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Optimization of dosages of Kerosene and MIBC on Coal flotation

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Abstract:
Froth flotation is a highly versatile method for separating particles based on differences in the ability of air bubbles to selectively adhere to specific mineral surfaces in a mineral/water slurry. The present study reported a new approach towards optimization of coal flotation process through combustible recovery. The experimental work was evaluated in two stages. In the first stage the ash content percentage of the froth was calculated using various dosage of collector and Frother. Methyl Isobutyl Carbinol is used as Frother and Kerosene is used as Collector for this experiment and finally the optimum dosage ratio of "Collector – Frother" were calculated to find the minimum ash content. In the second stage coal recovery values were calculated by floating various slurry concentration for 2,3,5,8 and 10 min of floatation times. Later Coal recovery (%) and ash recovery (%) values were also evaluated. Final concentrate was obtained with 93.08% of combustible recovery and 20.64% of ash content at optimum conditions after 10 minutes of flotation time.

Key Words: Flotation Cell, Frother, Collector

1. Introduction:

Froth flotation is a process used for selectively separating hydrophobic materials from hydrophilic. It is currently in use for many diverse applications, with a few examples being: separating sulphide minerals from silica gangue (and from other sulphide minerals); separating potassium chloride (sylvite) from sodium chloride (halite); separating coal from ash-forming minerals.

Once the particles are rendered hydrophobic, they must be brought in contact with gas bubbles so that the bubbles can attach to the surface. If the bubbles and surfaces never come in contact, then no flotation can occur. Contact between particles and bubbles can be accomplished in a flotation cell. The rotor draws slurry through the stator and expels it to the sides, creating a suction that draws air down the shaft of the stator. The air is then dispersed as bubbles through the slurry and meets particles in the slurry that is drawn through the stator. Particle/bubble collision is affected by the relative sizes of the particles. If the bubbles are large relative to the particles, then fluid flowing around the bubbles can sweep the particles past without coming in contact. It is therefore best if the bubble diameter is comparable to the particle diameter to ensure good particle/bubble contact.

Once a particle and bubble have come in contact, the bubble must be large enough for its buoyancy to lift the particle to the surface. The particle and bubble must remain attached while they move up into the froth layer at the top of the cell.

Collectors are reagents that are used to selectively adsorb onto the surfaces of particles. They form a monolayer on the particle surface that essentially makes a thin film of non-polar hydrophobic hydrocarbons. The collectors greatly increase the contact angle so that bubbles will adhere to the surface. Kerosene was selected as collector for this coal flotation operation as it is widely used in coal flotation process. Frothers are compounds that act to stabilize air bubbles so that they will remain well-dispersed in the slurry and will form a stable froth layer that can be removed before the bubbles burst. MIBC (Methyl Isobutyl Carbinol) was selected for this flotation operation for its soluble nature in water.

The aim of the present work is to optimize two reagent dosages, one is Frother which is MIBC and other one is collector which is Kerosene. After optimizing the dosages of frother and collector the combustible recovery values were calculated for different pulp density of slurry and minimum ash content were found for these slurries.

2. Material and Method:

2.1 Materials:

The Coal which was used for froth flotation operation collected from the coal washery plant, Himgiri, Sundergarh Odisha. The Chemical analysis of the coal sample was given in the Table 1. The XRD study of the sample showed that it contains the following minerals: quartz, serpentine-kaolin group minerals, illitite and amorphous matter. The calorific value of the sample was found to be 3836 Kcal/kg. The volatile matter of sample was determined as 29.40%. Besides, the ash content and the moisture content of sample were determined as 33.31% and 8.70% respectively. Kerosene which acts as collector in the flotation operation was collected from the Burla market, Sambalpur. MIBC (Methyl Isobutyl Carbinol) (95% purity w/w; M/s MERCK) was purchased from Merck India Pvt. Ltd.

