the data measured by the temperature sensor is fed back to the host controller, the PLC controller is used to adjust the temperature of the roadway. The temperature variation rate, integral time and differential time in the roadway are controlled by linear combination. The autocorrelation control state equation of temperature sensing data in high temperature drills is calculated.

\[
\int_0^\infty u(t) E(t) dt = \text{Autocorrelation of temperature data in high temperature tunnels}
\]

Where:
- \( L_q \) —— PLC logic programming control temperature change rate;
- \( T_I \) —— Integration time;
- \( T_E \) —— Differential time;

The exercise lane temperature control equation is expressed as

\[
\Delta v(t) = \theta_q \Delta f(t) + \theta_j f(t) + \theta_e [\Delta f(t) - \Delta f(t-1)]
\]

Where:
- \( \Delta v(t) \) —— Adjust the output of the output.
- \( \Delta f(t) \) —— The error of current system temperature and target temperature.
- \( \Delta f(t-1) \) —— The error value of system temperature and target temperature for the last sampling.
- \( \theta_q \) —— Tunnel temperature.
- \( \theta_j \) —— Integral parameter of temperature acquisition in drill roadway.
- \( \theta_e \) —— Differential parameters of temperature control in maneuver roadway.

By using the method of normal correlation state feature extraction and combining the advantages of automatic fuzzy matching of PID control regulation performance, a simple analytical control rule is introduced in fuzzy control theory, which can be expressed as follows:

\[
U = aE + (1-a)E_c, a \in [0,1]
\]

Where: \( U \) —— the amount of control;
$E_c$ —— control volume adjustment factor;

$a$ —— Configure weight coefficient

The fuzzy controller control deviation is compared. When the stability control deviation is large, the coarse adjustment is first performed. When the stability control deviation is small, the system is finely adjusted [6]. The temperature accuracy is maintained by the temperature adaptive adjustment of the high temperature exercise roadway. The control rules are shown in Table 1, and the temperature adaptive adjustment tracking curve is shown in Fig. 2.

| NB | NM | NS | ZO | PS | PM | PB | NB |
|----|----|----|----|----|----|----|----|
| NB | NS | ZO | NM | NM | NM | NS | NS |
| NM | NS | ZO | NM | NM | NS | ZO | PS |
| NS | NM | NM | NS | NS | ZO | PS | PM |
| ZO | NM | NS | NS | ZO | PS | PS | PM |

Fig. 2 Temperature control tracking curve

3.2. Smoke Exercise Control System

The smoke generation system consists of a smoke machine and a visibility detection sensor, and the smoke emitted by the smoking device is a non-toxic and harmless gas [7]. The concentration of smoke in the sides of the roadway is automatically controlled by the PLC. Assume that the length of the smoke lane is 25 m, and a smoke machine is placed every 5 m to divide the drill lane into five areas. Through the district to refine the flue gas compensation, each regional hood is responsible for the smoke concentration inside the area to maintain the visibility accuracy. Protection [8]. When the smoke concentration is maintained, the smoke concentration is set indirectly through the time of the smoke generation and the interval of the smoke generation.

3.3. Simulation

In order to verify the feasibility and effectiveness of the temperature fuzzy PID control algorithm, Simulink was used to simulate the temperature control system. First, enter the fuzzy open editor in the working window of Matlab, then add the input and output membership function to edit, select the triangle membership function, then add the control rules of the parameters, then compile the fuzzy controller in Matlab, and finally Establish a system simulation model, as shown in Figure 3.
Adjusting the PID initial parameters yields a simulation curve as shown in Figure 4. As can be seen from Figure 4, the adjustment time is at most about 180 s, the overshoot is $\% = 0$, and the steady state error is zero.

The simulation results show that the fuzzy PID control method can achieve the performance indexes required for temperature control such as short adjustment time, overshoot and zero steady state error. It has better temperature control performance and meets the temperature control accuracy requirements of high temperature exercise roadway.

4. Conclusion
   (1) The roadway disaster simulation control system of emergency rescue drill under high temperature and smoke environment mainly includes high temperature exercise control system and smoke exercise control system.
   
   (2) Based on PLC fuzzy PID control, an automatic control system for controlling temperature smoke is proposed, and an algorithm based on PLC to adjust temperature and smoke is given.
   
   (3) Temperature fuzzy PID control system can realize temperature control requirements with short mediation time, overshoot and zero steady state error.
   
   (4) The system can realistically simulate the high-temperature smoke environment and achieve the purpose of actual combat exercises. However, the research on the simulation system of other disasters
and the mine rescue team training system, equipment and technology research and development, sensor feedback data accuracy, and standardization construction must be further studied and improved.

Reference
[1] Li Xuecheng. China's coal mine safety [M]. Beijing: Coal Industry Press, 1998.
[2] Wang Daoqing, Jia Qiwen, Tian de Yu. Mine rescue [M]. Xuzhou: China University of Mining and Technology press, 2002.
[3] Liu Mao, Wu Zongzhi. Introduction to Emergency Rescue - Emergency Rescue System and Plan [C]. Beijing: Chemical Industry Publishing House, 2004.
[4] Hu She-rong, Jiang Dacheng. Research status and Prevention Countermeasures of spontaneous combustion of coal seam[J]. Chinese Journal of Geological Disaster and Prevention, 2000.11(4): 69-71.
[5] Wang Jiefan, Li Wenjun. China Coal Mine Accidents and Expert Comments [M]. Beijing: Coal Industry Publishing House, 2001.
[6] Yang Daming. Current situation of mine rescue in China [J]. contemporary miners, 2002. (4): 11-11
[7] Wang Xian Zheng. New technology of coal mine safety [M]. Beijing: Coal Industry Press, 2002.
[8] Wang Deming. Mine ventilation and safety [M]. Xuzhou: China University of Mining and Technology press, 2005.