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Advanced Coal Cleaning Technology for Challenges in Near Future

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Abstract

Beneficiation potential of a high ash (36%) medium coking coal to a low ash (12%) level is investigated. Characterization studies indicated that the coal must be processed after reducing the size to 1.18 mm in order to accomplish substantial yield of the clean coal. A gravity based flowsheet for the -1.18+0.5 mm fraction is developed to generate clean coal at 12% ash with 9.2% overall yield. Mechanical cell flotation circuit for the -0.5+0.15 mm size fraction resulted in additional 3.5% yield at the desired ash level. A flotation circuit for the fine fraction (-0.15 mm) is developed using Jameson Cell only that added further 3.0% yield in the overall mass recovery at 12% ash. Thus, a total of 15.7% yield of the clean coal with 12% ash is achieved by treating various size classes separately. Recycling of some of the intermediate product streams is recommended for continuous operation to enhance the overall yield of the clean coal significantly.

Keywords: *Coal washability; Spiral concentrator; Floatex density separator; Mechanical cell flotation; Jameson cell;*

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1. Introduction

The reserve of good quality metallurgical coal is far less than the demand. Expansion of the steel sector poses increasing demand of good quality coking coal. There is a strong need to conserve the resources by judiciously using the low grade raw material through improved enrichment technologies. The import of low ash (8-12%) coking coal, in the year 2007-08 was 21.50Mt at a cost of around US$2500 million [1]. The price of coking coal was US$ 200 per tone from US$ 129/ton in 2010. Due to the increased steel production in India, more coal is needed and the consumption is estimated to be around 1600 kg per ton of hot metal [2]. The dependence on low ash imported coal can be minimized by choosing a proper coke making technology as well as by beneficiation of medium coking coals. Therefore, the beneficiation of indigenous coal is very important as the coal ash is a vital parameter which directly affects coke making.

In an effort to lower the ash content in coal blend, the use of a minimum of 20-30% imported coal of high rank has become the norm in all Indian steel plants. This certainly reduces the ash content, but it can affect the coke cost adversely. Therefore, it is imperative to process the coal to produce clean coal with low ash content. Traditionally, Indian coking coals are processed to a level of 17% ash and the corresponding coke is comprised of 22-25% ash. Some organizations initiated actions for bringing down the ash level to 15%. The high ash in coke also results in large slag volume. Increased slag volume is also due to higher flux rate for desulphurization in Blast furnace hearth. Both these lead to higher fuel rate, lower productivity and corresponding adverse impact on cost competitiveness of Indian iron/steel making [3]. Our present technology can not treat the coal to bring the ash down to such low levels. In addition, the medium coking (MC) coal reserves is about five times the prime coking coal reserves of 5.3 Bt. This huge quantity of MC coal can be used as sweetener or direct injection in blast furnace. Therefore, the development of technology for the processing of MC coal to a low ash level is a challenging and necessary area.

2. Experimental

A high ash medium coking coal sample from the eastern part of India was taken up for studies.

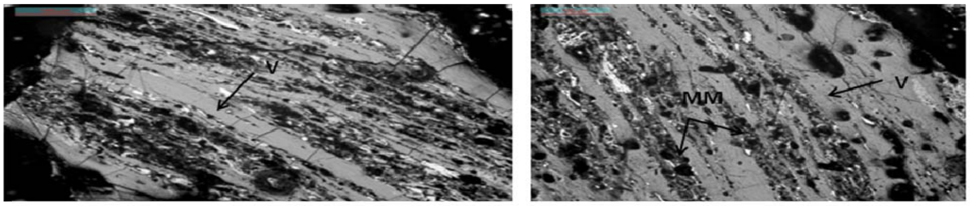
2.1 Raw Material and its Characterization

The ash content of the coal is around 35% while the volatile matter content is relatively low (Table 1). Petrographic studies were carried out on polished grains (Figure 1). It is observed that the vitrinite macerals contribute 41.0 % and occur with plain surface and grey colour. Inertinites are dominated by semifusinites with small cellular structures and brighter color, fusinites with prominent cell cavities and bright color, inertodetrinites in bright fragmental form and contribute 28.5%. Liptinite macerals occur with thread like appearance in dark colour (mainly sporinites) which contribute 5.8 %. The mineral matters, mainly the argillites and some carbonate minerals, occur in dark color either as cavity filling or in disseminated form and contribute about 24.7%.

