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Effects of operating Parameters on Recovery of non-floatable Coal by Column flotation

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Abstract

In this research paper, Investigation has done for comparison about mechanical flotation and Column flotation cell,, the similar properties were identified among mechanical flotation cell and column flotation cell for fine coal processing. Moreover the maximum values of operational variables are identified, those were essential to select in column flotation for desirable separation process. Therefore the frother height, Air flow rate, slurry flow rate, collector dosage, the wash water rate, the airflow rate and the pulp rate. The coal sample was collected from a classifying cyclone overflow stream consisting of nominally -500 μm material. The Proximate analyses of the coal sample were found to be 44.40%, 18.70%, 28.60% and 0.50%, respectively. Comparison of the column and mechanical flotation results indicated that column flotation was considerably more efficient than mechanical flotation for fine coal cleaning. High frother thickness and wash water addition during column flotation made it possible to obtain cleaner coals. The column flotation produced 15.60% product ash with 49.92% of clean coal and combustible recovery of 80.15%.

Keywords: Flotation cells, feed rate, Collector dosage, Airflow rate, slurry flow rate, pulp rate.

INTRODUCTION:

Flotation mechanism is one of the versatile processes to use and separate the fine coal cleanings extensively from 1918. Column flotation cell is a refined froth flotation method; it is elaborated as an alternative form of conventional flotation and mechanical flotation. The major role of the column flotation cell upon mechanical flotation contain outstanding separating capacity, a less capital and operating value, a low demand for plant area and flexibility to automatic control. The very essential parameter is differentiating between column flotation cell over mechanical flotation is the cell shape and the not in use of an impeller or a stator to get the air droplets. As per mechanical flotation air droplets were produced with the action of an impeller method although the air droplets are produced in column flotation with sprayer by the air compression process. Apart from this, clean coals are obtained in column flotation cell with addition of clean water with frother.

In flotation column, raw material was normally entered 3/4 height of the column by adding compression air through pervious material (sprayer) over the tailing output area of flotation column. Because of the coal particles travelling down combine along with the rise up bubbles of air in the collecting area. After, the attached lighter particles to the air bubbles go to cleaning section. The non floatable particles reaches to beneath of the flotation column, then carried out the segregation. The areas of the columns in the agitating section are most disadvantages, the major difficulties in the column height installations are at closed section of sparger. According to previous years, more number of design columns is incorporated to remove the difficulties to enhance recovery through producing micro bubbles. Few of the mare Leeds column, packed column, Flotaire column, Hydro chem. column, Jameson column, Microcel flotation column, Cyclone flotation column and Cyclonic column of micro bubble. In the previous works the column flotation cell performance indicated over and few parameters are identified that airflow rate, raw material feed rate, rate of wash water, thickness of the frother and collector dosage comparatively impact the performance of flotation.

As per research observations, increases the air flow rate, then increase the recovery it will gives high amount of yield and then it is going to be starts to decrease. Even though, many kinds of results come up from the studies done for the feed rate. Finch said that when the rate of raw material maximized, the holding period reduced and then the recovery enhanced. Even though, Goodland have confirmed that the reverse might be happen. As per research results conducted for cleaning water, it has confirmed that by the enhancing rate of washed water, grade is higher and lower recovery was obtained. As per more experimentation it was proved that instead of increase in the grade, and then the recovery do not reduced more. The parameters frother thickness and wash water rate are having same effect on flotation process.

Then the frother become hard, higher grade and lower recovery was obtained. The impact of collector dosage and frother concentration in flotation process is at most equal is recognized in mechanical flotation cell. According to different observations, at optimum value if collector dosage having an maximum level at that level recovery achieves the highest value in flotation.

