Study on the influence of coal particle size and evaporation time on water evaporation

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ABSTRACT

In this paper, the cumulative water evaporation of coal particles with different scales and different evaporation time is analyzed by laboratory test method, and the change law of water evaporation and evaporation time of coal particles with different scales is obtained. The results show that the cumulative water evaporation of coal samples of different scales increases with the increase of evaporation time, and the water evaporation loss is faster in the early stage of evaporation experiment. During the same evaporation time, the larger the coal particle size, the smaller the cumulative water evaporation amount. The water evaporation amount of 10 mm coal particle sample is the largest, followed by 20 mm coal sample, and 50 mm coal sample is the smallest. The larger the coal particle size, the shorter the duration of rapid evaporation and the shorter the time for the cumulative evaporation to stabilize. Coal particle size is directly related to coal water evaporation, basically showing a trend that the larger the coal particle size, the shorter the rapid evaporation duration and the smaller the cumulative water evaporation amount. The main reason is that the smaller the coal particle size, the more particles, the larger the overall particle surface area, the larger the air contact area, and the more water loss. The research results provide basic support for the later application of coal seam water injection dust removal engineering.

Keywords: Coal particle size, evaporation time, evaporation rate, water evaporation, influence law

1. INTRODUCTION

Coal is the cornerstone of China's energy security. In recent years, the annual output of coal has exceeded 4 billion tons[1,2]. With the gradual release of China's coal mine production capacity, the production intensity of the working face has become higher and higher, and the dust hazards brought by it have become more and more serious. According to statistics, by the end of 2022, China has reported a total of 1.038 million cases of occupational diseases; Among them, 923,000 cases of occupational pneumoconiosis, accounting for 88.9%, and coal workers pneumoconiosis accounted for more than 50% of occupational pneumoconiosis, occupational disease hazard prevention situation is still grim, the number of new occupational diseases, especially new pneumoconiosis reports is still high, the focus of mine dust production in mining, digging, transportation and other major workplaces, accounting for about 90% of the total mine dust production. Seriously harm the health of operators[3-6].

In recent years, as China attaches great importance to the prevention and control of occupational diseases caused by coal mine dust, a series of regulations and standards have been issued to effectively curb the rising trend of coal workers' pneumoconiosis[7-9]. The number of new pneumoconiosis patients is gradually decreasing every year, but the number of new pneumoconiosis patients every year still amounts to thousands, and the form of occupational hazards is still not optimistic. The main cause of pneumoconiosis is respiratory dust, and coal seam water injection is the most effective and direct dustproof means to reduce respiratory dust produced in the coal mine production process[10,11]. Although coal seam water injection can reduce dust generation from the source, the application of coal seam water injection technology is restricted by complex water injection links, poor water injection effect and other factors. The reason is that there are many influencing factors between coal seam water injection and dust fall, and the effect of these influencing factors on water injection is unclear. The law of water evaporation of coal particles of different scales after water injection is also an influential factor affecting dust removal by water injection. When coal particles are exposed to air after cutting and crushing, coal water is easily evaporated and lost, resulting in unsatisfactory dust removal effect[12-14]. Therefore, it is necessary to

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study the relationship between different coal particle scales and water evaporation amount. Then it provides the basic data support for the selection of water injection process parameters and the prediction of water injection effect.

2. EXPERIMENTAL SYSTEM

Coal particles of different sizes will be produced in the crushing process, and the size of coal particles will affect the adhesion ability of water on its surface. When coal particles are exposed to the air, water is easy to evaporate and lose. However, there are few studies on the law of water evaporation at present, and the relationship between the exposure time of coal particles and the amount of water evaporation is still unclear, and the impact on the dust removal effect is also unclear. Therefore, in order to study the law of water evaporation and loss of coal particles after water absorption under different scale conditions, this paper takes Caojiatan Coal Mine in Yulin City, Shaanxi Province, China as the background, and tests the law of water evaporation of coal particles at different scales through field sampling, laboratory crushing, screening method, soaking, natural evaporation and other experimental processes.

The experiment adopts weighing method for testing. The experimental system mainly consists of standard sample dividing screen, oven, electronic balance, sample soaking container, etc. The standard sample dividing screen is used to screen the recovered coal after crushing, the oven is used to dry the divided coal particles, the electronic balance is used to test the weight change of coal particles, and the sample soaking container is used to hold the coal particles and soak them. The experimental instruments are shown in Figure 1.

Standard sample sieve   Electronic balance   Experimental oven

Figure 1. Experimental instrument.

3. EXPERIMENTAL PROCESS

The test steps and processes of water evaporation after water absorption of coal particles of different scales are as follows:

(1) Sample preparation: Samples of coal with each side length greater than 300 mm are obtained on site, the coal is broken by hand hammer in the laboratory, and coal particles of 10 mm, 20 mm, 30 mm, 40 mm and 50 mm are screened by samples with different aperture sizes.

(2) Drying: In the laboratory, we took out 100 g of coal particles of five different scales respectively, placed them in different sample containers, and then put them in the oven for drying. The drying time was 30 min, and the water in the raw coal was removed.

