Effective flotation of weathered coal using frother blend

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Abstract

Froth flotation of weathered coal is a challenging task in a conventional flotation cell using commonly used collector and frother. Generally weathered coal shows the erratic flotation behaviour due to the surface oxidation as it makes the coal surface hydrophilic. When the surface gets oxidized, surface modifier is employed to float the clean coal. Frothers play significant role in stabilizing the mineralized bubble. It reduces the bubble size by reducing the interfacial tension at the air water interface. During this investigation, the flotation was carried out with two types of frothers namely; methyl isobutyl carbinol (MIBC), a weak frother and a strong polyglycol type. The Factorial design matrix was used for carrying out the experiments with the different ratio of frother blend, collector and promoter dosage. The high concentration of MIBC is found to be not effective for recovering the significant amount of carbon value as it causes less reduction of the interfacial tension at the air-water interface. The presence of a correct dosage of strong frother with weak one dramatically improves the flotation behaviour as it stabilizes the air-water interface and also reduces the consumption of the frothers.

Keywords: *Oxidized coal flotation, Surface modification, Frother blend, Critical micelle concentration*

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1. Introduction

Froth flotation, which exploits the difference in surface properties of minerals, is recognized as an efficient method for coal cleaning and processing of minerals. The efficiency in separating the impurities from coal by flotation is basically determined by the relative hydrophobicity of coal and the associated gangues. A frother is required to provide froth above the pulp that is stable enough to prevent under froth breakage and subsequent return of the particles to the pulp before the froth is removed; however, it is important that the froth breaks down rapidly once removed; otherwise problems occur in slurry pumping and in subsequent processing steps. Frothers also have an influence on the kinetics of the attachment of the particle to the bubble. Alcohols and treated compounds such as the glycol ethers are most widely used as frothers, largely because of their inability to adsorb on mineral particles, hence to act as collectors. Aromatic alcohols from natural sources, such as, pine oil or cresylic acid, have also been extensively used as frothers. Synthetic frothers, such as methyl isobutyl carbinol (4-methyl, 2-pentanol) and the propylene glycol ether are now widely used.

Coal generally responds readily to any of the common frothers but the choice of frother depends upon the availability, price and effectiveness for the particular coal being treated and its selectivity from gangue (Ozbayoglu, 1987). The floatability of the oxidized coal depends on the degree of oxidation and causes the poor adhesion between the bubbles and particles. Due to non- polar nature of coal, the non-polar collectors like diesel oil and kerosene are often used to float the clean coal (Fuerstenau et. al, 1983). The presence of oxygenated functional groups like carboxylic (-COOH), ester and phenolic (OH) on the coal surface reduces the f1oatability of the coal as the surface functional groups are hydrophilic in nature. Water molecules get adsorbed on the coal surface rendering it more hydrophilic and less floatable. Thus, the amount of adhesion of oil droplets onto low rank coals is very small, and the use of oil alone does not improve the flotation (Jia, 2002). The use of promoter along with collector improves the surface hydrophobicity. The objective of the study is to enhance the flotation performance of the oxidized coal for recovering the low ash concentrate using a mixture of two different types of frother.

2. Experimental

The non-coking coal from Talcher coalfield was used for the study. The proximate analysis of the coal carried out on a moisture-free basis indicates that the ash is 26.8% with 35.7 % volatile matter, which is quite high. The moisture content is relatively high (4.9%) and fixed carbon is 37.5%. The calorific value of the raw coal is 4525 kcal/kg which seems to be low.

The coal sample used in this investigation is oxidized in nature. The characterization studies showed that vitrinite maceral is partially oxidized and the cracks on the surface that indicates the weathering of the surface, and lowers the hydrophobicity of the coal significantly, making it less amenable to flotation. To improve the floatability of this type of coal, it was thought to use a mixture of frothers along with diesel oil as a collector and promoter. The experiments were performed in a 2.5 litre Denver flotation cell based on the factorial design taking three variables at two levels (Table 1). The variables considered were mixture of frothers, dosage of diesel oil and promoter. The pulp density and particle size were kept constant at 10% solid and 80% passing of 150 microns. The results were analyzed using AVOVA model of the Design expert software. The flotation performance was measured with respect to the ash of the clean coal and the yield.

