Powder Technology 339 (2018) 882–893

Contents lists available at ScienceDirect

Powder Technology

journal homepage: www.elsevier.com/locate/powtec

Evaluating of the performance of a composite wetting dust suppressant on lignite dust

Lei Zhou [a], Shuying Yang [a], Bin Hu [a], Zhulin Yuan [a], Hao Wu [b,*], Linjun Yang [a,*]

[a] Key Laboratory of Energy Thermal Conversion and Control of Ministry of Education, Southeast University, Nanjing 210096, Jiangsu, China
[b] School of Energy and Mechanical Engineering, Nanjing Normal University, Nanjing, 210042, PRChina

ARTICLE INFO

Article history:
Received 11 December 2017
Received in revised form 22 August 2018
Accepted 30 August 2018
Available online 31 August 2018

Keywords:
Lignite dust
Wetting ability
Dust suppressant
Fine particles
Chemical suppression

ABSTRACT

The traditional method of suppressing dust by spraying water is not effective for lignite owing to its hydrophobic characteristics. Thus, an effective composite wetting dust suppressant was designed to improve the suppressive efficiency of this method. In this study, proximate analysis and Fourier-transform infrared spectroscopy (FTIR) were conducted for lignite dust. The wetting ability of the surfactants, the atomization performance of droplets, as well as the effect of inorganic salt on the water evaporation rate, were also investigated. The effective composition of the dust suppressant was confirmed by simulating the spraying suppression process and conducting an experiment for industrial application. The results show that lignite has strong hydrophobic properties owing to its chemical properties and surface morphology. The wetting ability of the surfactants is shown to depend on the surface tension and chemical structure of the surfactants. The addition of surfactant could obviously reduce the diameter and increase the axial velocity of droplet. The evaporation rate was reduced after adding hydrating inorganic salt without affecting the surface tension. By adding a composite wetting dust suppressant with a composition of 0.1% T-1 and 0.9% $CaCl_2$, the total dust removal efficiency of the simulated spraying suppression system was improved from 75.11% to 96.73%, and the mass concentration of fine lignite particles was decreased from 83.37 to 15.153 mg/m^3. The results of the industrial application experiment show that the mass concentration of lignite dust was reduced from 747.2 to 21.3 mg/m^3, and the suppression efficiency reached ~97.1%.

1. Introduction

In recent years, China has frequently experienced haze weather caused mainly by airborne particulate matter with diameter <2.5 μm ($PM_{2.5}$) [1–3].The two main types of fine particle emissions include: organized and fugitive emissions. The amounts of organized emissions have been substantially reduced under the ultra-low emission reformation scheme for coal-fired power plants and by strengthening the control of motor vehicle exhaust emissions in China [4–7]. However, effective governing of fugitive emissions is difficult because they are complex and originate from a variety of sources [8,9].

On 06-17-2017, China's Ministry of Environmental Protection revised the air pollutant discharge standard (GB16297-1996). This revision enhanced the requirements for fugitive emission control measures in the transportation, loading, unloading, storage, and production processes in coal mines and coal-fired power plants. Several methods of reducing fugitive dust emissions include using a dust-proof net, hardening the surfaces of area in which dust accumulates, and spraying dusted areas with water [10–13].

Chemical dust suppression has recently become a more innovative and effective method for suppressing fine particles. However, it is difficult to create a universal, highly efficient but low-cost suppressant for different types of dust. Several different dust suppressants have been proposed for specific applications. The mining industry was one of the first to apply chemical dust suppressants [14–16]. In the 1930s, the United States Bureau of Mines used a wetting agent (Nonol W-433) to prevent the release of mining dust [17]. Miguel etal. developed an efficient dust suppressant by using a glycerol by-product of biodiesel, which effectively prevented the dispersion of PM, especially iron ore, into the atmosphere [18]. Wu etal. reported that the wetting performance of a surfactant could be significantly enhanced by changing its composition [19]. Du etal. suggested that compared with spraying water to suppress dust, spraying dust suppressant onto roads reduced water usage by 98%, reduced the cost of dust suppression by 31%, and increased the dust suppression efficiency to 98.4% [20].

With the depletion of high-quality coal, lignite has become one of China's primary fuel sources. However, the traditional method of spraying water for dust suppression is less effective when applied to lignite because this material is less hydrophilic [21]. The belt transport process at mining sites is characterized by significant amounts of pollution, which can cause pneumoconiosis, explosions, and other accidents

---

* Corresponding author.
E-mail addresses: wu-hao@njnu.edu.cn (H. Wu), ylj@seu.edu.cn (L. Yang).

https://doi.org/10.1016/j.powtec.2018.08.081

[22,23]. However, a lignite dust suppressant has not been reported thus far. Therefore, investigating an effective dust suppression agent specifically for lignite is important.

In this paper, the chemical structure of lignite surface is examined by FTIR, and the wetting ability of surfactant and the effect of inorganic salt concentration on the water evaporation rate are assessed. Various methods are adopted to select a non-ionic surfactant as the main body, which was then combined with a hydrating inorganic salt to produce an effective wetting dust suppressant.

2. Experimental set-up and methods

2.1. Experimental set-up

A wind tunnel was designed for conducting a dust suppression experiment that involved water spraying, as shown in Fig. 1. The experimental set-up included an axial flow fan, a plexiglass experimental storehouse, a screw feeder, a two-fluid atomization nozzle (XAAD050-C, BETE Ltd., USA), and the measurement system. Lignite dust was added at the top of the plexiglass experimental storehouse by using the screw feeder. The wind was generated by the axial flow fan, and the wind speed could be adjusted from 0 to 15 m/s by changing the axial fan's frequency. Afterwards, the wind speed and flow field were stabilized by a direction regulation device, the wind then suspended the lignite dust. The two-fluid nozzle was placed 30 cm behind the feeding hole. Water was then sprayed onto the lignite dust to conduct dust suppression.