In most of the research studies the cells were verified relatively, finally it has concluded that the column flotation cell produces a more recovery with less ash content, with the help of both the flotation cells attained washed coal, and having the ash percentages 11.50% and 12.30%, respective combustible recoveries are 80.10% and 76.50%, accordingly. Relatively, Harris, attained washed coals which are having the ash amount of 8.70% and 10.50% with grades of 35.30% and 30.10%, accordingly. Even though, Gu¨ney *et al*. (2002)has got that the opposite is achievable and confirmed that column flotation cell is having less performance relatively compare to mechanical flotation cell. Turkey coal samples percentage of ash around 43.12% are separated with help of flotation column. Washed coals are attained the percentages of ash like 13.07%, 14.13% and 15.11% ,respective combustible recoveries are 19.10%,31.70% and 39.10%. Finally with the help of mechanical flotation cell , clean washed coals are attained by the ash percentages of 12.30%, 19.41% and 21.15% and the combustible recoveries of 34.10%, 63.80% and 72.10%, accordingly.

MATERIALS AND METHODS:

The diagrammatic performance of the small scale column flotation cell used for experimentation as per Fig. 1. The flotation column containing height of 140 cm circular column and 6cm of diameter, 14 L volume of Raw material collection tank arranged with a compressor to supply the air. There are two positive displacement pumps for feed entering and the tailing exit, measurement of flow device, above the 5cm top of the column a jet-type wash water system arranged.

Material Used

The raw material collected by the coal washeries from Baurine coal mine. The slurry from raw material obtained through classifying section of overflow of the cyclone containing normally – 500 µm sample. The chemical analysis of the sample results are shown in Table 1.

The coal sample characterization data are shown inTable2.It shows 70% of coal sample having -76 mm size of the particle, which is having ash content of 46.40% and also total sulfur of 0.55%. Therefore, the coal was investigated as proportionately more content of ash and less sulfur of coal.

