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Effects of clay and calcium ions on coal flotation

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ABSTRACT

The microflotation of three single minerals, mixed coal–kaolinite and mixed coal–montmorillonite were examined to study the effects of clay and calcium ions on coal flotation. The results show that the ash content of flotation concentrate increases by 3% in the presence of clay minerals, and the ash content would further increase by 3% in co-presence of clay minerals and high concentration of Ca^{2+}. Scanning electron microscope (SEM) images and elemental spectrum analysis indicate that fine clay particles that coat on the coal surface, which is called slime coating, can affect the coal flotation. The slime coating would be induced much more easily in the presence of Ca^{2+}.

1. Introduction

The modernization of mining technologies increases the amount of mineral impurities in raw coal and puts the pressure on coal preparation [1,2]. The gravity separation method cannot separate the fine particles efficiently [3]. The problem will be more serious in those cases where the clay minerals and other fine impurity particles which accompany the fine coal are sent to the flotation process. Various types of clays, including kaolinite, montmorillonite and illite, are considered as the major components of fine mineral impurities [4].

In addition to the increased load on the flotation process, the presence of fine clay particles may have negative effects on coal flotation. The effects of fine clay on coal flotation have been investigated extensively over the last 60 years. The conflict of observations has been reported in studies [5–8]. Some investigators have noted that the presence of fine clay or other slime particles may inhibit coal froth flotation. It is mainly due to the slime coatings which inhibit bubble from attaching on slime-coated coal particles. Other investigators, however, have noted that essentially there was no loss in coal recovery in the presence of slimes, and indicated that the major problem with slimes is dilution of the froth with ash particles. The effects of slime coating on bitumen flotation were also studied that slime coating of clay on bitumen caused a loss in bitumen recovery [9,10].

Furthermore, differences in water chemistry due to Ca^{2+} and Mg^{2+}, in consort with slimes, may affect the coal flotation [11,12]. It is well known that gypsum is usually added into the tailing system to accelerate the settling of fine particles. However, the use of gypsum is anticipated to increase the concentration of calcium ions in the recycle water system. The precipitation of metal hydroxy complexes on coal surface can affect the hydrophobicity of coal and consequently depress its flotation [13,14].

2. Materials and experiments

2.1. Materials

The coal sample used to make pure coal was taken from coal flotation concentrates in Xingtai Coal Preparation Plant, China's Jizhong Energy Group. The highly pure fine coal was obtained from the float of coal float-and-sink test by using 1250 kg/m^3 density heavy-fluid. The ash content of the almost pure coal sample is 3.57%. The fine minerals of kaolinite and montmorillonite were purchased from Ward's Natural Science. Chemical analysis (Table 1) was carried out to ascertain the purity of clay minerals.

The high concentration calcium chloride solution (14 mmol/L) was prepared to adjust the concentration of calcium ions of flotation pulp.

2.2. Particle size analysis

The particle size distributions of three pure minerals were measured using a Malvern Mastersizer 2000.

2.3. Microflotation tests

The microflotation tests were performed in a microflotation machine with a plexiglass flotation cell with an effective volume

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Table 1
Chemical analysis of pure minerals.

Composition	Kaolinite	Montmorillonite
SiO_2	48.53	74.83
Al_2O_3	47.84	14.97
Fe_2O_3	0.29	3.02
CaO	0.16	2.96
MgO		2.13
Na_2O	0.15	1.76
K_2O	1.78	0.29
Ti_2O	0.79	
P_2O_5	0.16	

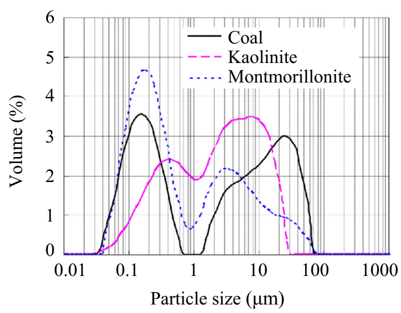

Fig. 1. Particle size distribution of three pure minerals.

of about 30 mL. The tests were divided into two categories: single mineral flotation and two 1:1 mix of coal–kaolinite and coal–montmorillonite flotation.

