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A novel dry beneficiation technology for pyrite recovery from high sulfur gangue

Chenlong Duan [a,*], Chenyang Zhou [a], Liang Dong [a], Yuemin Zhao [a], Qingxia Liu [a,b]

[a] Key Laboratory of Coal Processing and Efficient Utilization of Ministry of Education, School of Chemical Engineering and Technology, China University of Mining and Technology, Xuzhou 221116, China
[b] Canadian Centre for Clean Coal/Carbon and Mineral Processing Technologies, University of Alberta, Edmonton, Canada

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ABSTRACT

Pyrite in the gangue was considered as the waste causing harmful environmental problems. It is of great significance to enrich pyrite from high sulfur gangue. Due to the serious problem of water shortage especially in India, South Africa and North-West China, a novel dry beneficiation technology was firstly proposed for pyrite recovery of <50 mm size fraction in the study, namely combination technology of air dense medium fluidized bed and vibrated fluidized bed. Separation experiments of air dense medium fluidized bed showed that the yield of 13–50 mm and 6–13 mm samples were 67.91% and 64.13%. The recovery rate of 13–50 mm and 6–13 mm samples were 81.69%, 79.51%, respectively. Separation results of vibrated fluidized bed at optimal conditions were shown that the yield of 3–6 mm, 1–3 mm and 0.5–1 mm were 54.85%, 38.60% and 43.56%. The recovery rate of 3–6 mm, 1–3 mm and 0.5–1 mm were 75%, 65.64% and 71.45%. The results of XRD and XPS showed pyrite was the foremost mineral in the concentrate with the highest proportion. The study indicated that combination technology could be effectively used for pyrite recovery from high sulfur gangue.

1. Introduction

In 2016, the coal production is 34.1 million tons in China (BP, 2017), accounting for 47% of the global share where consumed more coal resource than any country. Along with the large production of coal in China, about 4.5 billion tons of gangue are produced during the coal preparation accounting for 10%–15% of raw coal, which is regarded as the largest proportion of solid waste (Liang et al., 2016). Many heavy metals, such as Zn, Cr, Cd, Cu are contained in the gangue, which may be harmful to people's health (Zhang and Ouyang et al., 2014; Sun et al., 2009; Leffa et al., 2010). In another aspect, gangue is also a mixture of mineral materials, which may have advantages in industrial production. At present, government have encouraged companies to improve the gangue utilization and decrease the gangue accumulation. Liang (Liang et al., 2016) reported that gangue can be backfilled to the underground. Especially the cemented coal gangue added with fly ash results in better fluidity. Liu et al. Qiu et al. and Guo et al. (Liu et al., 2011; Qiu et al., 2011; Guo et al., 2010) studied that the coal gangue can be used as a cementitious material, which is a substitute of clay in the process of cement manufacture. Guo et al. and Wang et al. (Guo et al., 2014; Wang et al., 2008) researched that many valuable elements could be obtained and the solid waste can be used as a fertilizer with the high content of N and P.

At present, high sulfur coal with much pyrite has already accounted for a large proportion in China (Yang et al., 2016; Luo and Bai, 2005). However, the pyrite may be considered as the waste in the gangue, which may be directly related to the spontaneous combustion damaging the air condition. Meanwhile, as important minerals, pyrite have been widely used for preparing smoke agent, rubber, paper, textile, matches, especially for the semiconductor materials in the chemical industry (Bulut et al., 2014; Patra and Natarajan, 2003; Shukla et al., 2014). Thus, it is of significance to enrich pyrite from the gangue not only for the environment protection but for the chemical industry. At the present, scholars from different countries have studied the cleaner production for pyrite recovery (Attia et al., 1988; Oliveira et al., 2016). Many traditional methods were proposed such as flotation (Yakup and İbrahim, 2002), shaking table (Lukwinski, 1975), jig (Hao and Wang, 2009) and cyclone (Huang and Tang, 2010). Due to the serious problem of water shortage and high investment, traditional separation technologies can't meet the industrial requirement (Mohanta et al.,

* Corresponding author.
E-mail address: clduan@cumt.edu.cn (C. Duan).

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2013). It is urgent to study efficient dry separation method. As hot topic in the field of dry separation, air dense medium fluidized bed (ADMFB) has drawn many attention all over the world due to the accurate separation efficiency (Luo and Chen, 2001; Mohanta et al., 2011a, 2011a, 2011b; Zhang et al., 2014, 2011b; Zhang et al., 2014). At present, Sahu et al. and Monhanta et al (Sahu et al., 2009; Mohanta et al., 2013). has used the ADMFB for separating 6–25 mm Indian high ash coal with the separation efficiency of 0.12 g/cm^3. Oshitani et al. reported iron ore separation using ADMFB (Oshitani et al., 2011). Particularly, Zhao and his group from China University of Mining and Technology has been successfully used ADMFB for 6–50 mm coal separation with a probable error (E) of 0.05. They also established the first industrial scale dry coal preparation plant in Xinjiang, China (Zhao et al., 2016). Thus, we can attempt to use the ADMFB for the pyrite recovery with the +6 mm size fraction in the study.

