Minerals Engineering 124 (2018) 98–102

Contents lists available at ScienceDirect

Minerals Engineering

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

Short communication

Improving column flotation of oxidized or ultrafine coal particles by changing the flow pattern of air supply

Junyu Wang, Liguang Wang*

The University of Queensland, School of Chemical Engineering, Brisbane, Queensland, Australia

ARTICLE INFO

Keywords:
Oscillatory air
Froth flotation
Difficult-to-float coals
Oxidized coals
Ultrafines

ABSTRACT

This paper proposes a simple method to improve the flotation performance of oxidized or ultrafine coals, that is, use of a solenoid valve to change the flow pattern of air supplied to a flotation column with a bubble diffuser/sparger. In the present work, the flotation tests were carried out at semi-continuous mode using a laboratory-scale flotation column to upgrade a coking coal in the absence of collector. An investigation of the effect of the frequency of oscillatory air on the flotation performance found that the preferred frequency was around 36 Hz. Further flotation tests for the coking coal with oxidation or without oxidation, at fine and ultrafine size fractions, were carried out with oscillatory air supply at 36 Hz, and the obtained results were substantially better than their counterparts with steady air flow.

1. Introduction

Recent advances in coal mining techniques have led to the production of larger amount of fine coals with particle size less than 0.5 mm. Effective beneficiation of raw coals in the fine size fraction is commonly achieved by froth flotation (Wills and Atkinson, 1991). Flotation is effective in a narrow particle size range, beyond which the flotation efficiency drops sharply. In coal flotation, it is a common practice to de-slime flotation feed and divert the ultrafines (−0.1 mm) to tailing dams because the technological constraints of coal flotation are dependent on ultrafines (Clarkson, 1991). Every year, good quality ultrafine coal discharged by Australian coal industry to tailings dams is in the order of millions of tonnes (Turner-Dauncey, 2010). Because of unfavorable underground mining conditions and increased environmental permit requirements on the surface, the coal mining industry has begun to consider re-mining coal waste, especially ultrafine coal refuse from slurry impoundments, as a source of marketable fuel. Ultrafine coal flotation typically shows slow recovery rates, owing to the low particle-bubble collision efficiency (Yoon and Luttrell, 1986), and large chemical consumption, due to the large specific areas of ultrafines (Barry et al., 2016). Also, the flotation performance is severely affected by clay particles, which contaminate the product clean coals by carryover with the froth and electrostatic attachment to the coals, and depress flotation by armour-coating the bubbles and particles (Arnold and Aplan, 1986). The ultrafine coals are often oxidized by weathering or by storage, leading to a reduction in surface hydrophobicity and floatability, making it very difficult to recover by flotation (Yoon and Luttrell, 1986; Barry et al., 2016). With the goal of extracting as much coal value as possible in the preparation process across all size ranges and reduce environmental burden, the coal mining industry wants to effectively recover the difficult-to-float coals (oxidized or ultrafine coal particles) (Osborne and Walton, 2016).

Various methods have been proposed to increase the flotation performance of difficult-to-float coals. The common objectives of these methods are to increase the hydrophobicity difference or reduce bubble size. Specifically, the research efforts aiming to improve ultrafine coal flotation have been focused on increasing the particle-bubble collision efficiency by decreasing the bubble size with the application of microbubble generation techniques (Edzwald, 1995) and increasing the apparent particle size using flocculants (Tian et al., 2017) or oil agglomeration (Laskowski, 1992). Other work towards improving the flotation performance of ultrafines include the development of chemicals and chemical schemes (Read et al., 1989), adoption of different chemical utilization techniques (Misra and Anazia, 1987), and ultrasonic treatment (Ozkan, 2012). Attempts made for improving the flotation of oxidized fine coals include the development of chemicals and chemical schemes (Ahmed and Drzymala, 2004; Jia et al., 2000), pretreatment by grinding (Sokolovic et al., 2012) or ultrasonication (Feng and Aldrich, 2005), the use of low concentration electrolytes (Bolat et al., 1998), and application of different flotation procedures such as dry-ground with collector (Xia et al., 2012). Few papers were found, however, to study the improvement of oxidized coal flotation by reducing bubble size.

The above-mentioned propositions comprising chemical additives or advanced equipment are expensive and face difficulties in

* Corresponding author.
E-mail address: l.wang@eng.uq.edu.au (L. Wang).

https://doi.org/10.1016/j.mineng.2018.05.018
Received 10 July 2017; Received in revised form 20 April 2018; Accepted 10 May 2018
0892-6875/

Table 1
The properties of the coal samples used for flotation tests.

Sample	Particle size (μm)	Ash content (%)	Properties
A1	P80 = 300	17	Hydrophobic, fine
A2	P80 = 300	17	Oxidized, fine
A3	−38	30	Hydrophobic, ultrafine
A4	−38	30	Oxidized, ultrafine

Methyl isobutyl carbinol (MIBC, 98% pure, Sigma-Aldrich, USA) was used as frother. Actual process water was used throughout the experiments.

applications. It is challenging to develop a universal chemical scheme which can be applied to any difficult-to-float coals. Also, with oxidized coals, grinding pretreatment can result in the generation of greater amounts of ultrafines, which would negatively affect the overall flotation performance of fines and the following dewatering process. Use of flocculants in ultrafine coal flotation may lead to a concentrate with high ash content owing to increased degree of entrainment.

