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Short communication

Effects of attrition on coarse coal flotation in the absence of collectors

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A B S T R A C T

Samples of clean coarse coal particles (0.5–0.25 mm) were used and the flotation process was conducted in the absence of collectors. Scanning electron microscope with energy dispersive spectrometer (SEM/EDS) was used to indicate the elementary composition on coal particle surface as well as particle shape. The attrition process was conducted in a flotation cell with a varied period of stirring process prior to the flotation process. Throughout this paper, it was found that the content of carbon element on coarse coal surface was reduced after attrition whereas the contents of aluminium and silicon elements were increased. A small part of organic matters could release from coarse coal surface by attrition. The attrition process rounded the edges of the coal particles. The flotation performance of coarse coal particles with round corner was worse than that of coal particles with sharp corner. A long period of attrition process could be conducive to obtain a low ash concentrate.

1. Introduction

The floatability of coal particle is a complex parameter which is determined by many factors. Even though the types of functional groups on coal surface play an important role in the hydrophobicity of coal surface, the surface elementary composition, surface morphology, particle size, and particles shape should be also considered as the primary factors determining the hydrophobicity of coal surface [1–4]. It is well known that low rank and oxidized coals are difficult to float because there are many hydrophilic oxygen-containing functional groups on their surface [5–7]. Therefore, the types of functional groups on coal surface are considered to be the most important parameter determining coal surface hydrophobicity [8–11].

The surface morphology has been proved to be an important factor affecting the hydrophobicity of quartz particle surface. Guven et al. [12] found that the blasted quartz particles with more angular and rougher surfaces had better floatability than the un-blasted quartz particles. Ulusoy et al. [13] revealed that calcite and barite particles with higher flatness and elongation ratio had higher apparent hydrophobicity. Ulusoy and Yekeler [14] found that the wettability degree of calcite and barite particles increased with the increase of surface roughness. Koh et al. [15] found that the ground ballotini particles had a higher flotation rate than the spherical ballotini particles. Rahimi et al. [16,17] found that the flotation kinetics constant of quartz particles increased with the increase of surface roughness and the particles with higher elongation and lower roundness had higher floatability. Ahmed [18] also found that the particle with rougher surfaces showed higher loaded froths and faster flotation kinetics than the particles with smoother and cleaner surfaces. Rough glass beads are proved to have higher flotation recovery than smooth ones since the interaction forces for the smooth glass beads were higher than that of rough ones as indicated by AFM [19].

In this paper, the attrition process was used to change the shape of coal particles. The premixing has been widely used in coal conditioning processes. Piskin and Akgun used premixing to remove the oxidized layer to improve the flotation of oxidized Amasra coal and found the premixing period of 1 min is the best for flotation improvement prior to oxidized coal flotation [20]. Xia et al. [21–23] found that the conditioning time could be as short as zero for the best flotation performance of oxidized coal. Coal particle shape can be changed after the premixing process as well as the attrition process. In addition, the elementary composition on coal particle surface can be changed since some components may be polished by the attrition process and release to the flotation pulp forming fine particles. The aim of this paper was to investigate the effect of particle shape and surface elementary composition on the natural floatability of coarse clean coal particles.

2. Experimental

2.1. Coal samples

Clean coal bulks were selected by hand from Coal Preparation Plant. The bulks were crushed by a jaw crusher. The crushed clean coal

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particles were screened in order to obtain 0.5–0.25 mm size fraction which was for the flotation tests in this investigation. The ash content of 0.5–0.25 mm size fraction is 8.50% which may be considered as low ash and clean coal indeed.

2.2. SEM and EDS measurement

Quanta 250 SEM (FEI, USA) and Bruker Quantax 400 -10 EDS were used to analyze the surface elementary composition and particle shape of coal particles (only for 0.5–0.25 mm). The coal samples were prepared by surface cleaning using absolute ethyl alcohol. After the surface cleaning, the coal samples were dried in air. Before SEM tests, the coal samples were sputter-coated with a layer of gold.

The magnification time of 33 was used to investigate the particle shape and the magnification time of 2000 was to study the surface elementary composition of coal particles. In here, more than 20 particles were selected to the measurements of surface elementary composition on coal surface. The particles for EDS testing were selected on a random basis. This selection method may be representative for the actually experimental data.

2.3. Flotation procedure

This paper was to investigate the natural floatability of clean coal particles, and hence the collectors were not used, but the frother (2-Octanol) was used to ensure the stability of bubbles. The dosage of frother was 200 g/t coal. The flotation tests were conducted in a 1.5 L XFD flotation cell. The impeller speed of flotation machine was 1800 r/min and the airflow rate was 4.0 L/min in each flotation test.

