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Comparison of flotation performances of low rank coal in air and oily bubble processes

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ABSTRACT

Low rank coal is typically difficult to float using traditional flotation processes. In this study, a novel flotation process, oily bubble flotation, was proposed and evaluated using samples of low rank coal. X-ray photoelectron spectrometer (XPS) and scanning electron microscope (SEM) were used to characterize the surface chemical and morphology properties of coal samples. Induction time tests were used to compare the mineralization degree between air or oily bubble and low rank coal particle surfaces. It was found that flotation selectivity in the oily bubble flotation process was considerably higher than that in the traditional flotation process. With the increase of collector dosage, the combustible matter recovery in the oily bubble flotation process increased from 62.92% to 82.65% while the ash content of the concentrate slightly increased from 7.43% to 8.21%. Moreover, the ash content of concentrate obtained from the oily bubble flotation process was slightly lower than that in the air bubble flotation process. Therefore, a comparison of the performances of air and oily bubble flotation indicated that the oily bubble flotation process was feasible for upgrading low rank coal.

1. Introduction

The efficient and clean technology development of coal preparation is the focus of researchers' attention worldwide [1–3]. Therefore, clean coal technology is becoming more and more important with respect to effective combustion as well as environmental pollution [4,5], especially in China, where there are many low rank coal beds produced in the Shendong Coalfield in Shanxi province. Moreover, it has proven difficult to achieve a high yield or combustible matter recovery with physical separation and traditional air bubble flotation methods using oily collectors, such as kerosene, diesel and fuel oil, because the coal surface was oxidized [6–8]. The oxidized surface of low rank coal covered with oxygen-containing functional groups such as phenol, carboxyl, and carbonyl, which reduce the hydrophobicity of the surface, easily forms the hydrogen bonds with water molecules [9]. To obtain a high yield or combustible matter recovery of fine low rank particles, a high dosage of oily collectors is required, which tends to increase the cost of the air bubble flotation process.

Recently, the reactive oily bubble technology has been applied to selectively floating bitumen from oil sand ores in Alberta [10–12] and found to improve the flotation of bitumen by increasing the contact angle between bubbles and particles and also decreasing the induction time [13]. As the flotation carriers, reactive oily bubbles are distinguished from air bubbles because reactive oily bubbles can easily control the oil/water interfacial chemistry by dissolving desired types and concentrations of water insoluble collectors in the oil phase [14–16]. Compared with conventional air bubble flotation which involves addition of a collector in the water phase, addition of collectors in reactive oily bubble flotation to the aqueous phase is called zero conditioning procedure [14]. This oily bubble technology was developed by Liu et al. [15] and Xu et al. [16].

Different from oily bubble technology developed by Liu et al. [15] and Xu et al. [16], the experimental apparatus designed by Xia and Yang [17] produced dodecane vapor in a heating jacket when the temperature reached about 215 °C. The dodecane steam was then injected into the flotation slurry. Due to thermal motions of air molecular and oil drop, the oily bubbles were produced in the pulp when the temperature of dodecane steam decreased from 215 °C to room temperature. Flotation results of these experiments were better than traditional air bubble flotation. However, the heating process requires a large amount of electric energy which is likely to increase the cost of the flotation process.

To date, the reactive oily bubble flotation has not been applied for low rank coal flotation in Chinese coal plants because it has proven difficult to achieve a high yield or combustible matter recovery with air bubble flotation method [9]. In this paper, the authors tried to enhance the flotation performance of low rank coal using oily bubble flotation technology. In the current study, the flotation performance of low rank coal in air and oily bubble flotation processes were compared using samples from the Da Liuta Coalfield. A modified experimental apparatus based on the designs of Liu et al. [15] and Xu et al. [16] was

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Table 1
Proximate analysis of Shendong low rank coal sample (air dried).

Mad (%)	Vad (%)	FCad (%)	Aad (%)
2.86	29.27	50.56	17.31

developed, and a 1.5 L mechanically agitated flotation cell was also used to separate the low rank coal particles. Induction time tests with air and oily bubbles and results from air and oily bubble flotation processes are expected to provide useful information concerning the improvement in low rank coal flotation performance.

2. Experimental

2.1. Materials

Low rank coal samples were provided by the Da Liuta Coal Preparation Plant in Shendong Coalfield in the Shanxi province of China. The coal samples were obtained prior to the concentration process, dried and sieved to less than 0.500 mm, and sealed for experiments. All experiments were conducted with the coal samples. Proximate analysis of low rank coal samples on air dried basis is shown in Table 1, where Mad is the moisture content, Vad the volatile matter content, FCad the fixed carbon content, and Aad is the ash content.

