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# Hydrophobic Flocculation Flotation For Treatment of Coal Fines

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***Abstract***

*Fine coals such as mine dust, slack coal, washing rejects and slurries are treated by methods usingflotation, oil agglomeration and flocculation, hydrophobic flocculation flotation. In this work, the hydrophobic flocculation flotationhas been used to treat fine coal particles below 75 µm. Finally the parameters studied in this work are dosage of non-polar oil addition, effect of pH, with change in pulp density. We have used kerosene as non-polar oil in case of hydrophobic flocculation flotation. Results reveal that the hydrophobic flocculation could be greatly enhanced by adding a little amount of non-polar oil. For finer size range this technique is more useful to recover valuable minerals and also to remove impurities associated with the coal. The results from both the methods were compared on the basis of parameters like % Ash Rejection (AR), % Combustible recovery (CMR), % Yield. Also the process has been compared with conventional flotation process. At constant collector dose (CD) of 0.5kg/ton, %Ash is varying from 19.54% to 17.54%, similarly for 0.75kg/ton values varying from 19.27% to 16.27% and for 1 kg/ton values vary from 19.91% to 16.56%.*

***Keywords:*** *gravity concentration, mineral processing, hydrophobic flocculation flotation*

## 1. Introduction

Coalis cleaned predominantly by dense media separation and jigging operation both in India and Worldwide. But when it comes to fine coals such as mine dust, slack coal, washing rejects and slurries, we talk about methods like flotation, oil agglomeration and flocculation. The attention regarding recovery and control over fines and ultra-fines increased not only because fines and ultrafine consist of valuable minerals which are generated in grinding circuits or from raw ores. Also there are some serious environmental concerns related to rejection of these harmful fines [1]. During last four decades, numerous investigations have been performed on fine coal and slimes to enhance their recovery and various physical separation techniques were developed. These techniques can be classified into two categories, i.e., increasing particle size through aggregation, and extending the lower size limit of standard separation methods. The former includes the techniques of polymer flocculation, hydrophobic flocculation and magnetic flocculation, etc. The latter includes micro-bubble flotation, high-gradient magnetic separation, and super-conducting separation [2-7], etc. One of the effective methods used was Hydrophobic Flocculation Flotation (HFF). Warren [8] indicated that shear flocculation is affected mainly by shear rate in conditioning and the degree of hydrophobization of the particles. Lu et al [9-10] showed that flocculation of fine particles depends on hydrophobicity.

In this paper, Hydrophobic Flocculation Flotation (HFF) has been used to treat fine coal particles below 75 µm. Firstly the process has been briefly described. Then HFF has been performed on different dosage of reagents. Also it has been found that hydrophobicity could be greatly enhanced by adding a little amount of non-polar oil. Finally the results were discussed on the basis of experimental data and compared with the conventional Froth Flotation (FF) process.

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**1.1 <u>HFF Process</u>**: Hydrophobic Flocculation Flotation process recovers the fine minerals and coal. It flocculates the hydrophobic particles and the flocs are subjected to flotation. Hydrophobicity is provided to minerals which are not hydrophobic by addition of surfactants and non-polar oil. Dispersants are used to render gangue particles hydrophilic. The process-wise description is as follows:

1) <u>Dispersion</u>- These are added during grinding of ore when fines are to be produced. Dispersion prevents the clotting of mineral and gangue particles and hence it has got marked effect on separation. Dispersants get stuck to the gangue particles to render them hydrophilic. Few examples are sodium silicate, sodium hexa-meta phosphate, tannic acid etc.
2) <u>Hydrophobization</u>- Surfactants are used to render the desired mineral particles hydrophobic and this hydrophobicity is enhanced and strengthened by the addition of non-polar oil. Oil consumption varies from about 0.2% to 1.5% on a dry feed basis.
3) <u>Hydrophobic Flocculation</u>- The agglomeration of the desired mineral particles is done under high stirring conditions for long durations (high shear rate). The fine hydrophobic particles coagulate to form flocs which are comparatively larger in size.
4) <u>Flotation of flocs</u>-Finally frother is added to collect the coagulated hydrophobic flocs to froth by means of air bubbles and these are separated as concentrates.

## 2. <u>Materials and Procedure</u>

### 2.1 Sample Preparation

The coal sample was collected from Topa Colliery (CCL Jharkhand). The sample was crushed in double roll crusher and was ground in ball mill and pulverizer. It was then screened to obtain -75 µm size and the further experiments were carried out at this size. Figure 1 shows the particle size analysis of the feed.

### 2.2 Reagents

Reagents used in the experiment were collector, frother and flocculant. Kerosene was used as collector with the collector dosages (CD) as 0.50 kg/ton (CD1), 0.75 kg/ton(CD2) and 1.00 (CD3) kg/ton. Frotherdose (FD) and flocculant dose (FlD) used in the experiment were pine oil and octyl-alcohol (with varying dosage of 0.50 kg/ton, 0.75 kg/ton and 1.00 kg/ton). Reagents were selected on the basis of previousexperiments and their chemical properties.