(3) The first weighing: After the drying, we immediately put into the one-thousandth balance to weigh the original weight of coal particles.

(4) Soaking: The container is filled with different scales of coal particles with water and soak. According to the water absorption capacity of coal particles, the soaking time is selected as 168 h.

(5) The second weighing: After soaking, the coal particles of different scales are weighed to obtain the moisture content of the coal sample after soaking.

(6) Evaporation: Coal particles of different scales are placed in the constant temperature and humidity laboratory for natural evaporation.

(7) Multiple weighing: At the beginning of the evaporation experiment, the coal sample is weighed at an interval of 10 min, and the weighing time is adjusted in real time according to the evaporation amount in the later stage of the experiment until the evaporation experiment is over.

The experimental process of water evaporation of coal particles of different scales is shown in Figure 2.

Figure 2. Experimental process.

In the above experimental process, the weight of five different scales of coal particles after immersion is repeatedly weighed, and the change rule of water evaporation of different scales of coal particles under different evaporation time can be obtained through statistical calculation.

4. ANALYSIS OF TEST RESULTS

Through testing the water evaporation of five coal particles of different scales after immersion for a week, equation (1) was used to calculate the change of water evaporation of coal particles of different scales at different times. The test results are shown in Table 1.

$$\rho_i = m_0 - m_i \quad (1)$$

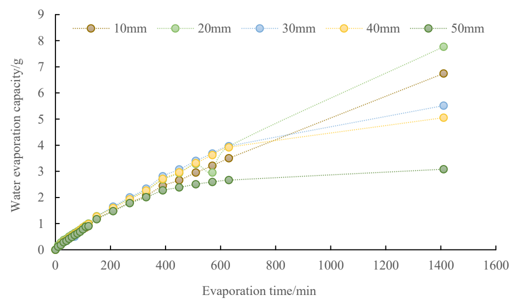
where, ρ_i is the cumulative water evaporation amount measured at the i weighing of evaporation experiment, m_i is the mass of coal particles tested at the i weighing after the evaporation experiment, g; m_0 is the initial mass of coal particles for evaporation experiment after soaking, g.

Table 1. Statistical data of cumulative water evaporation.

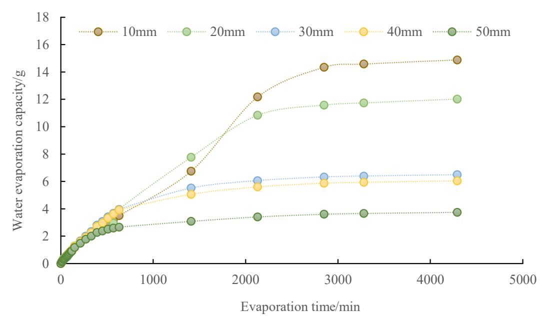
Time/min	**Coal particle size**					**Time/min**	**Coal particle size**					**Remark**
	10 mm	**20 mm**	**30 mm**	**40 mm**	**50 mm**		**10 mm**	**20 mm**	**30 mm**	**40 mm**	**50 mm**	
0	0	0	0	0	0	450	2.6614	2.9356	3.0749	2.9622	2.384	
10	0.097	0.1689	0.1022	0.123	0.1176	510	2.9522	3.2826	3.4022	3.3122	2.5078	
20	0.2215	0.2809	0.1994	0.2067	0.1832	570	3.2138	2.9539	3.6825	3.6243	2.5952	
30	0.3209	0.3707	0.2902	0.3068	0.2872	630	3.5015	3.9539	3.9614	3.92	2.6656	
40	0.374	0.4202	0.3426	0.3675	0.3435	1410	6.7457	7.7702	5.5162	5.0562	3.0833	
50	0.4593	0.5049	0.427	0.4542	0.4175	2130	12.1744	10.8419	6.0595	5.5954	3.4077	
60	0.5205	0.5712	0.499	0.5272	0.4902	2850	14.3457	11.5834	6.3256	5.8659	3.6045	
70	0.5894	0.6445	0.499	0.6014	0.5604	3280	14.5835	11.7431	6.3924	5.9336	3.6609	
80	0.6484	0.7013	0.6356	0.6705	0.6224	4290	14.8843	12.0217	6.4923	6.0368	3.7462	
90	0.7118	0.7715	0.7119	0.7456	0.6913	4710	14.9753	12.1282	6.532	6.0791	3.781	
100	0.7863	0.8583	0.8073	0.8466	0.7815	5730	15.1089	12.314	6.5968	6.1494	3.8415	
110	0.8515	0.9258	0.8781	0.9169	0.8835	6180	15.76	12.3868	6.6267	6.1809	3.8709	