Table 1: Levels of variable parameters

Variables	Levels	
	Minimum	Maximum
Conditioner, l/ton	3	6
Collector, kg/t	12	16
Frother blend (MIBC:PEG), @ 0.8kg/t	70:30	90:10

3. Results and Discussion

The flotation studies of weathered coal were carried out in a mechanical cell at different conditions and the results are discussed below:

The results of the experiments carried out on the basis of the design matrix are given in Table 2 and presented in the Figures. The surface of the coal was modified using the isopropyl alcohol and its dosage varies from 3l/ton to 6 l/ton. The effect of frother blend was studied from 70:30 ratio to 90:10 ratio by weight. The dosage of frothers blend was kept constant at

0.8 kg/t. The regression equations developed for the two responses of yield and ash of the concentrate are given below.

Yield%=63.99+2.42A+2.88B-7.06C+0.14AB+0.24AC+0.62BC-0.63ABC……. (1)

Ash%=17.43+0.71A+0.84B-1.39C+0.26AB-0.23AC-0.32BC-0.24ABC………. (2)

Where A=Conditioner, B=Collector dosage and C= Ratio of frother blend

Based on the regression equations, the predicted values were calculated and compared with the actual value as shown in Figure 1.The significance of the above two equations (1 and 2) implies that the increase in the conditioner and collector dosage improves the yield, and also increases the ash of the concentrate. The effect of reagent dosages on the yield of the concentrate and its ash are shown in Figures 2-4. The yield and ash of the concentrate reduces when the percentage composition of the MIBC in the mixture increases.

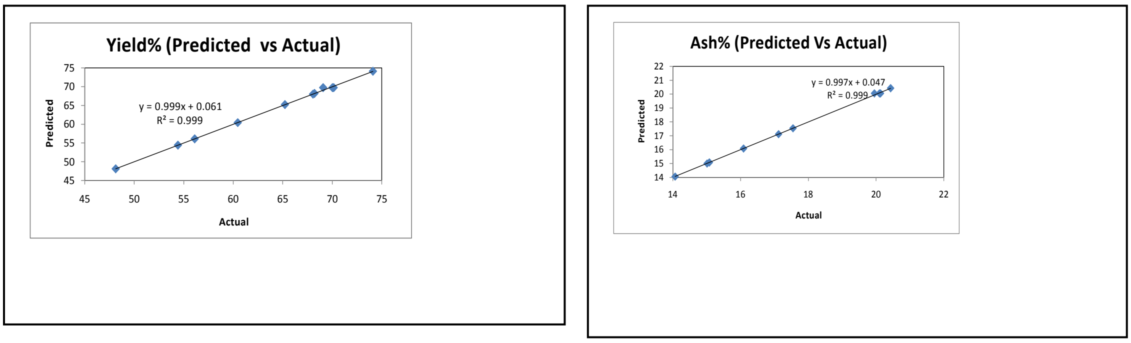

Figure 1: Predicted and actual values of the yield and ash

It was found from the Figure 2 that at the percentage ratio of 70:30 of MIBC and PEG in the mixture of frothers, the minimum ash in the concentrate is 17% with a yield of 68% when the collector and promoter are in the lower range. The maximum achievable yield is 75% with 21% ash (Table 2). It seems 4% increase in ash content for 7% yield. This attributed to the entrainment of the gangues in the lamellae of the froth. The dosage of PEG was reduced and the percentage ratio of MIBC and PEG became 80:20, the maximum yield recovered is about 68% at maximum dosage of collector and promoter that is 10% less than at 70:30 ratio; however, the ash in the concentrate is about 18%. The minimum ash in the concentrate could be reduced to 16% with yield of 60% at lower level of collector and promoter using the same frother blend. When the concentration of PEG in the mixture is further reduced to 10% by weight the minimum ash in the concentrate could be reduced to 15% ash with a yield of 50% at 12kg/t of DO and 3l/ton of the promoter. It is interesting to note that higher dosage of PEG in the mixture at any level of collector and conditioner increases the yield with high ash content. It was found that flotation with 1.2 kg/t of MIBC produces 40% yield at 16% ash level using 12kg/t of DO and 6ml/kg of the promoter. The presence of small amount of PEG (at 90:10 ratio of the frother blend) facilitates to improve the yield by 22% at the same ash level. The adsorption of the frother at the air-water interface reduces the interfacial tension. The presence of the strong frother in small concentration with MIBC has a positive interaction between the two different frother molecules that release energy and facilitates to stabilize the particle-bubble attachment and also provides enough strength by reducing the interfacial tension. The froth must be strong enough to support the weight of the mineral and floated and yet not be tenacious and non-flowing. The dominant effect of PEG is observed at higher concentration due to the negative interaction between the molecules of frothers (Pugh and Theander, 2003).

