International Journal of Mineral Processing 165 (2017) 15–19

Contents lists available at ScienceDirect

International Journal of Mineral Processing

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

Effect of scraper movement on the separation performance of air dense medium fluidized bed

Nianxin Zhou [a], Zhenfu Luo [a,*], Wei Huang [b], Yuemin Zhao [a]

[a] School of Chemical Engineering and Technology, China University of Mining and Technology, Xuzhou, Jiangsu 221116, China
[b] Julius Kruttschnitt Mineral Research Centre, University of Queensland, Brisbane 4068, Australia

ARTICLE INFO

Article history:
Received 12 June 2016
Received in revised form 8 March 2017
Accepted 24 May 2017
Available online 25 May 2017

Keywords:
Air dense medium fluidized bed
Scraper movement
Bed pressure drop
Minimum fluidized velocity
Bed density

ABSTRACT

Experimental studies on the influence of scraper movement on the fluidization of air dense-medium fluidized bed (ADMFB) have been conducted. The maximum bed pressure drop is about 3% when the scraper speed changes from 0 to 0.5 m/s. The minimum fluidized velocity U_{mf} decreases as the scraper speed increases. At the same time, the bed density only declines by 3.7%, and the density standard deviation decreases significantly which is mainly caused by the horizontal motion of the medium. The separation tests indicated that the most appropriate scraper speed is between 0.1 m/s and 0.3 m/s and it was reasonable to move the scraper at the appropriate rate to get the better separation performance.

1. Introduction

China is the largest country in terms of both the coal production and consumption, and the proportion of coal in total energy consumption has been up to about 70% (Sha et al., 2012; Lv et al., 2015). The traditional wet method for coal beneficiation has been applied widely, and the water consumption is huge. However, more than 2/3 of coal resource in China distributes in the arid area of northwest China, which limits the coal preparation proportion significantly (Deng et al., 2013; Mac Pherson and Galvin, 2010; Yang et al., 2012). ADMFB is a novel high-efficient dry separation technology, which is featured by the application of air-solid two-phase flow as the separation medium. The separation precision of ADMFB is close to that of the wet dense medium coal separation. This method is benefit for the coal preparation in arid area, which is important for sustainable development (Chen, 2006; Sahu et al., 2013; Song et al., 2012). In spite of above advantages, the industrial application of ADMFB is still limited by some technical problems. Among these, the effect of scraper movement plays an important role in the separation performance of ADMFB, which was neglected in the previous studies (Mohanta et al., 2013; Wei et al., 1998; Wang et al., 2016; Zhao et al., 2010).The scraper movement would have an influence on the bed pressure drop, the stability of bed density and the movement of material in bed in different degrees. Nevertheless, the effect of scraper movement on the fluidized bed has not yet been well understood. This paper introduces the experimental studies of the effect of scraper movement on the basic parameters of ADMFB. The changing trends of basic bed parameters caused by the scraper movement are investigated and analyzed to provide operational reference for the industrial ADMFB.

2. Experimental

The lab scale ADMFB system consists of a fluidized bed, a roots blower, an air bag, a rotor flow meter, a scraper system (including motor and reducer, inverter and scraper) and a pressure measuring device (Fig. 1.). The fluidized bed is formed by a plexiglass cuboid of 1200 mm × 250 mm × 500 mm, with accessories of air distribution plates and two trapezoidal air pre-distribution chambers.

The dense media used in this study are the magnetite powders, with the true density of 4.53 g/cm^3 and bulk density of 2.05 g/cm^3. The size distribution of the magnetite powder is given in Table 1.

In order to measure the bed pressure drop, the measuring ports of minimum fluidized velocity and bed density were drilled on the side wall of fluidized bed both in horizontal and vertical directions with the equal distance. U-tube was used to measure the pressure gap between different measuring ports. Coal particles of −25 + 13 mm were selected for float-and-sink test. Particles in the narrow densities were painted with different colors and used as tracing particles in the ADMFB separation test. The tracing particles enable

* Corresponding author.
E-mail address: zfluo@cumt.edu.cn (Z. Luo).

http://dx.doi.org/10.1016/j.minpro.2017.05.010

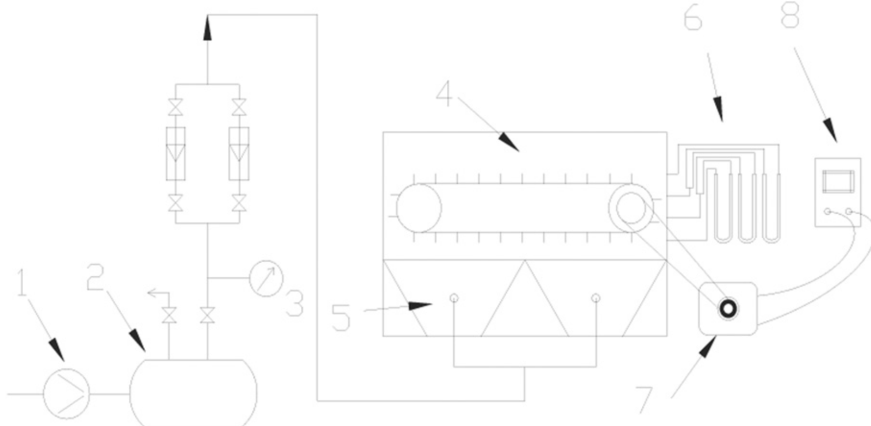

Fig. 1. Schematic diagram of the lab scale ADMFB system. (1) Roots blower (2) air bag (3) airflow meter (4) scraper (5) air pre-distribution chambers (6) device-tube (7) motor and reducer (8) inverter.

