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Experimental design of oily bubbles in oxidized coal flotation

Introduction

Oxidized coal is difficult to float using oily collectors in the conventional flotation process (Jena et al. 2008; Harris et al. 1995; Laskowski, Miller 1984; Fuerstenau et al. 1988). While the coal is oxidized, the hydrophilicity of the coal surface increases (Ding 2009). Lignite has been well used in Turkey, by gravity treatment and flotation (Ayhan et al. 2005; Temel et al. 2010; Ayhan et al. 2011). Some properties of oxidized coal are similar to lignite. Therefore, oxidized coal should also be recovered efficiently. An improved class of universal collectors for the flotation of oxidized coal had been proposed (Jia et al. 2000). The flotation collectors have a great effect on the flotation process of oxidized coal. Coarse coal oxidized in the air can obtain a higher flotation yield after a grinding process than that stored as fines (Fuerstenau et al. 1994). The floatability of Taixi oxidized coal can be improved by surface activation or grinding (Sokolovic et al. 2012; Xia et al. 2012a, b, c). The coal samples used in this investigation are also from the Taixi Coal Preparation Plant in China. Additionally, microwave radiation has proven to be useful for improvement in the flotation of low rank coal (Ozbayoglu 2009). The microwave pretreatment can improve the hydrophobicity of oxidized coal by decreasing the moisture content of oxidized coal (Xia et al. 2013a). Thus the flotation of low rank and oxidized coal can be improved by various pretreatments, i.e. grinding, ultrasonic, microwave, and heat treatments (Xia et al. 2013b).

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The oily bubble flotation process was created by Liu et al. (2002) and Xu et al. (2005). At the same time, the oily bubble flotation process has been successfully applied in bitumen flotation (Wallwork et al. 2003; Su et al. 2006; Tarkan et al. 2009). It has been found that the oily bubble flotation process can improve the flotation of bitumen by increasing the contact angle between bubbles and particles. The induction time also decreases using oily bubbles (Su et al. 2006). Due to the low floatability of bitumen, the oily bubble flotation process can be well applied in the flotation of bitumen. On the other hand, oxidized coal is also more hydrophilic and difficult to float than fresh coal. Therefore, the oily bubble flotation process may be useful to increase the flotation recovery of oxidized coal. The oily bubble flotation process may be especially suitable for the flotation of oxidized coal. This flotation process also floats oxidized coal more efficiently. The flotation process using oily bubbles is thoroughly described below. The study also compares the use of oily bubbles and air bubbles to float oxidized coal.

1. Experimental method and procedure

1.1. Materials

Coal samples were provided by the Taixi Coal Preparation Plant in China. The oxidized coal samples were dry-ground in a laboratory mill until more than 90% of the coals could pass through a 0.074 mm sieve. The analysis of this coal sample is as follows: $M^{ad} = 5.75\%$, $V^{ad} = 7.64\%$, $FC^{ad} = 66.50\%$, $A^{ad} = 20.11\%$, and $S_t = 0.60\%$, where M^{ad} is the moisture content, V^{ad} the volatile content, FC^{ad} the fixed carbon content, A^{ad} the ash content, and S_t is the total sulfur content.

1.2. Experimental design and description

Figure 1 is a sketch of the experimental apparatus of the oily bubble flotation process. The production process of oily bubbles is explained in Figure 2. Dodecane was used to produce the oily bubbles. It was held in a flask with three necks and heated in a heating jacket. When the temperature reached about 215°C, the dodecane was boiling and produced dodecane steam. The air inlet of the flotation machine was connected with one neck of the flask. The air with the dodecane steam was injected into pipes connected with the flotation machine. In this process, the dodecane steam was cold, and huge amounts of dodecane drops were created. The air with dodecane drops was injected into the flotation cell through pipes. While the air was injected into the flotation cell, it was minced into quantities of air bubbles. Each air bubble contained dodecane drops. Due to molecular movement or drops movement, these dodecane drops moved to the surface of the bubbles. The dodecane spread out and covered the bubbles at the exact moment the dodecane drops reached the bubbles' surface. The oily bubbles were formed at this stage. The production process of oily bubbles is also indicated in Figure 2.

The dodecane was also used. 2-octanol was used as a frother with the dosage of 1 kg/Mg in all flotation tests. The flotation tests were conducted in a 1.5 L XFD flotation cell using 100 g of coal at a pulp density of 6.25% solids. The impeller speed of the flotation machine was 1910 r/min and airflow rate was 1.2 dcm³/min.

For each flotation test, the pulp was first agitated in the flotation cell for 3 min, after which the 2-octanol frother (1 kg/Mg) was added and the pulp was conditioned for 1 minute.