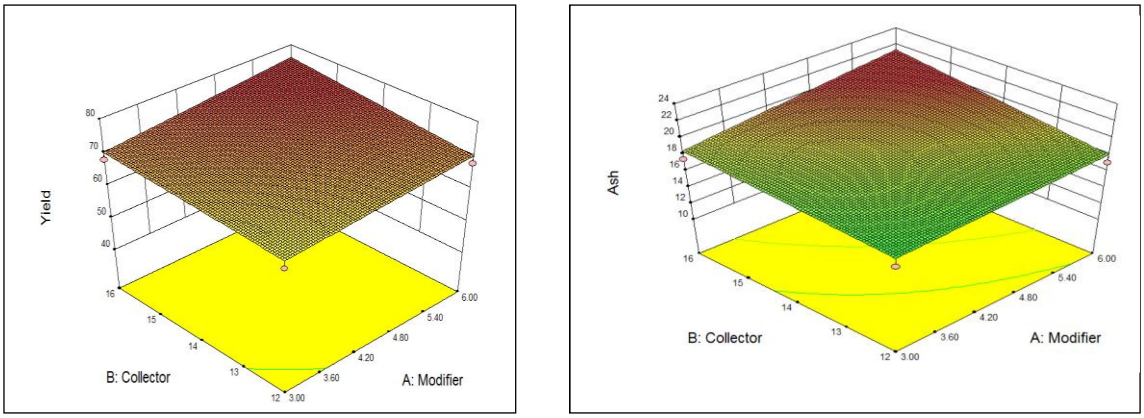

Figure 2: Effect of Collector and conditioner on yield of the concentrate and ash at percentage 70:30 ratio of MIBC and polyethylene glycol

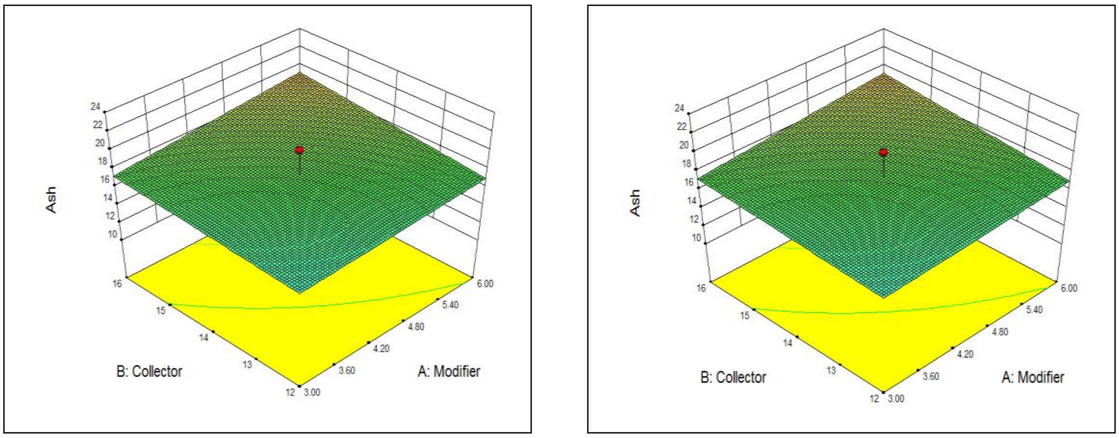

Figure 3: Effect of collector and conditioner on the yield of the concentrate and ash at a percentage ratio of 80:20 MIBC and polyethylene glycol

