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Experimental investigation on the changes of the wettability and surface characteristics of coal dust with different fractal dimensions

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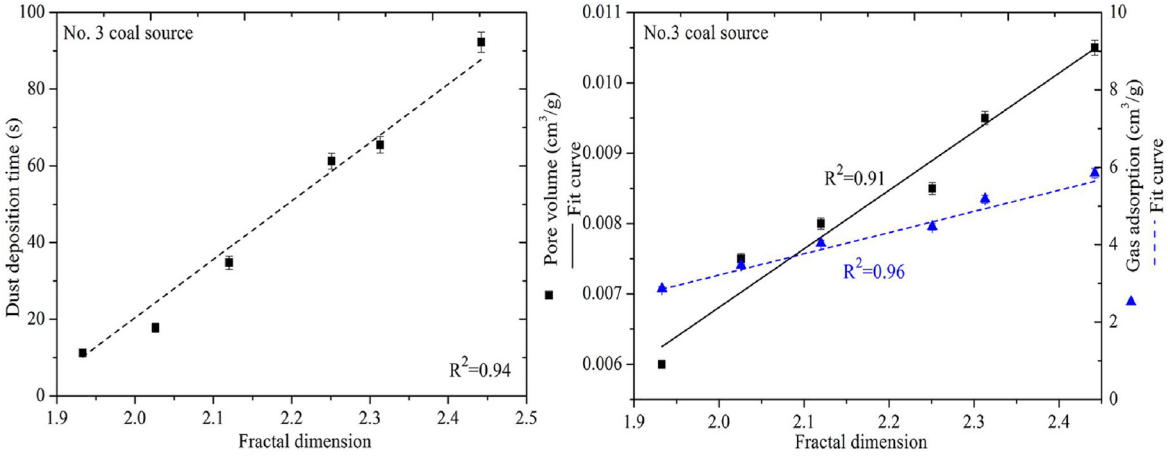
GRAPHICAL ABSTRACT



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ABSTRACT

To analyze the reasons leading to variations in the wettability of coal dust (from the same coal source) with different diameters (D50), in this study, we used fractal dimensions of the particle size distribution to evaluate the wettability and surface characteristics of the dust (specific surface area, pore structure and gas adsorption ability). These were investigated using dust deposition time and gas adsorption experiments. The results showed that the surface characteristics of coal dust exhibited strongly positive correlations with the fractal dimension. As fractal dimension increased, the specific surface area and gas adsorption ability of coal dust remarkably increased, which may cause the poor wetting performance due to the easier formation of a gas film around the dust. For example, for coal dust with a fractal dimension of 2.593, the specific surface area and gas adsorption increased by 46.1% and 79%, respectively, compared to the values for dust with a fractal dimension of 2.042. Moreover, among four different coal sources, the volume of pores was significantly enhanced with the fractal dimension increased, indicating the more pore structures were developed, increasing the difficulty of spreading a wetting solution on the dust surface. This study concluded that the wettability of coal dust acquired from the same coal source was variable and decreased as the fractal dimension increased.

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Table 1
Particle diameters (D50, μm) of coal sources corresponding to six mesh size ranges.

Meshes		80–160	200–250	250–350	350–450	450–500	≥500
Particle size (D50, μm)	No. 1	142.34	74.22	56.52	38.62	24.36	14.69
	No. 2	116.68	82.68	56.56	42.57	32.42	19.02
	No. 3	114.96	77.34	58.08	33.75	25.24	18.71
	No. 4	120.3	75.33	53.62	38.39	30.28	16.83

