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Selection and Properties of Dehumidifier Based on Coal Mine Environment

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Abstract: *In recent years, with the gradual increase of mining depth, the harm of high humidity in the shaft becomes more and more serious, and the labor productivity of workers and the physical and mental health of personnel working in the shaft will be affected, leading to the reduction of economic benefit of mine production. Therefore, dehumidification has become an urgent problem to be solved in the mining industry. Aiming at the high humidity hazard in coal mine, this paper aims to reduce the relative humidity of air current in working face by using silica gel as dehumidifier, so as to improve the comfort of working environment.*
Keywords: Macroporous silica gel, dehumidification.

1. SELECTION OF DEHUMIDIFIER

The working environment of underground coal mine is extremely harsh. The temperature and humidity of air current in coal mining face and tunneling face are relatively high.

Dehumidifiers can be divided into two categories, liquid dehumidifier and solid dehumidifier. Solid dehumidifier should be used for air dehumidification in underground coal mine. The materials in charge are non-corrosive; The operation and control requirements are simple. Silica gel is a kind of highly active adsorption material, which belongs to amorphous substance. It is insoluble in water and any other solvent, non - toxic, tasteless, stable chemical properties, is a good dehumidifier. Therefore, in view of the environmental characteristics of high humidity in the underground coal mine, macroporous silica gel was selected as air dehumidifier in this paper.

2. DEHUMIDIFICATION PERFORMANCE OF SILICA GEL

Dehumidifier is a physical process of mass transfer and heat transfer. As a result of the contact force between the porous medium and the surface of the particles, the water vapor molecules in the wet air are absorbed to the surface of the porous medium. Water vapor condenses on the gas-solid interface and enters the solid phase. The condensed water is discharged from the solid phase. The dehumidification process of silica gel is completed.

2.1 Study on Hygroscopic Properties of Silica Gel

The static adsorption performance of silica gel refers to that silica gel contacts with the static wet air in the closed space to absorb moisture until it becomes saturated. Experiments with constant temperature and humidity test chamber to explore silica gel in the relative humidity is 70% and 70%, the temperature is 20 ℃, 25 ℃ and 30 ℃ respectively under the environment of moisture absorption properties. Seal the silica gel dehumidifier with a certain quality, test the temperature and humidity of the test box with a high-precision digital thermometer, and then put the silica gel and electronic balance in the test box, and record the data every 15 minutes.

The adsorption characteristic curve of silica gel is shown in FIG. 1 and FIG. 2. The results show that relative humidity is constant, and the hygroscopic rate is high in the initial stage. At the same time, it increases with the rise of temperature and finally reaches stability, which is about 113%. At the same temperature, the higher the humidity in the initial stage, the faster the moisture content changes until it remains unchanged. It can be seen that in the natural state, silica gel has good hygroscopic properties and is a good choice as an air dehumidifier.