2.2. XPS measurement

X-Ray photoelectron spectrometer (XPS) was used to characterize the surface chemical properties of the low rank coal sample. XPS experiments were carried out at room temperature in an ultra-high vacuum (UHV) system with a surface analysis system (ESCALAB 250Xi, Thermo Fisher, USA) using Al Kα radiation (hv = 486.6 eV) from a monochromatized X-ray source. For all analyses, the takeoff angle of the photoelectrons was 90° and the spot size was 900 μm. The data processing (peak fitting) was conducted using XPS Peak Fit software using smart type background subtraction and Gaussian-Lorentzian peak shapes [18,19]. The binding energies were corrected by setting the C1s hydrocarbon (–CH2–CH2– bonds) peak at 284.8 eV.

2.3. SEM measurement

Scanning electron microscope (SEM) was adopted to identify the states of low rank coal sample and flotation concentrates. Coal samples including concentrates from air and oily bubble flotation processes, respectively, and raw coal were prepared for SEM by surface cleaning with absolute ethyl alcohol, air dried, and sputter-coated with a layer of gold. Quanta 250 SEM (FEI, USA) was used to analyze the surface morphology of the coal samples.

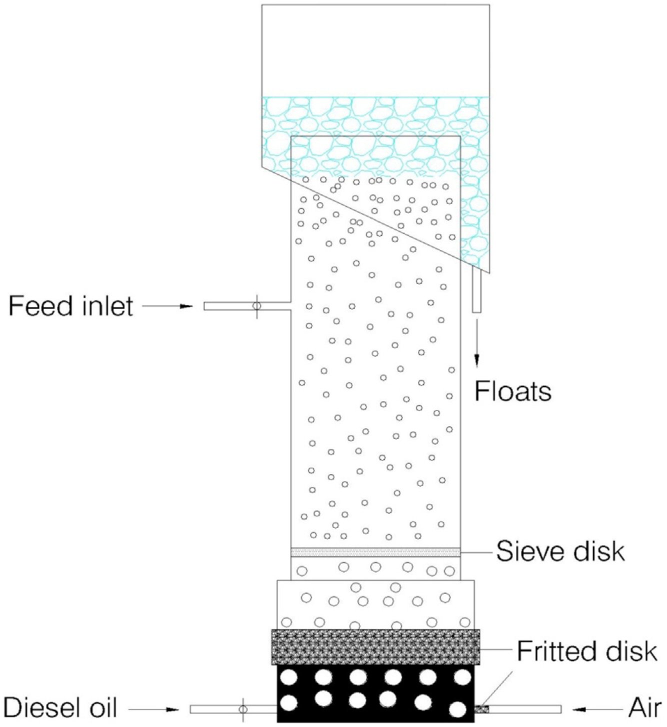

Fig. 2. The schematic of new designed oily bubble floatation instrument.

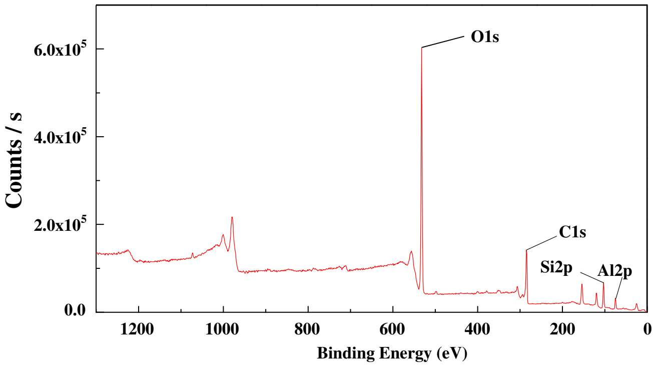

Fig. 3. XPS wide energy spectrum of Shendong low rank coal surface.

2.4. Induction time measurements

The hydrophobicity of samples was characterized by induction time tests. At a given hydrodynamic condition, shorter induction times

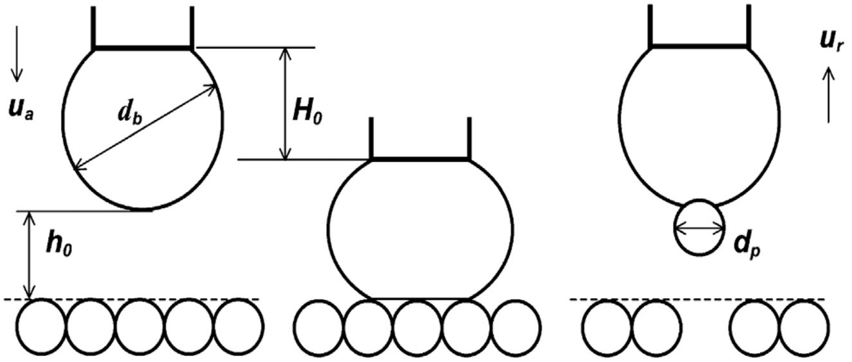

Fig. 1. A schematic of the measurement of induction time [16].