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Synergistic coal dust control using aqueous solutions of thermoplastic powder and anionic surfactant

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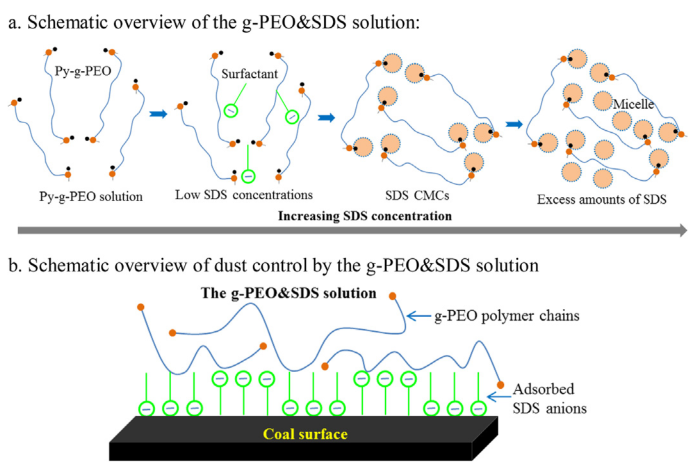
HIGHLIGHTS

- A new method of dust suppression with g-PEO&*SDS* was studied.
- Quantitative analysis by fluorescence revealed the *CMC* of g-PEO and *SDS*.
- The mechanism of coal dust control by g-PEO&*SDS* was analyzed.

GRAPHICAL ABSTRACT



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ABSTRACT

For the control of pulverized coal, we propose a dust suppressant by applying a blend of mixed polyethylene oxide (g-PEO) and sodium dodecyl sulfate (*SDS*). In our experimental study, the thermal characteristics, critical micelle concentration (*CMC*), wettability and adhesion of the dust suppressant are investigated. It was found that g-PEO had a low fusing temperature and its combustion temperature was close to that of coal, thus, the solution containing g-PEO applied coal dust control did not affect the use of the coal. Based on steady-state fluorescence using pyrene as a fluorescent label, quantitative analysis revealed that the *CMC*s of g-PEO and *SDS* were 1 and 20 g/L in g-PEO&*SDS* solution, respectively. The solution containing *SDS* had the best wettability, but it only had a short-term effect. The solution containing g-PEO showed negligible wetting ability to wet coal dust. The solution containing g-PEO&*SDS* had better wetting ability and adhesion. Scanning electron microscopy showed that the coal dust covered by g-PEO&*SDS* on its surface could form a thin layer of armor by holding the particles together after air-drying. It was concluded that the g-PEO&*SDS* solution containing g-PEO for 1 g/L and *SDS* for 20 g/L could suppress coal dust and maintain a long-term effect.

1. Introduction

It is well known that from the mining to the use of coal, many aspects (such as mining, transportation, transferring and storage)

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are involved in the whole process, which results in significant levels of dust. Dust particles smaller than 10 μm, known as airborne dust, are the most dangerous. The spread of combustible coal dust and its deposition may cause explosions [1]. Due to airborne dust containing free silica and being suspended in the atmosphere, long-term exposure of the human respiratory system can cause pneumoconiosis [2,3]. Airborne dust can also cause economic losses, mechanical equipment damage, pollution of the surrounding environment and affect surrounding residents [4].

In order to control coal dust, methods such as water spray, dust suppressant and aqueous foam have been mainly applied. The use of water spray to control particulate matter (PM) is a common method, and in many cases, this method is effective. However, water sprays that are used in dust control are effective only for short-time periods, therefore regular reapplication is required. Drop size, drop velocity, drop distribution, spray pattern and spray pressure can all influence the effect of dust control by spraying water [5–7]. In addition, the vast majority of dust features obvious hydrophobicity.

A more efficient and long-term approach of dust suppressant to suppress dust is required. Many studies have been conducted on dust control. Guy et al. [8] studied the wetting behavior of organic liquids in water on coal surfaces, namely, hexane, diiodomethane, cyclohexane, o-xylene, toluene, dichloromethane, oleic acid, hexan-L-ol and chloroform, but these organic liquids have defects such as volatility, insoluble in water, low toxicity or flammability. Copeland et al. [9] studied the influence of distilled water, acetylenic glycol and #2 fuel oil suppressant behaviors on sub-bituminous coal. They found that #2 fuel oil was more effective than distilled water and acetylenic glycol for dust control, but #2 fuel oil poses environmental hazards and has flammability. Wu et al. [10] studied sodium dodecyl sulfonic salt (SDS), dodecyl benzene sulfonic acid sodium salt and water glass as dust suppressants. They discovered that a complex wetting agents comprised of 6 wt.% water glass and 0.6 wt.% SDS is best for dust control, but the dust suppressant is easy to air-dried. Gillies et al. [11] studied four dust suppressants, namely, a biocatalyst stabilizer, a polymer emulsion, a petroleum emulsion with polymer and nonhazardous crude-oil-containing materials. They obtained good long-term efficiencies for controlling the emission of PM10 from public unpaved roads, but a disadvantage of these dust suppressants was that the materials could adhere to vehicle tires and other objects. Also, this type of application cause environmental and health concerns. Yan et al. [12] and Medeirosa et al. [13] studied glycerin for dust suppression, but its application and use are generally lacking. Aldrin et al. [14] studied a $MgCl_2$ solution for controlling road dust emission, but the dust suppressant poses environmental hazards. Amato et al. [15] and Norman et al. [16] studied a calcium magnesium acetate solution for controlling road dust emission, but the effect of controlling airborne dust is not obvious. Tanthapanichakoon et al. [17] tested a wetted wire screen for suppressing fugitive dust. However, the collection efficiency tended to decrease as the inlet dust concentration or the air velocity was increased.