### 2.3 Method

The hydrophobic flocculation flotation of coal (-75 µm) was carried out in a froth flotation setup with pulp density of 10%. The experiments were performed with 250 gm of coal sample in each experiment with 2.25 Lt of water was added in each experiment. Conditioning time was kept as 2 minutes and then the different reagents were added time to time accordingly and then froth were collected after 30 sec, 60 sec and 90 sec. This froth was then dried and weighed to report concentrate and further analysis was done.

## 3. <u>Experimental Procedure</u>

Experiments were carried out with 250 gm of sample taken in flotation vessel. Initially 2 liters of water was added slowly and rest was added while collecting froth. After addition of water, conditioning of the coal sample was done for two minutes and then collector was added. After 30 seconds flocculant was added and then again after 30 seconds frother was added according to the calculated dosage combination. For 90 seconds froth was collected after 10 seconds of addition of frother. The collected

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froth was dried in air oven and weighed. According to these weights, percentage of concentrated coal (%Yield), percentage of ash content (%Ash),percentage Combustible Matter Recovery (%CMR) and percentage ash rejection(%AR) were calculated from the formulae available in the literature.

**Table1: Size analysis of feed sample**

| Sizes (mm) | Wt (kg) | Wt % | Ash % | Cum. Wt% passing | Cum. Wt% retained |
|---|---|---|---|---|---|
| 12.5 | 1.866 | 34.25 | 31.42 | 65.75 | 34.25 |
| 6.3 | 1.526 | 28.02 | 28.91 | 37.73 | 62.27 |
| 3.35 | 0.576 | 10.58 | 27.96 | 27.15 | 72.85 |
| 1.7 | 0.207 | 3.8 | 27.81 | 23.35 | 76.65 |
| 1 | 0.177 | 3.25 | 27.68 | 20.1 | 79.9 |
| 0.5 | 0.232 | 4.26 | 27.57 | 15.84 | 84.16 |
| 0.074 | 0.273 | 5.02 | 27.51 | 10.82 | 89.18 |
| -0.074 | 0.59 | 10.82 | 28.33 | 0 | 100 |

% Ash in sample feed coal = **26.5993**

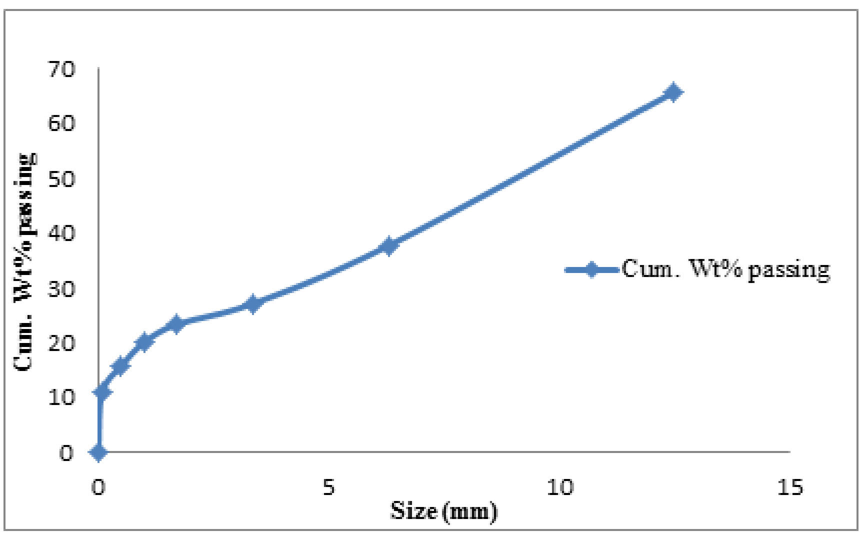


**Figure1: Particle size distribution curve of the feed sample**

## 4. Results And Discussions

The experiments were done and it is found that there is an enhancement in the %Yield with an increase in dosage of frother and flocculant at a constant collector dose, though at lower collector dose this enhancement is not significant. This enhancement may be because of increased coagulation of particles due to flocculants and simultaneous increase in froth formation. It is also apparent from the

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figure that %Yield first increases then decreases with increase in flocculant and frother dosage at constant collector dose, although better results are shown by HFF process than the latter as shown in Figure 2.

