Cooling principle of high temperature heat exchange machinery system with moderate cold source

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Abstract. High rock temperature in deep coal mine is a problem, which restrains the exploration of coal resources, we must reduce the temperature humidity at working face. The HEMS (High temperature heat Exchange Machinery System) were developed by using coal mine water as cold source. The system is applied in Jiahe colliery with moderate cold source in phase I, for phase II, we proposed water circulation at different elevations as cold source and the cooling system run effective. Operational principle for HEMS-I was presented and gave the theoretical basis for optimization design. After cooling, air temperature at C point on working face is from 28~29 °C, it is less than 30°C and conform to coal mine safety regulation.

1. Introduction
In China, Coal mine is a kind of major energy source and it occupy more than 70% of China’s total primary energy consumption. Because of long time mining, coal resource become increasingly exhausted with exploitation depth less than 1 km. Therefore, deep exploitation of coal mines becomes very important [1]. For deep mining, the rock temperature on working faces will reach up to 31~41 °C [2]. Coal mines safety regulations in China stipulate that miners are not allowed to work once environmental temperature is more than 30°C[3], so we must decrease the deep mine temperature.

We can find two cooling methods [4]; one is mine ventilation and the other is water or ice cooling systems [1]. The cooling effect of ventilation is not very good. The popular cooling method used for deep mine cooling is air conditioner, the problem is it consume a lot of electricity [5]. Ice cooling need ice machine to produce ice. When ice melt into water, the temperature is decreased [6-9]. Practice has shown that there are problems in designing pipelines for ice transportation; the problem is that ice is easy to block in pipe [10].

HEMS(High temperature heat Exchange Machinery System) is developed and cold energy can be provided by mine water inrush. The cooling system not only reduces the working face temperature but also provide heat for building in winter. It has good economic and environment effect.

2. Equipment and working principles

2.1. HEMS
The working principle of the system is extracting cold energy from water in coal mine at all levels, and cold water exchanges heat with hot air blowing to working face, and air temperature is reduced. HEMS comprise three components: HEMS-I, HEMS-II and HEMS-PT. HEMS-I is cold energy extracting work station. HEMS-II is energy exchange station for cold water and hot air. HEMS-PT work station is used for pressure and cold energy transmission [11]. Working principle of HEMS is shown in Figure 1 [12].

Preliminary ideas and design of the system were developed by CUMTB (China University of Mining & Technology Beijing). The detailed design was performed by CLIMAVEAENT and the Freezer Limited Company of Shenyang Yileng.

For the choice of HEMS-I, we calculate two kind of energy. First we calculate heat energy from work zone, second is cold energy loss from pipes. HEMS-II is energy exchange station for cold water and hot air. HEMS-PT reduces water pressure in pipes between HEMS-I and HEMS-II. The two stations are at different depth, HEMS-I at 500 meters underground and HEMS-II at 1000 meters underground, height difference makes high pressure and the pipes can not support the large pressure, so HEMS-PT is built between the two work stations [13].

The cold source provided for the system is mine water rush, which is convenient to use the cold energy during the discharging of mine water. There is no pollution and no gas and solid waste produced by HEMS, which protect the environment and achieve economic and social benefits.

2.2. HEMS-I
The HEMS-I consist of six parts: compressor, condenser, expansion valve, evaporator, spreader and control system. A diagram and component of HEMS-I is can be seen in Figure 2. Refrigerant used in HEMS-I is R134a.
3. Case Study

3.1. The working principle of Jiahe cooling model

For Jiahe coal mine, a cooling model for heat hazard control was proposed using moderate cold source. HEMS technology was used according to its mine water inrush [15].

The exploitation depth of Jiahe mine is more than 1000 meters underground, with the maximum depth of about 1250 m, and consequently heat problem is obvious. The air temperature on working face is about 36 °C without cooling system, and mine water is from 95 to 135m³/h.

The mine water in Jiahe coal mine is enough and can meet the need of HEMS-I refrigeration station. Cold energy can be extracted from mine water and it is used for deep mine cooling, at the same time hot water is produced and it can be used for build heating and taking a shower instead of using the boiler.

There are two phases cooling project in Jiahe coal mine based on its mine water, for phase I, there is enough mine water inrush and its operating process is can be seen in Figure 4 (I). for phase II, the mine water inrush is not enough and we should reuse the discharged hot water and make it cool through flowing along the roadway, its operating process is can be seen in Figure 4 (II). HEMS was built to cool the air temperature on two working faces and four tunnels’ faces.

Figure 4 HEMS working process in Jiahe mine for phase I and II
In phase II, water from HEMS-I was discharged to Sump C from Sump B, through a long pipeline and the water temperature is reduced, then the water is discharged into Sump A, Thus the cooling system of water circulation at difference elevation is formed.

3.2. Effect analysis
HEMS were installed in Jiahe coal mine in 2007. Before and after HEMS-II, The air temperature on working face was monitored at the points (A, B, C, F1 and F2) assigned in Fig.5. The preliminary monitoring started from the end of July 2007 until February 2008. The data from the first two months in 2007 were selected for analysis, which were August 1, 10, 20 and 30 and September 10. Temperature monitoring curves are shown in Fig.5 and Fig.6 for August 1 and 20 and September 10. Table 1 summarizes the average temperatures of all points of Fig.5 to Fig.6.

| Date       | F1 | F2 | A  | B  | C  | C  |
|------------|----|----|----|----|----|----|
| Aug.1, 2007| 32.5| 23.5| 25.8| 26.6| 29.0| 36.1|
| Aug.10, 2007| 32.5| 24.0| 26.4| 27.2| 28.8| 34.5|
| Aug.20, 2007| 32.0| 24.0| 26.4| 27.5| 29.0| 35.1|
| Aug.30, 2007| 31.6| 23.6| 25.5| 26.8| 28.5| 34.0|
| Sep.10, 2007| 30.4| 22.0| 24.5| 25.5| 28.5| 34.0|

Through the data analysis of the monitoring data, it is possible to verify that the air temperature of controlling point C is less than 30°C, and meet the China’s requirements of coal mine air temperature safety regulations.

![Temperature monitoring points](image)

Figure 5 Temperature monitoring points and its temperature monitoring curve on August 1 at No. 7446 working face

(F1) Air temperature tested point before air flowing to HEMS-II; (F2) Air temperature tested point after the air through HEMS-II; (A) Air temperature tested point outside of coal conveyor; (B) Air temperature tested point inside of coal conveyor; (C) Air temperature tested point at the end of the working face.
4. Conclusions

The main conclusions are:

HEMS cooling project using moderate coal mine water as cold source was built and successfully applied in deep Jiahe coal mine. For phase II cooling project in Jiahe coal mine, the water circulation at different elevations for cold source was proposed and run high efficiently.

The operational principle for the workstation HEMS-I was presented, which gives the theoretical basis for optimization design.

Air temperature tested on controlled point C at the end of the coal face is from 28~29 °C, which is less than 30 °C and meet China’s deep coal mine safety regulation; while before HEMS cooling, the air temperature is from 34 to 35 °C, so the cooling effect is obvious.

HEMS is a new cooling technology to solve the deep coal mine heat problem. There is no pollution gas or solid produced, so it protects the environment. The cold energy is from coal mine water so this technology have a good effect on energy saving. In a word, HEMS has good economic and social effect and will have good prospect.

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