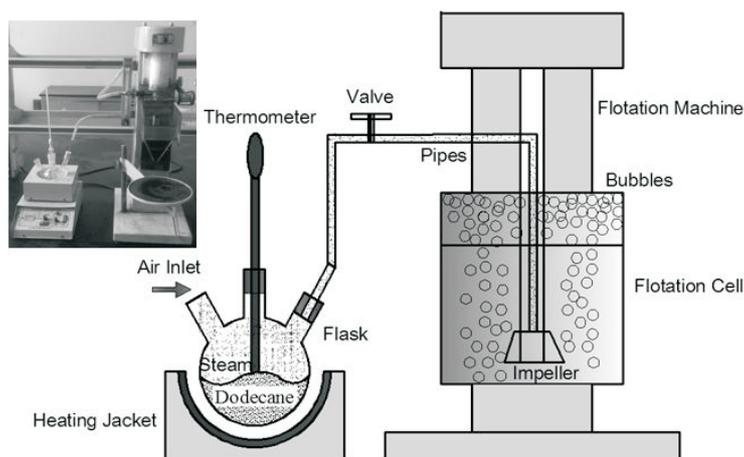


Fig. 1. A sketch of the experimental apparatus of oily bubble flotation process

Rys. 1. Schemat aparatury doświadczalnej procesu flotacji olejowej

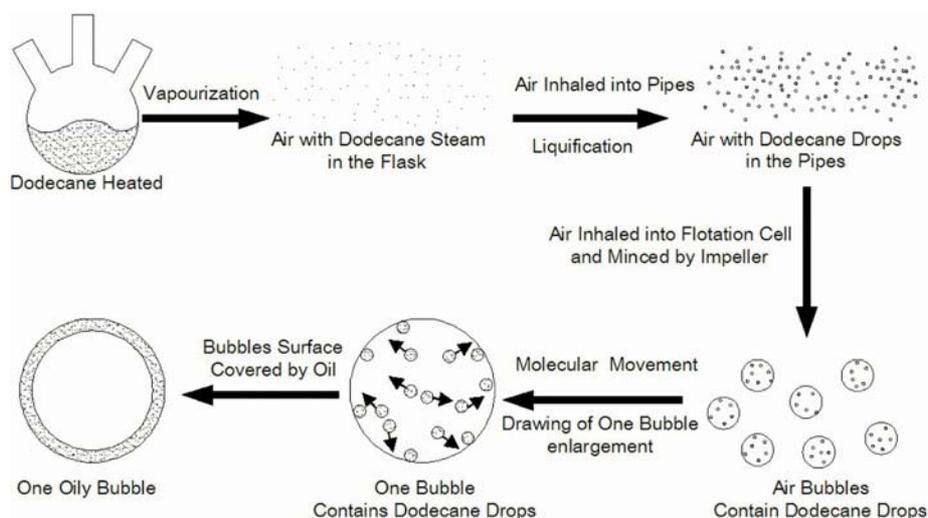


Fig. 2. A sketch of the production process of oily bubbles

Rys. 2. Schemat wytwarzania pęcherzyków olejowych

Then, the valve of the air inlet was opened. For the oily bubble flotation tests, the air with the dodecane steam was injected and the flotation process began. For the conventional flotation tests, however, the air was injected directly without dodecane steam. For each of the flotation tests, the collected time of flotation concentrate was 3 min. Flotation results were analyzed by three indexes combustible matter recovery, flotation efficiency index, and ash content of concentrate. Eq. (1) and (2) were used to calculate the combustible matter recovery and flotation efficiency index of the flotation experiments:

$$\text{Combustible Matter Recovery (\%)} = \frac{M_C (100 - A_C)}{M_F (100 - A_F)} \times 100 \quad (1)$$

$$\text{Flotation Efficiency Index (\%)} = \frac{M_C (A_F - A_C)}{M_F A_F (100 - A_F)} \times 100 \quad (2)$$

Where M_C is weight of the concentrate (%), M_F weight of the feed (%), A_C the ash content of the concentrate (%), and A_F is the ash content of the feed (%).

2. Results

Figure 3 shows that the combustible matter recovery using oily bubbles is higher than that using conventional air bubbles. The flotation efficiency index using oily bubbles is also higher than that using air bubbles. However, the ash content of a concentrate using oily bubbles is a little lower than that using air bubbles. The selectivity of coal particles in the oily flotation process is higher than that in the air bubble flotation process.