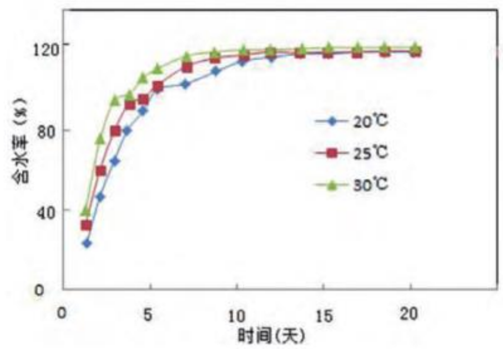

Fig.1 Silica gel adsorption characteristic curve when RH=70%

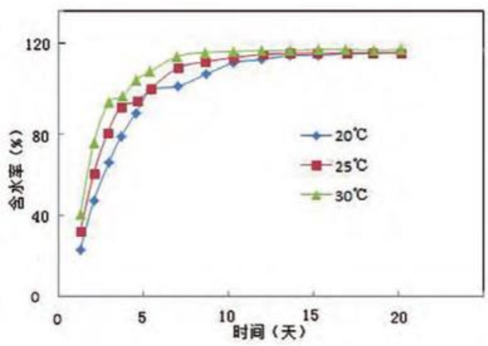

Fig.2 Silica gel adsorption characteristic curve when RH=90%

2.2 Simulation Analysis of Fluid Pressure Drop in Silica Gel

Silica gel structure is a loose and porous structure with different pore sizes. Therefore, silica gel is regarded as a porous medium in finite element analysis. Fluid flow in silica gel is simulated and analyzed by CFX, a hydrodynamic analysis software. The physical model was established as shown in figure 3. The finite element model was established with the help of the three-dimensional digital modeling software Pro/e, and was seamlessly connected with the ANSYS Workbench. Then, the fluid model of porous media was established in the ANSYS Workbench. The thickness d of the multihole medium to be selected is 20mm, 40mm and 60mm respectively for simulation analysis and experimental exploration. As shown in figure 4:

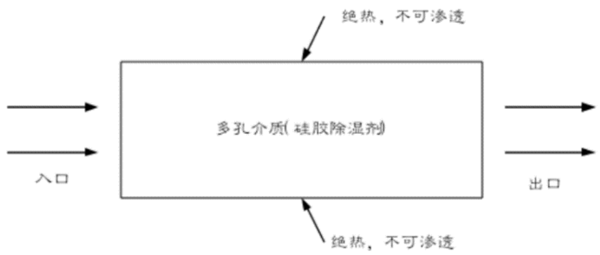

FIG. 3 Physical model of porous media adsorption

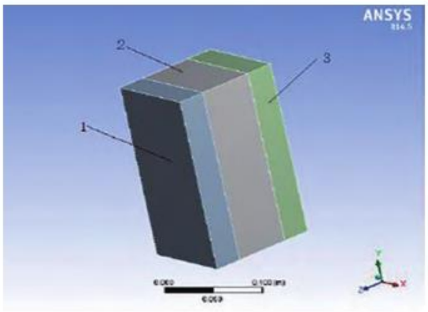

FIG. 4 Finite element model of porous media

The model was imported into CFX for flow analysis. The model was divided freely and the simulated parameters were set. When the thickness of silica gel is 20mm and the wind speed is 5m/s, 10m/s and 15m/s, through comparison, it can be seen that the pressure in the inlet area is the maximum, the pressure in the outlet area is the minimum, and the pressure in the porous media area drops rapidly.

This is because silica gel dehumidifier with a certain thickness is placed in the dehumidifier, which increases the ventilation resistance and forms the pressure difference. The pressure drop in the porous media region was 180pa when the wind speed was 5m/s, 680pa when the wind speed was 10m/s, and 1480pa when the wind speed was 15m/s. It can be seen that the thickness of silica gel is certain, and the pressure drop value increases with the increase of wind speed.

When the thickness of silica gel is 40mm, other conditions remain unchanged, and the results show that the pressure decreases in the porous media area. The pressure drop in the multi-hole media region was 280pa when the wind speed was 5m/s, 1280pa when the wind speed was 10m/s, and 2980pa when the wind speed was 15m/s. It can be seen that the pressure drop increases with the increase of wind speed at a certain thickness.

When the thickness of silica gel was 60mm, other conditions were the same as above. When the wind speed was 5m/s, the pressure drop in the porous media region was 480pa; when the wind speed was 10m/s, the pressure drop was 1980pa; when the wind speed was 15m/s, the pressure drop was 4480pa. Similarly, the pressure drop gradually increases as the wind flow velocity increases.

In summary, airflow velocity and silica gel thickness are the main factors influencing fluid flow. When the thickness is the same, the pressure drop of the fluid in the silica gel increases with the increase of wind speed, and the rate of change increases. When the airflow velocity is constant, the pressure drop increases with the increase of thickness.

