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Beneficiation and utilization of low volatile coking coal and non-linked washery Indian coking coals for metallurgical purposes

Indian coal industry is the world's third largest in terms of production and fourth largest in terms of proven coal resources. Coal deposits are of drift origin, high in ash content but low in sulphur. There are 20 major coalfields located in east and south eastern quadrant of the country. The coking coal reserves are less compared to the non coking coals and the good quality coking coals has been exhausted leaving behind poor quality feed stock for the metallurgical sector. For production of Iron & Steel through blast furnace route, coking coal is an important raw material. The good quality coking coals of the upper seams are fast depleting leaving behind the inferior quality lower seam coal. The lower seam coals presently being mined are mostly low volatile coking coal (LVC). They constitute about 50% of the total coking coal reserves in India. These coals are characterized by high raw coal ash content and poor washability characteristics. Beneficiation of the lower seam coals in the existing washery circuits (2 or 3 product) does not yield requisite quality demanded by the steel sector of the country and as a result it is termed as Non-Linked Washery (NLW) coals, and the entire production of inferior coals is diverted to the thermal power sector, thus, wasting the scarce coking coal resources. In this paper, an attempt has been made to focus the cost-effective and eco-friendly approach for utilization of the LVC/NLW coking coals illustrating with a case study.

Introduction

The National Steel Policy has a target for taking steel production up to 200 million tonnes by 2019-20. In fact, based on the status of MOUs signed by the private producers with the various state governments, India's steel capacity is likely to be of 293 million tonnes by 2030. Due to shortage of coking coals in the country and in order to lower the cost of coke production and lessen dependability on high quality imported metallurgical coals, it is imperative that coke makers take a fresh look at incorporating LVC and non linked washery coals in their blends after suitable beneficiation.

The country has a moderate reserve of LVC coal, amounting to nearly 16,000 Mt in and around Jharia and Bokaro areas i.e. about 50% of the total coking coal reserve. Jharia coalfields are the store house of coking coals where prime coking coals are available [1]. The coking coals in the Jharia coalfields may be segregated into two major sectors i.e., eastern and western. The characteristics of the coals in the eastern sector are generally superior in quality than the western sector. The good quality upper seam coals from Jharia coalfields are depleting at a faster rate leaving behind the inferior quality in lower seams. Annual productions from V/VI/VII seams of Jharia coalfields is presently about 10-15 Mt respectively. The low volatile high rank (LVHR) coals are of high rank (Rr % > 1.2%), high inertinite content, low reactive content (30-45%), low volatile matter content (18 to 22% or so), high ash (> 30%) and therefore, having lower coking propensities with difficult cleaning characteristics and as such categorized as non-linked washery coal (NLW).

Unfortunately, the washability potential of this coal is so poor that conventional two or three product washeries are not able to supply coals of ash 17-18% as desired by indigenous metallurgical industries and cannot stand in competition with foreign coals because of poor yield of cleans. As such, these coals are being treated as NLW (non-linked washery grade) and are supplied to the thermal power plants, against augmenting the demand of metallurgical coal for coke making [2].

It is a general recommendation that cost-effective utilization of this resource by optimum beneficiation will reduce the ever-increasing dependence on the imported washed coal in India as well as supplements the requirement of quality feed for power plants. Keeping this in view, a decade long study on the LVC coals of eastern sector has led to the concept of multi-product beneficiation of such 'difficult-to-wash' coal. The concept involves (a) multi-stage beneficiation of raw coal to four saleable products, and (b)

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multi-stream beneficiation of worse coals selectively to three products, specifically suitable for industries like, steel, foundry, PF and FBC power plants [3,4]. The paper highlights the studies carried out on typical LVC/NLW coal through laboratory and pilot plant studies.

Experimental

The run-off-mine LVC/NLW coal sample was collected from the western sector of Jharia coalfields for carrying out the detailed washability, and pilot plant beneficiation studies.

The raw coal was screened at 75 mm and the + 75 mm was crushed in a single roll crusher to below 75 mm, the overall combined fraction of the product below 75 mm was taken for further studies viz., characterization, screen analyses and float and sink tests. The characterization was done with respect to proximate analysis, carbonization properties and the data is shown in Table 1 and the petrographic analysis data is shown in Table 2.

