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High Ash Non-Coking Coal from India: Beneficiation and Implications

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Abstract

In the entire spectrum of industrialization from global perspective, coal as the primary source of energy is the fulcrum of major developmental factors on which hinges the growth of economy at macro level. This supposedly happens to be vital for improvement in quality of living conditions, thereby, impacting the lives of millions across the world. The International Energy Agency (IEA) as well as national/regional energy agencies have projected coal to be the key component of energy mix, well into the future. The primacy of coal as source of energy is factually expected to surpass the significance of oil as a typical and primary source of energy in next 4-5 years or even earlier. Indian coal has been observed to be of low quality on account of its high ash content attribute and the high ash non coking category coal constitutes sizeable quantity of near-gravity materials (NGM), which entails beneficiation to suit end-user or application specific qualitative level. The present manuscript demonstrates the beneficiation of high ash non-coking coal from Vasundhara mines, Odhisa, with 57% ash content intended for scaling down the ash content to 25% in obtaining clean coal at a reasonable yield, deploying physical beneficiation techniques. The coal was characterised thoroughly in terms of petrographic characteristics, size analysis, washability, chemical composition and the gross calorific value of the coal was observed to be 3221 Kcal/kg. The beneficiation process was initiated at a top size of 6.3 mm after initial deshaling of the ROM coal. Tactical combination of gravity separation and flotation techniques yielded clean coal with 25% ash at 40% yield and an intermediate clean product with 49% ash at 12% yield. Low ash content in the final clean coal is possibly achievable from the combined clean coal with 25% ash content adopting chemical beneficiation route.

Keywords: Non-coking coal; beneficiation; washability; gravity separation; flotation

1. Introduction

Coal is the vital energy fuel world-over, statistically contributing to 55% of installed energy generation capacity during the calendar year 2011 and it plays a pivotal role in the macro-economic development of the country (Indian Minerals Year Book, 2011). Indian coal has been observed to be of low quality on account of its high ash content attribute and the high ash non coking category coal constitutes sizeable quantity of near-gravity materials (NGM), which entails beneficiation to suit end-user or application specific qualitative

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level. The beneficiated coal has immense potential for being used as a blendable mix for metallurgical applications (Reddy and Biswal, 2006; Haldar, 2010; Sahu et al. 2011; Gouri Charan et al. 2011) and such blend formulation of clean coal facilities maximising the infusion of non-coking coal with scarce coking coal for catering to metallurgical industries, enabling lesser dependence on import of high-rank low ash content coke.

The present study demonstrates the physical beneficiation of high ash non-coking coal from Vasundhara mines of Odhisa with 57% ash content intended for scaling down the ash content to 25% for sponge iron in obtaining clean coal at a reasonable yield and the middlings for power generation.

2. Experimental

2.1. Raw material

High-ash non-coking coal sample from Vasundhra mines, Odhisa was taken up for the present investigation.

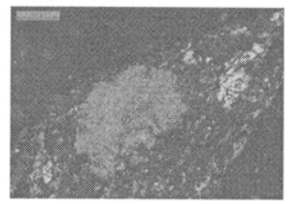
2.2. Petrographic Studies

Coal petrography was done though Advanced Polarizing Microscope DM 4500 (Leica, Germany) following IS-9127. Petrographic investigation on polished grains (–16 #) of Vasundhara coals unravelled vitrinite maceral is 14.7% (31.1% Vmmf) while oxidised vitrinite content is 1.2% (2.5% vmmf), thus, reveals deficiency of overall vitrinite maceral. Oxidised vitrinite shows oxidation cracks. Inertinites are dominant and are represented by semifusinites with small cellular structures and brighter colour, fusinites with prominent cell cavities and bright colour, inertodetrinites in bright fragmental form, contributing 25.2% (53.3% vmmf), while liptinite macerals occur with thread like appearance in dark colour 6.2 % (13.1% vmmf).

