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Study on Dust Control Technology of Fully Mechanized Driving Face in Hard-to-Wet and Outburst

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Abstract*:* **In order to solve the difficult problem of dust control in fully mechanized excavation of hard-to-wet and outburst coal seam**, the hard-to-wet and outburst coal seam is taken as the test object, the moisture absorption property of coal is improved by adding wetting agent. The coal seam infusion and high pressure spray are taken as the main measures, and the technical effect is investigated. The dust removal efficiency of total dust and respirable dust reached 92.1% and 87.4% respectively.

Keywords Hard-to-wet and outburst coal seam, Wetting agent, Coal seam infusion, High pressure spray

INTRODUCTION

This is a gas blow-out heading face, the coal dust is explosive, the original moisture content of coal is 1.02%, and the hardness coefficient f is 0.85. The roadway section is rectangular, 4.5m wide and 3.0m high, with forced ventilation and air volume of 680m^3/min. According to the field measurement, the total dust concentration at 15m away from the working face is 734.7mg/m^3. Due to the high wind speed at the working face, the dust generated by the roadheader when cutting coal spreads rapidly with the air flow and diffuses to the whole roadway space. The capillary reverse osmosis method and natural settlement method are used to analyze the coal seam, and the result shows that the coal seam is hard-to-wet.

DUST CONTROL TECHNOLOGY

Dust control measures for fully mechanized working face mainly include dust remover purification, coal seam water injection, spray dust reduction and foam dedusting. Due to the outstanding danger of the experimental mask, the "coal mine safety regulations" stipulates that when the local ventilator is used for ventilation in the outburst coal seam, the pressure must be adopted, so the dust removal and purification technology can not be used, and the coal seam water injection is difficult to damp the coal seam. If the result is limited, foam dedusting will greatly increase production costs [Ma et al, 2015, Cao et al, 2012]. Comprehensive technical and economic considerations ultimately choose to add a certain amount of wet dust reducing agent in dustproof water to improve the combination ability of coal and coal dust and water, and then adopt the measures of "coal seam water injection & spray dust reduction" to control the dust production of roadheader cutting[Liu et al, 1992].

Determination of Wetting Agent Concentration

Coal seam water injection is to achieve the effect of dust reduction by wetting the coal body, which is the self movement of water in the coal body under the action of capillary force [Liu et al, 2013, Xu et al, 2017]. The process of spray dust-fall is essentially a combination of dust particles to overcome the water surface tension and water mist, and to settle under the action of gravity [Wu et al, 2013, Ma et al, 2015]. According to the mechanism of coal seam water injection and spray dust suppression, the reasonable concentration of wetting agent is determined by capillary reverse osmosis and natural sedimentation method in laboratory.

Determination of Wetting Agent Concentration in Coal Seam Water Injection by Capillary Reverse Osmosis

Coal samples were taken from the working face. After drying, grinding and grinding in the laboratory, the coal dust was screened with 80 mesh. The coal dust was put into the bottomless glass tube with filter paper at the bottom. The glass tubes containing coal samples were placed in the aqueous solution of 0.1%, 0.2%, 0.4%, 0.6%, 0.8% and 1.0% respectively. The Δ m of the coal sample in the glass tube was tested by standing for 30min. The results showed that the weight was 22.1mg, 35.5mg, 49.8mg, 64.7mg, 63.6mg, 56.1mg, respectively. The test results are shown in Figure 1.

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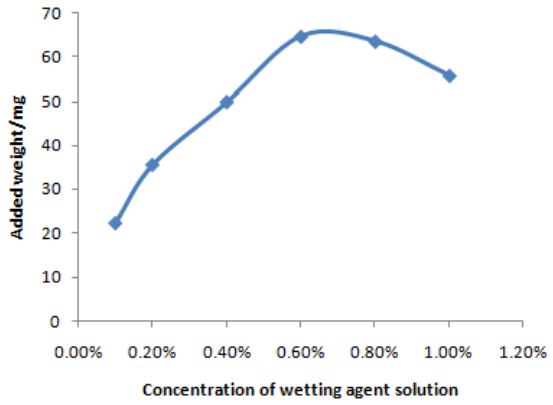


Figure 1. Weight gain of coal sample in wetting agent solution of different concentrations

It can be seen from Figure 1 that in the low concentration range, with the increase of wetting agent concentration, the Δm of coal sample increases. When the solution concentration increases to 0.6%, Δm reaches the maximum value. With the continuous increase of wetting agent concentration, Δm does not continue to increase, but tends to decrease slowly. The wetting agent solution with concentration of 0.6% and coal dust has the fastest infiltration speed. In coal seam water injection, the wetting agent solution concentration of 0.6% is more reasonable.

