Application of wetting agent in water injection of hydrophobic and difficult permeability coal seam

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Abstract. On the basis of introducing the mechanism of increasing permeability of wetting agent, taking the comprehensive excavation face of hydrophobic and difficult to penetrate coal seam as the test object, through the test of capillary reverse osmosis in the laboratory, the economic and reasonable concentration of 0.6\% wetting agent solution for coal seam water injection is determined. In the field, we use clear water and wetting agent solution to carry out the coal seam water injection test, and make a comparative analysis of the technical effect of coal seam water injection. Using clear water to carry out coal seam water injection, the coal seam wetting radius is less than 0.5m, using wetting agent solution to carry out coal seam water injection, the coal seam wetting radius can reach more than 1.5m. The efficiency of water injection with wetting agent solution is 43.06\% higher than that with clean water.

1. Introduction
With the improvement of mining technology, the dust pollution is becoming more and more serious. Coal seam water injection can pre wet coal body, which is an active measure to effectively reduce dust in coal mine production process. However, for the hydrophobic and difficult to penetrate coal seam, it is difficult to achieve the desired purpose by water injection, which will affect the dust reduction effect. In this paper, a certain proportion of wetting agent is added to the water for dust prevention to improve the combination ability of hydrophobic and impermeable coal seam with water, so as to improve the wetting effect of coal seam water injection and achieve the purpose of dust reduction \cite{1-3}.

2. Overview of test working face
The 10 coal seam where the test working face is located has outburst risk, the relative content of gas is 4.39m\textsuperscript{3}/t, the coal dust is explosive, and the original moisture content of coal body is 1.04\%. The design section of the roadway is rectangular, the width is 4500mm and the height is 3000mm. The forced local ventilation is adopted, and the air supply volume of the working face is 680 m\textsuperscript{3}/min. Due to the large air volume, high wind speed and low original moisture content of the coal, a large amount of dust is generated during the cutting operation of roadheader, which spreads rapidly with the air flow and spreads to the whole roadway space. Laboratory analysis and field practice show that the 10 coal seam is hydrophobic and difficult permeability.
3. Dust reduction mechanism of wetting agent and determination of additive concentration

3.1. Dust reduction mechanism of wetting agent

For the water injection of hydrophobic and difficult permeable coal seam, the key problem is to solve the binding ability of coal or coal dust and water, so as to improve the wetting effect and dust reduction effect of coal seam water injection. Wetting agent is a kind of surfactant which can significantly reduce the surface tension of solution and make the concentration of solute on the surface higher than that inside. The surfactant has two characteristics: one is the amphiphilic molecule on the chemical structure, that is, one end of the molecule is hydrophilic, the other end is lipophilic, which is called hydrophilic polar group and hydrophobic nonpolar group respectively; the other is the directional arrangement of molecules on the surface layer of the solution, that is, the hydrophilic end is inserted into the water, and the hydrophobic end is toward the air. Because of amphiphilicity, they can cover the surface of water as much as possible to reduce the surface tension of water, due to the directional arrangement of molecules, a certain surface layer can accommodate more molecules [4-5].

When the wetting agent is dissolved in water, its active molecules will be aligned on the surface of the aqueous solution, the hydrophilic group will face the interior of the aqueous solution, and the lipophilic group will face the surface of the solution, so that the surface properties of water can be greatly improved. When coal dust and other particles combine with the solution, the liquid surface resistance that needs to be overcome will also be correspondingly reduced. In addition, coal dust itself contains a large number of aromatic hydrocarbons and aliphatic hydrocarbons. Under the adsorption of wetting agent molecules, the equal polar groups are easy to contact with the droplets, so they can combine with the liquid smoothly, so as to achieve the purpose of being wetted.

3.2. Determination of adding concentration of wetting agent

Coal seam water injection is to achieve dust reduction effect by wetting coal body, which directly affects dust prevention effect of coal seam water injection. The wetting process of coal is a complex physicochemical process. Firstly, water flows along the cracks and voids of coal under the action of pressure difference. Its velocity and influence range depend on the permeability and water injection pressure of coal, and then the self movement of water under the action of capillary force and surface phenomenon. The uniform wetting of coal is mainly realized by capillary infiltration.