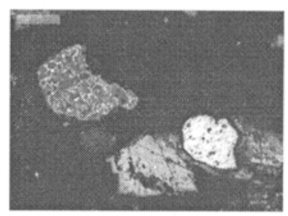
The mineral matters (mainly the argillites and carbonate minerals) occur in dark colour either as cavity filling or in disseminated form and contribute 52.7% (Table 1). The gross calorific value of the coal was found to be 3221 kcal/kg.

Table 1: Maceral constituents present in Vasundhara coal sample

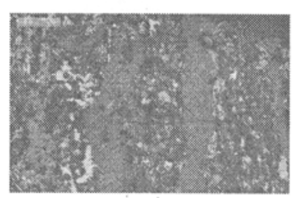
Petrographic constituents	Vol. %	Vol. % (Vmmf basis)
Normal Vitrinite	14.7	31.1
Vitrinite Oxidised	1.2	2.5
Inertinite	25.2	53.3
Liptinite	6.2	13.1
Mineral matter	52.7	-



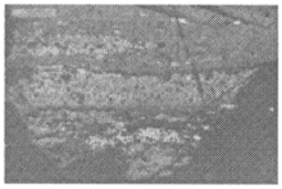
(a) Photomicrograph showing mineral matter (black and brown) under reflected light.



(b) Photomicrograph showing inertinite maceral (white) and vitrinite (grey) and mineral matter (brown) under reflected light.



(c) Photomicrograph showing vitrinite grain (grey) inertodetrinites (white) and mineral matter (dark) under reflected light.



(d) Photomicrograph showing vitrinite grain (grey) inertinite (white) and mineral matter (dark) under reflected light.

Fig. 1: Photomicrographs of macerals and mineral matter studied under DM4500 polarizing coal petrological microscope (studied under oil immersion using 20 X objective).

Chemical constituents through proximate analysis of raw coal are shown in Table 2.

Table 2: Proximate analysis of the coal sample

Moisture Content %	Volatile Matter%	Ash Content%	Fixed Carbon%
3.8	22.4	57.4	20.2

2.3. Size Analysis

The size analysis of non-coking coal, as received from Vasundhara mines, Odhisa was carried out by dry sieving techniques to identify the percentage of ash, volatile matter and moisture content at various size fractions. The raw coal was initially screened at 50 mm; the plus 50 mm fraction was crushed in a single roll crusher. The overall combined fraction of the product below 50 mm was subjected to screen analysis. The size distribution of coal crushed to 50 mm is shown in Table 3. It is seen that about 73% of the crushed material was above 10 mm. The – 0.5 mm fraction was about 6%, and its ash percentage varied from 49%.

Table 3: Size and chemical analysis of raw coal crushed to 50 mm

Size (mm)	Wt %	Ash %
– 50 + 25	44.13	57.51
– 25 + 20	15.30	58.04
– 20 + 15	1.18	57.62
– 15 + 10	13.04	56.49
– 10 + 8	1.24	60.38
– 8 + 6.3	3.87	60.18
– 6.3 + 3	5.71	59.84
– 3 + 2.81	0.21	60.66
– 2.81 + 1.68	5.07	59.29
– 1.68 + 1.20	1.30	58.02
– 1.20 + 0.85	1.06	56.84
– 0.85 + 0.50	1.43	53.74
– 0.50 + 0.42	0.61	56.26
– 0.42 + 0.30	0.95	53.74
– 0.30 + 0.21	0.46	52.44
– 0.21 + 0.15	0.38	54.79
– 0.15 + 0.10	0.35	55.65
– 0.10 + 0.075	0.30	58.43
– 0.075 + 0.063	0.10	48.94
– 0.063 + 0.045	0.29	58.02
– 0.045	3.01	62.01
Total	100.00	57.82