Determination of Spray Wetting Agent Concentration by Natural Sedimentation Method

1.0g coal dust samples were weighed and quickly poured onto the surface of wetting agent solution with concentration of 0.1%, 0.2%, 0.4%, 0.6%, 0.8% and 1.0% respectively, so that the coal sample naturally accumulated into a cone on the surface of the solution. When the dust began to contact the surface of the solution, press the timer switch to record the time required for complete dust settlement. The results were 140′ 30″, 92′ 42 ″, 44′ 54 ″, 21′ 30 ″, 23′ 24″, 24′ 48″. The test results are shown in Figure 2.

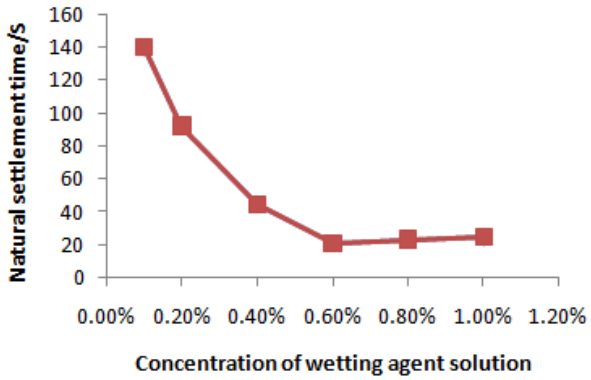
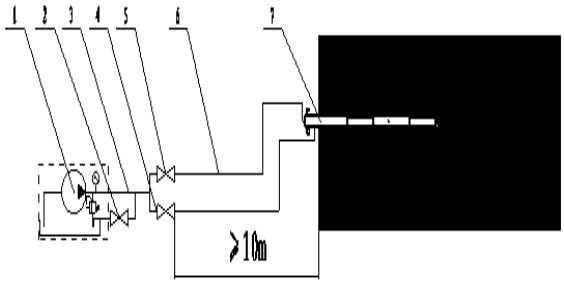


Figure 2. Settling time of coal dust in different concentrations of wetting agent solution

It can be seen from Figure 2 that with the increase of the concentration of wetting agent solution, the settling time of coal dust decreases sharply. When the concentration of wetting agent solution increases to 0.4%, the decreasing trend of settling time begins to slow down. When the concentration of wetting agent solution increases to 0.6%, the settling time is the minimum, and then with the increase of the concentration of wetting agent solution, the settling time does not change significantly. The settlement time of coal dust is minimum in the wetting agent solution with a concentration of 0.6%. In the process of spray, 0.6% is a reasonable wetting agent solution concentration.

Coal Seam Water Injection

In this paper, two-segmented hole sealer of FKSS-50/12 is used to seal and inject water in sections. The pressure relief zone, concentrated stress zone and original stress zone formed successively in front of coal body after excavation are used to inject water from outside to inside. The water injection system is shown in Figure 3.



1- High pressure water injection pump; 2- Regulating valve of return water; 3,6- High pressure hose; 4,5-Inlet valve; 7- Two-segmented hole sealer

Figure 3. Schematic diagram of water injection test system

In the test, a water injection test hole was drilled at the head-on and middle position of the heading face, with a hole depth of 6m. The drilling cuttings were taken once every 1m drilling, and the amount of drilling cuttings was not less than 100g and sealed for testing the original moisture content of coal seam. The layout of water injection test hole is shown in Figure 4.

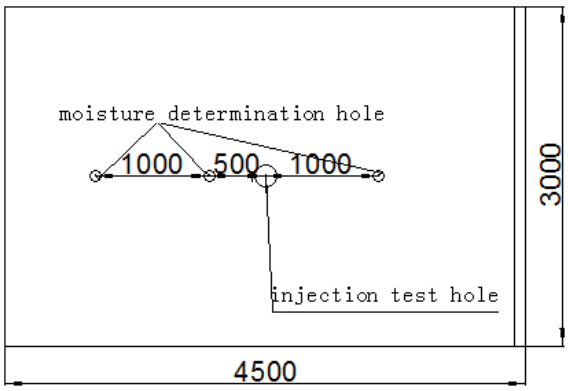


Figure 4. Layout of water injection test hole and moisture determination hole

Determination of Water Injection Pressure

In the water tank of the high-pressure pump, the wetting agent is added in advance according to the proportion of 0.6%, and the water injection pressure is adjusted to 6Mpa, 8Mpa, 10MPa and 12MPa in turn for coal seam water injection, and the time and water injection volume of injection are recorded. The test data of injection pressure, injection time and injection volume are shown in Table 1.