According to the mechanism of wetting agent improving the effect of coal seam water injection, the reasonable concentration of wetting agent solution was determined by capillary reverse osmosis in laboratory. Coal samples were taken from the working face, dried, crushed and ground in the laboratory, and coal dust was screened with 80 mesh. The coal dust was loaded into bottomless glass tube with filter paper sealed at the bottom. The glass tube containing coal samples was put into aqueous solution of wetting agent with concentration of 0.1%, 0.2%, 0.4%, 0.6%, 0.8% and 1.0% respectively, 30 minutes later, the Δm of coal samples in glass tube was measured. The Δm was 22.2mg, 35.5mg, 49.8mg, 64.7mg, 63.6mg and 55.8mg respectively. The test results are shown in Figure 1.

Figure 1. Weight gain of coal sample in different concentrations of wetting agent solution
Analysis of Figure 1: in the low concentration range, with the increase of wetting agent concentration, the mass increment \( \Delta m \) of coal sample increases. When the solution concentration increases to 0.6\%, \( \Delta m \) reaches the maximum value. With the continuous increase of wetting agent concentration, \( \Delta m \) does not continue to increase, but has a slow decreasing trend. In the capillary reverse osmosis test, the wetting speed of 0.6\% wetting agent solution with coal dust is the fastest. The capillary reverse osmosis test shows that it is most reasonable to add 0.6\% wetting agent in the process of coal seam water injection.

4. Field test and effect observation

4.1. Introduction of test system

The test system is mainly composed of high pressure pump station, water injection hole sealer, pressure gauge, flow meter, high pressure pipe, etc. The effective volume of water tank in high pressure pump station is 1.2m\(^3\), the rated flow is 125L/min, and the rated pressure is 40MPa. As shown in Figure 2, the high-pressure pump station is arranged in the Electromechanical chamber and connected to the hole sealer of coal seam water injection in the working face through the high-pressure pipeline.

![Figure 2. Layout diagram of test system](image)

4.2. Analysis of coal wetting effect

In order to investigate the influence of wetting agent on the wetting effect of coal seam water injection, clean water and 0.6\% wetting agent solution were used for dynamic pressure water injection to the coal seam respectively. The water injection pressure was 10MPa. A water injection hole was drilled at the center of the working face. The diameter of the hole was 50mm and the depth of the hole was 6m. In the process of water injection, the pressure gauge and flow meter were observed all the time. When the pressure gauge is constant and the flow meter has no flow data, the water injection is stopped. Three water injection test holes are drilled parallel to the water injection hole at the position 0.5m, 1.0m and 1.5m away from the water injection hole. The holes depth is also 6m, and the drilling cuttings are taken every 1m. The layout of water injection hole and water injection test holes is shown in Fig. 3 and Fig. 4. According to GBT / 211-2007 "determination method of total moisture in coal", the collected drilling cuttings were tested and analyzed in laboratory, and the test results as shown in Table 1.

![Figure 3. Layout of injection hole with clean water and test hole](image)
Figure 4. Layout of injection hole with wetting agent solution and test hole

Table 1. Test results of moisture increment of coal after injection with water and agent solution

| the depth of the hole | 1m   | 2m   | 3m   | 4m   | 5m   | 6m   | average |
|----------------------|------|------|------|------|------|------|---------|
| No.1-1               | 0.40%| 0.43%| 0.47%| 0.47%| 0.44%| 0.42%| 0.44%   |
| No.2-1               | 2.11%| 2.17%| 2.35%| 2.49%| 2.27%| 2.12%| 2.25%   |
| No.2-2               | 1.77%| 1.84%| 1.97%| 2.02%| 1.90%| 1.83%| 1.89%   |
| No.2-3               | 1.46%| 1.49%| 1.55%| 1.57%| 1.54%| 1.50%| 1.52%   |

It can be concluded from table 1 that when use clean water for injection, the average moisture increment of coal sample at 0.5m away from the injection hole is only 0.44%, and the wetting radius of coal seam water injection is less than 0.5m (the effective wetting radius is when the moisture increment is greater than 1.5%). When the concentration of 0.6% wetting agent solution is used for water injection, the moisture increment of coal sample at 0.5m away from the water injection hole is 2.25%, the moisture increment of coal sample at 1.0m away from the water injection hole is 1.88%, and the moisture increment of coal sample at 1.5m away from the water injection hole is 1.52%. The wetting radius of coal seam water injection can reach more than 1.5m.

