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Efficacy of gravity separation as an alternative to froth flotation for treating Jharia group coal fines

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ABSTRACT

In general, the Indian coals are difficult-to-wash due to their drift origin. Recovery of clean coal from coal fines is continue to be cost in-effective. Even though several advanced flotation technologies have been commercialized to treat fines, the results are not comparable with the washability data of fines. The Jharia group of coal fines are treated at Tata Steel presently in froth flotation. Keeping merit of gravity separation in view, the test results with water-only cyclone as an alternative gravity method to froth flotation for treating Jamadoba coal fines have been presented in this paper.

Key words : *Gravity separation, Coal fines, Water-only-cyclone*

INTRODUCTION

In the present day competitive global market and environmental regulations context, it is well known that the production cost of steel has to be brought down and simultaneously meet the customer driven product quality. Coal, in particular, metallurgical coal, is an important and critical raw material for Iron and Steel industry. Gradual depletion of high quality coal and adoption of more mechanised mining methods has led to generation of low grade ROM coal with more fines. Nearly, 2 billion tonnes of coal fines are in waste ponds of US and additionally 40 million tons are more added annually[1]. Adoption of increased mechanised mining of coal in India has resulted in generation of 20-25%[2] fines (below 0.5 mm) of the coals total coal treated. The process used for recovering of clean coal from these fines is not cost effective and environmental friendly. Hence, any effect to reduce the production cost of clean coal from these fines is of increasing significance to the industry. In this paper, the efficacy of gravity separation, in particular, water- only cyclone, as an alternative to froth flotation, to treat Jamadoba washery coal fines are presented.

Treatment of Jharia group Coal Fines

In general, the Indian coals are characterised as difficult-to-wash coals in view of their drift origin that resulted in high ash. The coals from this area belongs to prime coking coal category. Jharia group coals at Tata Steel are presently treated in Jamadoba and Bhelatend washeries . In these washeries, DM cyclones are used to treat coarser sizes (-25/15+0.5 mm) while froth flotation cells are used to treat fines (below 0.5 mm). At Tata Steel, the present economic level of ash in clean coal from its coal washeries is 17%[3]. The clean coal obtained by treating fines at Jamadoba washery is analysing ~ 13% ash at a yield of 88%. In order to get composite clean coal ash 17 %, the fine clean coal ash could not exceed 15.5%. Unfortunately, this circuit arrangement results in inefficiency due to the fact that the unit operations are operated to treat material outside their optimum particle size range. The coal recovery achieved by froth flotation decreases significantly for particle sizes >0.21mm and usually it is optimum between 0.15 and 0.075 mm[4].

Froth Flotation and its Applications

Froth flotation, a physico-chemical processes, is the versatile technique commonly and widely used to treat coal fines (0.5 to 0 mm). Several advanced flotation technologies have been commercialised with advancements in uniform micro-bubble generation system, size of the bubbles, improved bubble-particle environments, constructional feature to promote superior axial mixing in the cell, reduced entrainment of gangue and use of consistent, cost-effective quality reagents[5-7].

Froth flotation falls far short of the ideal separation obtained using coal washability analysis. Numerous studies comparing washability curves to flotation results have found that density based processes are always more efficient at treating coals containing a significant amounts of middlings[8,9]. This may be due to inability of surface based processes to reject locked middling particles. Recent studies suggest that a particle with >95 % mineral matter with <5% coal as inclusions by weight can be readily recovered by flotation[10,11]. Thus, the froth flotation technique has some inherent problems such as, recovering middling particles, non-selectivity to ultra fines (below 0.038 mm), environmental unfriendlyness and much costly due to use of chemicals. A possible solution to the short coming of the froth flotation process is the use of enhanced gravity separation, which provides centrifugal force needed to effectively treat fine coal particles[12]. The centrifugal force provider units are Water- only cyclone (WOC), Dense Media cyclone (DMC), Kelsey Centrifugal Jig (KCJ), Falcon concentrator and Multi- Gravity separator (MGS). The MGS is developed for the selective separation of flotation-size particles based on difference in density[13]. In this study WOC is used to treat Jamadoba coal fines

Water-only-Cyclone

Water-only cyclone, has been used to clean metallurgical and steam coals sine 1950. It is preferable due to its simple design, low cost to capacity ratio and the ability to clean fine coal without using an artificial, costly heavy medium and its auxiliary set up[14,15]. The expected specific gravity of separation varies from 1.5 to 2.52 and E_p from 0.13 to 0.25 as the feed size range decreases from 6.35-4.7mm to 0.15 -0.075 mm[16]. Tests were conducted in a 3" Water-Only-Cyclone[17] which was fitted to a laboratory test rig having a slurry tank of about 100 liters capacity. The slurry is kept in circulation in closed circuit and the equipment is kept provided with a sample cutter to draw underflow and overflow simultaneously for predetermined time period when needed.

Calculated quantity of water and coal fines were put into the tank to make slurry of desired solids content. Before adding coal into the tank-water, the stirrer was switched on and pump also started. The system was allowed to run for sufficient time for attaining a steady state condition. The overflow and underflow timed samples were drawn, dried, weighed and analysed for their ash content. Experiments were conducted at different levels of vortex and spigot diameters to identify the optimum parameters. Under the optimum conditions, further tests were conducted by varying the slurry pressure.

EXPERIMENTATION

About 75 kg coal fines from Jamadoba group of collieries were received for carrying out the study. Representative sample was drawn, by coning and quartering, after drying and homogenisation. Before carrying out the tests, the coal was subjected to the following analysis.

Proximate Analysis

The sample was analysed for its proximate analysis by conventional ash fusion techniques to know the quality of the sample.

