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Process optimization for coal cleaning by enhancing the air-distribution stability of dry separator

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ABSTRACT

With 0.3–0.074 mm vanadium-titanium magnetite powder used as the fluidized medium, the overall fluctuation of bed pressure drop and the uniformity and stability of bed density in the secondary air-distribution fluidized bed (SAFB) were experimentally investigated. Compared with the conventional fluidized bed (CFB), SAFB demonstrated smaller fluctuations of bed pressure drop, generated more smaller-sized bubbles, and had a more even bed density, which indicated more stable separation condition. A larger value of $(U_{mb} - U_{mf})$ in SAFB indicates the larger stability region in the bed, which improves the applicability of fluidized bed. To ensure the bed stability within suitable superficial gas velocity U, the operating factors of the secondary air-distribution bed height H_d and the weight fraction of coarse magnetite powder in the mixture of separating medium α should be adjusted to vary in the ranges of 13–17 mm and 80–90%, respectively. With the optimal operation parameters of the static bed height H_s, U, H_d, and α, orthogonal array testing technique was adopted to design and perform the separation experiments of 6–25 mm Yiluo coking coal. Finally, the ash and sulfur contents of coal sample were reduced from 38.98% and 1.31% to 12.26% and 0.82% in SAFB, respectively. The cleaning coal with a yield of 60.74% was obtained at a separating density of 1.64 g/cm^3 and a probable error E_P value of 0.05 g/cm^3. Therefore, SAFB presents better separation efficiency than that of CFB, which indicates a favorable application prospect in industry.

1. Introduction

As an important energy resource, coal currently accounts for a high proportion of the primary energy consumption of the world. The proportion of coal consumption of China reaches 70% in recent years [1,2]. Given the low washing rate of run-of-mine (ROM) coal in China, the rapid coal consumption has brought unprecedented pressure to the environment. Remaining solid waste from coal combustion, such as coal cinder and coal ash, occupy surrounding land. Thus, enhancing the washing rate of ROM coal, improving the coal quality, developing new types of environmentally friendly, widely available technologies, advanced equipments are of great significance to save coal resource and protect environment. Traditional coal preparation technology is mainly based on wet processing, which uses water as the separating medium, including hydraulic jigging, dense medium separation, hydro cyclone separation, spiral separation and flotation, etc. [3–7]. However, water-shortage has become a worldwide problem that human must face and encounter, especially in China, India, South Africa, etc. Considering that two-thirds of available coal resource is located in the west and north arid regions of China, water-shortage severely restricts the coal washing, as well as its comprehensive exploitation and utilization. In the past few years, as a representative dry cleaning technique, air dense medium fluidized bed (ADMFB) has attracted considerable research attention because the gas–solid fluidized bed shows the advantages of low cost of investment, no water use, high separation efficiency, wide range of separating density, etc. This technology sufficiently solved the problem of coal beneficiation in the areas and countries that suffer from water-shortage [8–11].

In recent years, ADMFB has become a focused subject that attracted the attention of the scientists in many countries [12–14]. For instance, the study on the removals of ash and concentrated mercury of Alberta sub-bituminous coal was conducted with ADMFB as the main equipment in University of Alberta [15,16]. J. Oshitani from Okayama University utilized ADMFB to separate particulate iron ore and achieved satisfied separation results [17–19]. Considerable theoretical and practical researches on the gas–solid fluidization beneficiation technology have been carried out by China University of Mining and Technology (CUMT) since the year of 1984 [20–25]. The dry separation of ADMFB can realize highly efficient and clean utilization of ROM coal with the use of the mixture of air and magnetite powder as the separating medium based on Archimedes' law. Then, the cleaning coal and tailing were separated out from ROM coal by density difference. The most important factors

