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Study of interactions of frother blends and its effect on coal flotation

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ABSTRACT

Frothers are surface active molecules and facilitate to produce more mechanically stable froth by reducing the surface tension at air–water interface. It adsorbs at the air–water interface and serves to reduce the loss of water from the lamellae of bubble. In this investigation weak and powerful frothers, like methyl isobutyl carbinol (MIBC) and polyethylene glycol-600 (PEG) were used for studying the surface tension of frother blends at various concentrations. Gibb's surface excess adsorption and surface area were determined from the rate of change of surface tension with logarithm of concentration. The high surface area per molecule of PEG signifies that little amount is enough to significantly reduce the interfacial tension at the air–water interface. The foam volume and its stability were measured for single frothers and their blend. The foam stability (foaminess) of single MIBC is very less however; it could be improved significantly using a small amount of strong frother (PEG).
Flotation studies of coal fines from eastern part of India were carried out with the above two types of frothers and their blend. The performances were compared with reference to recovery of combustibles for clean coal and rejects. It was found that coal concentrate contains high ash with single PEG due to high froth stability that results the entrainment of the gangues, while single MIBC produces high grade concentrate with low recovery. It was observed that the recovery of carbon value increases significantly when a 10% (w/w) of powerful frother was added with MIBC. The recovery of carbon at 90:10 ratio of frother blend is 77.6% at 17% ash. The recovery could be increased to 86% when ash in clean coal increases to 19.7% and loss of combustibles in the tailing could also be reduced to 14%.

1. Introduction

The froth flotation process is a physicochemical separation process, which commonly requires a large variety of flotation reagents. Collectors and frothers are considered as important reagents. Collectors render the valuable minerals hydrophobic. Frothers are used for froth generation and also to facilitate the air dispersion into fine bubbles. According to Leja-Schulman's penetration theory [1,2] frothers accumulate preferentially at the air–water interface and interact with collector molecules adsorbed onto solid particles in the particle-to-bubble collision and attachment.

It is well accepted that pure liquids do not foam. A liquid can foam when it is able to form a membrane around the gas bubble which opposes the thinning of the lamellae. Foaming does not occur in pure liquids because no such mechanism for the retardation of lamellae drainage exists [3]. When the surface active molecules are present, their adsorption at the gas/liquid interface serves to retard the loss of liquid from the lamellae and produces a more mechanically stable system. This directly relates frother activity to its surface tension. The decrease in the interfacial tension at the air–water interface is due to adsorption of frother molecules. They prevent bubble coalescence and provide the surface elasticity of the bubble lamellae. However, the concentration ranges in which frothers affect foaming and bubble size, the water surface tension is affected very little [4,5]. Many researchers have worked on the properties of frothers [6–9]. It was found that frothers control the size of bubbles by decreasing the bubble coalescence and that can be entirely prevented at the frother concentrations exceeding the critical coalescence concentration (CCC).

1.1. Frother blend

It is observed that frother blends can be more effective than single frothers in achieving the best technical and economic advantage. Limited research has been undertaken to understand the action of frother blends in froth flotation process. Tan et al. [8] found that mixtures of low and high molecular weight polypropylene glycols showed better foaming properties compared to single frothers. This is due to the formation of a close packed cohesive film at the interface. The presence of surfactant molecules at the air/liquid interface stabilizes the liquid film surrounding a bubble, retards the drainage of liquid from the bubble lamella and hence inhibits bubble coalescence.

The interactive effects of different frothers have been used to demarcate by different methods. The most common methods are the

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measurement of surface tension, froth stability and cloud point of the solutions. A review of the literatures shows that the surface tension and froth stability method is amenable for evaluating the interaction between frother molecules. Some of the researchers [10–15] have studied on the behavior of the mixtures of surfactants; however very little investigation so far being reported for the flotation of coal or any other minerals.

Coal generally responds readily to any of the common frothers but the choice of frother depends upon the availability, price, effectiveness for the particular coal being treated and its selectivity from gangue [16]. In this investigation, coal flotation was aimed for recovering the maximum carbonaceous matter leaving the ash-forming minerals aside. Commonly in coal flotation, diesel oil is used as collector and methyl isobutyl carbinol (MIBC) as frother. The MIBC being a weak surface active reagent and its consumption is higher than powerful frother. It is more selective, however less effective than high molecular weight frother. Therefore, for MIBC the loss of carbonaceous material is found to be high in the rejects. The powerful frothers are less selective and more effective for recovering the combustibles. Hence powerful frother reduces the loss of combustibles in rejects. The suitable combination of powerful and soft frother can be successful to improve the recovery of combustible selectively for generating a high ash rejects.

The objectives of the study are to highlight the effect of single frother of different types and their blend at air–water interface. The effects were characterized by the Gibb's surface excess, area of the surface excess and froth stability (foaminess). The frothers have significant role in flotation performances. Therefore, the effect of frother blends of weak and powerful in coal flotation was studied for recovering the valuable carbonaceous matter and minimizing the loss of carbon value in tailing.

