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Field experiment on coalmine heat disaster governance using cold source from surface water

Guo Pingye [a,b], Zhu Guolong [a,b,*], Liu Yuqing [a], Duan Mengmeng [a], Wu Junyin [a]

[a] State Key Laboratory of Deep Geomechanics and Underground Engineering, China University of Mining & Technology, Beijing 100083, China
[b] National Energy Key Laboratory of Safe Mining and Disaster Control, Beijing 100083, China

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ABSTRACT

Regarding the lack of cold source for underground cooling systems from either mine inflow or return air, field experiments were taken in a high temperature deep coal mine with abundant cold source from surface water. Taking Sanhejian coal mine as an example, this paper introduced the technology scheme of heat disaster governance using surface water cold source. The paper presents the basics of this field experiment at the beginning, following by the design and site layout of the cooling system including the analysis and calculation of cold source. Numerical calculation method is also applied based on the operation parameters to simulate the influence to the surface river ecosystem. The results suggest that the temperature of surface water shall be lower than 34 °C after heat exchange, and when more cooling capacities are needed in the future, increasing the water flow is more favorable than increasing the cooling range of water, which is better for the ecological environment protection.

1. Introduction

With the trend of mechanization and mining depth increase, heat disasters become more and more serious in mines. Especially in the central and eastern parts of China, heat disaster governance is one of the key technical problems restricting deep coal mining, which draws more and more attention of domestic and foreign scholars [1–4]. Yet in recent years we have seen a flowering of cooling technology in China and other countries to govern heat disasters for deep mining activities and these technologies can be classified by the phase of refrigerant, the icy refrigeration technology, water refrigeration technology and the compressed air refrigeration technology. Air refrigeration system cannot meet the demands in most of the deep mines because of its scarce capacity in cold energy transport. The icy cooling system is gradually eliminated for its frequent blocking and large loss of cold energy. Therefore, water cooling system becomes the main cooling technology used in China, but it faces severe issues such as the cold source capture, the mixed wind cooling problems and etc. For now, there are some coal mines obtaining cold source from mine inflow or underground return air, but the cooling capacity sometimes cannot meet the demand in mines [5–10]. In this paper, field experiments have been performed to govern heat disasters by using surface water cold source in Sanhejian coal mine.

2. Background of experiment site

Sanhejian coal mine is located in the northern part of Xuzhou city with a warm monsoon climate. Local climate information has been investigated, and the local atmospheric pressure is 101.23 kPa, with average temperature 14.5 °C, maximum temperature 40.6 °C, minimum temperature −15.8 °C, and relative humidity around 69%. The rainfall concentrates in summer from June to August with the average rainfall around 831.7 mm per year. A river called Yaolou River runs through the mining zones with a large flow in summer and an average flow velocity of 0.28 m/s.

As shown in Fig. 1, from May to October, the average daily temperature is over 22 °C, and the highest temperature of the day is over 30 °C. Fig. 2 shows that the relative humidity from February to March exceeds 70% because of the spring rainfall, and that from May to October even reaches over 90%. Clearly, the period from May to October is the hottest and the most humid period for the Xuzhou region, aggravating the underground heat disaster problems in deep coal mines. Therefore it should be regarded as the target period for heat hazard governance.

3. Field experiment

3.1. Basics of experiment

This field experiment system belongs to water refrigeration technologies, instead of using mine inflow; the surface water from

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* Corresponding author. Tel.: +86 15810099581.
E-mail address: zhu.guolong.tt@gmail.com (G. Zhu).

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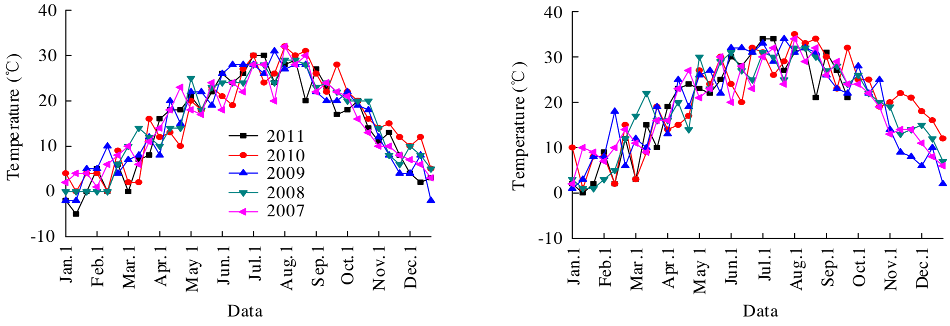

(a) Average daily temperature (b) Daily highest temperature

Fig. 1. Temperature variation from 2007 to 2011, Xuzhou.