Table 1. Test results of injection pressure, injection time and injection volume

No.	injection pressure/ MPa	injection time/min	injection volume/ L
1	6	＞1h	234
2	8	＞1h	277
3	10	36	941
4	12	32	988

It can be seen from table 1 that when the water injection pressure is lower than 10MPa, the water injection quantity is very small, and the water injection volume basically remains unchanged for a long time. When the injection pressure increases to 10MPa, the water injection volume increases significantly and the injection time is shortened obviously. However, when the injection pressure reaches 12MPa, the water injection volume does not increase obviously. Therefore, the injection pressure is determined as 10MPa.

The Investigation of Moisture Increment

As shown in Figure 4, three moisture determination holes shall be drilled parallel to and away from the water injection test hole 0.5m, 1.0m and 1.5m, with depth of 6m. The drilling cuttings shall be taken once every 1m while drilling, and the drilling cuttings amount shall not be less than 100g, sealed and stored. The drilling cuttings collected from the water injection test hole and the moisture determination holes are tested and analyzed, and the moisture increment is calculated. The results are shown in Table 2.

Table 2. Test results of moisture increment (%)

The depth of the hole	The moisture determination holes		
	1	2	3
1m	2.13	1.80	1.47
2m	2.16	1.86	1.51
3m	2.37	1.93	1.57
4m	2.51	1.99	1.59
5m	2.29	1.90	1.53
6m	2.11	1.83	1.50
Average	2.26	1.89	1.53

It can be seen from table 2 that the average moisture increment of coal is more than 1.5% within the range of 1.5 m from the water injection test hole, and the effective wetting radius of water injection can be determined as 1.5 m.

Determination of Water Injection Parameters

According to the results of water injection test, the injection pressure is 10MPa and the time is 35 to 40 minutes. According to the effective wetting radius of water injection, two water injection boreholes are arranged on the working face (as shown in Figure 5), which can basically ensure the wetting effect and cover the whole face.

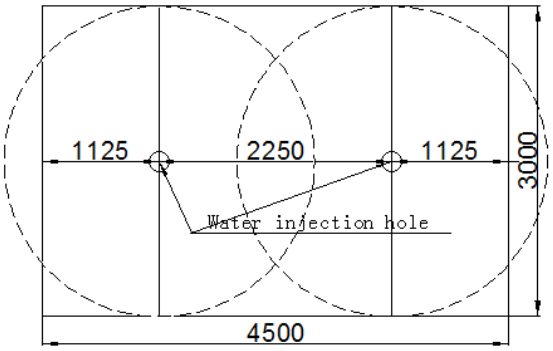


Figure 5. Layout of water injection holes in working face

Spray and Dust Suppression Technology

A large number of research results and practices show that high-pressure spray has higher dust removal efficiency than static pressure water spray, and the water consumption of the same effect is lower. Therefore, high pressure spray technology is used to spray coal dust for roadheader cutting, and 0.6% wetting agent is added to spray water.

Nozzle Selection

During the cutting process of roadheader, a large number of dust particles are concentrated around the cutter. Due to the disturbance of air flow, the dust will move and diffuse rapidly. Therefore, it needs high speed and high density water mist to settle the dust in time. So the solid cone-shaped G-type nozzle with high spray velocity and high mist particle density is selected.

Spray droplet diameter is the key factor affecting the efficiency of dustfall. The droplet diameter of spray is related to spray pressure and nozzle aperture. The three nozzles with 0.8mm, 1.0mm and 1.2mm aperture are tested under pressure of 6MPa, 8MPa, 10MPa and 12MPa respectively, and the results are shown in Table 3.

