Fuel 220 (2018) 159–166

Contents lists available at ScienceDirect

Fuel

journal homepage: www.elsevier.com/locate/fuel

Full Length Article

Effect of slimes on the flotation recovery and kinetics of coal particles

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ARTICLE INFO

Keywords:
Slimes
Coal
Flotation
Recovery
Kinetics

ABSTRACT

To investigate the effect of slimes on the flotation recovery and kinetics of coal particles, batch flotation and flotation rate tests were carried out using flotation mixtures including slime particles and coal particles within 0.5–0.25 mm, 0.25–0.125 mm and 0.125–0.074 mm size ranges, respectively. Six flotation kinetic models were applied to fit all the flotation test results. It was found that both the flotation recovery and rate of coal particles decreased with the increase in the mass proportion of slime particles under the mixed flotation conditions, especially coarse coal particles. Compared with the flotation performance of coal particles in the individual flotation, slimes enhanced the flotation recovery of coal particles at a low mass proportion of slime particles. In contrast, slimes decreased the flotation recovery of coal particles at a high mass proportion of slime particles. Furthermore, for the coal particles in 0.5–0.25 mm size range, slimes increased its flotation rate at a low mass proportion of slime particles, otherwise slimes decreased its flotation rate. Slimes mainly improved the flotation rate of coal particles in 0.25–0.125 mm size range, while it primarily reduced flotation rate of coal particles in 0.125–0.074 mm size range.

1. Introduction

With the unprecedented demand for resources and the rapid depletion of high quality mineral resources, there is increasing need to process low-grade and hard-to-handle ores [1–2]. For the coal mine, it is also facing the same dilemma [3]. Flotation is the most effective method for beneficiating fine coal [4–5]. However, fine coal usually contains excessive levels of ultrafine gangue particles and other materials such as clays, known as slimes, as the quality of fine coal deteriorates. The slimes in turn leads to a major problem for handling fine coal, i.e., the slimes enter into the froth product and contaminate the clean coal during the flotation process, resulting in the high ash content of clean coal [6–8]. The contamination of slimes on clean coal is also the most serious problem in fine coal flotation to date.

Although there are few studies on the contamination behavior of slimes in coal flotation, the contamination behavior of fine gangue particles in mineral flotation process has been widely studied [6–11]. Since sufficient dissociation of valuable minerals and gangue minerals needs a much smaller dissociation particle size than that in the dissociation process between coal and gangues. The mechanism of gangue particles contaminating the flotation concentrates includes mechanical entrainment, entrapment, composite particles, and slime coating [11]. Among them, the mechanical entrainment is considered to be the most dominant mechanism for gangue particles entering into the clean coal [11–13]. Furthermore, there are numerous factors that affect the recovery behavior of gangue particles during flotation process including water recovery, froth characters, particle size, bubbles size, flotation agent types and dosage, etc [8,11,14,15]. Numerous studies have further proposed the method to reduce the contamination of fine gangue particles to concentrate during the flotation process from the angle of flotation flowsheet, flotation equipment, and flotation agents [16–20]. These results can provide reference for the study of slimes contamination in coal flotation. However, little attention has been devoted to the effect of slime on coal flotation behavior, especially coal flotation kinetics.

An actual flotation process is a highly complex separation process involving three phases (air bubbles, water, and solids) and a large number of sub-processes, such as particle-bubble collision and attachment, transport of particle-bubble aggregate to the froth phase, and recovery of particle from the froth phase to concentrate launder [21,22]. From a macroscopic view, the flotation process is also considered as a time-rate recovery process, since the cumulative recovery of floatable minerals is undoubtedly proportional to the flotation time [23,24]. Therefore, the flotation time-recovery profiles are widely used to describe the kinetics of flotation, which can also be completely described using mathematical models [25]. Numerous flotation models have been proposed to investigate flotation kinetic behavior [24,26]. It is also a widely adopted method for studying the flotation kinetics.

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https://doi.org/10.1016/j.fuel.2018.02.003
Received 8 November 2017; Received in revised form 18 January 2018; Accepted 1 February 2018
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Table 1
Proximate and ultimate analysis results of the coal particles.

Proximate analysis (wt%)				Ultimate analysis (wt%)				
M_{ad}	A_d	V_{daf}	FC_d	St_d	O_{daf}	C_{daf}	H_{daf}	N_{daf}
1.00	8.81	41.36	53.47	0.37	16.13	76.79	5.16	1.51

d = Dry basis; ad = Air dry basis; daf = Dry ash-free basis; M = Moisture content; A = Ash content; V = Volatile matter; FC = Fixed carbon.

In this study, six flotation kinetic models were selected to test their applicability for various size fractions of coal particles under the mixed flotation condition of coal and slimes, and a major attempt was to completely discuss the effect of slimes on the flotation recovery and kinetics of different particle size coal.

2. Experimental

2.1. Materials

The coal sample was collected from a coal preparation plant in Shandong province, China. It was the bituminous coal. From this coal sample, the lump coal with a size range of 25–13 mm and a density of less than 1400 kg/m^3 was obtained via the screening test and float-and-sink test. Then, the lump coal was crushed to a size below 0.5 mm by a jaw crusher. The obtained coal particles having unique characteristics were used in this study.