Table 1

Property	
C (%)	42.56
H (%)	4.14
N (%)	1.65
O (%)	7.11
S (%)	2.82
Moisture (%)	8.7
Ash (%)	33.31
Volatile Matter (%)	29.40
Calorific Values (Kcal/kg)	3836

2.2 Slurry Preparation:

For a standard coal flotation experiment, a sub-sample (0.5 kg) was grounded in a stainless-steel mill under dry medium. The ball mill in which the grinding operation will be carried out had the dimensions of 200×200 mm and was charged with 10 kg of stainless-steel balls. The grinding times were 10, 15 and 20 min, giving particle size distributions of d_{80} = 0.355, 0.250 and 0.104 mm, respectively. Kerosene oil (0.8 gr/cm^3) and Methyl Isobutyl Carbinol (0.807 gr/cm^3) supplied by MERCK, India limited which were used as reagents. At different dosage amount of MIBC and kerosene were mixed with tap water to obtain stable emulsions in condition tank of the Jameson flotation cell. For the preparation of slurry feed for the Jameson flotation cell, ground fine coal was added in solution and conditioned for 5 min. All flotation experiments were conducted at normal pH (7.0–7.5) where no flocculation of gangue on the sample was thought to be observed due to high surface of both at this pH. The pulp was then floated for 2, 3, 5, 8 and 10min adding wash water.

2.3 Jameson flotation cell setup and its operating characteristics:

Laboratory batch flotation tests were made in a Jameson flotation cell which was constructed in stainless steel. The Jameson flotation cell can be divided into two main zones. These are down comer (2.0 cm in diameter and 100 cm in length) and separation tank (10 cm in diameter and 75 cm in length) [3]. Pulp is conditioned in the 30 L tank and pumped into the down comer, which is the primary contacting zone of particles swarmed with bubbles. There is a nozzle at a relatively high level of the down comer to provide a high-pressure jetting action. When the slurry passes the nozzle, atmospheric air is sucked into the down comer due to the venturi effect. The jetting impact of slurry pool in the down comer and the air sucked plunge into the separation tank (plunging jet) [4]. In the mixing zone, i.e., top part of the slurry pool in the down comer, the hydrophobic particles have opportunity to collide with and adhere to fine air bubbles (e.g., 400–700 lpm) generated within the water jet shearing action [1]. The Jameson cell is an effective device for gas–liquid contacting. Small bubbles are formed in a high shear region surrounding the plunging jet, leading to high interfacial area per unit volume of gas [2]. Flotation recovery of Jameson cells is an important issue and can be variable depending on operating parameters.

2.4 Analysis:

After the flotation experiment the froth and tailings were collected, filtered and dried in an oven at 90 ± 5º C to constant weight and assayed. Their ash levels were determined at 850ºC. Ash content of froth, feed and tailings were determined as per the ASTM guidelines. In the present study Best frother (MIBC) and Collector (Kerosene) dosage ratio for coal flotation were investigated. Coal recovery (%), and Ash Recovery (%) were estimated for various slurry concentrations and time of operation of flotation.

In the second stage the study, the results of the flotation test results were evaluated by percentage of combustible recovery.

$$Combustible\ Recovery\ (\%) = \frac{\mathrm{Mc}\ (100 - \mathrm{Ac})}{\mathrm{Mf}\ (100 - \mathrm{Af})}$$

Where A_c = ash content of clean coal,
A_f =ash content of feed,
M_c= mass of clean coal,
M_f =mass of feed.

3. Results and Discussion

Water-insoluble hydrocarbons are widely used as collectors to increase the affinity of coal particles towards the air bubbles. These collectors are basically non-polar oils such as kerosene, crude petroleum, fuel-oil and certain coal-tar distillates [5]. Kerosene, the zpc of most of the coals are below 5.5 and bears negative charge in neutral pH [6]. The kerosene droplets also bear negative charge at neutral pH. Therefore, the interaction of coal and kerosene is possibly due to hydrophobic interaction [7]. The floatability of coal increases with the adsorption of kerosene and there is increase in recovery. Klimpel and Hansen [8] reported the similar results but they also observed decrease in flotation rate constant at high collector dosage. With the increase in

hydrophobicity of coal particles, inter-particle attraction will increase, and agglomeration is likely to take place. The decrease in grade is due to flotation of progressively
higher mineral matter particles with the increase in recovery. The increase in collector dosage also causes high recovery of finer coal particles. The use of oil improves flotation rate of particles of all sizes and specific gravities, but the effect is more for the locked or mineral particles [9]. It is well known that the collector dosage of coal flotation is an important variable.