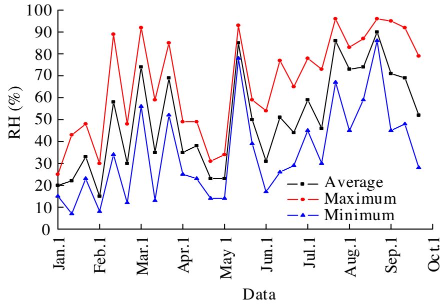

Fig. 2. Relative humidity variation in 2011.

Yaolou River is used as the cold source. The detailed design principles are shown in Fig. 3. The whole system can be divided into three parts, the cold source extraction system, the refrigeration module and the cooling module. Refrigerating module is composed by compressor, condenser, throttle valve and evaporator, consisting of two isothermal and two isentropic circulation processes. In the inverse Kano cycle thermodynamic process, the total quantity of cold Q_2 is transferred to the cooling system by the evaporator, and at the same time, the underground heat from surrounding rock and machines, as the total Q_1 demand, is transferred to the cold source through condenser, releasing heat to mine water, return air or surface water through the heat exchanger. It should be guaranteed that the total cold quantity is larger than the sum of required cold quantity Q_2 and W, the power of the compressor [11–12].

3.2. Design of the field test

Fig. 4 shows the procedure of this test. The first step is the collection of engineering conditions, including climate parameters, which have been introduced in Section 2, the heat source parameters and cooling source parameters, etc. The climate parameters include yearly temperature parameters, relative humidity changes and extreme climate conditions. Heat source parameters is the basis to calculate the underground heat source, mainly including the working face temperature, rock temperature, supplied air rate, working hours, daily coal quantity and the mechanical dissipate heat, etc. The cold source parameters are the ones that related to cold source in the mining area, including the capacity and temperature of mine inflow and return air.

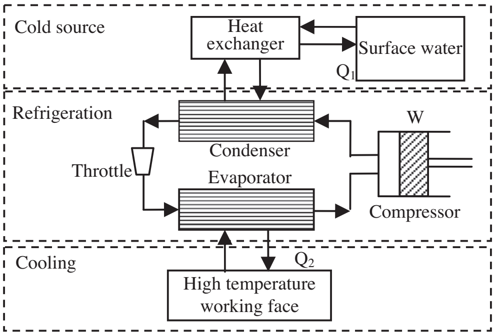

Fig. 3. Principle diagram of field test system.

The second step is the cold quantity demand calculation of the system according to the climate parameters and underground heat source parameters. At the same time, the analysis of the cold source is proceeded to see whether the cold quantity from mine water, return air and surface water can meet the demand of total cooling load. Thirdly, the design of experiment system is performed, including the cold source engineering design, heat exchange station design, the refrigeration workstation design and the cooling workstation design. Finally, the operation and debugging tests are conducted. Thermodynamic parameters of the system could be obtained before the adjusting and determination of optimal parameters for this cooling system.

All the parameters for cold quantity calculation are listed in Table 1, and the results are as follows: the cold quantity for cooling working face and heading end should be larger than 3960 kW, with the heat dissipation of mechanical and electrical equipment considered, the total amount of cold quantity should be 6000 kW [13–14].

Table 2 presents the detailed information about cold source in Sanhejian coal mine. The only cold source underground is return air, with only 2 MW cold quantity, which cannot meet the needs of cold for cooling. Surface water has to be considered as main cold source in Sanhejian mine. Based on roughly calculation, the surface cold source could be as much as 38 MW, which could meet the 6 MW demand as calculated in last section. Therefore, surface water should be used as the cold source for heat disaster governance in Sanhejian mine.

Fig. 5 is the site layout of main equipment in the cooling system. As shown in Fig. 5, HEMS-T is set on the ground by the Yaolou River, capturing the cold quantity from surface water; HEMS-PT and HEMS-I are located on −700 m level underground, transferring cold quantity to the refrigeration station of the system; HEMS-II is put on −980 m level, respectively, for the cooling of working faces and heading faces.

4. Discussion

4.1. Equilibrium parameters

When the cooling system enters the stage of stable operation, the equilibrium parameters could be acquired through the data