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Recovery of coal fines from rejects by column flotation

P. S. R. REDDY, S. K. BISWAL, S. PRAKASH,
S. K. BHAUMIK and S. R. S. SASTRI
Regional Research Laboratory, Bhubaneswar - 751 013, India

ABSTRACT

Investigations were carried out using column flotation to recover coking coal fines from the tailings generated at flotation plant of one of the operating washeries. Columns of different diameter designed and developed by RRL, Bhubaneswar were used in these studies. Washability studies indicated that the tailings have the potential to yield 60% of clean coal at 15.0% ash level. Flotation studies in cell indicated that a product with 16% ash can be obtained at 50% yield from these tailings. Results of column flotation had indicated that the performance of column is superior to cell and close to washability data. Most of the coal values being rejected presently can be recovered by using the flotation column. The results obtained by 100 mm and 220 mm diameter laboratory columns could be reproduced on pilot column of 1000 mm diameter, confirming the validity of design and scale up criteria.

Key words : *Column flotation, Coalfines, Recovery from talings*

INTRODUCTION

The estimated coking coal reserves are around 30 billion tonnes and amount to 15% of the total coal reserves in India, where as the recoverable reserves up to 600 m depth are only 8,63 billions tonnes. The prime coking coal is 18%, medium coking coal is 78% and the balance is semicoking coal[1]. In general coking coals in India contain high ash and have inferior coking properties due to dirt origin. It is established that the washability characteristics are very poor due to the presence of higher near gravity material. The average ash content varies from 20-35%. The ash content is increasing day by day due to depletion of good quality coal and adaptation of bulk mechanised mining. This led to crushing the coal to finer sizes before washing. During the process of washing fines less than 0.5mm in size amounting to 15-20% of coal processed which contain 20-20% ash are generated. These fines need to be beneficiated to reduce the ash content below 17% in order to utilise in steel plants. The most effective technique to date for cleaning these coal fines is conventional froth flotation.[2].

The most neglected area in Indian coal washing is the fine coal cleaning. Some of the Indian washeries do not have flotation circuit and the fine coal is being mixed with clean coal or rejected based on the ash content. Very few washeries have flotation facilities and that to they are not operated properly due to design defects and operational problems. More over conventional froth flotation circuits using cells are often inefficient in recovering fine coal. Common problem includes loss of fine coal, poor and inefficient clean coal quality. As a result the rejects of flotation plant still contain considerable coal values which can be recovered by using more efficient equipments like flotation column[3-7]. An attempt has been made to recover fine coal values that are being lost in tailings of flotation plant of one of the washeries in Bihar, India by using flotation column. This paper deals with the column flotation studies carried out on the tailings generated at flotation plant. The effect of different design and operating parameters were studied in treating these tailings. Design and scale-up criteria were developed to install semi-commercial plant at the washery site to treat the tailings generated at the existing flotation plant.

EXPERIMENTAL

Materials

About 10 tonnes of tailings produced at flotation circuit of West Bokaro WasheryII operated by M/S Tata Steel were collected in wet slurry form. The associated water was decanted and the sample was thoroughly mixed and further sampled to small quantities to carry out different investigations.

Reagents

Commercial grade light diesel oil was used as collector while commercial grade pine oil and analytical grade Methyl Iso Butyl Carbinol(MIBC) and their combinations were used as frothers.

Apparatus

Batch flotation tests were carried out in Denver D12 sub-aeration flotation machine with 10 liter capacity cell. Column flotation tests were conducted in 100 and 220 mm diameter glass columns designed and developed by Regional Research Laboratory. The schematic diagram of the experimental set-up is presented in Fig.1 and described elsewhere[8,9]. Tests were also conducted using the semi commercial pilot plant of 1000 mm diameter installed at West Bokaro Washery II in collaboration with TATA STEEL. Details of the pilot plant are shown in Fig. 2 and described elsewhere[10].