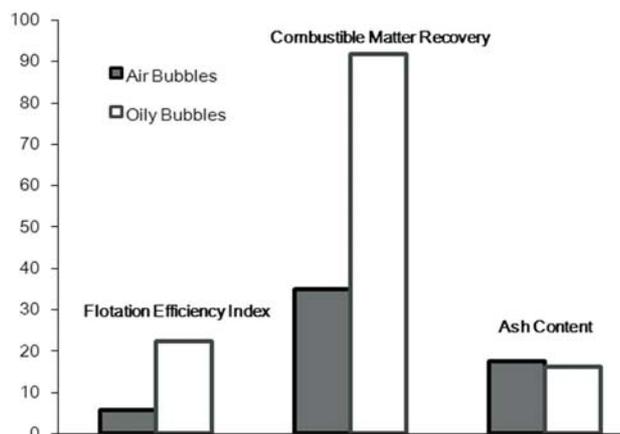


Fig. 3. Flotation results using oily bubbles and air bubbles

Rys. 3. Wyniki flotacji przy użyciu pęcherzyków oleistych i pęcherzyków powietrza



Fig. 4. Foam images using air bubbles (on the left) and oily bubbles (on the right)

Rys. 4. Zdjęcia pęcherzyka powietrznego (lewa strona) i pęcherzyka oleistego (prawa strona)

Figure 4 shows the foam images using air bubbles and oily bubbles. The images were obtained from the collecting vat of the concentrate after allowing to stand for 5 min. It indicates that the foam image using oily bubbles is glossier than that using air bubbles. This might be due to the large amount of collector added into the flotation cell while the air with dodecane drops was injected into the flotation cell.

Conclusion

This study designed an oily bubble flotation process, using oily bubbles instead of the conventional air bubbles, to increase the flotation recovery of oxidized coal. The oily bubble flotation process obtained much higher combustible matter recovery and a higher flotation efficiency index than the conventional air bubble flotation process. However, the ash content of the concentrate using oily bubbles is lower than that using air bubbles. The selectivity of coal particles in the oily flotation process is higher than that in the air bubble flotation process.

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PROJEKT EKSPERYMENTALNEJ FLOTACJI OLEJOWEJ UTLENIONEGO WĘGLA

Słowa kluczowe

Pęcherzyki oleiste, pęcherzyki powietrza, flotacja, węgiel utleniony

Streszczenie

Węgiel kamienny jest bardzo trudno wzbogacalny w procesie konwencjonalnej flotacji z zastosowaniem odczynników (kolektorów) olejowych. Badania miały na celu zaprojektowanie procesu flotacji, nazywanej flotacją olejową, do zwiększenia efektywności wzbogacania utlenionego węgla. Opisano proces flotacji olejowej. Badania dotyczyły porównania flotacji olejowej i konwencjonalnej do wzbogacania utlenionego węgla. Niektóre właściwości utlenionego węgla są podobne do właściwości węgla brunatnego. Odczynniki flotacyjne (kolektory) mają wielki wpływ na proces utlenionego węgla. Flotowalność utlenionego węgla z Taixi (Chiny) może być poprawiona przez aktywację powierzchni bądź rozdrabnianie węgla. Wstępna obróbka mikrofalowa może zwiększyć hydrofobowość węgla utlenionego poprzez zmniejszenie zawartości wilgoci w węglu utlenionym. Wyniki pokazują, że flotacja z pęcherzykami oleistymi jest bardziej efektywna, gdyż uzyskuje się substancję organiczną (koncentraty węgla) o wyższej zawartości substancji palnych niż w konwencjonalnym procesie flotacji. Wskaźnik efektywności procesu przy zastosowaniu flotacji olejowej jest również wyższy niż przy zastosowaniu konwencjonalnej flotacji.

EXPERIMENTAL DESIGN OF OILY BUBBLES IN OXIDIZED COAL FLOTATION

Key words

Oily bubbles, air bubbles, oxidized coal, flotation, design

Abstract

Oxidized coal is difficult to float using oily collectors in the conventional flotation process. This study was aimed at designing the flotation process, namely the oily bubble flotation process, to float oxidized coal efficiently. The flotation process using oily bubbles is thoroughly described. The study compared using oily bubbles and air bubbles to float oxidized coal. Some properties of oxidized coal are similar to lignite. Therefore, oxidized coal should also be recovered efficiently. The flotation collectors have a great effect on the flotation process of oxidized coal. The floatability of Taixi oxidized coal can be improved by surface activation or grinding. The microwave pretreatment can improve the hydrophobicity of oxidized coal by decreasing the moisture content of oxidized coal. The flotation results show that the oily bubble flotation process can obtain higher combustible matter recovery than the conventional flotation process. The flotation efficiency index using oily bubbles is also higher than that using air bubbles.