TABLE 1: PROXIMATE AND CARBONIZATION DATA OF RAW COAL

Proximate				Carbonization	
Moist %	Ash %	V. M %	F.C %	CSN	LTGK
1.0	46.1	14.7	38.2	1	C

TABLE 2: PETROGRAPHIC ANALYSIS

Petrographic analysis (macreal comp. % v/v)					Mean
Vitrinite	Semi-vit	Exinite	Intertintie	Min. matter	Ro %
20.8	2.8	0.6	53.1	22.7	1.2

TABLE 3: SCREEN ANALYSIS OF THE RAW COAL CRUSHED AT 75MM

Size, mm	Wt.%	Ash%
75-50	23.6	49.3
50-25	34.6	46.3
25-13	18.4	45.3
13-6	8.0	50.0
6-3	5.5	45.6
3-0.5	5.2	43.8
-0.5	4.7	46.8
	100.0	47.0

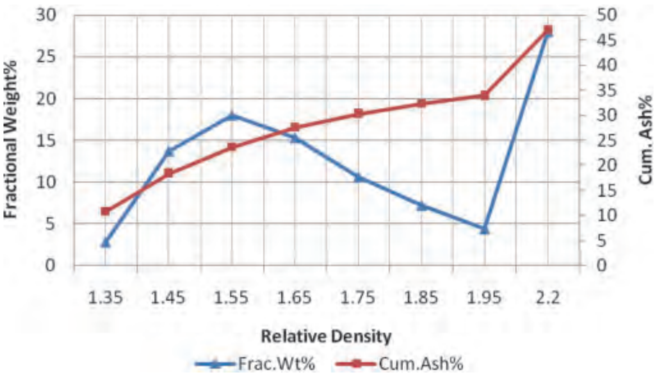

Fig.1 Plot for relative density vs fractional wt% and cum. ash %

The screen analysis of the raw coal rushed at 75 mm is shown in Table 3 and the individual size fractions of the coals crushed to 75mm was subjected to float-and-sink tests, and the relative density range was 1.40 to 2.00 and the combined washability data as shown in Table 4, The plot relative density vs fractional weight % and cumulative ash % is shown in Fig.1.

The minus 0.5 mm coal fraction was subjected to laboratory flotation tests. Laboratory batch flotation studies were carried out in Denver D12 sub aeration flotation machine, with a cell capacity of 2.5 L. The studies were carried out keeping the normal collector and frother dosage (1.25 kg/t and 0.25 kg/t). The rpm was kept constant at 1500 for each test. About 250gm of sample was taken and conditioned with required amount of collector at 40% solids concentration for 2 minutes. Then the slurry was adjusted to 10% solids concentration by adding fresh water and then frother was added and further conditioned for one more minute. The aeration was started by opening the air valve and the froth floated as concentrate was collected, dewatered, dried and weighed. The air dried concentrate/clean were sub-sampled and ash content of each sample was determined. The flotation cleans yield % was about 57.9% and the ash content is 17.7%, while the tailings ash content is 73%.

The characterization tests of raw coal revealed that ash percentage of coal is 46.1% and moisture percentage (on as

TABLE 4: COMPOSITE WASHABILITY DATA SIZE (75-0.5 MM)

Sp.gr	Wt %	Ash %	Cum. float		Cum. sink		Ch. wt %	Mayer's pt.value
			Wt.%	Ash%	Wt.%	Ash%		
<1.40	2.8	10.8	2.8	10.8	97.2	48.0	1.4	0.3
1.40-1.50	13.7	20.0	16.5	18.4	83.5	52.6	9.7	3.0
1.50-1.60	18.0	28.4	34.6	23.6	65.4	59.3	25.5	8.2
1.60-1.70	15.3	36.5	49.8	27.6	50.2	66.2	42.2	13.7
1.70-1.80	10.6	42.9	60.4	30.3	39.6	72.5	55.1	18.3
1.80-1.90	7.2	49.7	67.7	32.3	32.3	77.5	64.0	21.9
1.90-2.00	4.4	57.3	72.0	33.9	28.0	80.7	69.8	24.4
>2.00	28.0	80.7	100.0	47.0			86.0	47.0
	100.0							

received) of the coal is 1.0%. The sample tested is low volatile in nature, the VM% being 14.7. The results of the carbonization tests on the head sample shows that the coal tested is not having coking properties with CSN being 1 and LTGK coke type being C. The petrographic analysis of the head sample revealed that the vitrinite% is 20.8, ineretinite% is 53.1 and the mean Ro% is 1.2.