Aqueous foam is an effective method for dust control [18], which can capture dynamic dust, as well as suppressing fugitive dust from static dust. However, it retains dust suppression only for a short time. After it is volatilized and air-dried, the dust is raised again, so, regular reapplication is required [19]. In view of the disadvantages of dust control technology, a new dust suppressant is the firstly put forward for coal dust control. It is mainly composed of thermoplastic powder and anionic surfactant, has the following properties: no side effects with coal quality, suppressant longevity, ease of particle engulfment, interparticle adhesion forces and non-toxic for effective PM control.

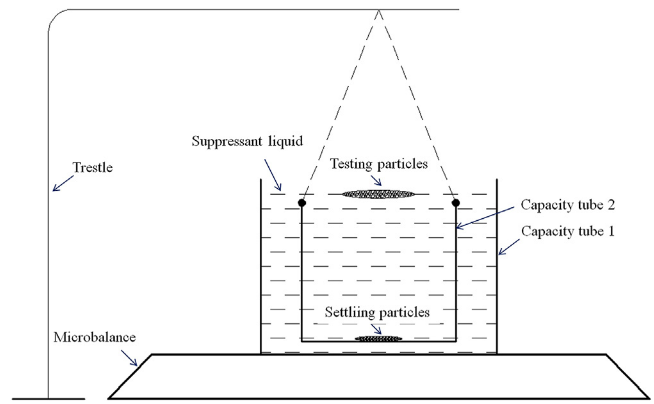

Fig. 1. Self-made sinking test apparatus.

2. Materials and methods

2.1. Materials

The thermoplastic powder was mainly comprised of a mixture of industrial-grade polyethylene oxide (g-PEO). The anionic surfactant was mainly SDS (Aladdin, 99%). Pyrene was used as a fluorescent label (Py, Aladdin, Analytical-grade). Milli-Q purified water was used throughout the study. The coal sample had a particle size less than 150 meshes (0.1 mm) and was collected from Nanjiang Wharf, Tianjin Port, China.

The Py-g-PEO solutions were prepared as follows. Pyrene was added into a flask under a stream of nitrogen, then, PEO and water were added in turn. The Py-PEO solutions were prepared at concentrations of 0.05, 0.10, 0.20, 0.40, 0.60, 0.80, 1.00, 1.20, 1.40, 1.60, 1.80 and 2.00 g/L, and the final pyrene concentration was 2 mg/L in every Py-PEO solution. As for the above method, the Py-PEO solutions were prepared at a concentration of 1 g/L for eleven parts, then, SDS was added into the Py-PEO solutions. The obtained SDS concentrations were 2, 4, 6, 8, 10, 15, 20, 25, 30, 40 and 50 g/L.

2.2. Methods

The g-PEO combustion was carried out using an SDT Q600 simultaneous differential scanning calorimeter/thermogravimetric analyzer. During the experiment, the sample was placed in an alumina crucible and heated from 27 to 650 °C at a rate of 10 °C/min. An industrial grade air bottle was used for conducting the combustion experiment.

Steady-state fluorescence studies were carried out using a Cary Eclipse fluorescence spectrophotometer (VARIAN). The sample emission spectra were acquired by exciting at 334 nm and the excitation and emission slits were 5.0 and 2.5 nm, respectively. All samples were examined at room temperature.

Fig. 1 shows the self-made sinking test apparatus, which was used to test the soakability of the coal sample in solutions containing either SDS, g-PEO or g-PEO&SDS. By taking 500 mg coal samples and sprinkling them on the solution surface, it is known that the test coal samples will be wetted and pass through the solution surface until they can settle onto the bottom of capacity tube 2. The weight displayed on the microbalance (accuracy of 1 mg) gradually decreases with time and the particles from the buoyancy are ignored.

The ability of the solutions containing SDS, g-PEO and g-PEO&SDS to soak into the coal bed for a coal dust particle size of less than 0.1 mm was measured. The micro-morphology was observed on the g-PEO&SDS covering the coal bed before air-drying by a stereomicroscope and the surface morphology of the coal bed cov-