The proximate and ultimate analysis results of the coal particles are given in Table 1. The coal particles were pressured into a flat surface and measured the static contact angle using the dropping method. As illustrated Fig. 1 (a), the static contact angle of the coal particles was 97°.

The slime particles were prepared using lump gangue, which was also collected from the same coal preparation plant. The density of the lump gangue was heavier than 2000 kg/m^3, and its ash content was 85.16%. The lump gangue was first crushed to a size below 3 mm with a jaw crusher, and then it was ground to below 0.045 mm using a laboratory ball mill. The grinding product was the slime particles.

The mineral compositions of the slime particles were determined using an x-ray diffractometer, and the results are presented in Fig. 2. The principal mineral matters of the slime particles were quartz, kaolinite, dickite and nakrite. Furthermore, there were small amounts of calcite and pyrite in the slime particles. The static contact angle of slime particles was also measured using the dropping method. As described in Fig. 1 (b), the static contact angle of slime particles was 23°.

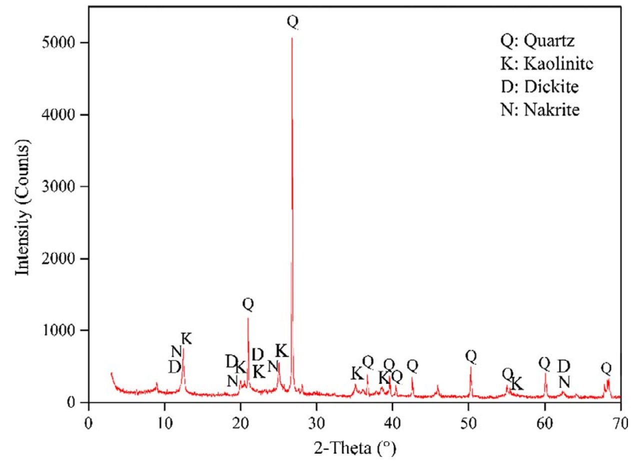

Fig. 2. X-ray diffraction patterns of the slime particles.

2.2. Flotation tests

The flotation tests were performed in a 1.5-L RK/FD-11 flotation cell at an impeller speed of 1800 rpm and a constant air flow-rate of 0.24 m^3/h. No collector was added to the flotation tests, and an analytical grade 2-octanol (purity greater than 98.0%) was used as the frother. The dosage of the 2-octanol for a ton of coal was 100 g, and the amount of coal used for each flotation test was also 100 g. Tap water was used to maintain the flotation pulp level. The detailed operating method of the flotation tests can be found elsewhere [27].

The test sample was a mixed sample of the coal particles and slime particles, and the mixing ratio was 80:20%, 65:35%, 50:50%, 35:65% and 20:80% by weight. In order to facilitate the separation of coal particles and slime particles, the size range of the coal particles was 0.5–0.25 mm, 0.25–0.125 mm and 0.125–0.074 mm, respectively, while that of the slime particles was below 0.045 mm in size.

During the flotation speed tests, the froth products collected from the flotation tests were divided to 5 products according to the collection periods: 0–5 s, 5–10 s, 10–30 s, 30–60 s and 60–180 s. However, in the conventional flotation test, the collection time for the only one froth product was 180 s. After the flotation tests, both the collected froth products and tailings were wet sieved at a size of 0.045 mm. Then the sieved samples were filtered, dried and weighed. Therefore, the flotation yield of the coal particles and slime particles can be calculated respectively. In these flotation tests, the flotation yield was also the flotation recovery.

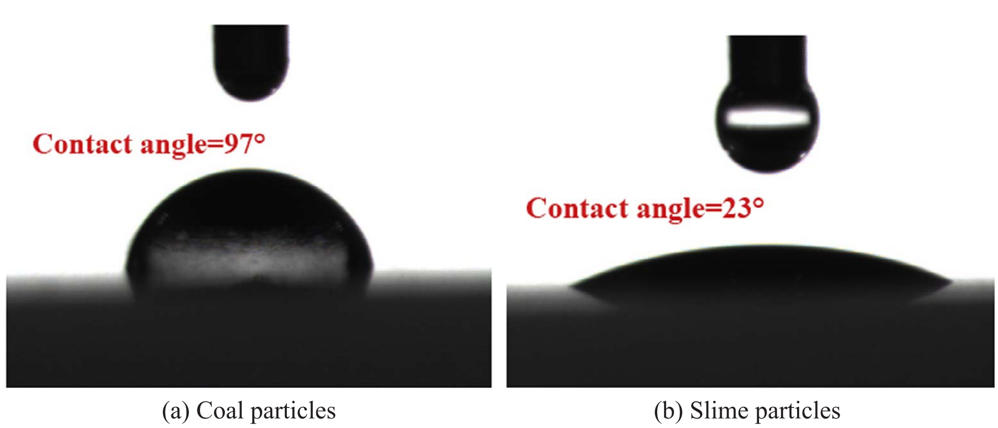

Fig. 1. The static contact angle of coal particles (a) and slime particles (b).

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