Effect of water quality on wettability of coking coal dust

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Abstract. Water quality has certain influence on the wettability of coal dust, so we studied the wettability of coking coal by reclaimed water and mine water and distilled water. The surface contact angle and forward permeability time of various kinds of water on coking coal dust were measured firstly, the wetting effect of reclaimed water was better than those of other water types. Through infrared spectra analysis, we found that the functional groups contained in reclaimed water promoted the wettability of coal dust to some extent.

1. Introduction
Dust produced in the process of coal production is a threat to the safety production of coal mine. Meanwhile workers take in the coal dust will lead to pneumoconiosis and silicosis, both disabling and possibly fatal lung diseases, therefore the removal technology of coal dust has been the research focus[1, 2].

Coking coal has the characteristics of high carbon content, large brittleness, high yield, and small particle size, which makes it difficult to control dust. Many domestic scholars have studied the wettability of coal dust and the studies showed that contact angle and forward permeability test are the main methods to determine the wettability of coal dust[3-5]. In general, the smaller the contact angle, the stronger the wettability of coal dust[3, 8].

The efficiency of dust suppression process mainly depends on not only physicochemical properties of coal surfaces but also the quality of water[6]. At the same time, many studies have shown that surfactant can improve the wettability of coal dust[3, 3]. If the water already contains surfactant, then it may improve the wettability of coal dust to some extent.

In this experiment, several kinds of water including reclaimed water and a surfactant-alcohol polyoxyethylene ether (JFC) were selected as non-ionic surfactants to improve the wettability of coal dust[11]. Reclaimed water in mine with rich surfactants has certain wetting effect on coal dust.

2. Material and methods

2.1. Preparation of Coal Sample
The coal sample was selected coking coal with large dust production capacity and strong viscosity. The coal sample was collected in Heze mine. The proximate analysis of coal sample was shown in Table 1.
Table 1. Proximate analysis of coal sample

| Sample number | Sample name (Aad)/% | (Mad)/% | (Vad)/% | (FCad)/% |
|---------------|---------------------|---------|---------|----------|
| 1             | Coal in Heze mine   | 5.13    | 0.38    | 29.33    | 65.16    |

2.2. Preparation of Water Sample

Three kinds of water samples which were distilled water, mine water and reclaimed water were used in this study. The mine water A, B and C were taken from different coal mines, and the water quality varied greatly. The reclaimed water we chose were from washing and bathing after simple precipitation. Table 2 showed the basic data of the water quality of distilled water, mine water and reclaimed water.

Table 2. The quality indexes of water sample

| Water sample | Coal Sample | pH   | COD (mg/L) | Surface tension (20℃) |
|--------------|-------------|------|------------|-----------------------|
| Distilled water | 7.2       | ---- | 70.5      |                       |
| Mine water A   | 3.49       | 32.1 | 56.5      |                       |
| Mine water B   | 7.7        | 20.4 | 71.6      |                       |
| Mine water C   | 7.62       | 18.3 | 61        |                       |
| Reclaimed water | 7.82      | 60   | 28.3      |                       |

---was not detected

It could be seen from the table 2 that the pH of mine water in different regions was quite different. The reclaimed water was weakly alkaline, with the largest COD and the smallest surface tension, indicating that the water contained some organic substances.

2.3. Experimental design of Wettability of Coal Dust

2.3.1. The Contact Angle of coal Dust

The contact angle between solution and coal sample was determined by DSA100 video optical contact angle measuring devices. Coal samples were collected to make tablets. The status of different water droplets and wetting agents generated on the surface of coal samples had been imaged and the contour line of the wetting result was displayed on the image of the drops. All the results of contact angle could be automatically acquired and displayed. The measuring error of the instrument is 0.01°[3].

2.3.2. Forward permeability test

2 grams of coal dust was first put into the glass tube with an inner diameter of 6 mm, and the length of coal dust filled in the glass tube was more than 5 cm. The bottom of the glass tube was sealed with a medical tape and inserted beside the vertical plank with scale. Finally, a pipette was used to absorb different volume of wetting solution slowly into the coal dust and a stopwatch to record the time when the liquid level reached to the required locations. Under the same conditions, the faster the solution permeated down, the better the wettability of the solution.
2.4. FT-IR analysis
Fourier transform infrared spectroscopy (Nicolet 6700, Thermo Fisher Scientific, USA) was used to analyze the chemical groups and bonds on the near-surface region of the coal dust using potassium bromide method. Spectra were acquired in the range of 4000-5000 cm\(^{-1}\) with 0.5 cm\(^{-1}\) resolution and processed using OMNIC software. The solid samples were prepared for the investigation by mixing with potassium bromide (KBr), then ground and pressed into tablets.

3. Results and Discussion

3.1. The effects of different kinds of water on wetting performance of coal dust

| Water sample      | Coal sample | Average value of coking coal sample | Wetting time of coal dust at 3 cm depth (s) |
|-------------------|-------------|------------------------------------|------------------------------------------|
| Distilled water   | 73.30       |                                    | 2338                                     |
| Mine water A      | 75.90       |                                    | 2163                                     |
| Mine water B II   | 74.42       |                                    | 2080                                     |
| Mine water C I    | 71.56       |                                    | 2256                                     |
| Reclaimed water   | 57.78       |                                    | 978                                      |

Table 3 showed wetting characteristics of coking coal with different kinds of water. It could be seen from table 4 that the average contact angle between reclaimed water and coking coal samples was 57.78, which was 21.17% lower than that of mine water and ordinary distilled water, respectively. The smaller the wetting angle, the better the wettability of coal dust[3]. So the results showed that the wettability of reclaimed water to coal dust was better than that of other water samples.

According to the corresponding water quality indexes, the pH value of reclaimed water was close to that of other water, COD were obviously higher than those of other water, indicating that there was more organic oxygen consuming components in it. The surface tension of reclaimed water was also greatly reduced and it could promote the wettability of coal dust.

3.2. Comparison analysis of infrared spectrum
In order to study the effect of the difference of organic composition between JFC and reclaimed water on the wettability of coal dust, the infrared spectra of JFC, water, reclaimed water were analyzed respectively. The infrared spectrum was shown in Figure 2.
Figure 2. Comparison of infrared spectra of reclaimed water, JFC and distilled water

In figure 2, the absorption peaks of JFC were mainly in the range of 1000 cm\(^{-1}\)-1100 cm\(^{-1}\) and 2800 cm\(^{-1}\)-3000 cm\(^{-1}\). Reclaimed water had the same absorption peak in 2800 cm\(^{-1}\)-3000 cm\(^{-1}\) with JFC while distilled water didn’t have. Therefore, reclaimed water could enhance the wettability of coal dust than distilled water.

4. Conclusions

In this paper, taking the coking coal as an example, the wetting characteristics of coal dust with reclaimed water and non-ionic surfactant were investigated by contact angle test and forward permeability experiment. The results were as follows:

(1) The contact angle and forward permeability time of reclaimed water were measured, and the wetting effect of reclaimed water on coal dust was better than that of other water types such as mine water.

(2) From the infrared spectra analysis, it was found the functional groups contained in reclaimed water promoted the wettability of coal dust to some extent.

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