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The role of surface cleaning in high intensity conditioning

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ABSTRACT

Slime coating, defined as a layer of fine or ultrafine hydrophilic particles coated on the larger value mineral surface, has been recognized to have an important effect on froth flotation. These slimes on the mineral surface prevent value mineral particles from contacting with collectors and/or air bubbles, consequently resulting in a lower flotation recovery. It is demonstrated that the high intensity conditioning is an effective way to improve flotation performance. However, the relative significance of its mechanisms on high intensity conditioning still needs to be explored, especially the surface cleaning. In this work, the role of surface cleaning in high intensity conditioning was investigated by carrying out a series of tests including conditioning-flotation, microscope visualization, laser particle size analysis and Focused Beam Reflectance Measurement. The combustible matter recovery is employed to evaluate the flotation performance. The results show that the high intensity conditioning greatly improves the hydrophobicity of coal surface by producing a complete clean surface and consequently enhances the adhesion between coal and collector, which results in a significant increase of the combustible matter recovery no matter with or without the collector. It is also found that surface cleaning is an important factor in the reduction of the reagent consumption. In addition, it is noted that surface cleaning is the internal driving force for the significantly increased recovery of the coarse coal particles. Based on the findings in this work, a prospective high intensity conditioning-flotation process is presented.

1. Introduction

Froth flotation, a physicochemical separation technique that greatly relies on the differences in wettability of different materials, is the most effective way to treat fine and ultra-fine materials in mining industry, paper recycling or waste-water treatment. However, in mining industry, this process is always threatened by slime coating defined as a layer of fine or ultrafine hydrophilic particles coated on the larger value mineral surface, preventing value mineral particles from contacting with collectors and/or air bubbles, consequently resulting in a lower flotation recovery [1–3]. Previous literature has proved that high intensity conditioning prior to flotation could significantly improve the flotation recovery. For instance, G. Chen et al. found that high intensity conditioning apparently increased the recovery and rate of the pentlandite from a nickel ore contained in the 8–75 μm particle size range, whereas the recovery and rate of the particles < 8 μm was not significantly increased by the high intensity conditioning [4–6]. Recently, Bo Feng et al. also observed the significant improvement in pentlandite flotation by high intensity conditioning [7]. Pronounced effects of high intensity conditioning were also reported in the flotation of copper sulphides, gold, uranium oxide and pyrite with increasing the kinetics rate values, metal recovery and concentrate grade [8,9].

In the meantime, it is noticed that high intensity conditioning greatly benefits the performance of coal flotation, improving the combustible recovery and flotation selectivity, and at the same time reducing flotation reagents consumption [10–15]. So far three main mechanisms accounting for the effect of high intensity conditioning are: 1) uniform distribution or diffusion of the reagents; 2) effective collision between mineral particles and reagent droplets (for oily collector); 3) hydrophilic slime or impurities removal from value mineral surface termed as “surface cleaning” [5,10–12,16–18]. Besides, it is postulated that the shear flocculation of ultrafine value mineral particles and their adhesion towards coarse particles termed as “carrier flotation” enhanced by agitation also contributes to the effect of high intensity conditioning [8, 18–21]. In the nickel ore flotation where the ionic collector is used, it is demonstrated that slime removal termed as “surface cleaning” mechanism which removes impurities from mineral surface and renders the surface fresh, dominating the high intensity conditioning process [4,5]. While in the case of coal flotation, most of work has been focused on the first two aforementioned mechanisms since it is believed that the effective diffusion of oily collector and its collision with coal particles plays a critical role in high intensity conditioning [10,12,14,16,17]. By contrast, less attention is paid to the surface cleaning in coal conditioning process. However, it has been demonstrated that surface cleaning contributed to the favorable effect of ultrasonication which is reported

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Table 1
Size and ash analysis of the coal sample.

Size (μm)	Yield (%)	Ash (%)	Oversize cumulative (%)		Undersize cumulative (%)	
			Yield (%)	Ash (%)	Yield (%)	Ash (%)
>417	28.51	48.98	28.51	48.98	100.00	43.61
417–300	13.82	40.63	42.33	46.25	71.49	41.47
300–125	31.17	37.69	73.50	42.62	57.67	41.67
125–75	11.61	40.26	85.11	42.30	26.50	46.37
75–45	6.24	47.44	91.35	42.65	14.89	51.12
<45	8.65	53.78	100.00	43.61	8.65	53.78
Total	100.00	43.61				

to notably improve the floatability of oxidized sulfide ores and high-sulfur coal [22,23]. Therefore, surface cleaning in coal high intensity conditioning cannot be underestimated.

Nowadays it is reported that to maximize coal production and utilization, coal mining operations and preparation have been highly mechanized, which produces high proportions of fine coal [24]. Additionally, the world coal industry, no matter in China, India, Turkey or Australia etc., is facing the challenge of processing problematic coal because of the substantial depletion of high quality coal deposits [25–32]. The proportion of fine coal in run of mine coal is increasing and meanwhile its ash content is rising. There are a lot of fine coal stay in ponds per year and need to be processed by flotation. However, the fine coal flotation is being challenged by slime coating [1,33–36]. Therefore, high intensity conditioning as an effective way to promote coal flotation should be given more attention. It is reported that BGT-slurry conditioning machine invented by China University of Mining and Technology (Beijing) has been successfully used in coal preparation plants in China, which acquires good technical and economic indexes [10]. However, its mechanism in coal conditioning has not been fully clarified. On one hand, a high shear strength is beneficial for surface cleaning; but on the other hand, a high shear strength also increases the desorption of collector from coal surface. Therefore, it is necessary to make a deep understanding of the high intensity conditioning in order to provide a theoretical support for the practice.