the replacement of float-and-sink test by hand-select, which are benefit for the fast evaluation of separation performance.

3. Results and discussion

3.1. Effect of scraper movement on bed pressure drop

If the scraper moves too fast, the light and heavy composites will be directly discharged before efficient separation. Therefore, the maximum scraper speed is determined to 0.5 m/s and parameters are measured with the speed of scraper between 0 and 0.5 m/s. The bed stability, which plays a key role on the fluidization separation process, is affected by the fluidized bed pressure drop (He et al., 2013a,b; Tang, 2015). Based on the principal of fluidized bed separation, the experiments were conducted under following conditions:

The static bed height was fixed at 300 mm, and measurements of bed pressure drop were conducted at different airflow rate and scraper speeds. If the airflow rate is smaller than 0.75 U_{mf} of the fluidized bed with on scraper moving, the scraper is difficult to move due to the high resistance. Hence, the measurements of pressure drop for the bed with moving scraper starts from 0.75 U_{mf}. As shown in Fig. 2, a significant protuberant point can be found in the fluidization characteristic curves of the left, middle or right part of the fluidized bed when the scraper is static. As the scraper speed increases, the protuberant points become less significant and even disappear after the scraper speed reaches 0.4 m/s. Also, the bed pressure drop decreases slightly as the scraper speed increases.

This appearing of the protuberant points can be attributed to the change of internal friction form of the medium as the result of scraper movement. The movement of scraper provides part of the energy required by the fluidization bed in the form of mechanical energy, which overcame part of the static friction among medium powders. During the conversion from static bed to fluidized bed, the friction among particles in bed converts from static friction force f_s to kinetic friction force f_m. Before the static bed changes to fluidized bed, the airflow has to overcome a big resistance among particles in bed as the f_s is bigger than f_m. For the fluidized bed, the larger f_s has been replaced by the smaller f_m, and the protuberant points disappear on the fluidization characteristic curves. On the other hand, with the interference of scraper movement, additional mechanical force is provided to overcome part of the static friction force f_s, which can help to reduce the resistant force among bed body particles and the pre-fluidized bed body. Therefore, a small air flow speed can realized the fluidization of particle bed, with a lower bed pressure drop. This also causes the disappearance of the protuberant point. It can be found that the decrease of bed pressure drop with the increase of scraper speed is slight. This can be attributed to the horizontal direction of the force exerted by the scraper on fluidized bed. In addition, the movement of scraper does not change the total medium mass in the bed. Thus the bed pressure drop only decreases for 3% at scraper speed of 0.5 m/s if compared to that of the test with static scraper.

Table 1
Particle size distribution of the magnetite powders.

Size/mm	−0.074	−0.15 + 0.074	−0.3 + 0.15	−0.5 + 0.3	+0.5
Yield/%	12.00	17.00	64.00	6.00	1.00

3.2. Effect of scraper movement on the minimum fluidization velocity

The minimum fluidization velocity (U_{mf}) can be estimated from the intersection point of the extensions of the straight sections in the fluidization characteristic curves of static bed and fluidized bed (Yang et al., 2013; Manasi and Bhatu, 2017). Fig. 3 depicts that, the value of U_{mf} decreases with the increase of scraper speed rapidly in the beginning, and then the decreasing rate slows down at higher scraper speed. As the scraper speed increases from 0 to 0.5 m/s, the value of U_{mf} decreases by 5.6% from 8.85 cm/s to 8.35 cm/s.

The effect of scraper movement on the value of U_{mf} can be explained by the conversion of internal friction among medium powders. Airflow has to overcome the static friction force among particles to convert the static bed into fluidized bed. Part of the static friction force among particles in the initial fluidization period is offset by the mechanical energy provided by the moving scraper. Therefore, the airflow rate required to fluidize the bed reduces if compared with those in tests with static scraper.

3.3. Effect of scraper movement on the bed density

The bed density determines the proportion of floated and sunk materials in the separation product. The stability of bed density associates with the accuracy of separation. Thus, the measurement of the medium density for the fluidized bed with moving scraper is of great importance. In order to reflect the total density stability of the cuboids bed in this study, 9 well-distributed measuring ports are selected. The standard deviation ($\Delta = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(\rho_i - \overline{\rho})^2}$) of the measured data is used to represent the stability of the total bed density, and results are shown in Table 2.