Frothers are compounds that act to stabilize air bubbles so that they will remain well-dispersed in the slurry and will form a stable froth layer that can be removed before the bubbles burst. The most used frothers are alcohols, particularly MIBC (Methyl Isobutyl Carbinol, or 4-methyl-2-pentanol, a branched-chain aliphatic alcohol) or any of several water-soluble polymers based on propylene oxide (PO) such as polypropylene glycols. In the present study MIBC act as frother for the coal slurry.

The aim of this work is to obtain high calorific value products from coal fines cleaning wastes by flotation with kerosene and MIBC mixing. The optimum dosage of (frother) MIBC and (Collector) Kerosene were obtained and Coal recovery (%) and Ash Recovery (%) were estimated for various pulp densities and time of operation of flotation. Finally, the combustible recovery and ash content percentages were compared for various slurry densities and optimum values were obtained.

3.1 Effect of dosage of collector:

Ash content increased with increasing kerosene concentration in slurry. The value of ash content was maximum for 25% of slurry density and minimum for 10 % slurry density. But these values were rather lower than the values that were obtained without using any reagent.

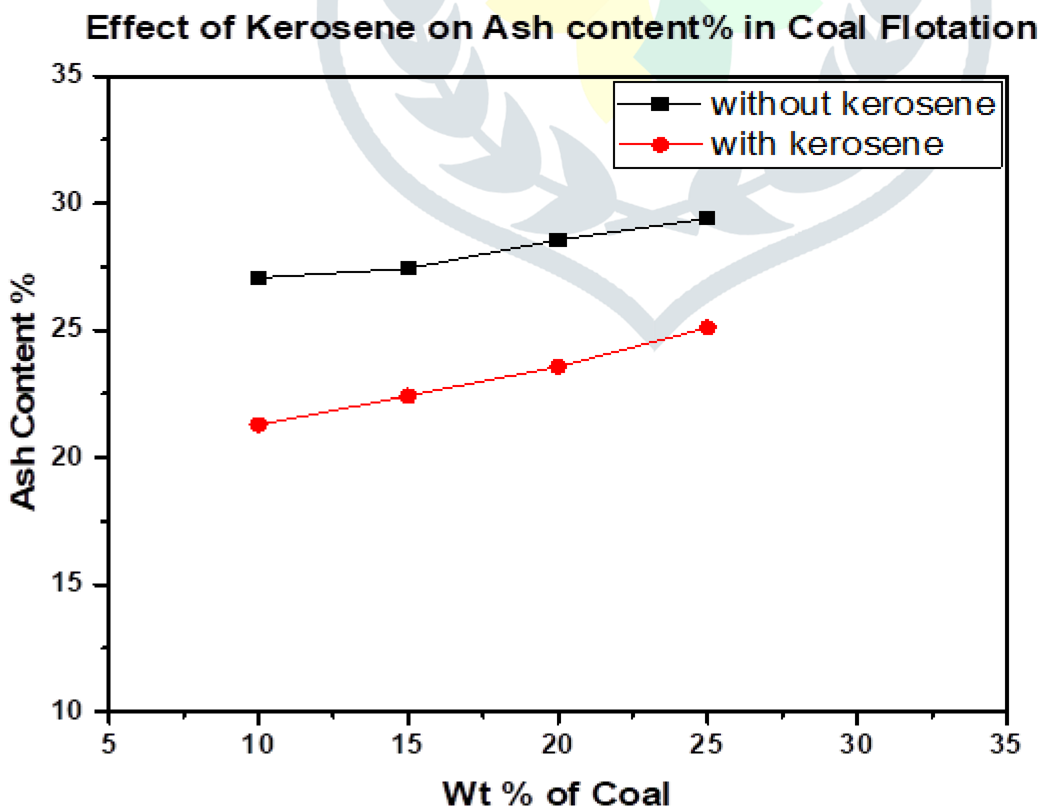

Figure 1: comparison of ash content with and without collector

3.2 Effect of dosages Frother and Collector:

Ash Content of coal in froth increased with increase in kerosene concentration however it decreased substantially with addition of MIBC. The minimum ash content was achieved for 100 ppm of Kerosene in slurry of 20% coal concentration and 400 ppm of MIBC in slurry of 20% coal concentration. The minimum ash content for MIBC is lower than the minimum ash content with kerosene. Hence lower concentration of kerosene and higher concentration of MIBC has to be maintained for optimum flotation of coal.