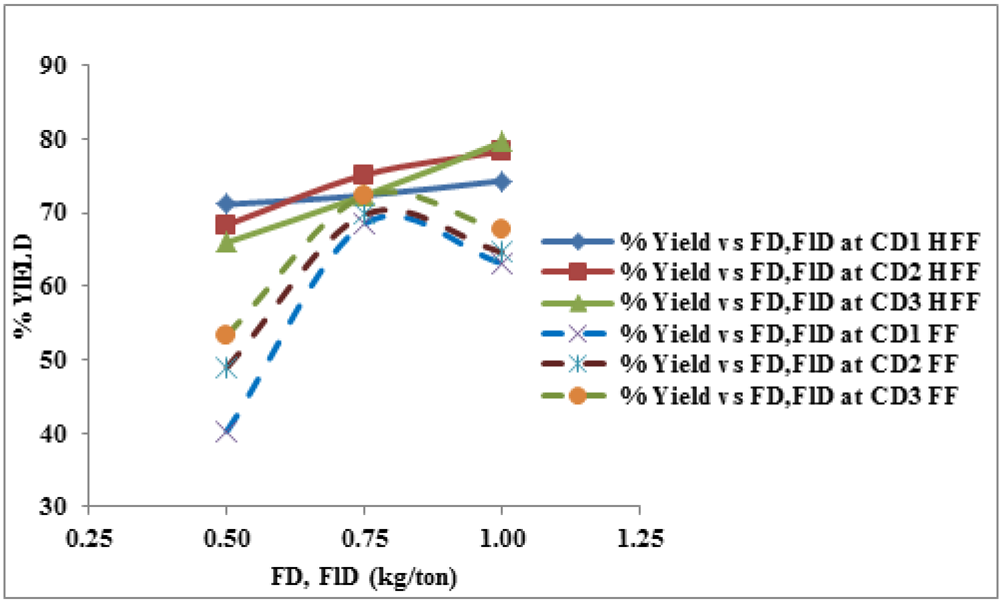


**Figure 2: Performance comparison of HFF and FF in terms of % Yield vsFrother dose (FD) and Flocculants dosage (FlD)**

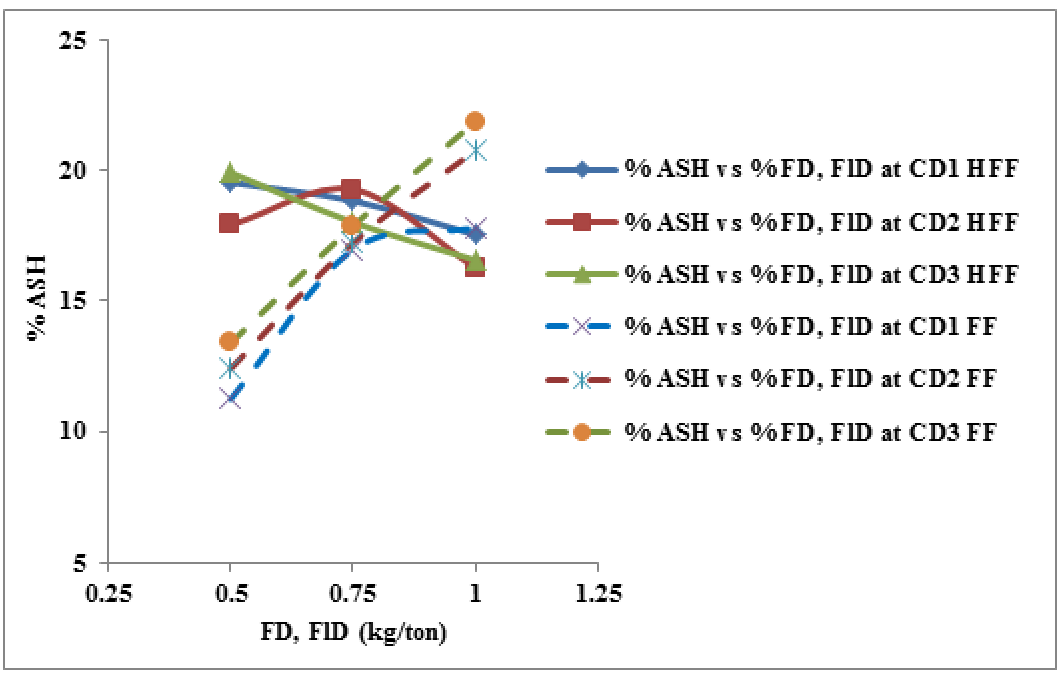


**Figure 3: Performance comparison of HFF and FF in terms of %Ash vsFrother dose (FD) and Flocculants dosage (FlD)**

As it is clear from the above Figure 3 that at % Ash is decreasing at all dosage except CD at 0.75kg/ton and this can be due toimproper collection of sample for ash analysis or while collecting frother

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from the test. % Ash is decreasing in increase in flocculant and frother dosage. Increase in flocculant dosage resulted in lower ash and this can be because of enhanced flocs formation of clean coal or rejection of gangue minerals.Thus it can be seen that more is the %Ash, less is the %Ash Rejection. As we can see from the Figure 3, % Ash is decreasing with increase in collector dose from 0.5 kg/ton to 1 kg/ton but lower %Ash was found at collector dose 0.75 kg/ton except at frother dose and flocculantdose 0.75 kg/ton. At constant collector dose of 0.5kg/ton %Ash is varying from 19.54% to 17.54%, similarly for 0.75kg/ton values varying from 19.27% to 16.27% and for 1 kg/ton values vary from 19.91% to 16.56%. It can also be seen that %Ash increases significantly with increase in flocculant and frother dose at a constant collector dose in froth flotation process.