Table 1: Proximate analysis of the as-received coal

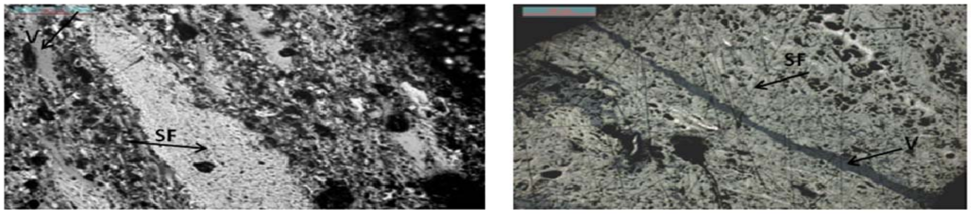
Constituent	Wt%
Moisture	1.94
Ash	34.85
Volatile matter	22.34
Fixed carbon	42.81

Beneficiation of the coal was initiated by crushing the coal from coarse to fine sizes, viz. -6mm, -3mm and -1.18mm. Washability studies, which indicate the benchmark of clean coal yield recoverable at different ash levels, were carried out to establish the amenability of the coal to be processed by suitable gravity methods. The top size of the coal required for carrying out the beneficiation studies is also assessed. The results of washability studies are given in Figure 2. It is found that when the coal is crushed to a top size of 6 mm, clean coal at 12% ash can be achieved with only 3% yield under ideal conditions. The coal, when crushed to 3 mm top size, can produce clean coal with 12% ash at around 14% yield under ideal conditions. However, when the top size is lowered to 1.18 mm, this coal can produce about 24% clean coal at the 12% target ash level which is the theoretical maximum achievable.



Vitrinite, liptinite (thread like black structures and mineral matter under reflected light. Some bright inertodetrinite grains are also seen.

Vitrinite maceral and mineral matters under reflected light



Vitrinite, semifusinite and mineral matters under reflected light.

Semifusinite, vitrinite and mineral matter under reflected light

Figure 1. Micrograph of macerals and mineral matters studied under DM4500 Polarizing Coal Petrographical microscope

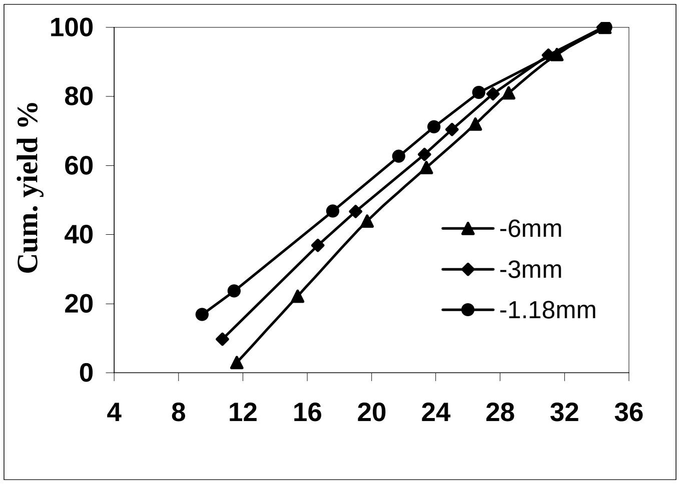


Figure 2. Comparative study of washability characteristics of -6mm, -3mm and -1.18mm coal

From the above characterization studies it was established that the mineral matter content of the coal is quite high and it is intricately associated with the combustible material requiring fine crushing for liberation. Adequate liberation is achieved at a top size of 1.18 mm only and a significant increase in the theoretical maximum possible yield at 12% target ash in the clean coal is observed. In view of the above observations it was decided to crush the entire coal to -1.18 mm before processing. The crushed coal was subjected to size and ash analysis. The size distribution along with the distribution of ash is shown in Figure 3. It is interesting to note that the ash is distributed almost evenly in all size fractions.