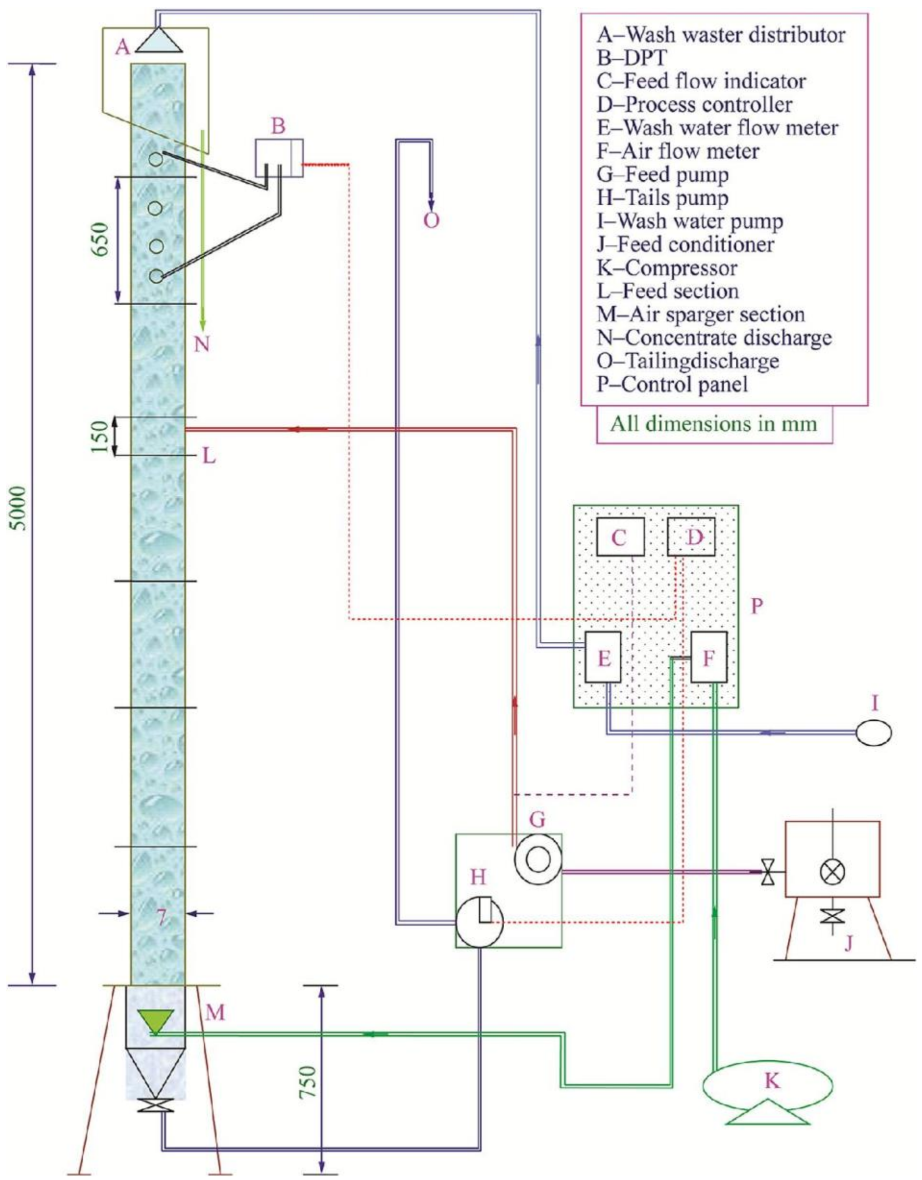

Figure 1. Column flotation cell Experimental set up

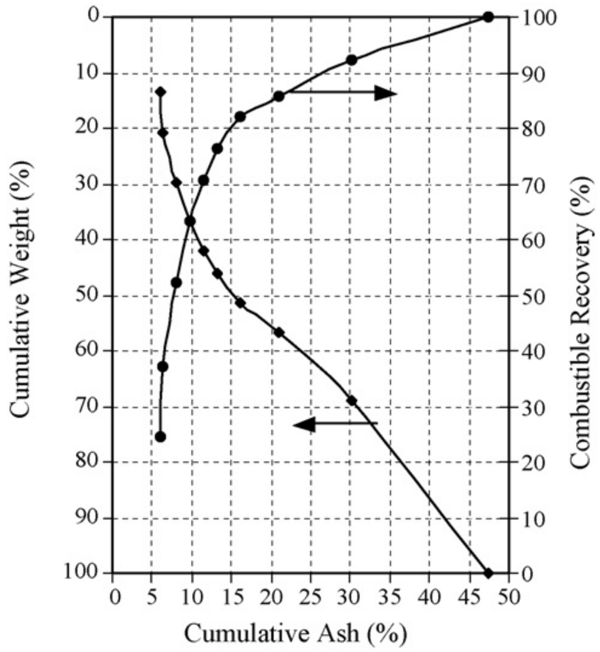

Figure 2. Cumulative weight in percentages and combustible recovery in percentages-vs.-cumulative ash percentages curves from tree (release) analysis experiment.

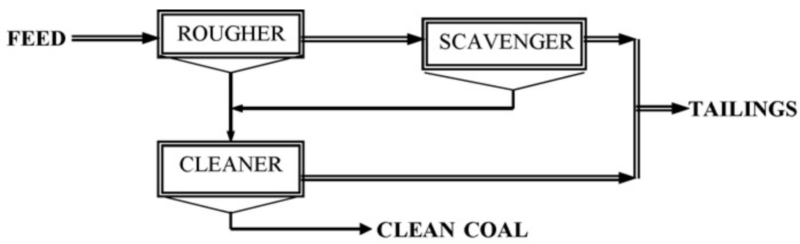

Figure 3. Rougher–scavenger–cleaner circuit diagram.

Table 1. Characterization of coal (air dry basis) (Proximate Analysis)

A_{ad} (%)	44.40
V_{ad} (%)	18.70
FC_{ad} (%)	28.60
Total sulfur (%)	0.55
Upper calorific value (kcal/kg)	4200

Table 2. For the various size fractions Distribution of weight, ash and combustible recoveries.

Size fraction (mm)	Weight retained (%)	A_{ad} (%)	Combustible Recovery (%)
+6	3.50	6.60	7.10
—6+2.8	3.77	4.45	7.41
—2.8+1.68	5.12	4.90	10.15
—1.68+0.85	6.04	19.45	10.42
—0.85+0.5	6.70	19.20	11.00
—0.5	59.27	59.14	47.95

By using release analysis calculated the affectivity of flotation which is given by Dell (1964) performed in (Fig.2).