The objective of this paper is to investigate the role of surface cleaning in high intensity conditioning, which is expected to gain an insight into the complex mechanism affecting the results. Fine coal middlings was used in this work and its size and ash distribution was analyzed. A series of batch flotation tests under different controlled conditions were conducted to study the effect of surface cleaning on coal flotation. The static particle size analysis (Laser Diffraction Particle Size Analyzer) and in-situ dynamic particle tracking (Focused Beam Reflectance Measurement) coupled with digital optical microscopy was employed to monitor the potential interfacial changes of the particle caused by surface cleaning, which is anticipated to give a whole understanding to the surface cleaning in high intensity conditioning.

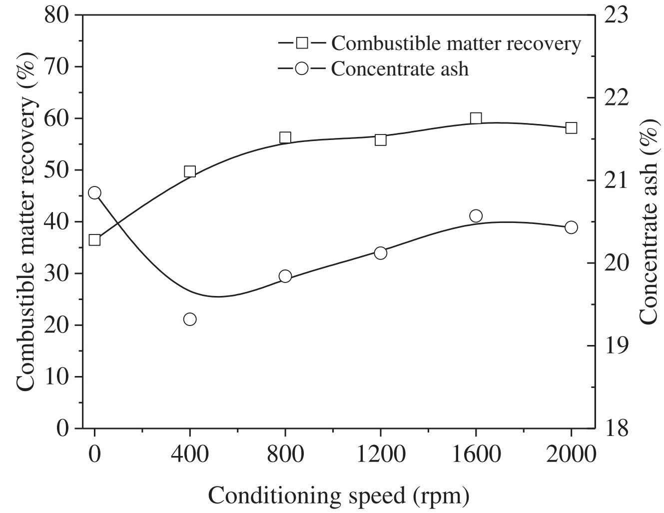

Fig. 2. The effect of conditioning speed on combustible matter recovery (conditioning time was 10 min; the dosage of collector and frother was 0 μl and 12 μl, respectively).

2. Experimental

2.1. Samples and reagents

Middlings, composite ores consisting of value minerals and gangue minerals, has a combined interfacial property of the two components [37,38]. Coal middlings contain a large number of hydrophilic gangue minerals and have an intermediate hydrophobicity between pure coal and gangue mineral, thus report into either the concentrate or tailings depending on the specific ratio of pure coal and gangue mineral when treated by flotation [39]. Therefore, coal middlings should be more sensitive to monitor the potential interfacial changes induced by the "surface cleaning". In this study, a fine coal middlings from Huoshaopu coal preparation plant (Guizhou, China) was employed to investigate the role of the surface cleaning in high intensity conditioning. 200 g of samples were first wetly screened into six fractions through five sieves with different sizes of 417, 300, 125, 75 and 45 μm, then each fraction was dried and weighed for the weight and ash analysis. The result of size and ash analysis is shown in Table 1. It can be seen that the relative coarse coal (>75 μm) with an ash content of 42.30% accounts for 85.11%. By contrast, the relative fine coal (<75 μm) accounts for 14.89% but having a higher ash content of 51.12%, indicating that numerous ash-bearing particles enrich in fine fraction. The high ash fine fraction would deteriorate the flotation performance due to the potential slime coating and mechanical entrainment [25,40,41]. The fraction of 417–75 μm accounts for 56.60%, having a relatively lower ash content (38.94%, weighted) compared with that of other fractions. It is indicated

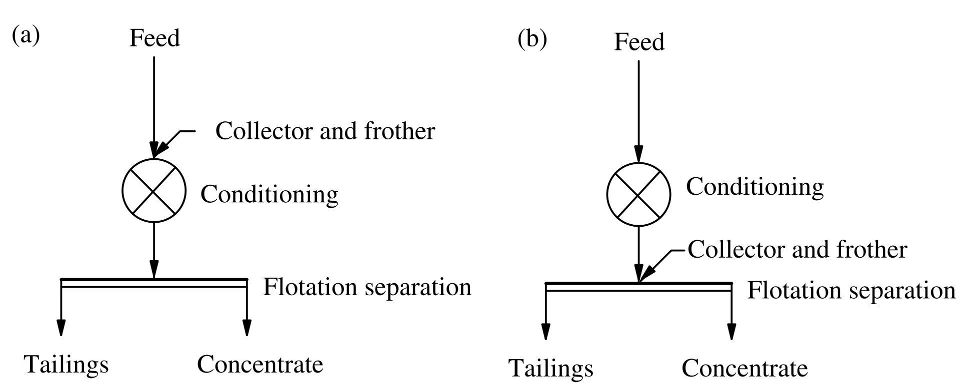

Fig. 1. Flow diagrams of two different conditioning-flotation processes. (a) is the conventional process; (b) is the novel process.