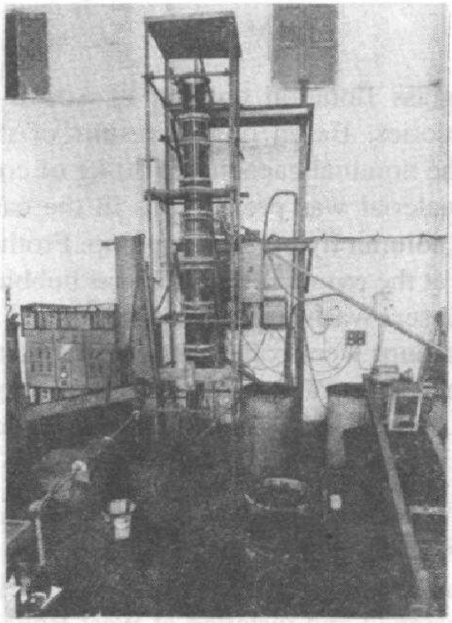

Fig. 1 : Experimental set-up for 220 mm column

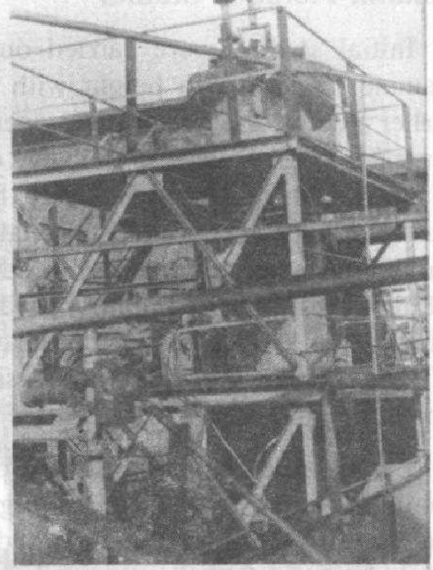

Fig. 2 : Pilot flotation column of 1000 mm diameter

PROCEDURE

Washability Characteristics

About 10 kg representative bulk sample was classified into different size fractions using standard test sieves to produce different close sized fractions. These close sized fractions were used in sink-float studies using organic liquids of different specific gravities ranging from 1.3 to 1.8. A mixture of bromoform and benzene was used as medium. The products so obtained were analysed for ash. The ash yield curves were constructed for each size.

Batch Flotation Studies

Batch flotation studies were carried using standard Denver D12 Sub-Aeration flotation cell with 10 liter capacity. The following procedure was adopted for all the experiments, 800 grams of the sample was conditioned with 1.2 liter of water and required amount of collector for 2 minutes. Then the slurry was diluted to 10% solids concentration by adding 6.0 liters of additional water. Then frother was added and air was released. The froth was collected for three minutes time. Cell rpm was maintained at 1500 for all the studies. The effect of collector and frother was evaluated.

Column Flotation Studies

Initial studies were carried out using glass flotation column of 100 mm diameter and 2.6 m height with all accessories. Based on the results of the earlier studies, the column was operated at the nominal capacity of 20 kg of coal fines per hour. Requisite quantity of feed material was prepared as in the case of batch studies and continuously fed to the column by peristaltic pump. Frother was also pumped by similar peristaltic pump at the required rate. Air was bubbled through an inverted conical shaped air dispenser. Wash water was maintained at 2 litters per minute. Sample of product and tailings were collected at steady state, which was ascertained by consistence of their flow rates. The collector dosage of 0.6g per kg was used in these studies, which was fixed based on batch floatation studies.

Large scale column tests were carried out using 220 mm diameter glass column at capacity of 70 to 150 kg per hour. Same procedure was adopted as in the case of 100 mm column. Based on the laboratory results a semi commercial pilot plant of 1.0 m diameter column was designed and installed at West Bokaro Washery II in collaboration with TATA STEEL. Data collected during commissioning and testing was also included in this paper. The pilot column was operated continuously by varying different operating parameters.

These studies were aimed at optimising different operating and design variables and determining carrying capacity of the column for treating this type of coal fines. The yield and recoveries were calculated in each case. The effect of operating variables such as air, solid concentration in feed, wash water and frother concentration was studied.

Determination of Carrying Capacity

Carrying capacity is the maximum solids rate per unit cross sectional area of the column that can be floated in the column. It is related to the maximum available particle coverage of bubbles and constitutes an upper limit to the particle collection process. The technique used to measure this parameter is based on a series of column runs with increasing feed solids rate until a maximum production rate of solids to the concentrate is reached. This maximum concentrate rate divided by the column cross sectional area gives the carrying capacity (e.g. tonnes per hour per square metre). The procedure involves running the column at constant residence time with different feed percent solids. Timed samples of the tailings and concentrate streams were collected along with the feed.

RESULTS AND DISCUSSIONS

The physical and chemical properties of the tailings generated at flotation plant of West Bokaro Washery II are presented in Table 1. The results indicated that d_{80} passing size of the tailing sample is around 600 microns. The sample on average contains 34.6% ash. The ash is distributed uniformly in all the size fractions except in -75 microns. The fines below 75 microns contain more ash compared to coarse fractions. The washbility data are presented in Table 2. It is clear form the washability data that considerable amount of coal is being lost in the tailings and there is ample scope to recover additional clean coal from these tailings. The washability indicates that clean coal with 15% ash can be recovered at 60% yield from these tailings of the flotation plant by recovering about 87.5% combustibles. These results have also given sufficient indication that most of the coal is liberated from the gangue.