Time/min	Coal particle size					Time/min	Coal particle size					Remark
	10 mm	20 mm	30 mm	40 mm	50 mm		10 mm	20 mm	30 mm	40 mm	50 mm	
120	0.9148	1.0013	0.947	0.9849	0.9047	7620	15.2465	12.5376	6.6856	6.2449	3.9301	
150	1.1861	1.2818	1.2651	1.2682	1.172	8610	15.2968	12.62	6.7276	6.2872	3.9687	
210	1.494	1.6201	1.6506	1.5975	1.4782	9060	15.3263	12.6582	6.7533	6.3138	3.9922	
270	1.8049	1.9705	2.0067	1.9299	1.7819	11490	15.4089	12.7959	6.8562	6.4279	4.1066	
330	2.0727	2.2718	2.3367	2.265	2.0086	12930	15.3975	12.8	6.8597	6.4365	4.1215	
390	2.4447	2.6876	2.8122	2.7156	2.2712	14370	15.2683	12.7034	6.7812	6.366	4.0663	

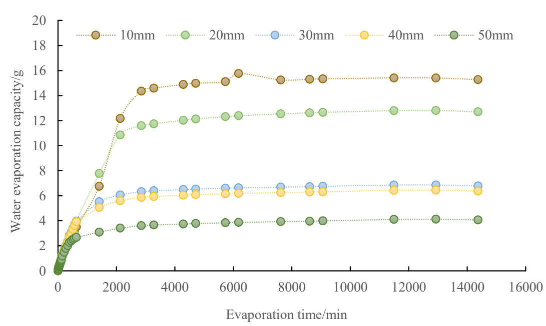
Based on the data of water evaporation of coal particles of different scales during different natural evaporation times, this experiment analyzed the water evaporation law of coal particles of different scales after water absorption by using the accumulated water evaporation of 1440 min, 4320 min and 14370 min respectively. The change curve of water evaporation of coal particles of different scales under different evaporation times was shown in Figure 3.



(a) Evaporation 1440 min



(b) Evaporation 4320 min



(c) Evaporation 14370 min

Figure 3. Change curve of water evaporation of coal particles at different scales under different evaporation time.

From the change curves of water evaporation during the immersion time of 1440 min, 4320 min and 14370 min, it can be seen that the water evaporation of coal samples of different scales increases with the increase of evaporation time, and the water evaporation loss is faster in the early stage of the evaporation experiment. The growth rate of water evaporation of five coal samples gradually slowed down. When the soaking time reached 4320 min, the water evaporation of the five coal samples gradually became stable.

From the perspective of different coal particle sizes, during the same evaporation time, the larger the coal particle size, the smaller the cumulative water evaporation amount. The water evaporation amount of 10 mm coal particle sample is the largest, followed by 20 mm coal sample, and 50 mm coal sample is the smallest. In the initial 1440 min, the water evaporation rate of 10 mm and 20 mm coal particles is relatively high, and the duration of high evaporation rate is also longer. In general, the larger the coal particle size, the shorter the duration of high evaporation rate.

From the perspective of water evaporation, at the beginning of the immersion experiment, the water evaporation of coal samples of five scales increased rapidly. The coal particles of 10 mm scale began to decrease at 2850 min, while the coal particles of 20 mm scale showed a turning point of decreasing evaporation at 2130 min. At 1410 min, the coal particles of 30 mm scale began to show a turning point of decreasing evaporation, and at 630 min, the coal particles of 40 mm and 50 mm scale began to show a turning point of decreasing evaporation.

After nearly 10 days of evaporation experiment, the water evaporation of 10 mm coal particles is the largest, reaching 15.2683 g, accounting for about 12.12% of the evaporation. Water evaporation of coal particles at 20 mm scale can reach 12.7034 g, accounting for about 10.69%. The water evaporation of coal particles at 30 mm and 40 mm scales ranges from 6.366 g to 6.7812 g, accounting for about 5.46% to 5.83%, and the evaporation law at this scale is similar. The water evaporation of coal particles at 50 mm scale is 4.0663 g, and the proportion of evaporation is only 3.52%, which is the smallest.

According to the above experiments, it can be seen that the coal particle size is directly related to the coal water evaporation amount, which basically shows a trend that the larger the coal particle size, the shorter the rapid evaporation duration and the smaller the cumulative water evaporation amount. The main reason is that the smaller the coal particle size and the larger the particle number, the larger the overall particle surface area and the larger the contact area with the air, and the increased water loss.

5. CONCLUSIONS

The cumulative water evaporation of coal samples of different scales increases with the increase of evaporation time, and the water evaporation loss is faster in the initial stage of evaporation experiment.

During the same evaporation time, the larger the coal particle size, the smaller the cumulative water evaporation amount. The water evaporation amount of 10 mm coal particle sample is the largest, followed by 20 mm coal sample, and 50 mm coal sample is the smallest.

The larger the coal particle size, the shorter the duration of rapid evaporation and the shorter the time for cumulative evaporation to stabilize.

The experiment shows that coal particle size is directly related to coal water evaporation, basically showing a trend that the larger the coal particle size, the shorter the rapid evaporation duration and the smaller the cumulative water evaporation amount. The main reason is that the smaller the coal particle size and the larger the particle number, the larger the overall particle surface area, the larger the contact area with the air, and the increased water loss.

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