In this investigation, flotation procedures were introduced as follows: First, 100 g coal was added into flotation cell with about 0.75 L water and agitated/attrited for a period. The period of stirring and attrition process was 1 min and 60 min. The attrition process was achieved based on the attrition produced by the impeller of flotation machine in a high pulp density. Second, the frother of 200 g/t was added into flotation pulp and conditioned for 2 min. Third, another 0.75 L water was added to the flotation cell and the flotation process begun and the froth products were collected. The flotation products were collected, dried, weighted and forward to size composition and ash content tests.

In this investigation, The coal particles before and after the attrition process without flotation were screened to pass 0.25 mm to investigate the crushing of coal particles during coal flotation and attrition processes. The particles with >0.25 mm size were forwarded to SEM/EDS measurements.

3. Results and discussion

3.1. Flotation results

Fig. 1 is the comparison of products yields in the two flotation procedures using different periods of attrition process. The yield of <0.25 mm in the concentrate are similar but different in the tailings. The yield of <0.25 mm in the tailings of 1 min attrition flotation is lower than that in the tailings of 60 min attrition flotation. Some <0.25 mm coal particles are formed by the crushed products from >0.25 mm coal particles during the attrition process. The period of 60 min attrition process could produce some fine particles <0.25 mm. The yield of >0.25 mm in the concentrate of 1 min attrition flotation is much higher than that in the concentrate of 60 min attrition flotation. In contrast, the yield of >0.25 mm in the tailings of 1 min attrition flotation is much lower than that in the concentrate of 60 min attrition flotation. It indicates that 60 min attrition process has a negative effect on flotation performance of coarse coal flotation. The floatability of coarse coal can be reduced by a long period of attrition process. Further discussion will be given by SEM/EDS results.

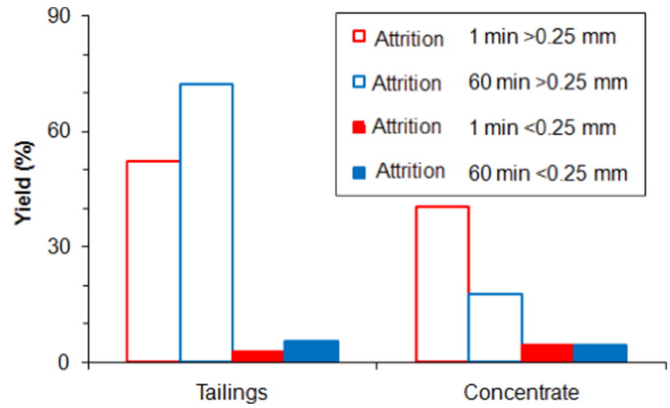

Fig. 1. Comparison of products yields using 1 min and 60 min attrition processes.

Fig. 2 is the comparison of products ash contents in the two flotation procedures using different periods of attrition process. It indicates that the ash contents of both 0.5–0.25 mm and <0.25 mm size fractions in both the tailings and concentrate of flotation under 1 min attrition are higher than those under 60 min attrition. A long period of attrition can be conducive to obtain low ash concentrate. It proposes an important message that increasing the attrition time can produce qualified clean coal with lower ash content.

3.2. SEM/EDS results

Figs. 3 and 4 are the SEM pictures of coarse coal particles with varied attrition processes. It is obviously that the coal particles with 1 min attrition own many shape corners whereas the coal particles with 60 min attrition own many round corners. The attrition process polishes the surface of coal particles and the shape corners are polished into round corners [1,20]. During the attrition process, some coal fines are produced because of the attrition process. In addition, the particle crushing may also produce fine coals. As a result, a long period of attrition process produces more fines than 1 min attrition process. Fig. 1 proves that the yield of coal fines in 60 min attrition flotation is about 10% which is higher than that (about 7%) in 1 min attrition flotation.

Based on Figs. 3 and 4, the roundness of each particle is obtained using the image processing technology with MATLAB software [24]. As shown in Fig. 5, the distribution of roundness of coal particle after 1 min and 60 min attrition processes. It indicates that the roundness

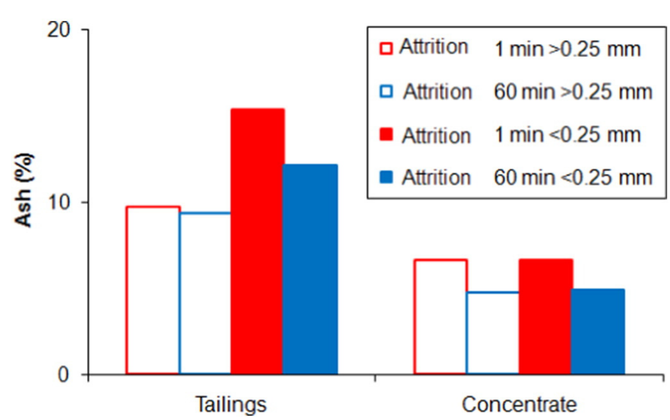

Fig. 2. Comparison of products ash contents using 1 min and 60 min attrition processes.