Procedure:

One Kilo gram of coal sample was taken and added few amount of tap water was kept in conditioner tank by adding density of pulp is 10% (wt) and conditioning period is about 05 minutes. Therefore, the sample of coal was diluted uniformly with water. Then the kerosene is used as collector and MIBC as frother are added, stirred up agitating about 5 min up to required amount was obtained. Then the prepared pulp was kept into the column with speed of constant rate of feeding. The concentrate and tailing were attained in every stage of column flotation.

In column flotation experiment single step flotation was carried out to get maximum values of dosage collector, thickness of frother, rate of wash water, rate of airflow and density of the pulp. Another way, the system will produce the two products. Rougher clean coal and rougher tailing. Later on, it became clear that a single stage was not efficient enough for column flotation. Thus, rougher cleaner coal and rougher tailings were again sending to the column flotation cell then the cleaning process was carried out under the similar operating conditions. The circuit configuration of this process is shown in Fig.3

The combustible recovery attained from the flotation experiments was determined by the following equation:

$$Combustible\ Recovery\ (\%) = [W_c X\ (100\text{-}A_C)\ /\ W_f\ X\ (100A_f)]\ X\ 100$$

W_c is Clean coal by weight (%). W_f is feed by weight (%). A_c is clean coal ash content by weight (%).A_f is feed ash content by weight(%).

RESULTS AND DISCUSSION:

Impact of concentration of frother

The impact of concentration of frother on flotation column was determined there are MIBC was used as frother. It has selected like frother to give the much amount of froth at various concentrations like 20 mg/l, 25 mg/l, 30 mg/l and 35 mg/l. Table 3 indicates different MIBC concentrations results at end of the tests conducted.

Table 3. Impact of concentration of frother on the flotation column.

Frother (MIBC) (mg/lt)	Collector (Kerosene) (g/t)	Frother thickness (cm)	Rate of Wash water (cm/s)	Air flow rate (cm/s)	Feeding rate (cm/s)	Clean coal ash (%)	Clean coal yield (%)	Combustible recovery (%)
20	1200	25	0.20	2.00	0.40	20.00	41.40	63.08
25	1200	25	0.20	2.00	0.40	20.45	44.04	66.73
30	1200	25	0.20	2.00	0.40	21.25	44.56	66.84
35	1200	25	0.20	2.00	0.40	23.40	45.02	65.68

Table 4. Impact of collector on flotation column.

Collector dosage (g/t)	Frother (MIBC) (ppm)	Frother thickness (cm)	Rate of Washwater (cm/s)	Airflowrate (cm/s)	Feed rate (cm/s)	washed coal ash (%)	Clean coal yield (%)	Combustible recovery (%)
500	25	25	0.20	2.00	0.40	18.15	41.32	63.00
1000	25	25	0.20	2.00	0.40	20.55	44.30	67.04
1500	25	25	0.20	2.00	0.40	21.10	44.87	67.43
2000	25	25	0.20	2.00	0.40	22.55	44.80	65.15

Then the concentration of frother was 20 mg/l, 25 mg/l and 30 mg/l, the combustible recoveries are 62.05%, 65.33% and 65.14%, accordingly. If frother concentration enhanced about 30 mg/l, then combustible recoveries were done. Then concentration of frother about 35 mg/l, combustible recovery reduced to 64.57%. According to frother concentration, ash content of washed coal achieved to maximum value (22.30%) by mineral entrainment. Finally maximum frother concentration determined by the test results was 25mg/l.

Impact of collector dosage

In this experiment selected collector was Kerosene. The experiment has performed at different dosages of kerosene like 500 g/t, 1000 g/t, 1500 g/t, 2000 g/t were shown Table 4. When dosage of collector increased 500 g/t to 2000 g/t it shown the content of ash percentage washed coal enhanced 18.15% to 22.55%, accordingly. On other hand, enhancing the dosage of the kerosene dose not given appropriate changes about combustible recovery. Then dosage collector is around 1000 g/t 20.55% and 67.04%, are ash content and combustible recovery of clean coal respectively. Then the maximum amount of collector noted about 1200 g/t.