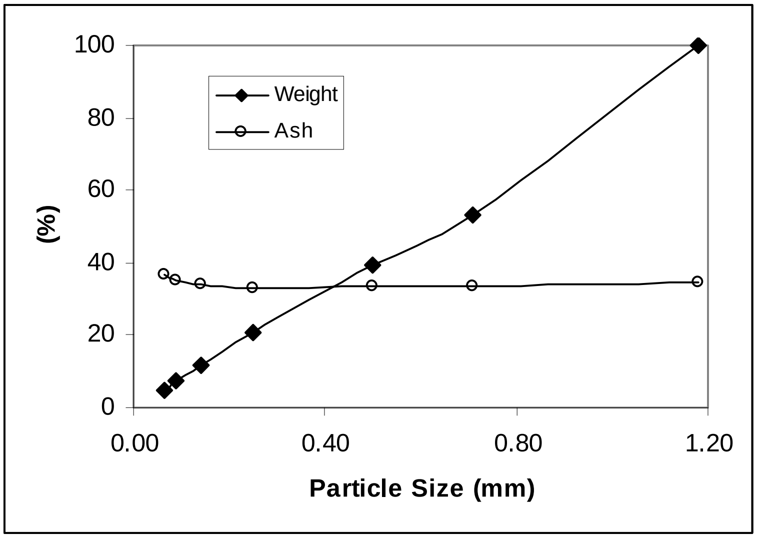


Figure 3. Particle size and ash distribution of -1.18mm coal

2.2 Methods

Since the objective of the study is to produce a clean coal with a low ash (12%), it is envisaged that the feed must be processed in a narrow range for getting an effective separation from a particular unit operation [4]. The -1.18mm coal was classified into three different size fractions, viz., -1.18+0.5 mm, -0.5+0.15 mm and -0.15 mm. The proximate analyses of the three fractions were carried out and the data are shown in Table 2. The coarsest fraction (-1.18+0.5mm) was subjected to gravity separation while the intermediate size fraction (-0.5+0.15mm) was treated using froth flotation in mechanical cell. The finest fraction (-0.15 mm) was treated using Jameson cell flotation.

Table 2: Size and ash distribution of -1.18mm coal sample

Size, mm	**Wt, %**	**Ash%**
-1.18+0.5	61.8	35.2
-0.5+0.15	23.6	33.5
-0.15	14.6	33.1

3. Results and Discussion

The results of the processing of the three narrowly sized fractions are discussed in the following sections.

3.1 Processing of -1.18+0.5mm size fraction

A spiral-FDS circuit was employed to recover the clean coal efficiently. The spiral is used as a roughing unit while the FDS is used as a cleaning unit with a two stage operation [5]. However, the desired ash level is still not achieved in the FDS concentrate and a re-cleaning operation on the FDS concentrate was carried out using Multi-gravity separator (MGS). The MGS concentrate did produce the desired ash level.

There is significant reduction of ash in the clean coal from 35.2% to 23% with the narrowly sized feed (-1.18+0.5mm) using spiral concentrator. This concentrate was then subjected to 2-stage processing in floatex density separator to generate the product with 16.4% ash. This was further processed in multi gravity separator (MGS) to achieve the target ash. The complete process showing the unit opeations with -1.18+0.5 mm fraction is given in Table 3. It is seen from this table that clean coal with 12.1% ash is obtained using this process flowsheet at 9.2% overall yield. The first tails of the FDS can be mixed with spiral feed while the second FDS tails and the MGS tails are products for other applications.