Granulometric Studies

Wet sieve analysis was carried out using test sieves between 500 and 53 microns and each size fraction was dried, weighed and analysed for ash content and mineralogical information generated to understand the nature and size-wise distribution of ash minerals.

Mineralogical Studies

Mineralogical studies were carried out under optical microscope to characterise the different minerals, their proportion, quality of processed products.

Pure coal particles were separated by density fractionation and observed under microscope for its purity. The separated coal particles were analysed for ash content. The inherent ash was calculated for assessing the theoretical grade of the clean coal.

RESULTS AND DISCUSSION

The coal fines contain 18.7% ash, 22.8% volatime matter and 58.5% fixed carbon. From this it can be observed that this sample contains 3.2 units more ash than minimum required and to this extent it is desirable to lower ash by Water-Only-Cyclone.

The size analyst results indicated that +0.5, -0.5+0.053 and -0.053 mm fractions are about 6, 53 and 41 % respectively. About 47 % ash is distributed in -0.054 mm fraction From this it can be observed that by classification at 0.053 mm it is possible to lower the ash to 16.8 % but the yields would be only 60%.

The granulometric test results are given in Table 1

Table 1 : Size analysis of the sample

Size, microns	Wt., %	Ash, %	Ash distribution, %
+500	5.64	20.80	6.3
-500+250	15.03	15.43	12.4
-250+150	15.34	16.90	13.9
-150+100	8.30	16.62	7.4
-100+075	6.86	15.62	5.7
-075+053	7.86	17.40	7.3
-053	40.97	21.47	47.0
Total	100.00	18.30	100.0

Mineralogical results of coal sample are given in Table 2 and 3.

Table 2 : Mineralogical results

Constituents	Proportions, %	Ash contribution, %
Coal	84.4	14.6
Clay	12.6	58.5
Quartz	4.2	23.0
Limonite, pyrite & others	0.8	3.9
Total	100.0	100.0

Table 3 : Mode of occurrence of mineral matter

Particle make up coal : mineral	Mode of occurrence	Vol., %
>90 : <10	Surface scales/coatings	15
80-90 : 10-20	Disseminations	30
50-80 : 20-50	Intergranular patches	14
<10 : >90	Free	41

The studies indicated that about 15% of total ash is contributed by coal itself and can not be lowered by physical beneficiation. The remaining 85 % of ash is contributed by discrete mineral phases (clay, quartz etc.). Out of this 35 % total ash (i.e., 6.6 units) is in free form, which can be removed by physical beneficiation without any size reduction and the rest 50% in locked from (as surface scales/coatings, dissemination, inter-granular matrix). From this it can be observed that it is theoretically possible to lower ash to about 13 % with 93 % yield by physical beneficiation methods.

The sink-float test results are given in Table 4. The results show that it is possible to produce a clean coal between 11 and 15 % ash and yields between 70 to 94 % by gravity methods.

Table 4 : Sink-float test results

Product	Wt., %	Ash, %	Cum. ash, %	Cum. wt., %
1.30 Float	14.69	4.59	4.59	14.69
1.40 float	37.81	10.02	8.55	52.50
1.50 float	17.74	16.42	11.03	70.24
1.60 float	18.16	18.18	13.46	88.40
1.70 float	3.94	27.84	14.68	92.34
1.80float	1.04	37.47	14.90	93.38
1.80 Sink	6.62	73.47	18.47	100.00
Total	100.00	18.42		

Water-Only-cyclone optimisation experiments test results are given in Table 5 and 6.

Table 5 : Water-only-cyclone test results

(Slurry density = 13% solids by weight inlet pressure of slurry = 0.8 kg/cm²)

Test No.	Vortex dia., mm	Spigot dia., mm	Clean coal		Rejects Ash, %
			Yield, %	Ash, %	
1	30	13	92.18	16.56	43.93
2	30	17	90.31	15.73	46.38
3	30	19	63.70	15.12	24.98
4	30	30	53.92	14.87	23.18
5	32	13	90.20	16.52	38.68
6	32	17	88.82	15.68	42.69
7	32	19	65.72	15.35	25.12
8	32	30	52.50	14.73	23.09
9	35	13	89.50	16.20	40.00
10	35	17	88.20	15.53	42.39
11	35	19	62.10	15.41	24.09
12	35	30	49.70	14.56	22.11
13	37	13	83.85	17.90	64.60
14	37	17	90.65	17.58	53.14
15	37	19	86.90	16.50	49.88
16	37	30	58.20	15.40	21.12

Table 6 : Water-only-cyclone further optimisation test results
(Vortex dia, 30 mm, Spigotdia, 17 mm)

Test No.	Pressure, kg/cm²	Clean coal	
		Yield, %	Ash, %
1	0.2	84.18	15.12
2	0.4	88.31	15.47
3	0.6	89.70	15.82
4	0.8	90.92	15.87
5	1.0	92.50	16.01

From the data shown in Table 6, it can be observed that at optimised conditions (vortex finder diameter of 30 mm, spigot diameter of 17 mm, 0.4 kg/cm^2 pressure and 13 % pulp density), the clean coal produced analyses 15.47 % ash with a yield of about 88 %. By adopting WOC in place of froth flotation it is possible to lower production cost and improve environmental friendliness to considerable extent. The expected benefit towards reagents saving alone will amount to Rs. 50 lakhs/year.

CONCLUSION

Under optimum conditions, by treating Jharia group coal fines in Water-Only-Cyclone, it is possible to produce a clean coal with 15.5 % ash and about 88% yield. This indicates the combination of Dense Media Cyclone and Water-Only-Cyclone can produce similar quantity of composite clean coal with 17 % ash and simultaneously lower production cost with more environmental friendliness.

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