2.4. Washability Studies

In order to study the feasibility of deploying gravity based techniques for coal cleaning, washability studies were carried out on the Vasundhara coal sample. Considering the high ash content of this coal, the washability characteristics were determined at a top size of 6.3 mm first. The size fractions - 6.3 + 3 mm, - 3 + 1 mm, - 1 + 0.5 mm and - 0.5 mm were subjected to float and sink tests, and the relative density range was observed to be 1.40 to 2.00. The generated data was used for plotting washability curve to establish the washability characteristics. The theoretical maximum yield at 25% ash level was observed to be around 20%. Not much improvement was observed in washability characteristics when crushed to a top size of 3 mm, however, quite a bit of improvement is observed when the same crushed to 1.18 mm top size. The washability characteristics are shown in Fig. 2.

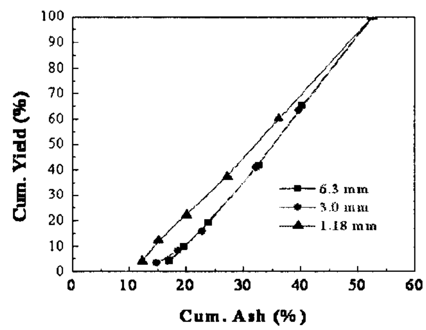


Fig. 2: Washability characteristics of vasundhara coal

3. Results and discussion

3.1. Physical beneficiation

This coal (ROM) had very high ash content (~57%). Initially, it was targeted to obtain a clean coal with around 25% ash at a reasonable yield through physical beneficiation and then adopt chemical route to achieve low ash target. The washability data indicated that over 30% yield is achievable in the clean coal through gravity concentration at a target ash level of 25% when the coal is crushed to - 1.18 mm size. The maximum yield drops below 20% when crushed to a top size of 6.3 mm. However, considering the high ash of the feed, it was decided to deshale the feed ROM coal and then initiate the processing at a top size of 6.3 mm. The following Table 4 gives the deshaling data reveals that around 20% of the material is rejected at an ash level of 77%. The deshaled feed still contains nearly 53% ash and this material is considered the raw feed for subsequent processing.

Table 4: Deshaling data of raw coal

Products	Wt%	Ash%
ROM Coal	100	57.5
Rejects	20.2	77.2
Deshaled Feed	79.8	52.7

Processing was initiated at 6.3 mm top size for this coal. The coal was crushed and the size analysis of the crushed feed is shown in the following table. Table 5 illustrates the ash distribution in the size classes as indicated for the process feed.

Table 5: Ash distribution of process feed in different size classes

Size (mm)	Wt%	Ash%
- 6.3 + 3	34.7	53.8
-3 + 1.18	34.6	52.6
- 1.18 + 0.5	14.3	51.4
- 0.5	16.4	50.2
Total	100.0	52.5

The deshaled feed material was crushed to a top size of 6.3 mm and was fractionated into - 6.3 + 1.18, - 1.18 + 0.5 and - 0.5 mm size classes. The coarse fraction was treated in jigging operation to recover a relatively cleaner product with 42% ash. The jig concentrate was crushed to - 1.18 mm size and the - 1.18 + 0.5 mm fraction was treated in a spiral-floatex circuit, while the - 0.5 mm fraction was subjected to flotation. The spiral-floatex circuit produced a clean coal with 24.6% ash at a mass yield of 10.4%. The tailings streams were mixed with the original intermediate size fraction. The jig tails had 69% ash and this product was crushed to - 0.5 mm size for flotation.

The combined - 1.18 + 0.5 mm fraction was treated in a separate spiral-floatex circuit which generated clean coal with 26.5% ash at 10% yield. One of the tailings from this circuit had 79% ash which was considered a reject. The other tailing stream had 60% ash and was crushed to - 0.5 mm size for flotation.