3.2 Processing of -0.5+0.15mm

The amount of -0.5+0.15mm fraction in the feed is 23.6% with an ash content of 33.5%. This fraction was subjected to flotation in mechanical cell. The flotation tests were carried out using a synthetic collector and MIBC as frother under different conditions with and without sodium silicate as dispersant. The flotation test results indicated that it is not possible to achieve 12% ash in the clean coal in a single stage. Therefore, two stage flotation tests were carried out under different conditions.

Table 3. The complete process details for -1.18+0.5mm fraction coal with overall yield and ash values

Feed			Process	Concentrate		Tails – 1		Tails - 2	
Stream ID	Yield (%)	Ash (%)		Yield (%)	Ash (%)	Yield (%)	Ash (%)	Yield (%)	Ash (%)
Fresh Feed	61.8	35.2	Spiral Concentration	37.1	23.0	24.7	53.5	-	-
Spiral Concentrate	37.1	23.0	Two-stage Floatex	18.9	16.4	7.4	35.4	10.8	26.0
Floatex Concentrate	18.9	16.4	Multi-gravity separation	9.2	12.1	9.7	20.4	-	-

The final process flow for washing this fraction is shown in Table 4. It can be seen that significantly low yield is obtained for such a low target ash of 12%. The tailings of the cleaner flotation contained around 29% ash which was further treated in scavenger flotation. In this stage, substantial amount of coal is recovered with an ash content of 23.8% which can be mixed with the rougher concentrate. The rougher and scavenger tails can be further ground and used at appropriate point in the fine (-0.15 mm) circuit.

Table 4. The complete process details for -0.5+0.15mm fraction coal with overall yield and ash values

Feed			Process	Concentrate		Tailings	
Stream ID	Yield (%)	Ash (%)		Yield (%)	Ash (%)	Yield (%)	Ash (%)
Fresh Feed	23.6	33.5	Rougher Flotation	11.6	23.7	12.0	43.0
Rougher Concentrate	11.6	23.7	Cleaner Flotation	3.5	12.2	8.1	28.7
Cleaner Tailings	8.1	28.7	Scavenger Flotation	5.7	23.8	2.4	40.4

3.3 Processing of -0.15mm coal

The -0.15mm fraction generated is 14.6% by weight with an ash content of 33.1%. This fraction was subjected to Jameson cell flotation. It was again not possible to produce clean coal with 12% ash in a single stage operation with any significant yield. Two stage flotation tests were performed under different conditions. Tests indicated that when no reagent is added in the first stage the best overall flotation results

piral
Concentrator

are obtained in the second stage with addition of reagents. Under these conditions about 3% overall yield is obtained at 12% target ash level by flotation of this size fraction in Jameson cell.

4. Conclusion

In the present study, a scheme for the beneficiation of a high ash medium coking coal is developed to reduce the ash content of raw coal from 35% to 12% in the clean coal. Washability and petrography studies indicate that a reasonable yield of the clean coal with the target ash can be achieved only at a top size of 1.18 mm. Size fractionation and differential processing of the fractionated materials are shown to produce the desired clean coal with a reasonable yield. Gravity based concentration for the -1.18+0.5 mm fraction is shown to be applicable with overall 9.2% yield of the clean coal with 12% ash. A spiral concentrator and floatex density separator circuit with a cleaning stage using multi-gravity separator can give the desired results. While mechanical flotation is applicable for the -0.5+0.15 mm size fraction, the -0.15 mm fraction did not respond well in mechanical cell flotation. The fine fraction (-0.15) needs to be treated using Jameson Cell flotation. 3.5% and 3.0% overall mass recovery can be achieved using multiple stages of flotation for the intermediate and the fine fractions. In the present study, the overall yield achieved for a target ash of 12% in the clean coal is 15.7%. However, recycling of various intermediate product streams is recommended which will enhance the recovery of combustibles substantially during continuous operation.

5. Acknowledgements

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