The washability studies showed that the amount of material above 2.0 is 28% and ash content is also above 80%. Based on the interpretation of the washability data, the theoretical yield% at ash content of 18%, was estimated to be 15.7%, while the rejects ash% is 52.4% and the specific gravity of cut is 1.5. Further, it is clear from Fig.1, that if the coal is deshaled at 2.00 specific gravity, the cumulative ash% of the deshaled cleans is about 34% and this desaled clean may further be processed. The coal fines responded to conventional flotation tests.

From the laboratory studies, it may be concluded that to achieve clean coal of 18% ash content, when the raw coal is crushed at 75 mm and deshaled, the deshaled cleans may be of better quality and on further processing may yield the targeted ash content suiting for metallurgical purposes. Hence, the pilot scale studies were oriented in such a way that the raw coal was crushed to 75 mm and deshaled in a jig washer and the deshaled clean coal was further studied for developing a conceptual flow sheet.

PILOT STUDIES

The coal washing pilot plant at Central Institute of Mining & Fuel Research is a unique installation and works with lot of flexibilities so that the coals may be studied with as many as eight different alternative circuits. The main units of the coarse coal pilot plant are coal handling plant, Baum jig and heavy medium drum separator, while the fine coal treatment pilot plant constitutes units like heavy medium cyclone, froth flotation etc.

The raw coal from the underground bunkers is drawn through a travelling chain feeder moving on the armoured conveyor and then carried by means of a series of belt conveyors to a grizzly after passing over the tramp iron separator. The oversize coal (above 75 mm) from grizzly is crushed below 75 mm in an adjustable single roll crusher. The crushed product is stored in a bunker for onward transmission to washing section.

The crushed coal is drawn from the storage bunker to the conveyor through an adjustable gate and chain feeder. The coal fed to the Baum jig is delivered through a roll feeder from a bucket elevator. It has six chambers in two compartments (Fig.2). Each cell is provided with slide air valve, which admits and exhausts air to and from the system according to the cycle of operation desired.

The cycle of operation may be varied from 25 to 65 pulsations per minute. Requisite amount of air and water are provided for jigging action. A fish float is provided in each compartment to maintain proper bed height. While washing the NLW coals the jig was operated for two product separation wherein the first cut was maintained at 2.0 specific gravity. The air and water rate were controlled for suitable pulsation so that in the 1st compartment, the sp.gr of cut is maintained at 2.0. The jig rejects from the 1st compartment was taken out. The rejects are discharged from the Jig box through the bucket elevators and a representative sample was collected for estimating ash content in the rejects. The clean coals are carried by the circulating water to a settling tank and are taken out by the bucket elevator and a representative sample was collected for estimating ash content in the cleans. It is then stored in a bunker for further studies. The overflowing water along with the jig effluent from the settling cone is sent to the settling ponds, where it is clarified and water being re-circulated.