2. Experimental

2.1. Coal sample

Experimental work was carried out with coal from Talcher belonging to the eastern part of India. The proximate analysis of the coal sample is given in Table 1. The moisture and volatile matter both appears to be high in this sample. The presence of high inertinite supports the high ash in the as-received sample. The useful heat value of the as received sample is 18,137 KJ/kg. The characterization of the coal shows that it is inertinite-rich, medium rank and high volatile non-coking coal.

2.2. Methods

2.2.1. Equilibrium (static) surface tension

Triple-distilled millipore water prepared by a Q baffle system was used for all experiments. The resistivity of the water was more than 1.5 MΩ. The surface tension measurements were performed with a Kruss Digital Tensiometer K10T coupled with a Du Nouy ring method. The measuring device was a platinum-iridium ring, which was suspended horizontally for the measurement. The instrument was adjusted for zero setting with respect to air before the surface tension measurements were performed. After zero adjustment, the ring was dipped into the sample solution and then pulled out with a servomotor to the solution surface. When the reading is complete the servomotor stops and the surface tension value is displayed digitally on the instrument. Surface tensions were measured for different concentrations of single frother namely methyl isobutyl carbinol (MIBC), polyethylene glycol-600 (PEG) and also with their blends of different composition. The frother blends were prepared by adding 10–30% of PEG in MIBC.

Table 1
Proximate analysis of coal sample.

Proximate analysis % (dry basis)	
Ash	28.75
Volatile mater	25.83
Moisture	4.15
Fixed carbon	45.22

2.2.2. Foam characterization

The characterization of the single frothers and their blend was studied in two phase air–water system by measuring the foam volume and foam stability (foaminess). The tests were conducted using a foaming vessel as shown in Fig. 1. The foaming vessel was a cylindrical column made of plexiglass with 8 cm diameter and 150 cm height, fitted with an air sparger at the bottom. The column was fixed with a measuring scale to measure the foam volume. Foam is generated by sparging air through air sparger. The flow rate of air was controlled via a rotameter and a needle valve. The superficial air velocity of the air was kept constant at 0.55 cm/s for all the tests. The volume of foams generated for wide range of frother concentrations was measured. In this case, the stability of the froth is represented by a factor called foaminess (Σ) which is the ratio of foam volume (V_f) and the volumetric flow rate (Q) of air [17].

2.2.3. Coal flotation

Flotation tests were carried out using coal sample of 150 μm size in a 2.5 l Denver flotation cell at pulp density of 10% solids. Impeller speed was kept constant at 1200 rpm. The proximate analysis of the sample shows the presence of high ash. Therefore, 2 kg/ton of sodium silicate was used as depressant. High speed diesel oil at 2.5 kg/ton was used as a collector [18]. The dosage of sodium silicate and collector were kept constant for all flotation tests. Methyl isobutyl carbinol (MIBC), polyethylene glycol-600 (PEG) frother and their blends were used with varying dosages. The flotation runs were conducted under similar conditions to compare the effect of frothers on recovery of combustibles in the products and tailing ash.

3. Results and discussion

3.1. Equilibrium surface tension of single frothers and their blends

The frothers help to produce mechanically stable froth by reducing the surface tension. The frother molecules lower surface tension through disrupting the hydrogen bonding between water molecules [19]. The surface tensions of single MIBC studied between 0 to 2000 ppm concentrations and 0 to 1250 ppm for PEG frother at 27 °C are shown in Fig. 2. These indicate that the reducing rate of interfacial tension by PEG is more pronounced compared to MIBC. The equilibrium

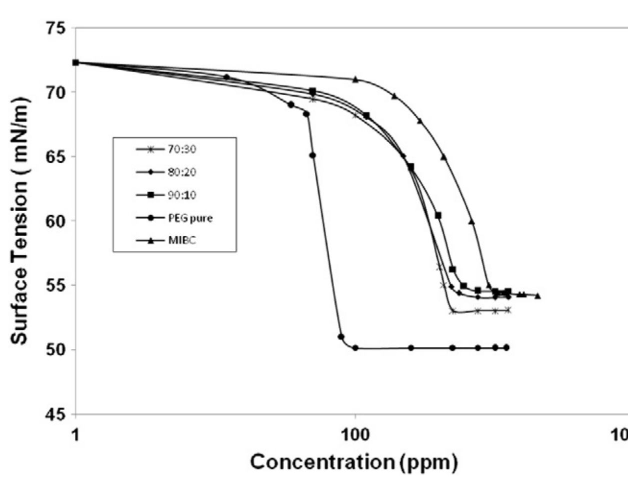

Fig. 1. Interfacial tension of MIBC, PEG and their mixtures.