Table1 : Size and ash distribution of tailing

Size, micron	*Weight, %*	*Ash, %*
+ 500	32.2	34.2
-500 + 210	34.4	31.2
-210 + 75	12.0	29.6
-75 + 45	6.2	37.3
-45	15.2	46.2
Head	100.0	34.6

Table 2 : Washability characteristics of the tailings

Sp. Gravity	Weight, %	Ash, %
Float 1.3	16.7	4.2
1.4	37.6	9.3
1.5	47.2	11.4
1.6	62.2	15.1
1.8	74.7	19.8
Sink 1.8	25.3	70.9
Head	100.0	32.7

Batch flotation studies using conventional cell have been carried out with a view to optimize collector and frother dosage to get clean coal with high yield. Initially these studies were aimed at fixing the collector and frother dosage so that same amounts can be used in the column studies. These results are presented in Fig. 3 & 4. The effect of collector on recovery at different frother dosages is shown in Fig. 3. It is clear from the figure that about 600g/t of diesel oil in sufficient to float this type of tailings. The recovery of combustibles increases with the increase in frother concentration. MIBC is giving better performance when compared to pine oil for same dosages. The results of batch flotation are compared with washability in Fig.4. It in clear from the figure that at higher ash levels the flotation results are close to washability data whereas at lower ash levels the flotation yields are significantly lower. A product with 16% ash can be obtained at 50% yield from these tailings using conventional cell.

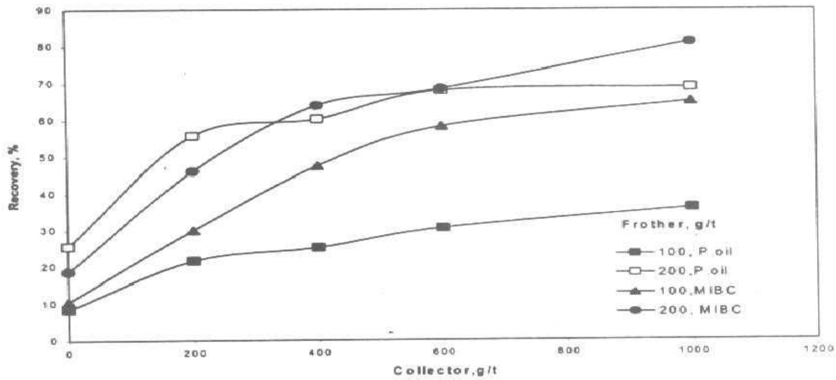

Fig. 3 : Effect of collector on coal flotation in cell

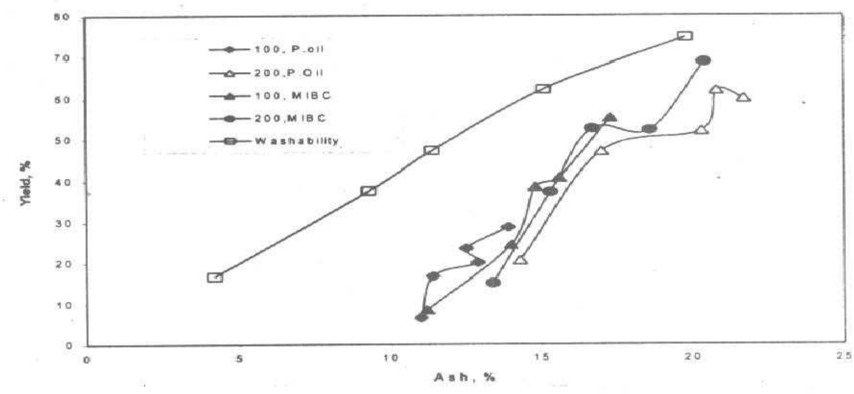

Fig. 4 : Results of batch flotation tests

The results of studies on flotation column are presented in Fig. 5. Typical results obtained with 100, 220 and 1000 mm columns are depicted in this figure and compared in Table 3. Effect of operating variables such as air rate, frother concentration and feed rate were evaluated[10]. These results indicate that the performance of column flotation depends on variety of operating and design parameters such as air flow rate, reagent dosage, column height, feed rate, wash water rate and pulp density. The operating parameters are inter-related. Some primarily effect grade and other effect grade and recovery. Frother is mainly responsible for grade and air flow rate for recovery. The yield ash relationship of these results are shown in this figure. The results are also compared with washability in the same figure. It is clear from the figure that performance of all these column are similar and close to washability. The efficiency of the column increases with the size 1.0 meter pilot column has given superior performance when compared to 100 and 220 mm diameter laboratory columns. The results of all the these columns are compared in Table 3. These results indicate that laboratory results on 100 and 220 mm column could be reproduced in pilot column of 1000 mm diameter. Most of the carbon values lost in the tailings could be recovered by using flotation column. The specific column capacity related to product ash is shown in Fig. 6. Based on the results the following design criteria has been arrived[10]. All the parameters were fixed as the basis of specific cross sectional area of the column. Feed rate : 4-5 t /hr.m^2 ; solids in feed : 20%; wash water 30 T/hr.m^2 ; air : 30m^3/hr. m^2 and frother : 750 ml/t. This criteria may be used to design a commercial column to treat the tailings generated at the flotation plant.