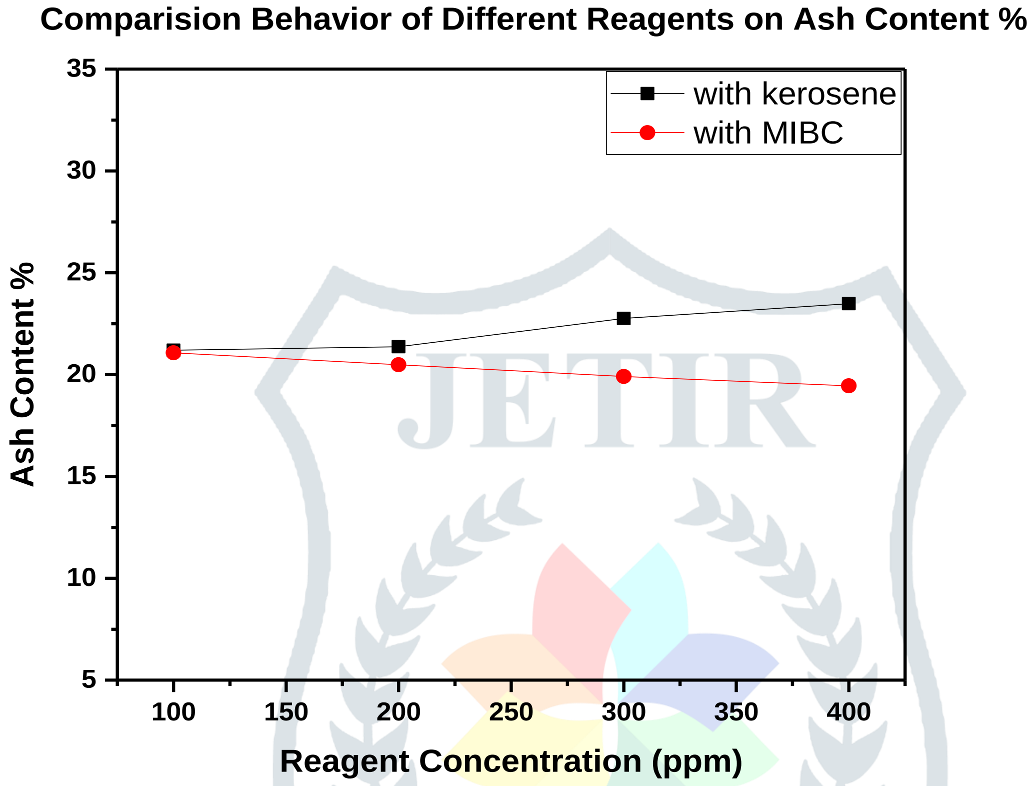

Figure 2: Comparison of variation of ash content with kerosene and MIBC dosage

3.3 The effect of slurry density with the dosage of frother[MIBC] and collector [kerosene] on ash recovery and Coal Recovery.

The experiment was conducted by adding various amount of coal 150,225 and 300 gm of coal in 1500 ml of water. Both frother [MIBC] and collector [kerosene] were added of 200 ppm each. Average particle size used were of size d_{80} (0.104mm) .10%,15% and 20% slurry density were prepared for froth flotation. This experiment was conducted for 2,3,5,8 and 10 minutes.

3.3.1 Ash Recovery:

From the below graph it is shown that the ash recovery percentage are high for 15 % slurry density followed by 20% & 10 % slurry concentration. Here the ash recovery values were calculated from the graph it is shown that initially the value of ash recovery percentage was high for 10 % slurry concentration for 2 minutes. This is due to the high flotation rate at the initial stage.