4.3. Investigation on dust reduction effect of water injection

According to the influence range of wetting radius of wetting agent solution injection, two injection holes are arranged as shown in Figure 5 working face, the wetting effect can basically cover the whole working face. Then, the dust reduction effect of injection with wetting agent solution was investigated. During the cutting process of roadheader, the dust concentration in the roadway 15m away from the working face without injection, with clean water injection and with 0.6% wetting agent solution injection was tested. The test results are compared and analyzed to calculate the dust reduction efficiency. The results are shown in Table 2.

Figure 5. Layout of injection hole with wetting agent solution and test hole
Table 2. Dust test results before and after injection with clean water and wet agent solution

|       | before injection | injection with clean water | injection with wet agent solution |
|-------|------------------|---------------------------|----------------------------------|
| 1     | 451.4 mg/m³      | 329.9 mg/m³               | 164.9 mg/m³                      |
| 2     | 462.2 mg/m³      | 355.8 mg/m³               | 143.4 mg/m³                      |
| 3     | 433.1 mg/m³      | 363.7 mg/m³               | 161.2 mg/m³                      |
| average | 448.9 mg/m³     | 349.8 mg/m³               | 156.5 mg/m³                      |
| dust reduction efficiency | —— | 22.08% | 65.14% |

It can be seen from table 2 that the dust reduction efficiency is 22.08% after using clean water for injection, and 65.14% after using wetting agent solution for injection. The dust reduction efficiency of coal seam water injection with wetting agent solution is 43.06% higher than that with clean water.

5. Conclusion

(1) The laboratory test results show that in the capillary reverse osmosis test, the weight gain rate of coal sample in 0.6% concentration of wetting agent solution is the fastest. It is reasonable to use 0.6% concentration of wetting agent solution in 10 coal seam.

(2) The coal seam water injection test is carried out by using clean water and 0.6% concentration of wetting agent solution, and the wetting effect of water injection is analyzed. The wetting radius of coal body injected with clean water is less than 0.5m, and the wetting radius can reach 1.5m by using 0.6% concentration of wetting agent solution.

(3) The dust reduction efficiency of coal seam water injection with clean water and wetting agent solution was tested respectively. The dust reduction efficiency of coal seam water injection with clean water was only 22.08%. The dust reduction efficiency of coal seam water injection with 0.6% concentration of wetting agent solution was 65.14%. The dust reduction efficiency of coal seam water injection with wetting agent solution was 43.06% higher than that with clean water.

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References

[1] Ma Wei, Liu Yong, Chen Fang. Fine dust prevention and control technology of rapid fully—mechanized working face in wetting difficulty seam[J]. Coal Science and Technology, 2015(01):23-26.
[2] Wang Weihu. Aplication Present status and outlook of seam water injection dust control technology [J]. Coal Science and Technology, 2011, (01): 57-60.
[3] Hu Fu, Wang Jie, Huang Weigang, Liu Nanqin, Chen Li. Study on properties of coal dust compound wetting agent[J]. Mining Safety and Environmental Protection, 2011, (03): 13-16.
[4] Xu Hengheng, Liu Tao, Zhang Maoyu, Lu Ke. Study on influence factors of water injection wetting radius of coal seam at fully mechanized coal mining face[J]. Coal Technology, 2017, (10): 50-52.
[5] Liu Kui, Guo Shengjun, Gong Xiaobing, Huang Weigang, Hu Fu. Suppression test of water spray added with wetting agent against hydrophobic coal dust in fully mechanized face with high air velocity[J]. Mining Safety and Environmental Protection, 2013, (03): 10-12.
[6] Wu Quanzhen, Guo Zhenxin, Liu Tao, Han Junjun. Experimental study on dust control of fully mechanized coal face with high efficiency dust reducing wetting agent[J]. Coal Engineering, 2013, (7):66-68+71.
[7] Yu Guijun, Wang Hetang. Application of high pressure spray and dust reduction with wetting agent in fully mechanized heading face of outburst coal seam[J]. Safety in Coal Mines, 2018, (3):121-124.