2.3 Simulation Experiment of Silica Gel Dehumidification

(1) Experimental Device

This experiment mainly studied the effect of porous silica gel thickness on dehumidifier dehumidification effect. Wind speed sensors 1 and 2 measure the air speed before and after the media respectively. Sensor 1 and 2 simultaneously measure the temperature and humidity of wet air without and through porous media. The u-type pressure gauge is used to measure the pressure drop in different working conditions at the positions before and after the media, and the corresponding data is read and recorded every 15 minutes. The thickness of silica gel used in this experiment was respectively 0mm, 20mm, 40mm and 60mm. The experimental device is shown in figure 5.

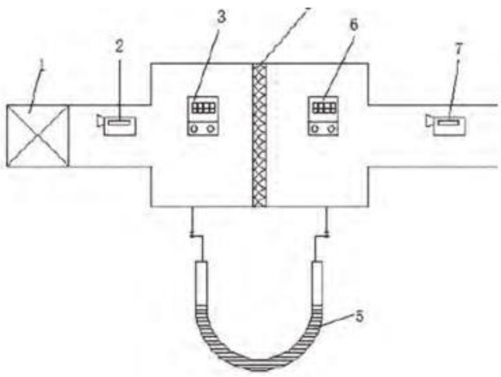

FIG. 5 Experimental device

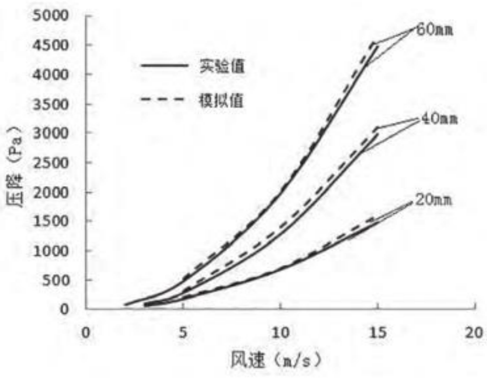

FIG. 6 Effect of thickness on pressure drop at inlet and outlet

(2) Analysis of Experimental Results

The data obtained from the experiment were observed and compared and analyzed when the experiment was conducted for 30 minutes, as shown in table 1.

It is concluded from table 1 that with the increase of wind speed, the temperature difference between the inlet and outlet of the silica gel air of each thickness is smaller, and the change speed is smaller and smaller. In addition, the temperature of the air at the outlet is higher than the temperature at the inlet, which is caused by the heat released by the change of water vapor into liquid during the process of silica gel moisture absorption. At a certain wind speed, the moisture content at the outlet increases with the decrease of the silicone thickness, and the pressure drop increases with the increase of the silicone thickness.

2.4 A Comparative Analysis

It can be seen from FIG. 6 that the simulated value is basically consistent with the experimental value, and the experimental value is smaller than the simulated value, which verifies the correctness of the numerical simulation analysis.

Table 1 Experimental data

硅胶板厚度（mm）	进口风速 (m/s)	进口温度 (℃)	进口相对湿度（%）	出口风速 (m/s)	出口温度 (℃)	出口相对湿(%)	U 型管液位差（mm）
0	5	28	99	5	28	99	0
	10	28	99	10	28	99	0
	15	28	99	15	28	99	0.1
20	5	28	99	5	29.3	53	1.2
	10	28	99	10	28.7	71	4.8
	15	28	99	15	28.5	79	10.9
40	5	28	99	5	30.4	34	2.4
	10	28	99	10	29.2	56	9.6
	15	28	99	15	28.8	67	21.8
60	5	28	99	5	31.2	23	3.7
	10	28	99	10	29.7	45	14.9
	15	28	99	15	29.2	57	33.5

3. CONCLUSION

As a dehumidifier, macroporous silica gel has good hygroscopic properties in natural state, which is a good choice for dehumidifying mine air. Relative humidity and temperature have an important effect on the hygroscopic properties of silica gel. Wind speed and thickness are the key factors influencing the dehumidifier effect. When the thickness of silica gel is constant, the greater the wind speed, the better the dehumidification effect.

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