The combined - 0.5 mm material was treated in flotation through a rougher-cleaner-recleaner circuit. The rougher tailing was a reject with 80% ash and 24% yield, while the cleaner tailing with 68% ash content was also considered a reject. The re-cleaner tailing with 49% ash can be recycled as cleaner feed. The concentrate of the re-cleaner contains 25% ash with a mass yield of ~20%. All the clean coal streams with around 25% ash are combined to give a mass yield of 40%. The process flowsheet is shown in Fig. 3 and the product streams of physical beneficiation are summarized as follows:

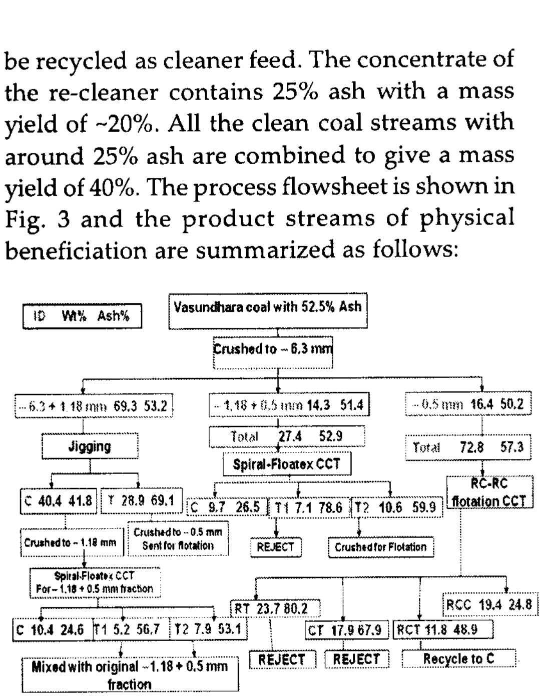


Fig. 3: Physical processing flowsheet of Vasundhara coal

1. Clean coal with 25% ash at 40% yield
2. Intermediate clean product with 49% ash at 12% yield
3. Intermediate reject product with 68% ash at 18% yield
4. Reject stream with 80% ash at 30% yield

In view of the fact that nearly 73% of the raw material is ending up being treated in flotation circuit, exploring the possibility of treating the entire deshaled coal by flotation alone was felt desirable. The raw material was crushed to - 0.5 mm and was treated in a rougher-cleaner-recleaner circuit. The following Table 6 gives the flotation data.

Table 6: Flotation results of raw coal crushed to - 0.5 mm

Rougher	Wt%	Ash%	Cleaner	Wt%	Ash%	Re-cleaner	Wt%	Ash%
Conc.	69.2	40.7	Conc.	48.4	29.7	Conc.	33.8	25.3
Tails	30.8	79.6	Tails	20.8	66.3	Tails	14.6	39.9
Feed	100.0	52.7	Feed	69.2	40.7	Feed	48.4	29.7

Clean coal with 25% ash is generated at a mass yield of 34%. The reject stream (rougher tailing) has 80% ash content and 31% yield. The re-cleaner tailing (40% ash and ~15% yield) is intended for recycling as cleaner feed. The cleaner tailing (66% ash at 21% yield) may also be considered as a reject stream. This coal has poorer floatability, thus, unsustainable for being treated by flotation alone.

4. Conclusions

Indian coals in general are of drift origin. Most of the non-coking coals have high ash content which is not suitable for direct utilization. The high ash non-coking coal from Vasundhara mines of Odhisa was characterised thoroughly in terms of petrography, size analysis, washability and chemical composition and the gross calorific value of the coal was observed to be 3221 Kcal/kg. The coal was initially deshaled and subsequently processed at a top size of 6.3 mm. Tactical combination of gravity separation and flotation techniques yielded clean coal with 25% ash at 40% yield and an intermediate clean product with 49% ash at 12% yield. A suitable flow scheme for beneficiation of high ash non-coking coal was suggested. Low ash content in the final clean coal is possibly achievable from product mix of clean coal with 25% ash content, adopting chemical beneficiation route.

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