



Full Length Article

Effect of dissolved gases in natural water on the flotation behavior of coal

Chenwei Li^a, Kunkun Zhen^a, Yanan Hao^a, Haijun Zhang^{b,*}^a School of Chemical Engineering and Technology, China University of Mining and Technology, Xuzhou 221116, Jiangsu, China^b Chinese National Engineering Research Center of Coal Preparation and Purification, China University of Mining and Technology, Xuzhou 221116, Jiangsu, China

ARTICLE INFO

Keywords:

Dissolved gas
 Dynamic froth stability
 Rheology
 Settling
 Induction time

ABSTRACT

The effect of dissolved gases in natural water on the flotation behavior of coal was investigated by a combination of flotation tests, dynamic froth stability measurements, pulp rheology measurements, settling tests and induction time measurements. Better flotation performance with a lower dynamic froth stability (DFS) value was achieved in natural water compared to degassed water. Both pulp rheology and settling results showed that the gases dissolved in natural water enhance the formation of bubble-included aggregates. In addition, dissolved gases reduce the induction time between coal particles and bubbles, resulting in the easier capture of coal particles by the bubbles. All these variables are responsible for the improved flotation performance observed in natural water.

1. Introduction

Froth flotation is widely used to treat fine coal particles [1]. This process is based on differences in the surface hydrophobicity of coal and gangue [2]. Coal is a naturally hydrophobic material, and the hydrophobicity can be enhanced by adding collector at the conditioning stage. When air is injected into the pulp and bubbles are formed, the hydrophobic particles attach to the bubbles and are transferred to the interface between the pulp and foam. The apparent size of the particles and surface properties are two key factors determining the overall collection efficiency, which operate via collision events with bubbles and attachment to the bubbles, respectively [3,4].

Dissolved gases in water have been shown to have a significant effect on the hydrophobic attractive forces between hydrophobic macrobodies [5–8]. From the view point of classical Derjaguin–Landau–Verwey–Overbeek (DLVO) theory, the behavior of a colloidal particle is governed by two additive components, the van der Waals dispersion force and the electrostatic double layer force. For interparticle interactions, the electrostatic double layer force is repulsive due to the same sign and magnitude of the surface charges. However, the van der Waals dispersion force is always attractive due to the constant positive sign of the Hamaker constant calculated using the combination rules [2]. An increase of the van der Waals force is possible via adsorption of a gas on a solid surface [9], exceeding the repulsive electrostatic double layer force and inducing the aggregation of the particles. For bubble–particle interactions, both van der Waals and electrostatic double layer forces are repulsive due to the negative Hamaker constant and same charge

sign, but a hydrophobic attractive force could induce the attachment of particles to bubbles, whose range and magnitude depend on the dissolved gas. The two-stage attachment model proposed by Dziensiewicz and Pryor indicates that the efficient attachment of particles to conventional-sized air bubbles improves if the mineral surface is first frosted with tiny bubbles [10]. Interestingly, Miller et al. [11] reported that dissolved butane gas could be accommodated by interfacial water at a hydrophobic silicon surface using in-situ Fourier-transform infrared spectroscopy/internal reflection spectroscopy (FTIR/IRS) measurements. They also found that the gas absorption intensity decreased with the advancing contact angle of the solid surface. One year later, Lou et al. [12] directly obtained images of nanometer-sized gas bubbles using atomic force microscopy probing technology consisting of an alcohol–water exchange method based on differences in the gas solubility. From then on, this method has been widely used to evaluate the accumulation of dissolved gas on hydrophobic surfaces [13–17]. Subsequently, Ishida et al. [18] reported similar results; however, they also pointed out that no gaseous domain was detected on hydrophobic surfaces in the absence of exposure to air, indicating the importance of dissolved gases in water for the formation of nanobubbles. Gu et al. [19] reported that the contact angle on a bitumen surface increased in the presence of gas nuclei in water. A likely mechanism for the enlargement of the contact angle with the aid of nano-microbubbles was proposed by Zhou et al. [20] based on the precondition of tiny bubbles frosted on the solid surface. Benefiting from the fast development of modern measuring and testing techniques, the direct measurement of attractive forces in particle–particle and particle–bubble systems using

* Corresponding author at: Chinese National Engineering Research Center of Coal Preparation and Purification, China University of Mining and Technology, Xuzhou 221116, Jiangsu, China.

E-mail address: zhjcumt@163.com (H. Zhang).

<https://doi.org/10.1016/j.fuel.2018.06.104>

Received 6 February 2018; Received in revised form 31 March 2018; Accepted 26 June 2018
 0016-2361/© 2018 Elsevier Ltd. All rights reserved.

atomic force microscopy colloidal probing techniques in the presence of dissolved gases has been widely reported [21,22]. These results have shown that dissolved gases play a key role in the hydrophobic attractive forces between hydrophobic surfaces and between bubbles and particles. A detailed discussion of the mechanisms of hydrophobic attractive forces can be found elsewhere [23–25].

All the above mentioned studies were carried out under mild conditions. In real flotation processes, however, the particles are subjected to rather high intensity hydrodynamic conditions, for example, the agitation used for the dispersion of particles and the oily collector. It is unclear whether nanobubbles and/or nanopancakes can bear these conditions and remain stable on a hydrophobic surface. On the other hand, coal and minerals exhibit surfaces with intrinsic roughness. It thus cannot be unequivocally concluded whether dissolved gases or the so-called nanobubbles operate in the same manner in those rough surfaces that on model smooth surfaces.