A recent study (Wang et al., 2017) shows that the flotation efficiency of a coal sample, which was relatively easy to float with 80% passing size being 220 μm, could be improved by using a fluidic oscillator to change the flow pattern of air supplied to a flotation column. In that study, the experiments with the fluidic oscillator were carried out at a single frequency of 75 Hz for the produced oscillatory air flow. In the present work, a solenoid valve was used to generate oscillatory air flows with different frequencies (0–200 Hz). The preferred frequency of oscillatory air flow for coal flotation was identified, and a series of flotation tests at the preferred frequency was carried out. The results offer a novel and robust solution to improving the column flotation performance of oxidized or ultrafine coals.

2. Materials and experimental methods

2.1. Materials

A coal sample (A1) was collected from the feed stream of a coal flotation plant in Australia. Particle size analysis found that the 80% passing size (P80) was 300 μm. Its ash content was 17%. Preliminary test results show that there was no need to add collector during flotation and thus Sample A1 was considered hydrophobic. A proportion of Sample A1 was oxidized in an oven at 120 °C for 10 h to obtain an oxidized sample (A2). Some of Sample A1 was sieved to obtain an ultrafine sample (A3) with particle size being less than 38 μm and ash content being 30%. A proportion of Sample A2 was sieved to obtain an oxidized ultrafine sample (A4). Table 1 summarizes the properties of the coal samples, A1, A2, A3 and A4, used for flotation tests.

2.2. Coal flotation

Fig. 1 shows the experimental set-up for the flotation tests. A fast-switching valve (purchased from FESTO) was used to convert a steady air flow into an oscillatory air flow, whose frequency was adjusted by a control unit and a PC. A flotation column, which was 5 cm in diameter and 135 cm in height, was used with a 50 μm pore sized sparger placed near the bottom. More detailed information on the configuration of the flotation column can be found elsewhere (Wang et al., 2017).

Prior to each flotation test, a coal sample was mixed with the process water and was agitated vigorously in the feed sump before being pumped into the flotation column using a peristaltic pump at a predetermined rate. Oscillatory air, generated by the solenoid valve, was then introduced into the column through a sparger. During flotation, the concentrate and tailing streams were sent back to the feed sump. A small bucket, which was connected to the tailing discharge port, was used to control the pulp-froth interface.

All flotation tests were carried out under the following conditions:

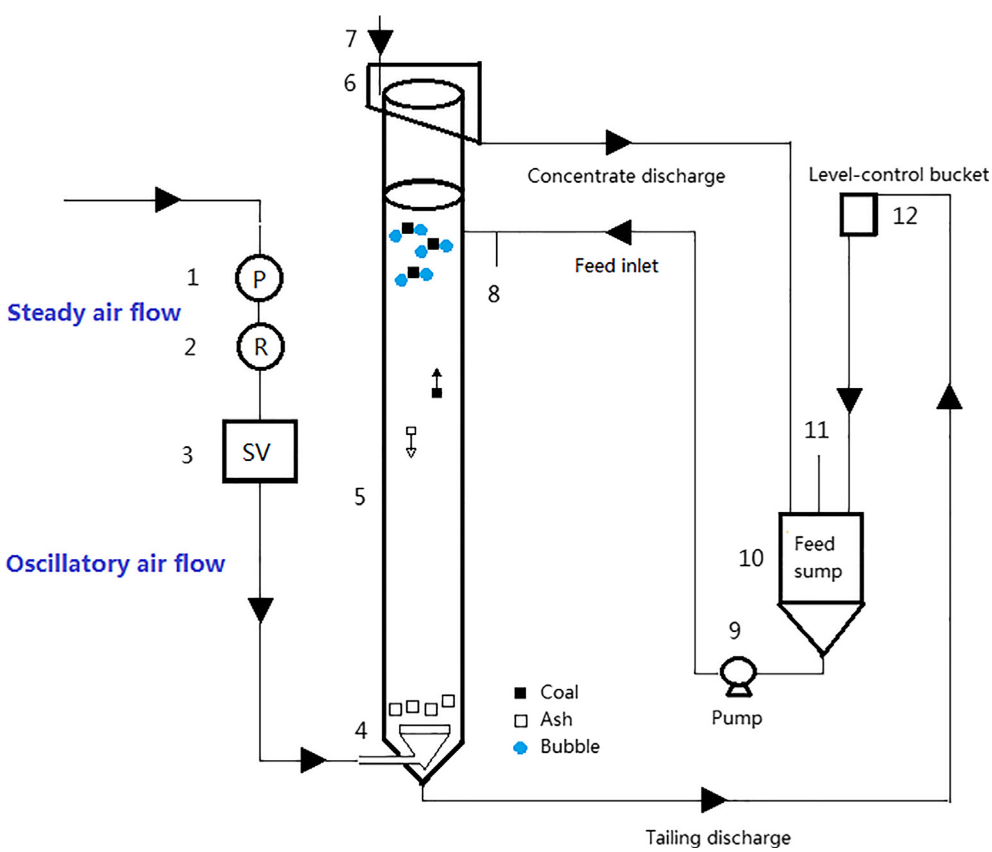

Fig. 1. Schematic of the experimental set-up for the flotation tests with oscillatory air supply generated from steady air flow using a solenoid valve (SV): 1, pressure gauge; 2, air rotameter; 3, solenoid valve; 4, sparger; 5, flotation column; 6, concentrate launder; 7, compressed air assisting concentrate discharge; 8, two-way valve; 9, pump; 10, feed sump; 11, stirrer; 12, level-control bucket.