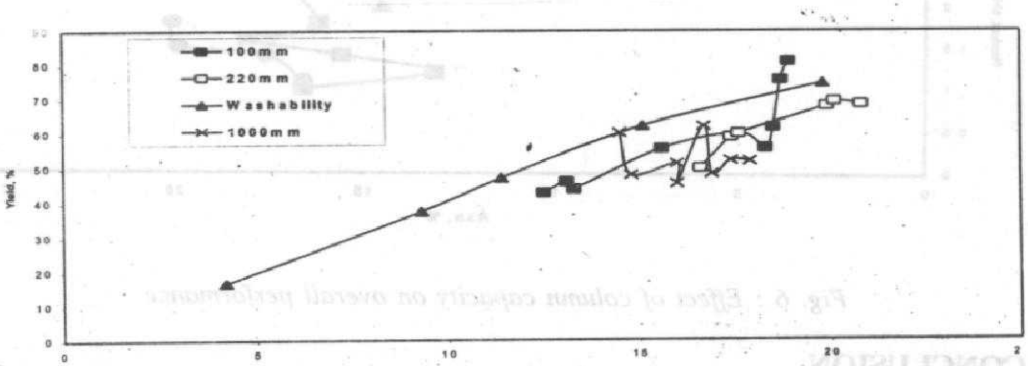

Fig. 5 : Effect of collector in cell

Table 3 : Comparison of results of laboratory and pilot column

Column dia.,mm	Ash, %			Yield, %
	Feed	Product	Tails	
	31.0	13.1	46.3	46.1
	34.3	13.3	50.0	44.0
100	34.5	16.8	56.4	40.2
	31.6	18.5	52.8	61.8
	31.3	16.2	52.4	47.2
	34.0	16.6	51.4	50.0
200	31.4	17.6	52.1	60.0
	32.5	19.9	58.2	68.0
	33.0	15.0	43.7	37.2
1000	31.5	16.0	44.5	45.5
	33.5	16.9	46.2	43.3
	32.6	17.4	49.1	52.2
	32.9	17.9	49.2	52.0

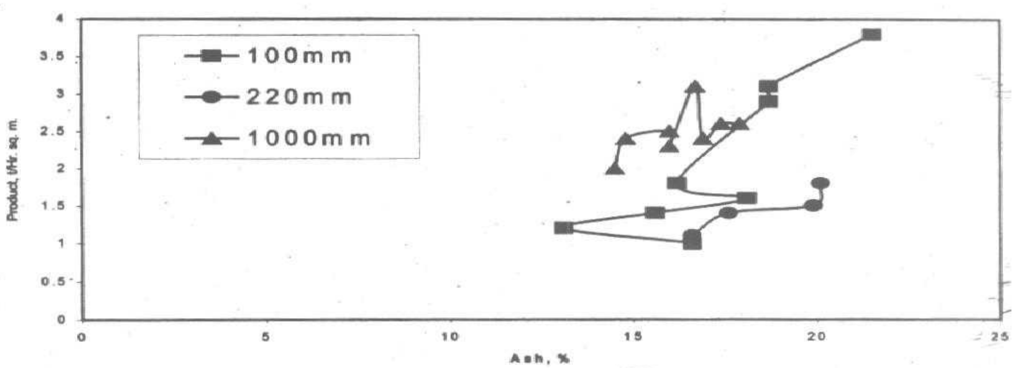

Fig. 6 : Effect of column capacity on overall performance

CONCLUSION

Investigations carried out on the tailings of flotation plant at West Bokaro washery II indicated that the rejects had got the potential to yield 60% clean coal at 15% ash level. The flotation results in conventional cell had shown that a product with 16% ash can be obtained at 50% yield. Column flotation studies carried out using 100 , 220 and 1000 mm column indicated that the performance of the column is much better than cell and close to washability. It is also proved that higher diameter column gave good performance. The results also indicated that the performance of the pilot column (1000 mm diameter) is almost similar to that of laboratory columns. The laboratory results were reproduced in pilot column and the validity of design and scale-up was confirmed. This design criteria may be used to size commercial column to treat the tailings generated at the flotation plant to recover additional clean coal so that overall output of the washery can be increased.

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