In addition, pyrite would be existed in the gangue with fine particles, which need to be crushed with -6 mm size fraction for the liberation. Traditional dry separation method couldn't effectively meet the requirements for fine particle (<6 mm) beneficiation. Therefore, different dry method has been proposed for fine minerals beneficiation, like vibrated fluidized bed (VFB) (Yang et al., 2013a, 2013b; Dong et al., 2017). Yang used VFB for coal beneficiation with probable error E values of 0.06–0.125, which is of great significance for the fine minerals beneficiation in the dry method area. Meanwhile, fine pyrite beneficiation need the higher cost in the wet beneficiation filed, which caused the limitation on the development of pyrite recovery. Thus, the attempt of fine pyrite recovery using VFB is essential for the industrial process in the future.

In the study, we have proposed a novel dry beneficiation technology for pyrite recovery from high sulfur gangue, namely combination technology of ADMFB and VFB. ADMFB and VFB were respectively used for pyrite recovery of >6 mm and <6 mm size fraction. The basic characteristics of high sulfur gangue was investigated with advanced measurement equipment. In addition, the effects of operation conditions on the beneficiation efficiency was analyzed in the experiments.

2. Experimental

2.1. Experimental apparatus

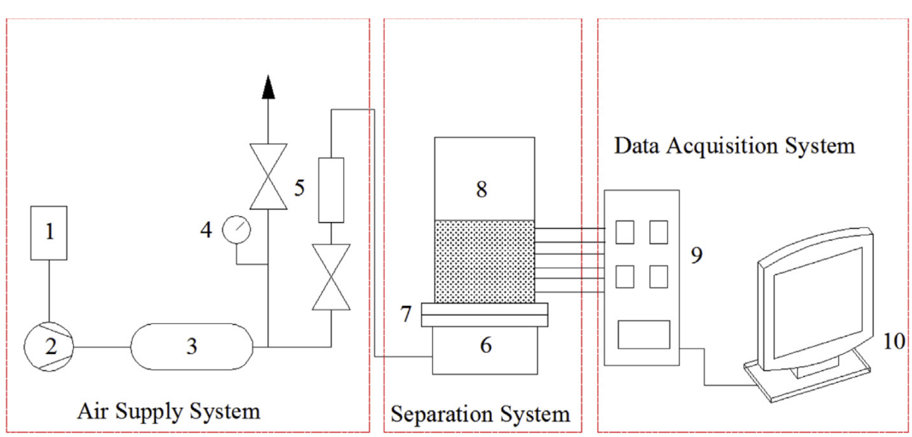
The apparatus of ADMFB is shown in Fig. 1, which is mainly composed of air supply system, fluidized bed and data acquisition system. Air supply system mainly includes a blower, an air bag and flowmeters. Fluidized bed is made of plexiglass with diameter of 300 mm and height of 450 mm. Data acquisition system is mainly composed of pressure data analysis system, which is applied to analyze the pressure drop, density fluctuation and bubble behavior. In the separation experiments, the pseudo-fluid is generated with a stability density. Particles (>6 mm) with less density would float on the surface of bed, or the particles would sink at the bottom of bed. The static bed height was average divided into four layers in the axial direction from top to bottom and the top layer was regard as the first layer.

As shown in Fig. 2, The apparatus of VFB was mainly contained four parts: air supply system, vibration generator system, fluidized bed and data acquisition system. Vibration generator system mainly includes the vibration platform and computer control system. Fluidized bed is made by plexiglass with diameter and height of 120 mm and 300 mm, respectively. Air supply system and data acquisition system is the same as that of ADMFB. In the separation experiments, raw minerals is directly put in the fluidized bed without dense medium. With vibration energy and gas introduced, the dilute phase area is generated for particles separation due to the density variation. As a result, particles with less density would accumulated in the upper of bed whereas particles with heavy density would accumulated in the bottom of the bed.

2.2. Mineral properties analysis

2.2.1. Components analysis of high sulfur gangue

The high sulfur gangue was supplied by a mining company from Inner Mongolia. A scanning electron microscope (SEM, FEI quanta 250, America) coupled with an energy dispersive spectrometer (EDS, Bruker QUANTAX 400-10, Germany) was used for the appearance and components of high sulfur gangue was obtained from Inner Mongolia. As shown in Fig. 3, the sample was mainly contained the elements of Si, Al, S and Fe. The surface analysis of element distribution showed that S and Fe mainly appeared in the same position, indicated that the sample may contained amount of pyrite. An X-ray fluorescence spectrometer (XRF, Bruker S8 Tiger, Germany) was used for analyze the chemical composition accurately. As shown in Fig. 4, S and Fe were the main elements in the gangue, accounting for 26.13% and 22.77%, which further depicted that the pyrite was the main composition in the gangue.



1.Air blower;2.Valve;3.Pressure tank;4.Pressure gauge;5.Rotameter.;6.Air chamber; 7. Air distributor;
8. Fluidized bed body; 9. Signal acquisition system; 10. Data analysis system.

Fig. 1. Schematic diagram of air dense medium fluidized bed experimental apparatus system.