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Studies on the cleaning potentialities of high ash Indian non-coking coals for meeting the MOEF's stipulations

The non-coking coal constitutes about 85% of the Indian coal reserves and the depositions remained mostly as low rank sub-bituminous and non-coking type. The vast reserves of the non-coking coal are usually high moisture, high ash, high volatile and sub-bituminous types (Ro% ranging between 0.4 and 0.65). The stipulation laid by the Ministry of Environment and Forest (MOEF), Government of India to transport coal of ash not exceeding 34% beyond 500 km is posing problems to different coal suppliers for the dispatch of its coal to the power plants. The only solution to this problem appears to be the setting up of washeries to reduce the ash content. With a 66% share of installed power generation capacity, the coal industry has a major role to play in the nation's development. The coal washing capacity from all the 52 washing plants is 131Mtpa, indicating that around 30% of the coal is being washed before it is used in power stations. The paper highlights the washability studies carried out on high ash coals, the beneficiation methods required for coal washing in India and various technologies being adopted thereof for washing of Indian coals.

Introduction

India is endowed with considerably huge reserves of non-coking coal, the major proportion of which is being used for power generation. According to recent estimates, the total coal reserve of India is more than 315.149 billion tonnes, of which 89% [1] is non-coking type. Due to its availability in India, as compared to other fossil fuels, coal is the obvious choice as the primary source of fuel. Indian coals are of Gondwana origin, which are inferior in quality. The characteristics of these coals differ significantly from other coals of Gondwana origin, particularly in their chemical and petrographic makeup, which have direct bearing on their utilization potential. Almost 70% of the Indian non-coking coal produced in India has high ash content (40-45 per cent on an average) and the users especially the power sector are unhappy with the quality of the coal being supplied by the coal producer. [2].

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Coal washing is one of the practices being promoted as a measure to encourage clean coal technologies. Coal washing is an important area both from economic and environment points of view. A number of studies carried out earlier have clearly highlighted benefits of using washed coal in improving the economics of power generation and also reduction of emissions. Coal beneficiation allows the lowering of production costs through improved thermal efficiency and also reduces the amount of material to be transported [3-5].

Government of India has promulgated a Gazette Notification (GSR 560(E) and 378(E), dated September 19, 1997 and June 30, 1998 respectively) on use of beneficiated/ blended coal containing ash not more than 34 per cent w.e.f. June 2001 and the distance was further reduced to less that 500 km w.e.f January 2016. It needs to be mentioned that restriction of ash level to 34% in washed coal is in no way linked to the optimum quality parameter of boiler feed, but is an outcome of the initiatives taken by MOEF to reduce the existing level of pollution, the load in transportation etc. The objective of washing should be the optimum rejection of these non-combustibles and not merely to achieve a prefixed ash limit [6-7]

However, with the advent of more and more opencast, mechanized mining (accounts for 85-90% of total production of power grade coal); the quality of the coals being supplied to the power stations is deteriorating. The average calorific value of coal produced from the coalfields have reduced significantly from an average of 5000 kcal/kg in 1970 to an average of 2500 -3000 kcal/kg in 2015. The problem is further aggravated because of the multiplicity of coal sources fed to the power plants [8-10]. Quality control of coal fed to the power plants being one of the most important ingredients for improvement in present energy situation; there is an absolute need for beneficiation [11] of Indian non-coking coals to the extent to meet the qualities required and the specifications is shown in Table 1.

Table 1: Coal specifications for power

	Characteristics	Requirement
1	Total moisture content, %	8 to 12 max
2	Volatile matter (air dry basis), %	19 min
3	Ash, % (annual average)	34 max
4	Sulfur, %	0.8 max
5	Chloride, %	0.01 max
6	Size, mm	200 max
7	GCV kcal/kg	5000 min

CSIR-CIMFR, had carried out extensive R&D studies on coal from different coalfields and the paper will highlight some of the findings related to the cleaning potentialities, flow sheet development and equipment sizing.

Washability studies of non-coking coals

The raw coal was collected from different coalfields viz., Mahanadi Coalfields Limited (MCL), Eastern Coalfields Limited (ECL), Central Coalfields Limited (CCL), Western Coalfields Limited (WCL), Northern Coalfields Limited (NCL) and Singareni Collieries Coalfields Limited (SCCL) for characterization and washability studies. The raw coal was crushed to 75 mm and screened at sizes 50, 25, 13, 6, 3 and 0.5mm. Size wise float and sink tests were carried out and the composite data 75-0.5 mm washability data from all the sources is shown in Table 2.