Impact of frother thickness

The test was performed at different frother thicknessesd like 15 cm, 20 cm, 25 cm, 30 cm were shown Table 5. if thickness of frother increased, and then ash content and combustible recoveries of coal were decreased. The very important consideration for this is by the result of frother thickness increased, the holding time of the particles in the frother section rise up and drop back potential of gangue minerals performed with rising of water because of reduces the froth with water. According to flotation experiments, maximum value of the frother thickness was calculated as 25cm.

Impact of the rate of wash water

According to the tests conducted by the different rates of wash water 0.10 cm/s, 0.20 cm/s, 0.30 cm/s, 0.40 cm/s were shown Table 6.Finally observed content of ash from clean coal attained more rate when wash water rate less. When rate of wash water 0.1 cm/s, then clean coal ash percentage 24.82%; if this is 0.40 cm/s, 17.45% reduced. Combustible recoveries at 0.1 cm/s and 0.40 cm/s are 70.36% and 51.66%, accordingly. As per flotation test it is check out thourouly the impact of the rate of wash water on flotation test, the maximum rate of wash water was determined about 0.2cm/s.

Impact of the airflow rate

As per Table 7 the experiment carried out based on different air flow rates like 1.50 cm/s, 2.00 cm/s, 2.50 cm/s and 3.00 cm/s. Apart from this, if rate of air flow is more, due to clean coal ash content. If air flow rates are 1.50 cm/s and 3.00 cm/s, then ash contents are 20.18% and 24.22%, accordingly. Because of ash content 2 cm/s the flow rate of air disorder in the flotation process. Stabilization of froth is also in disorder.

Table 5. Impact of thickness of frother on flotation column.

Frother thickness(cm)	Frother (MIBC) (ppm)	Reagent dosage (g/t)	Rate of Wash water (cm/s)	Airflow rate (cm/s)	Feed rate (cm/s)	Clean coal ash (%)	Clean coal yield (%)	Combustible recovery (%)
15	25	1200	0.20	2.00	0.40	22.10	45.90	68.10
20	25	1200	0.20	2.00	0.40	21.45	45.08	67.44
25	25	1200	0.20	2.00	0.40	20.95	44.48	66.97
30	25	1200	0.20	2.00	0.40	19.55	40.16	61.54

Table 6. Impact of rate of wash water on flotation column .

Wash water rate (cm/s)	Frother (MIBC) (mg/l)	Reagent dosage (g/t)	Frother thickness (cm)	Air flow rate (cm/s)	Feed rate (cm/s)	Clean coal ash (%)	Clean coal yield (%)	Combustible recovery (%)
0.10	25	1200	25	2.00	0.40	25.82	50.51	71.36
0.20	25	1200	25	2.00	0.40	21.46	45.11	67.48
0.30	25	1200	25	2.00	0.40	19.06	41.46	63.92
0.40	25	1200	25	2.00	0.40	17.45	33.49	52.66

Table 7. Impact of air flow rate on flotation column.

Airflow rate (cm/s)	Frother (MIBC) (mg/l)	Reagent dosage (g/t)	Frother thickness (cm)	Wash water rate (cm/s)	Feed rate (cm/s)	Clean coal ash (%)	Clean coal yield (%)	Combustible recovery (%)
1.50	25	1200	25	0.20	0.40	20.28	41.28	62.68
2.00	25	1200	25	0.20	0.40	21.35	44.90	67.26
2.50	25	1200	25	0.20	0.40	22.95	45.80	67.17
3.00	25	1200	25	0.20	0.40	25.22	47.45	67.58

Table 8. Impact of feed rate on flotation column.

Feed rate (cm/s)	Frother (MIBC) (mg/l)	Reagent dosage (g/t)	Frother thickness (cm)	Wash water rate (cm/s)	Air flow rate (cm/s)	Clean coal ash (%)	Clean coal yield (%)	Combustible recovery (%)
0.30	25	1200	25	0.20	2.00	21.55	46.25	68.11
0.40	25	1200	25	0.20	2.00	21.82	45.90	67.35
0.50	25	1200	25	0.20	2.00	21.60	45.50	66.94
0.60	25	1200	25	0.20	2.00	21.10	43.15	63.84

Impact of the pulp rate

The different experimental values of pulp densities were shown. For various pulp densities like 0.30 cm/s 0.40 cm/s, 0.50 cm/s and 0.60 cm/s, then content of clean coal ash almost equal. The combustible recoveries are 68.11%, 67.35%, 66.94% and 63.84% for similar feed rates, accordingly. When the feed rates are high then the combustible recoveries are less. If increase feed rate which reduced holding period of particles in flotation column and coal recovery less. Due to this maximum pulp density achieved 0.40 cm/s.