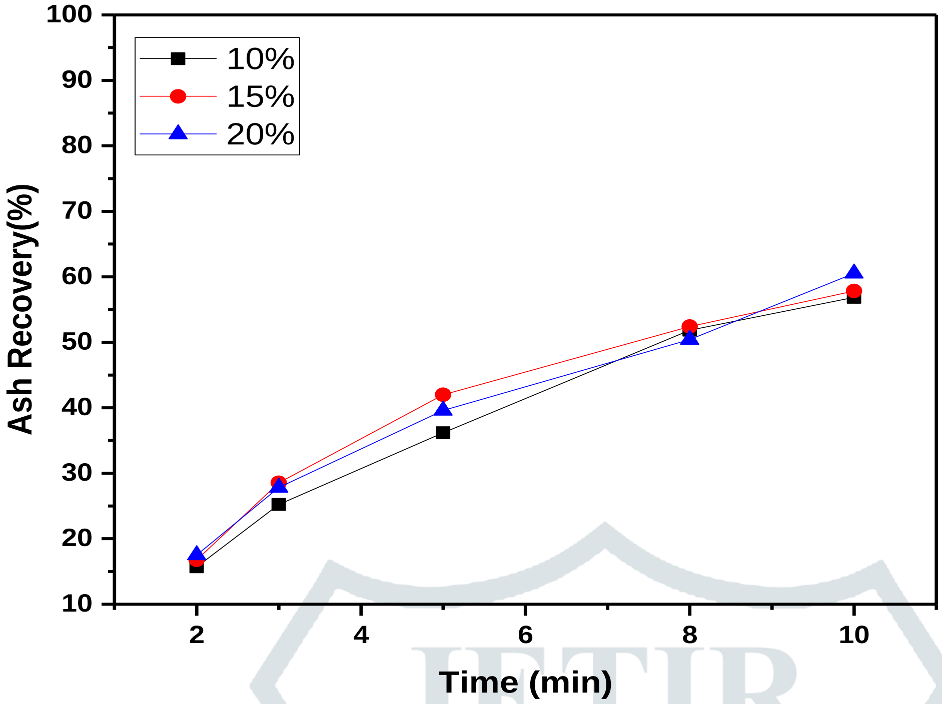

Figure 3: Variation of ash recovery with time in both kerosene and MIBC dosage for various slurry concentrations.

3.3.2 Coal Recovery:

From the below figure for 15% slurry concentration coal recovery values were high up to 4 minutes after that the values were decreased, whereas for 10% slurry the initial recovery values were low and it went maximum for 5 minutes. Eventually for 20% slurry density the coal recovery value was highest for 8 minutes which was because of the involvement of gangue material.

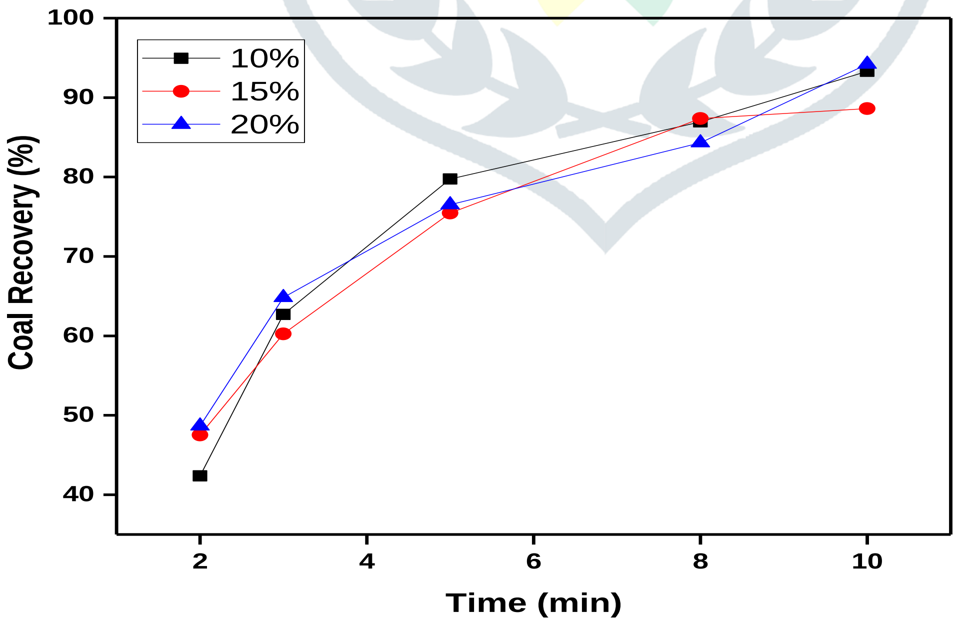

Figure 4: Variation of coal recovery with time in both kerosene and MIBC dosage for various slurry concentrations.