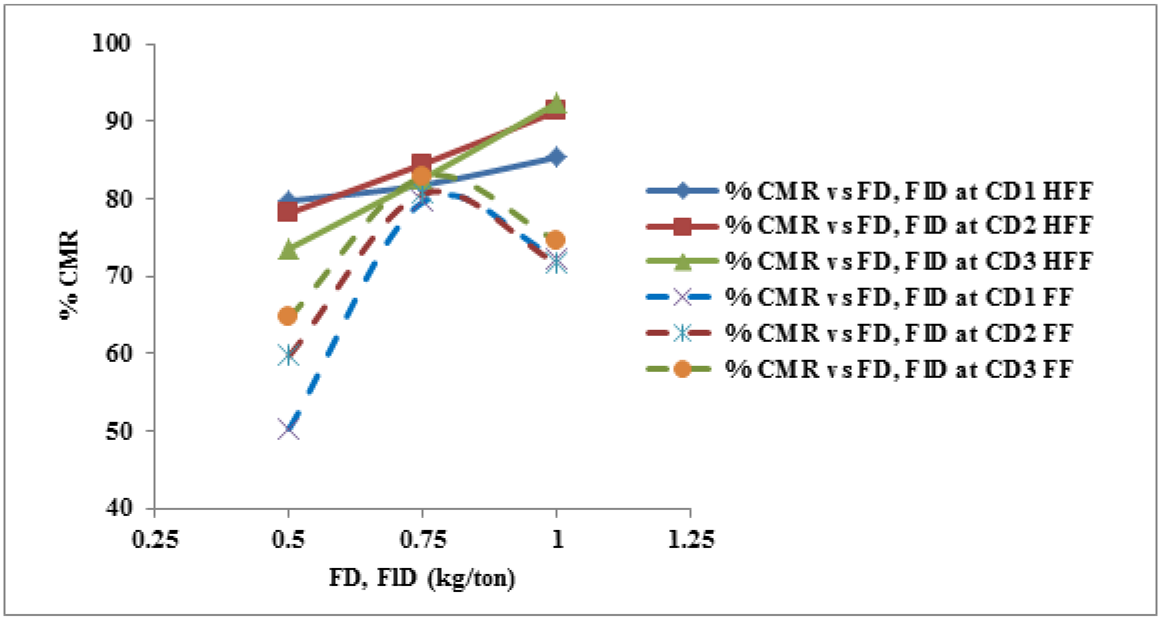


**Figure 4: Performance comparison of HFF and FF in terms of %CMR vsFrother dose (FD) and Flocculants dosage (FlD)**

Figure 4shows that %CMR shows an increase on increase in flocculant and frother dose at constant collector dose. At collector dose 0.5kg/ton, %CMR increases from 78.12% at FD 0.5kg/ton to 85.35% at FD 1kg/ton. This may be because the increased flocculants bring together more coal particles hence increasing the coal matter recovery. The dotted figures show that the %CMR first increases then decreases with increase in flocculants and frother dosage at a constant collector dose. The figures represent the better results of HFF process over FF process.

## 5. Conclusions

This paper concludes that the Hydrophobic Flocculation Flotation (HFF) shows better results than the Froth Flotation (FF) process. From the graphs at lower dosage of collector (Kerosene Oil) i.e. 0.5 kg/t, flocculant and frother (0.5kg/ton), % Yield and % CMR shows better result i.e. 71.20 and 79.70respectively and %Ash has less value in comparison to Flotation process at higher collector dosage.In HFF, at constant FD and Flocculants i.e. 0.5 kg/t and increasing collector dosages i.e. 0.5, 0.75 and 1.00 kg/t, % Yield is more at lower dosages of collector, frother and flocculants.Thus, it can be seen that maximum %Ash Rejection is at lower flocculant and frother dose and collector dose 0.75kg/ton. In the same way, %CMR shows maximum value at highest collector, flocculant and frother dose and minimum at lowest of their dosage.This paper shows that the HFF consumes fewer amounts of collector, frother and flocculant dosages than Flotation and gives better %Yield. The optimum condition found to be

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at 0.75kg/ton of collector, frother and flocculant dosage.HFF is economically favorable and takes almost same time like Froth Flotation (FF) process.

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