Differentiation of conventional flotation cell: According to conventional flotation cell results, 5 Lts of Denver flotation column used for laboratory scale. Optimal operating variables are estimated doing the series of experiments before studies. Therefore, the exact flotation test achieved with 10% pulp density (wt) also agitating speed was 900 rpm. The collector dosage (kerosene) was used around 1000 g/t and 20ppm concentration of frother.

Firstly, single-stage flotation experiment is carried out. After that attained rougher clean coal and rougher tailing are re-fed and floated again. The circuit configuration is relatively similar to flotation column.

As per single-stage column flotation cell clean coal was attained and ash percentage was 20.55% and combustible recovery was around 67.80%, similarly the mechanical flotation cell clean coal had an ash percentage of 22.15% and a combustible recovery was around 67.72%.

Table 9. Optimal operating variables of bituminous coal

Column diameter/height	Solids ratio (%)	Frother (MIBC) (ppm)	Reagent dosage (Kerosene) (g/t)	Frother thickness(cm)	Wash water rate (cm/s)	Air flow rate (cm/s)	Feed rate (cm/s)
7/150	10	25	1200	25	0.20	2.00	0.30

Table 10. Column flotation cell results under optimum conditions

Flotation stage	Product	Ash content (%)	Yield (%)	Combustible recovery (%)
Single stage	Clean coal	21.55	45.37	67.80
	Tailings	69.05	54.63	32.20
Rougher–scavenger–cleaner	Clean coal	15.60	50.92	81.85
	Tailings	80.59	49.08	18.15

Table 11. Mechanical flotation cell results under optimal conditions

Stages of flotation	Product	Content of ash (%)	Yield (%)	Combustible recovery (%)
Single stage	Clean coal	23.15	46.95	68.72
	Tailings	69.05	53.05	31.28
Rougher–scavenger–cleaner	Clean coal	19.52	53.70	82.32
	Tailings	79.95	46.30	17.68

Therefore, discarding of ash from both flotation system are found to be 53.63% and 50.26%, accordingly.

With help of rougher–scavenger–cleaner circuit system flotation column, clean coal was attained by higher combustible recovery 80.85% and lower ash percentage of 16.60%. Inspite of that, mechanical flotation has given the clean coal which is having combustible recovery 81.32%. Even though, the ash percentage was obtained high amount of (19.52%). Therefore, discarding the ash from both flotation system found to be 67.15% and 58.90%, accordingly.

CONCLUSIONS

1. By increasing the collector dosage which increases the flotation yield. In spite of that, the above mentioned dosage, the flotation process opposite. By addition of much amount of MIBC and frother like Kerosene, then decreases the combustible recovery slowly. In other hand clean coal of ash amount was higher. The maximum reagent dosage and frother (MIBC) contents are determined 1000 g/t and 25 mg/l, accordingly.
2. If the frother thickness increases clean coal was attained. In addition to that, if the frother level increases, flotation yield decreases. The maximum frother thickness was obtained 30 cm.
3. By addining wash water gangue minerals performed with frother then it is re washed and removed them and passing through the washed coal,by increasing the rate of wah water, clean coals are attained. Even though, at higher wash water rates, constant frother not attained then slowly decreases the yield. The maximum rate of wash water calculated about 0.20cm/s.
4. As per lower airflow rate required frother thickness couldn’t achieved, thus, the yield becomes less. At high air flow rates, the yield becomes more. Even though, above at particular rate, ash content of increases enormously. Then optimal air flow rate was calculated as 2cm/s.
5. By adding more feed rate, then the flotation yield was less. In addition to that ash content in clean coal do not vary at any point. The maximum feed rate obtained was 0.30cm/s.
6. If single stage flotation process carried out in both the flotation columns, do not extract much coal. The combustible recoveries of the tailings are determined 32.20% and 31.28%, accordingly, those are comparatively more values.
7. If the tailings from rougher and rougher clean coals are continuous floated separately for rougher–scavenger–cleaner circuit, more combustible recoveries (80.85–81.32%) are attained from both of the flotation cells .Moreover, by removal of ash, then it is identified column flotation cell was most efficient. Finally, by the column flotation cell the ash percentages of the bituminous coal was decreased from 46.50% to 17.60% and yield of combustible recovery was 80.85%. With help of mechanical flotation cell ash percentage of similar coal was decreased to 20.52% and 81.32%
8. The experimental values of the column flotation cell are very near to that of release analysis values. Apart from this, column flotation cell highly efficient than the mechanical flotation cell for fine coal separation.

