Fuel 219 (2018) 492–501

Contents lists available at ScienceDirect

Fuel

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

Full Length Article

Fluidization and separation characteristics of gas–solid separation fluidized bed with wet coal

Bo Lv[a,b], Zhenfu Luo[a,b,*], Bo Zhang[a,b]

[a] Key Laboratory of Coal Processing and Efficient Utilization of Ministry of Education, China University of Mining & Technology, Xuzhou 221116, China
[b] School of Chemical Engineering and Technology, China University of Mining and Technology, Xuzhou 221116, China

ARTICLE INFO

Keywords:
Gas–solid separation fluidized bed
Agglomeration
Fludization characteristics
Moisture content
Coal sorting

ABSTRACT

Raw coal is usually sorted using a gas–solid separation fluidized bed in a dry environment. However, when wet coal is sorted, the moisture carried by the coal causes the fluidized environment in the gas–solid separation fluidized bed to become extremely complex. In the present study, the mechanism whereby moisture is transferred to the medium particles was examined, the phenomenon that the coal and medium particles were subject to an agglomeration mechanism was found. The surface bonding properties of coal are affected by the particle size, moisture content, and the relative motion of the coal and medium particles, which is determined by the formula for calculating the bridging force. The effect of the moisture content on the fluidization characteristics is such that an increase in the water content exacerbates the agglomeration of the media particles, especially once the water content exceeds 1%, with channel flow and local collapse occurring in the fluidized bed (e.g. S_p = 0.33 in the axial direction), which adversely affects the sorting. Through a study of the coal surface adhesion and sorting, it was revealed that the critical amount of external moisture for the effective separation of coal falls with the particle size. For medium- and fine-grained coal, the critical moisture content can be as low as 2% and 1%, while the value can be as high as 4% for the coarse-grained coal.

1. Introduction

Coal constitutes the main source of energy in China, with a move towards the clean utilization of coal being a current trend. The traditional wet separation technology not only leads to a waste of water resources, but may also cause pollution of the environment. At the same time, in the northwest region, which is characterized by a lack of water while being rich in coal resources, wet sorting technology is difficult to utilize effectively. Therefore, in this area, dry sorting without using water is an important technique. A gas–solid separation fluidized bed uses a gas–solid two-phase flow as the separation medium, so that coal can be sorted effectively without the use of water, making it one of the main types of dry-sorting technique [1–5]. With the popularization and application of gas–solid separation fluidized bed technology, the range of materials that can be sorted has been expanded. When sorting wet coal, however, due to the involvement of water, the fluidization characteristics change considerably, which can affect the sorting process. A study of the effect of wet coal on the fluidization and sorting would be beneficial to the post-industrial application of gas–solid separation fluidized bed technology.

After wet coal enters a dry separation system, the moisture from its surface is brought into the fluidized bed and combines with the fluidizing medium. To overcome the impact of moisture in a fluidized bed, previous developments have relied mainly on a chemical-based approach to control the fluidization granulation, with the object of research mainly being the attainment of a uniform particle size. Masoumeh et al. [6] showed that the addition of water leads to the occurrence of particle agglomeration, and then went on to briefly describe three types of agglomerate. Fan et al. [7] studied the different characteristics of an evaporative liquid jet being injected into a gas–-solid fluidized bed, with the results clearly exhibiting the effects on the bubble phenomenon and fluidization quality. McDougall et al. [8] suggested that, with the continuous wetting of the fluidized bed particles, the particles exhibit agglomeration behavior, while the bound particles of the transport disengaging height (TDH) decrease in number and the particle size distribution changes. Zhang et al. [9] studied the wetting and drying processes of fluidized bed particles used for pharmaceuticals, and proposed that the moisture content of the granules and the apparent gas velocity are the two main factors affecting the bubbling behavior of the bed. Weber et al. [10] used powdered sugar as the fluidized medium to study the effects of the physical properties on the stability of sugar-syrup agglomerates. They proposed that the

* Corresponding author at: School of Chemical Engineering and Technology, China University of Mining & Technology, Xuzhou 221116, China.
E-mail address: zfluo@cumt.edu.cn (Z. Luo).

https://doi.org/10.1016/j.fuel.2018.01.071
Received 10 November 2017; Received in revised form 29 December 2017; Accepted 19 January 2018

smaller and lighter agglomerates contained more water, and discussed the combination and fragmentation of agglomerates in the fluidization process. McDougall et al. [8] suggested that the introduction of a liquid into a fluidized bed may result in the formation of wet agglomerates that settle to the bottom of the bed, while the liquid may also spread over the particles, increasing their agglomeration and reducing the bed fluidity. Zhou et al. [11] established the fluidization mechanism of a wet gas–solid fluidized bed with different liquid addition rates at high temperatures, with their results showing that, with a low-speed liquid, the liquid evaporation increases the apparent air velocity to promote fluidization in the bed, while the liquid bridge between the particles leads to bed reunion with a high-speed liquid, thus preventing fluidization. Sutkar et al. [12] was the first to use the PIV technique to measure the velocity of the particles in a spouted bed, and found that the moving velocity of the wet particles in the bed was lower. However, for a gas–solid separation fluidized bed, the impact of the external moisture of the coal fed into the fluidized bed was rarely involved.