Table 3. Test results of moisture increment

Aperture of nozzle	——	Pressure /(MPa）			
		6	8	10	12
0.8mm	Droplet diameter(μ m)	96	56	45	41
	Water consumption(L/min)	3.12	3.14	3.21	3.31
1.0mm	Droplet diameter(μ m)	158	107	81	66

	Water consumption(L/min)	4.24	4.41	4.83	4.98
1.2mm	Droplet diameter (μ m)	221	153	116	95
	Water consumption(L/min)	4.97	5.27	5.78	6.36

According to table 3, when the spray pressure is the same, the diameter of the droplet produced by the nozzle with aperture 0.8mm is much smaller than the others, and the water consumption is relatively small. In order to reduce the influence of spray water on the coal quality, the nozzle with aperture 0.8mm is chosen.

Determination of Spray Pressure

According to the test results of dust particle size distribution of working flour, the dust below 50 μ m accounts for 68.74% of the total dust, the dust removal efficiency is higher when the dust particle size closer to the droplet diameter. It can be seen from table 3 that under the pressure of 8 to 10MPa, the diameter of the droplet produced by the nozzle with aperture 0.8mm is 45 to 56 μm, which is the closest to the dust particle size. Therefore, the spray pressure is determined to be 8 to 10MPa.

Design of Spray Device

According to the structure of the cutting part of roadheader, the spray device is designed as a "n". As shown in Figure 6, six nozzles are arranged on the upper part, and each 2 nozzles are arranged on the left and right sides. The spray device is installed at the root part of the cutter of the roadheader, and the spray head of the roadheader cutter is formed on the top, left and right sides.

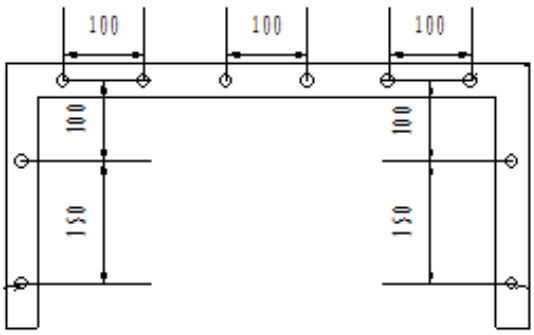


Figure 6. Schematic diagram of spray device

INVESTIGATION ON DUST REDUCTION EFFECT

In order to investigate the dust reduction effect of coal seam water injection, high-pressure spray and comprehensive measures of coal seam water injection and high pressure spray, dust concentration tests were conducted 15m away from the working face before and after the measures were taken, and the dust reduction efficiency was calculated. The results are shown in table 4.

Table 4. Dust concentration and reduction efficiency before and after measures

Mea-sures	Dust concentration /(mg/m^3)		Reduction efficiency	
	Total dust	Respirable dust	Total dust	Respirable dust
None	734.7	191.4	——	——
Injection	281.4	55.3	61.7%	71.1%
Spray	199.1	72.2	72.9%	62.3%
Injection &Spray	58.1	24.1	92.1%	87.4%

It can be seen from table 4 that after the coal seam water injection, the total dust is reduced from 734.7mg/m^3 to 281.4mg/m^3, and the dust reduction efficiency is 61.7%; the respirable dust is reduced from 191.4mg/m^3 to 55.3mg/m^3, and the dust reduction efficiency is 71.1%. The total dust and respirable dust were 199.1mg/m^3 and 72.2mg/m^3 respectively after high pressure spray, and the dust removal efficiencies were 72.9% and 62.3% respectively. After taking the comprehensive measures of coal seam water injection and high-pressure spray, the total dust and respirable dust were 58.1mg/m^3 and 24.1mg/m^3 respectively, and the dustfall efficiency of total dust and respirable dust reached 92.1% and 87.4% respectively.

CONCLUSION

(1) Through capillary reverse osmosis and natural sedimentation test, the wetting agent added in coal seam water injection and spray dustfall is 0.6%.

(2) The effective wetting radius is more than 1.5m when the injection pressure is 10MPa. After water injection, the total dust and respirable dust decreased to 281.4 mg/m^3 and 55.3 mg/m^3 respectively, and the dust reduction efficiency was 61.7% and 71.1%.

(3) The reasonable pressure of high pressure spray is 8 to 10MPa. After high pressure spray, the total dust and respirable dust were 199.1mg/m^3 and 72.2mg/m^3 respectively, and the dust removal efficiencies were 72.9% and 62.3%.

(4) After taking the comprehensive measures of coal seam water injection and high-pressure spray, the total dust and respirable dust were 58.1mg/m^3 and 24.1mg/m^3 respectively, and the dustfall efficiency of total dust and respirable dust reached 92.1% and 87.4% respectively.

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