REFERENCES

[1] Andrew Mohns C (1997) Effect of particle size on coal flotation kinetics (PhD thesis). Queen’s University, Kingston:pp1–4

[2] Arnold BJ, Aplan FF (1989) the hydrophobicity of coal macerals. Fuel 68(5):651–658

[3] Bensley CN, Nicol SK (1985) The effect of mechanical variables on the flotation of coarse coal. Coal preparation 1:189

[4] Boylu F, Laskowski JS (2007) Rate of water transfer to flotation froth in the flotation of low-rank coal that also requires the use of oily collector. Int J Miner Process 83:125–131

[5] Brady GA, Gauger AW (1940) Properties of coal surfaces. J ind eng chem 32:1599–1604

[6] Dey S, Pani S (2012) Effective processing of low-volatile medium coking coal fines of Indian origin using different process variables of flotation. Int J Coal Prep Util 32:253

[7] Ding LP (2009) Investigation of bituminous coal hydrophobicity and its influence on flotation. Energy fuels 23:5536–5543

[8] Gosiewska A, Drelich J, Laskowski JS, Pawlik M (2002) Mineral matter distribution on coal surface and its effect on coal wettability. J Colloid Interface Sci 247(1):107–116

[9] Khoury DL (1981) Coal Cleaning Technology. NDC, Park Ridge Koca S, Bektas Y, Koca H (2010) Contact angle measurement on lignite surface. Proceedings of the XXV International Mineral Processing Congress (IMPC) Brisbane 2049

[10] Konar BB, Banerjee SB, Chaudhuri SG, Choudhury A, Das NS, Sen Kalyan (1997) In: Coal Preparation. Allied Publishers Ltd New Delhi, CFRI Golden jubilee monograph

[11] Laskowski JS (2001) Coal flotation and fine coal utilization. Elsevier Science, Amsterdam, p 225

[12] Mukherjee AK, Chatterjee CN, Ghose S (1982) Coal Resources of India:it’s formation, distribution and utilisation. Fuel Sci Tech-nol 1:19–34

[13] Peng FF (1996) Surface energy and induction time of fine coals treated with various levels of dispersed collector and their correlation to flotation responses. Energy fuels 10:1202–1207

[14] Shobhana Dey, Gyana Manjari Paul, Santosh Pani (2013) Effective flotation of weathered coal using frother blend. In: Coal preparation technology CSIR - CIMFR Jharkhand

[15] Vasumathi N, Vijaya Kumar TV, Subba Rao S, Prabhakar S, Bhaskar Raju G, Shiva Kumar S, Raman Uma (2013) Eco-friendly and cost effective reagent

Sokem 590C for coal flotation. Int J Eng Res 2(7):418–433

[16] Yenigalla GR (2013) Coal Beneficiation: A road to clean coal Technology. In CSIR - CIMFR Jharkhand India: Coal Prepara-tion Technology Proceedings

[17] Yoon RH, Luttrell GH, Asmatulu R (2002) Extending the upper particle size limit for coal flotation. J South African Inst Mining Metallurgy 102(7):411–415

[18] Harris, M. C., J. P. Franzidis, A. W. Breed, and D. A. Deglon, ‘‘An On-Site Evaluation of Different Flotation Technologies for Fine Coal Beneficiation,’’ *Miner.Eng.*,7,699(1994).