Fig.2 Baum jig 20 tph capacity

Fig.3 Heavy medium cyclone

Fig.4 Pilot scale flotation plant

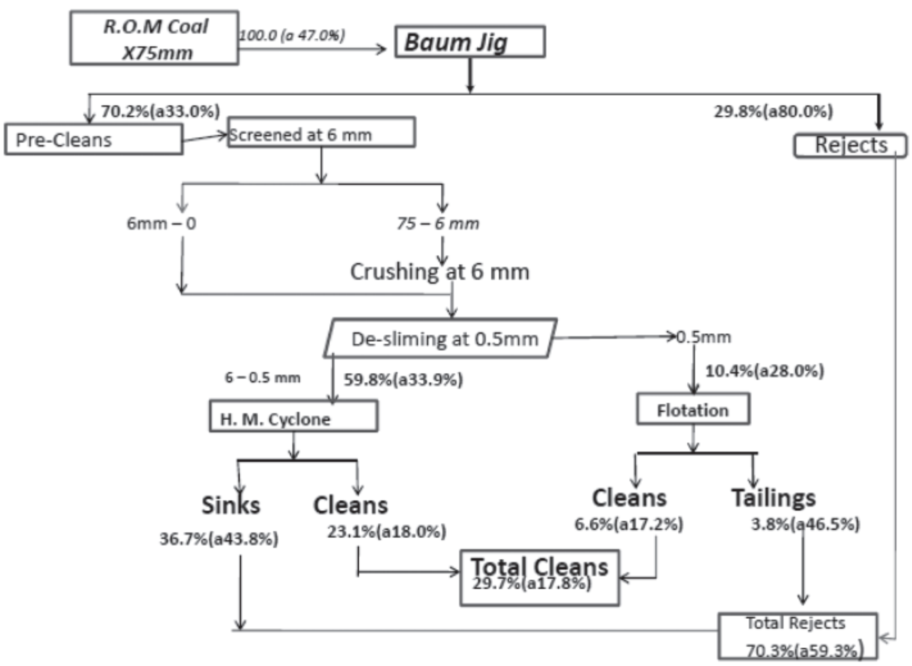

Fig.5 Typical flow sheet for washing LVC/NLW coal

The jig was operated under stable conditions and it was observed that the yield of pre cleans was 70.2% and the ash being 33.0%. This pre cleans was crushed at 6 mm and deslimed at 0.5 mm. The fraction 6 - 0.5 mm constituted 59.8% at the ash content 33.9%, while the fraction below 0.5 mm constituted 10.4% and the ash content was noted to be 28.0%.

Basic studies carried out on the combined 6-0.5 mm fraction of the coal indicated that the coal need to be cut at about 1.45 sp. gr. in heavy medium cyclone to achieve the cleans of about 18% ash content. The fraction 6-0.5 mm was fed to the heavy medium cyclone pilot plant unit and was operated at pre-determined conditions. The yield of cleans was noted to be 23.1% at the ash level 18% and the corresponding sinks were observed as 36.7% at ash of 43.8%.

The fraction below 0.5 mm was subjected to pilot scale flotation unit (Fig.4) and the plant was operated under controlled conditions. The unit was operated by adding collector dosages at the rate of 1.25 kg/t and frother at the rate of 0.25 kg/t. The flotation cleans and tailings were dewatered and the products were characterized. The flotation cleans constituted 6.6% at the ash content 17.2% while the tailings constituted 3.8% at the ash content 46.5%.

On combining the HM cyclone cleans and flotation cleans, the total clean coal yield was obtained as 29.7% at the ash content 17.8%. The flow scheme is depicted in Fig.5.

Characterization of the clean coal

Characterization tests of total clean coal revealed that ash percentage is 17.5% while the moisture percentage is 1.0%. The volatile matter improved to 19.3% compared to 14.7% in the feed coal. The coking propensities of the clean coal improved to that of the feed coal CSN being 4.5 and LTGK coke type being G. The petrographic analysis shows the vitrinite content improved to 46.5 compared to 20.8% in the raw coal. The reflectance is high having the value of 1.22% which shows the high maturity of coal. The clean coal may be used as a blend with imported coal for coke making.

Conclusions

- The inferior quality low volatile coking coals from lower seams of Jharia coalfields may be upgraded to the desired quality if the coals are judiciously beneficiated.
- In order to deal efficiently with the changed feed characteristics, the existing washeries are required to be suitably modified/modernized to optimize plant performance in terms of capacity utilization and yield of clean coal of better quality.

- Future coking coal washeries should focus attention on source, capacity, new technology and meeting the quality demands of different metallurgical industries.
- The analyses on the raw coal and the clean coal samples in terms of proximate analysis coking properties and petrography have proved that the qualities of the cleans have improved remarkably and these may be gainfully utilized for coke making and metallurgical purposes.

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