In the experiment, 1.0 g for single mineral flotation or 1.0 g of each mineral for mixed sample was first conditioned for 5 min in flotation cell with different concentrations of Ca^{2+}, at a stir rate of 2000 r/min. The dosage of kerosene and 2# oil were 3 and 1 kg/t, respectively. Kerosene and 2# oil were then added for an additional 1 min of conditioning successively, the froth collecting time was 5 min under an airflow rate of 0.7 mL/min. After this, the flotation products were dried and weighed, then calculating the recovery of flotation concentrate and assaying the ash content of flotation concentrates [15,16].

2.4. Scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDS)

SEM studies were conducted to observe the slime coating on the coal particles. The pure minerals and the concentrates of microflotation tests were gold coated, and then electron images were acquired in a HITACHI S-3400N scanning electron microscope equipped with energy dispersive X-ray spectroscopy (EDS).

The EDS studies were used to analyse the elemental composition [17]. The elemental analysis was performed in a "spot mode" in which the beam is localized on a single area manually chosen within the field of view. The location is represented on the provided SEM images by a "+". The intensity of the peaks in the EDS is not a quantitative measure of elemental concentration, although relative amounts can be inferred from relative peak heights.

3. Results and discussion

3.1. Particle size analysis

The result of particle size analysis is a record of particle volume fraction in each size class. It can be plotted as percentage of particle volume distribution (Fig. 1) and cumulative distribution (Fig. 2). Fig. 1 shows that the ranges of particle size of three pure minerals

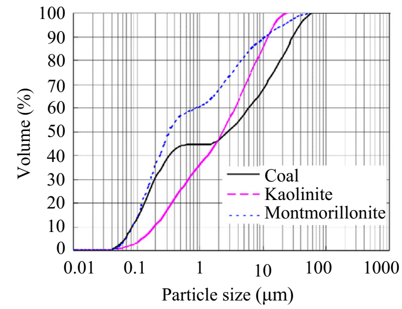

Fig. 2. Particle size cumulative distribution of three pure minerals.

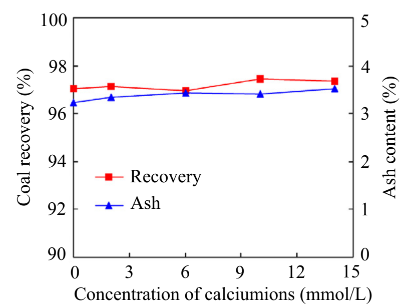

Fig. 3. Effects of concentration of calcium ions on single coal flotation.

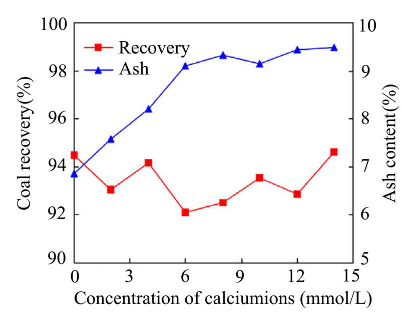

Fig. 4. Effects of concentration of calcium ions on mixed coal–kaolinite flotation.

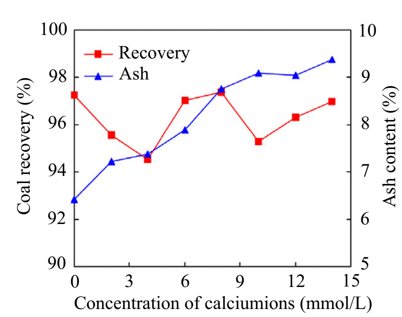

Fig. 5. Effects of concentration of calcium ions on mixed coal–montmorillonite flotation.

are all between 0.02 and 70 μm. From the cumulative distribution curve of particle size, we can see that the mean size by volume of coal, kaolinite and montmorillonite are 3.24, 2.72 and 0.39 μm, respectively, and the percentages of particle size less than 1 μm are 44.53%, 34.91% and 60.14%, respectively.