4. Optimization:

For determination of optimum solids ratio of pulp, three ratios,10 wt.%, 15wt.% and 20 wt.%, used in the tests. The selectivity Index (SI) values of 10 wt.% and 20 wt.% were very close (3.65 and 3.85). Thus, 15 wt.% was tested as a middle value of solid ratios. The calculated results of combustible recovery and ash content (%) for the three solid ratios were given in Fig. 5. The combustible recovery and ash content were 95.62% and 25.75% respectively for 10 wt.%. For 15 wt.% as a middle value, the combustible recovery was 91.00% and ash content was 23.94%. The best results was obtained at 20% pulp density with 20.64% ash content and 93.08% combustible recovery. Hence, 20 wt.% was selected as an optimum solid ratio.

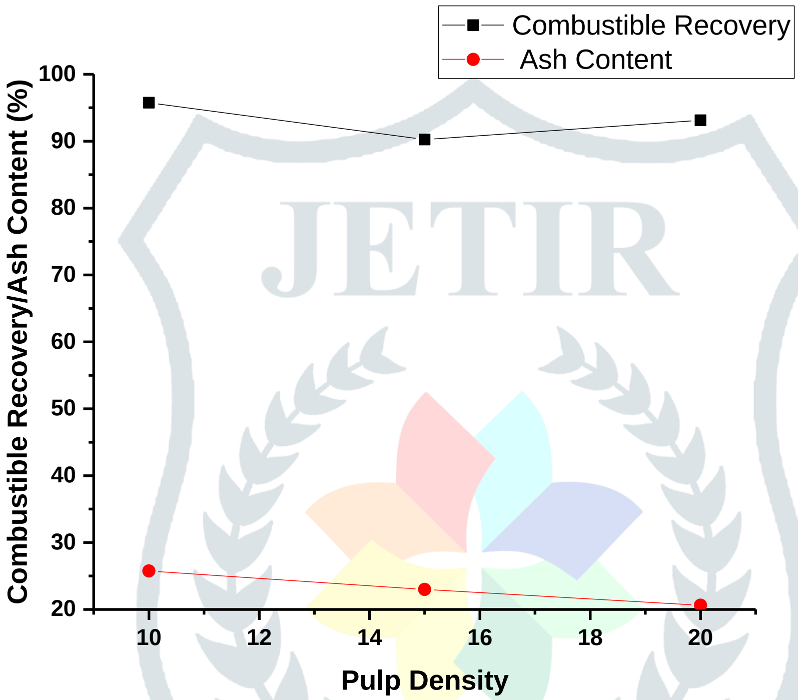

Figure 5: The effect of pulp density on combustible recovery and ash content; variable; pH 7–7.5; particle size: -0.104mm; MIBC/ kerosene ratio: 1/1; flotation time: 10 min).

5. Conclusions:

The following major conclusions are drawn from the present work:

- Ash content of coal in froth decrease with kerosene treatment compared to no treatment for any coal conc. in slurry.
- Lower ash content is registered at lower coal concentration. As the pulp density increases the ash content percentage increases.
- Ash percentage in froth increased with increase in kerosene dosages however it decreased substantially with addition of MIBC.
- A product with 20.64% ash content and 93.08% combustible recovery could be obtained after 10 min of flotation operation at d_{80} = 0.104 mm particle size, 1/1 MIBC/kerosene ratio, 20% solids pulp density.

- It is expected that the coal flotation optimization work will provide a significant contribution to the field, i.e., that the work either will provide something new to the field or will improve some existing knowledge or methodology in the field.

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