Table 2: Effect of frother blend on yield and ash

Frother Ratio @ 0.8 kg/t	Collector Dosage (kg/t)	Conditioner (l/ton)	Yield (%)	Ash (%)
90:10	12	3	50	15.0
	12	6	55	15.5
	16	3	56	16
	16	6	62	16
80:20	12	3	60	16
	12	6	62	16
	16	3	65	17
	16	6	68	18
70:30	12	3	68	17
	12	6	70	18
	16	3	71	19

	16	6	75	21
Single MIBC (1.2kg/t)	12	6	40	16

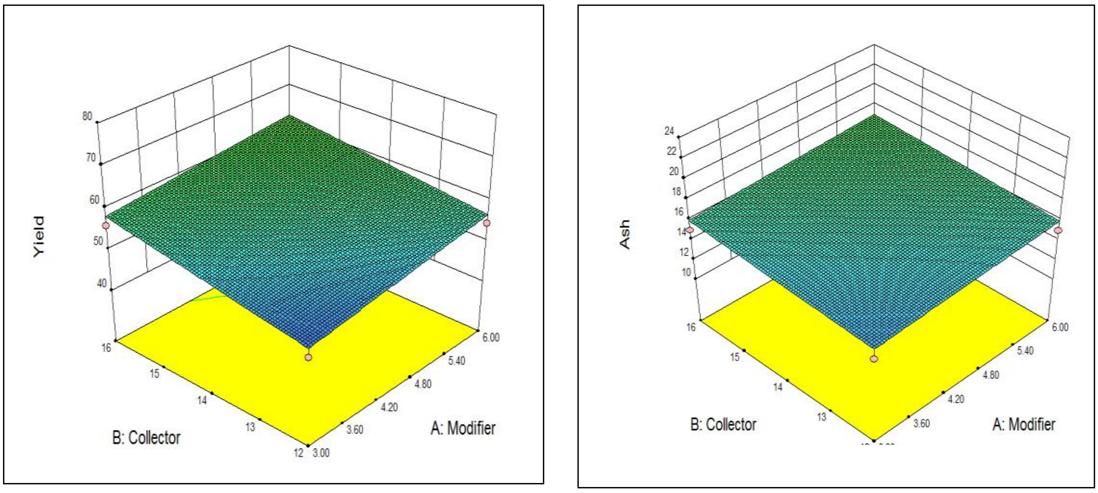

Figure 4: Effect of collector and conditioner on the yield of the concentrate and ash at a percentage ratio of 90:10 MIBC and polyethylene glycol

4. Conclusion

The floatability of the oxidized coal is inferior due to the presence of hydrophilic groups on the surface and that hinders the adsorption of the collector. The surface modifiers improve the degree of adsorption of the collectors; however, according to the Leja-Schulman's penetration theory (Leja & Schulman, 1954; Leja, 1982), frothers accumulate preferentially in the water/gas interface and interact with the collector molecules adsorbed onto solid particles in the particle-to-bubble collision and attachment. The flotation with single MIBC at 1.2 kg/t could produce 40% yield with 16% ash. The strong frothers possess less selectivity but generate small bubbles (Lin and Somasundaran, 1994); however, when it is present in accurate dosage, it improves the flotation performance. From the above investigation it was found that the oxidized coals possessing less floatability needs strong frother, as there is not adequate adsorption of the collector onto the coal surface to float the clean coal containing low ash. The presence of strong frother like polyethylene glycol with MIBC for the 90:10 percentage ratio of MIBC and PEG improves the performance of the oxidized coal as it stabilizes the mineralized bubble and transport to the pulp phase. At this level of frother blend, low dosage of collector and promoter can produce 50% yield at 15% ash level and 62% yield at 16% ash level which is 22% more than that with single MIBC.

Acknowledgements

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