During the experiment, the feeding speed was maintained. Opening the axial flow fan adjusted the frequency to 15 Hz, which produced an internal wind speed of 5 m/s, and the wind suspended the falling lignite dust. The surfactant solutions were atomized into small droplets by the two-fluid nozzle and were then sprayed onto the falling lignite dust. The water volume and air flow of the two-fluid nozzle were 60 L/h and 3m^3/h, respectively. The lignite dust particles could be collected from the high-speed section of the experimental set-up, and the total dust suppression efficiency of the suppressant was calculated as follows:

$$\eta = \frac{C_a - C_b}{C_a} \times 100\%, \tag{1}$$

where η is the total dust suppression efficiency (%), C_a is the mass concentration of the lignite dust before spraying (mg/m^3), and C_b is the mass concentration of the lignite dust after spraying (mg/m^3).

2.2. Measurement technique

A laser particle size analyzer (BT-9300ST, Baxter Technology *Co*., Ltd. China) was used to measure the particle size distribution of the lignite dust. The concentration of fine particles was determined by an electrical low-pressure impactor plus (ELPI+, Dekati Ltd., Finland) in real timebefore and after the spraying process. The ELPI+ has 14 stages (13 channels), with a measurement range of 0.030 to 9.314 μm. The lignite dust in the set-up was collected by a flue dust sampling instrument (WJ-60B, LSDZ Ltd., China), and the total dust concentration and suppression efficiency were calculated according to the Chinese national standard (GB/T16157-1996). The functional groups and bonds on the lignite's surface were identified by using FTIR (Voctor22, Brukr Spectral Instrument *Co*. Ltd., German), and spectra within the range of 4000–500 cm^{-1} were acquired. An automated interfacial tension instrument (BCZ-800, ZBBCYQ*Co*. Ltd., China) was used to measure the surface tension of the surfactant solution. The solid-liquid interface's Zeta potential of lignite particles immersed in surfactant solution was measured by using a zeta meter (JS94J, Powereach Instrument *Co*. Ltd., China). Based on the measurement of droplet's scattering angle, the size distribution and axial velocity of atomized droplets were determined by using a laser phase Doppler anemometry system (PDA, Dantec Dynamics *Co*. Denmark). During the test, the sampling point was 20 cm below the two-fluid nozzle, and the air pressure and water pressure of the nozzle were 0.3 MPa and 0.2 MPa, respectively. An intelligent atmospheric sampling instrument (Laoying-2050, LATRI*Co*. Ltd., China) was used to collect all lignite particles suspended in the workshop.

2.3. Experiment materials

The particle size distribution of the lignite dust used in the experiment is presented in Fig. 2. The lignite particles were smaller than 100 μm, with a median diameter (D_{50}) of 26 μm. In addition, PM_{10} and $PM_{2.5}$ accounted for 18% and 4.3% of the total dust, respectively. This indicates that the particles of lignite sample could not easily be captured

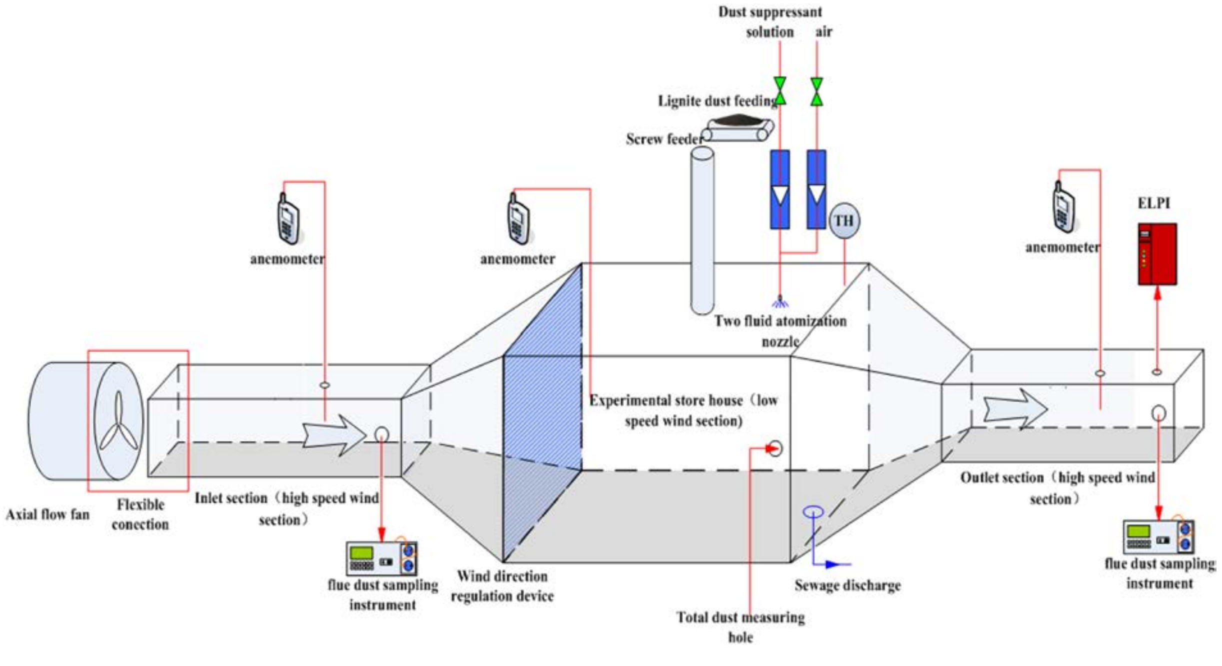

Fig. 1. Schematic diagram of the experimental set-up for dust suppression.