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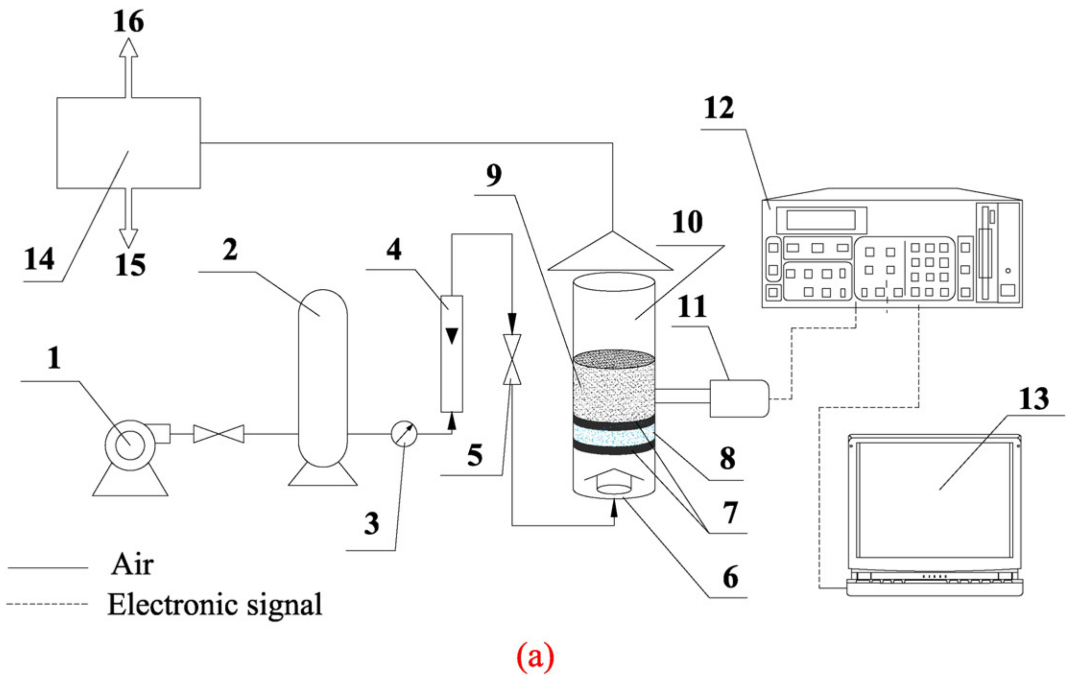
are to create favorable fluidization stability and provide uniform density distribution in the three-dimensional spaces of the fluidized bed [26–28].

Normally, the conventional fluidized bed (CFB) used the self-designed air distributor to ensure the uniform distribution of feeding air, which was installed at bed bottom. However, equipment enlargement and decline in coal quality greatly restricted the development of CFB, which caused the deterioration in bed stability and the decrease in separation efficiency of coal. Therefore, the secondary air-distribution fluidized bed (SAFB) was proposed recently in order to improve the fluidization quality and density stability of the bed by introducing the secondary air-distribution layer (SAL) [29]. In the study, the added air-distribution layer in the SAFB was mainly composed of 0.3–0.074 mm magnetite powder as well. Magnetite powder between two air distributors will expand and fluidize in a small range with the increase of gas velocity. More uniform and small-sized bubbles will be produced under the action of gas and fluidized medium. Thus, a stable and uniform bubbling fluidized bed can be formed, and the bad fluidization performances of intense turbulence, slugging, and the back-mixing of fluidized medium particles were greatly reduced and avoided.



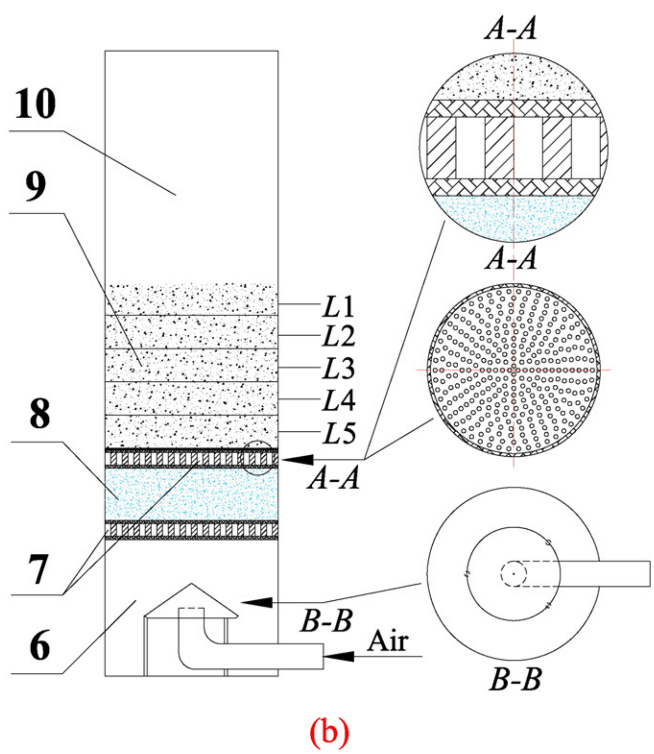


Fig. 1. Schematic of the experimental apparatus based on the SAFB: 1. fan blower; 2. air buffer; 3. air valve; 4. rotameter; 5. butterfly valve; 6. air chamber; 7. air distributor; 8. secondary air-distribution layer; 9. separating space; 10. gas–solid fluidized bed separator; 11. pressure transducer; 12. data transmission and control device; 13. data receiver; 14. dust collector; 15. settled dust; 16. clean air.