In this study, we evaluated the effect of dissolved gases in water on the performance of coal flotation processes based on the interactions between coal particles and between particles and bubbles. The rheology behavior was measured in both natural and degassed water to explore the effect of dissolved gases on the apparent size distribution of coal. The induction time was determined to study the potential effect of said gases on the attachment of coal to bubbles. Based on the above results, flotation tests were carried out. The results of this research are expected to provide basic understanding of the improved flotation performance induced by dissolved gases and a new direction to intensify flotation processes.

2. Experimental

2.1. Materials

Coal chunks were collected from a coking coal preparation plant in Hebei province. The low-ash coal was prepared as follows: first, the coal chunks were broken to a size < 3 mm with a hammer mill. Next, the 3–0.5 mm size fraction from the crushed coal samples was subjected to float–sink separation in a ZnCl_2 solution with a 1350 kg/m^3 density fraction. The floating coal particles were collected and thoroughly washed with hot de-ionized water to remove ZnCl_2 from the coal surface. After drying at 65°C for 3 h, the samples were dry-pulverized and then sealed with Parafilm to prevent their oxidation. The size distribution of the flotation feed was measured with a laser particle size analyzer (S-3500, Microtrac Inc). The results are shown in Fig. 1. It can be seen that approximately 70% of the particles are smaller than 0.25 mm.

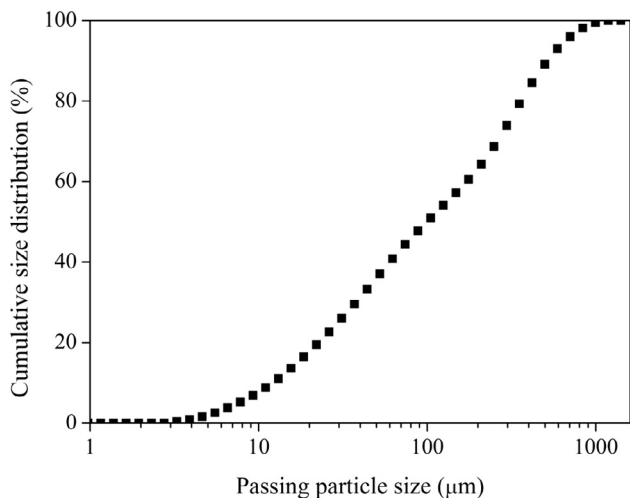


Fig. 1. Coal size distribution.

To explore the role of dissolved gases in natural de-ionized water on the flotation of coal, all tests conducted with degassed water were also carried out in parallel with natural water. To prepare the degassed water, de-ionized water was boiled at 100°C for 90 min and then cooled and stored in a sealed bottle for future use. This method was able to remove most pre-existing gas nuclei from the water [26,27]. The flotation performance using degassed water was compared to the case where no gases were intentionally dissolved (natural water sample) to explore the effect of the dissolved gases on the coal flotation. It should be noted that the gas content in the degassed water would return to the initial value in the natural water by overnight equilibrium with the atmosphere upon exposure to air [26]. Therefore, the degassed water should be used as soon as the degassing operation is finished.

2.2. Methods

2.2.1. Flotation tests

Flotation tests with natural and degassed water were conducted on a XFD-III 1.0 dm^3 laboratory flotation machine. Coal slurry (80 g/L) was transferred into a flotation cell and pre-wetted for 2 min at an agitation speed of 1800 r/min. Octanol, used here as the frother, was added to the slurry and conditioned for another 0.5 min at the same agitation speed. The dosage of frother and the air flow rate were kept at 150 g/t and $0.1 \text{ m}^3/\text{h}$, respectively. When flotation commenced, four concentrates were collected after cumulative times of 0.5, 1, 2, and 3 min. The concentrates and tailings were filtered and dried at 80°C . It should be noted that no optimization of the flotation conditions was carried out at this stage.

2.2.2. Dynamic froth stability measurements

Dynamic froth stability measurement tests were carried out in a self-made laboratory counter-current flotation column with 400 mm in height and 50 mm in diameter. The air inlet of the column was connected to an air compressor via an air rotameter. A graduation ruler was glued at the top of the column to measure the froth height at all times. A sketch of the apparatus is shown in Fig. 2. Coal (32 g) was pre-wetted with 400 mL of de-ionized water using a magnetic stirrer for 2 min and then conditioned with octanol (the frother) for another 0.5 min. The slurry was carefully transferred to the flotation column to avoid exposure to air when degassed water was used. The froth height was recorded as a function of time by a video camera after aeration until it reached the equilibrium. As a measure of froth stability, the dynamic froth stability (DFS) index was calculated using the following formula [28]:

$$\text{DFS} = \frac{V_f}{Q} = \frac{H_{\max}A}{Q} \quad (1)$$

where V_f and Q refer to the foam volume and gas volumetric flow rate, respectively; H_{\max} refers to the maximum height of the foam, and A to the cross-sectional area of the flotation column.

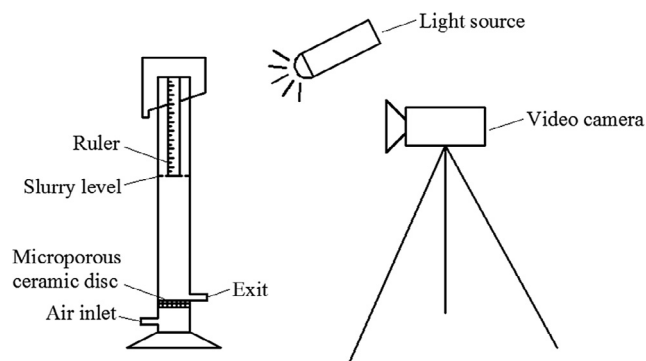


Fig. 2. Schematic of the setup for the dynamic froth stability measurements.

Download English Version:

<https://daneshyari.com/en/article/6630277>

Download Persian Version:

<https://daneshyari.com/article/6630277>

[Daneshyari.com](https://daneshyari.com)