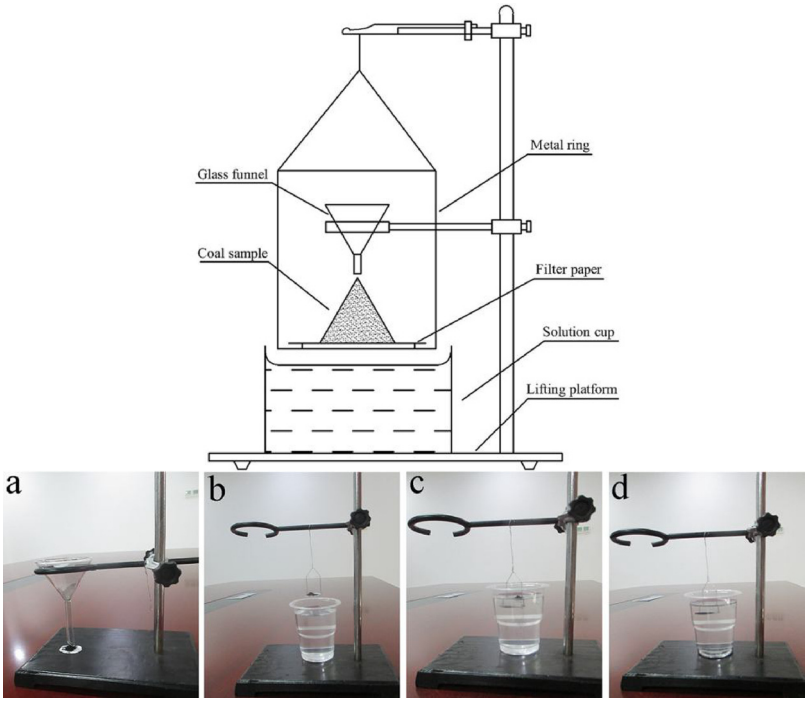

Fig. 1. Experimental system used to measure dust deposition time (a: the formation of a coal dust pile; b: the metal ring carrying the coal dust pile; c: the separation between the filter paper and coal sample; d: the whole coal sample became immersed).

1. Introduction

Coal dust has been a serious problem endangering coal workers' health globally, but especially in China because most of China's coal is exploited in underground mines [1]. According to incomplete statistics, the number of Chinese coal workers diagnosed with pneumoconiosis exceeded 446,000 by the end of 2015 [2]; this disease not only causes enormous pain for the pneumoconiosis patients but also imposes a huge economic burden on the coal mining industry [3]. Therefore, solving mine dust problems has become an urgent demand of the coal mining industry.

At present, dust suppression technologies using water are widely applied in underground coal mines [4]. However, the dust control efficiency of water-based techniques is commonly low, especially for respirable dust (< 40%). Most scholars attribute low dust suppression efficiency to the poor dust wetting ability of water and the hydrophobic properties of coal dust [5,6]. However, these reasons do not completely explain why the dust control efficiency of water spray is poorer as the diameter of coal dust particles (from the same coal source) decreases. The crude grade of the coal dust surface could also affect the wettability of the dust [7]. Therefore, it is necessary to study other factors (specific surface area, pore structures and gas adsorption ability) affecting the wetting features of coal dust.

Recently, many scholars have conducted relevant research on the wettability of different metamorphic coals. Xu et al. [8] reported that the aromatic and fat hydrocarbon structures (C═O) of coal increased as the metamorphic grade of coal increased, decreasing the wettability of coal dust. Zhou [9] and Cheng et al. [10] found that coal dust with a greater content of polar functional groups (−COOH, −OH, etc.) had better wettability than dust with lesser contents of these groups. In addition, extensive research on the wettability of coal dust has been conducted using proximate analysis, for which results indicated that the content of fixed carbon is negatively correlated with the wettability of coal dust [8,11]. However, from the perspective of physical characteristics of coal dust from the same coal source, few studies have been conducted on their effects on the wettability of coal dust.

Some researchers thought that the self-weight of particles with different diameters was the important factor causing the variation in the wettability of coal dust (from the same coal source) [12,13]. However, for coal dust with diameter < 20 μm, which is suspended and transported long distances in wind [14], the self-weight of coal dust would not be the critical factor hindering the wetting effect between coal dust and wetting solution. Furthermore, the coal dust surface was found to be relatively rough and to contain many tiny pores [15], increasing the difficulty of spreading a wetting solution on the coal dust surface and possibly affecting the wettability of coal dust. And for the crude degree of coal dust surface, some researchers reported that the surface profile of coal dust can be evaluated by the fractal dimension of particle size distribution, i.e. with the increase of the fractal dimensions, the coal surface become rougher [16,17]. Additionally, Li [18] founded that fractal dimension as a quantitative parameter could more comprehensively evaluate the particle size distribution features of coal dust than the medium diameter of coal dust (D50), because the experimental coal dust generally contains lot of particles with different diameters. Nevertheless, the changes of the wettability and surface characteristics of coal dust (from the same coal source) with different