The present study considered a gas–solid separation fluidized bed, with the aim of studying the moisture transfer mechanism for different-size particles (between coal and media particles) or uniform-size particles (between medium particles), investigating the influence of moisture on the fluidization characteristics, and determining the maximum amount of external moisture that may be present on the coal for dry sorting.

2. Experimental

2.1. Experimental system and method

The test facility, shown in Fig. 1, consisted of a rectangular fluidized bed model (160 mm (L) × 160 mm (W) × 400 mm (H)) made of Perspex and equipped with an air chamber, an air distribution plate, a bed body, a U-type pressure gauge to measure the pressure drop in the bed, and a high-speed dynamic camera to capture the fluidization state of the fluidized bed under different operating conditions.

The fluidization characteristics of the gas–solid separation fluidized bed are mainly reflected in the bed pressure drop and bed density, while the density of the fluidized bed is obtained by converting the measured pressure drop. The pressure drop measurement points are set out as shown in Fig. 1. Since the height of the bed varies with the velocity of the airflow, the bottom of the bed was used as the reference point for all measurements. When the axial pressure drop is measured, the center of the bed was used as the measuring area, and measuring points were set at points every 20 mm from the air distribution plate, giving a total of seven measurement points. When the radial pressure drop is measured, a cross-section of up to 60 mm is taken as the measurement area, which is divided into nine segments for measurement. To examine the mechanism whereby water is transferred between the media particles and the coal, the coal is divided into three grades: fine-grained (6–13 mm), medium-grained (13–25 mm), and coarse-grained (25–50 mm), with different external moisture contents. The coal is placed in a fluidized bed for a short time, and the weight of the agglomerates of coal and the medium particles is measured to calculate the cohesiveness of the coal. During the separation experiment, coal samples with different particle sizes and amounts of external moisture were sorted. After sorting for a set period, the process was shut down and the sorting products were extracted from four layers, evenly along the axial direction. After drying, screening, and then ash detection, the degree of ash segregation was calculated to evaluate the separation efficiency of the coal when using a gas–solid separation fluidized bed.

2.2. Material

The medium particles used in the experiment were industrial grade magnetite powder, the particle sizes of which are listed in Table 1. To accurately prepare the moisture content of the fluidized medium, a 101-3AB electrothermal blast drying box was used to preheat and dry the magnetite before the start of the experiment. The coal used was bituminous coal, and particles with a size of 6–50 mm were used.

2.3. Evaluation method

An important index of the fluidization stability of gas–solid separation fluidized beds is the density fluctuation variance *Sp*, given as follows:

$$S_P = \sqrt{\frac{\sum_{i}^{n} (\rho-\rho_o)^2}{n}} \tag{1}$$

where ρ is the local bed density (cm/s); ρ_o is the average density (cm/s); and *n* is the number of measurements.

For the agglomeration process of the coal and medium particles, the bridging force is evaluated from the agglutinating value *G* of the coal surface, as given by Eq. (2):

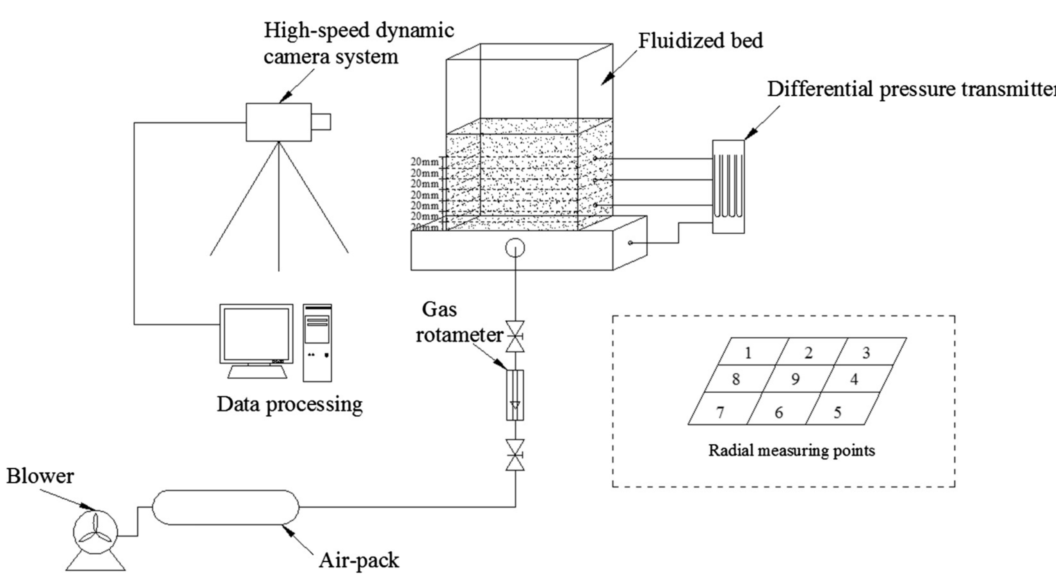

Fig. 1. Experimental system.