It may seen from Table 2, that above 2.00 specific gravity the weight% varied from 24.9% to 31.0% at high ash content, indicating that the material over 2.0 specific gravity is free shales/stones. Table 3 shows the data on yield of cleans, sp.gr. of cut, NGM at 34% ash content. It is clear from the Table 3 that the NGM is less than 20 for the coals of ECL, CCL, WCL and MCL, while it is marginally above 20 for the coals of SCCL and NCL.

Fig.1 shows the typical density vs fractional yield% curve. It may be seen from Fig.1 that for all the coal sources tested, there is steep rise in the fractional yield% at 2.0 specific gravity and the general behaviour of the coarser fraction is that the specific gravity of separation to achieve

Table 3: Yield of cleans, sp.gr. of cut, NGM at 34% ash content

Source	Sp.gr. of cut	Cleans		Rejects		NGM
		Wt%	Ash%	Wt%	Ash%	
ECL	1.88	53.5	34.0	46.5	73.2	18.1
CCL	1.82	42.0	34.0	58.0	68.9	19.9
WCL	1.89	53.5	34.0	46.5	73.2	19.1
SCCL	2.04	76.3	34.0	23.7	82.2	20.7
MCL	1.84	61.3	34.0	33.9	76.9	15.0
NCL	2.06	80.2	34.1	19.8	83.3	20.5

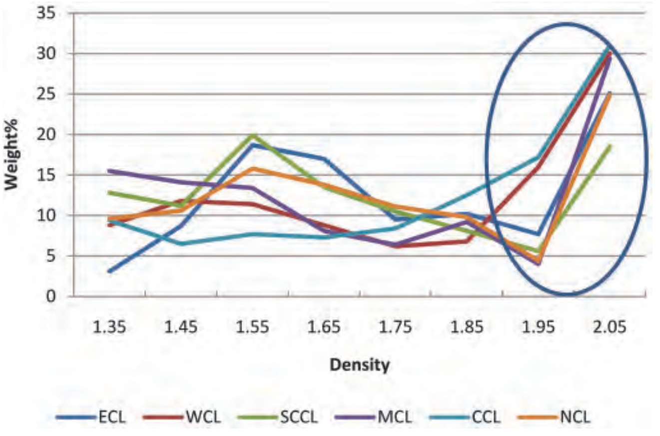

Fig.1 Density vs fractional yield% curve for all the sources

34% ash in the clean coal falls in the range of 1.82 to 2.06 and the amount of near gravity material at this specific gravity of cut is less than 20% for four different sources and marginally higher for other two sources.

Choice of equipment

From the detailed washability data now the question of choice between heavy media washing and jigging for beneficiation of coal is always present in the minds of plant designers and operators. With the development of large diameter heavy medium cyclones and proven efficiencies in modern under bed pulsated jigs, for the same particle size, has made the choice between the two technologies even more difficult. There are a few major guiding parameters which

Table 2: Washability data of coals samples collected from different coalfields.

Sp. gr.	ECL		WCL		SCCL		MCL		CCL		NCL	
	Wt%	Ash%	Wt%	Ash%	Wt%	Ash%	Wt%	Ash%	Wt%	Ash%	Wt%	Ash%
<1.40	3.1	8.9	8.8	11.7	12.8	8.8	15.5	14.0	9.4	13.5	9.6	7.8
1.40-1.50	8.7	20.5	11.8	24.6	11.2	23.9	14.1	29.5	6.5	27.0	10.6	16.5
1.50-1.60	18.7	29.5	11.4	34.7	19.9	35.7	13.4	39.6	7.7	35.2	15.8	25.6
1.60-1.70	17.0	37.9	8.8	43.0	13.5	45.7	8.1	46.4	7.3	42.8	13.8	35.1
1.70-1.80	9.5	43.5	6.2	48.4	10.5	51.6	6.4	50.9	8.4	48.1	11.1	42.9
1.80-1.90	10.2	49.8	6.8	54.4	8.1	58.2	9.2	58.3	12.5	55.2	9.8	50.8
1.90-2.00	7.7	59.1	16.0	62.1	5.6	65.1	4.0	67.3	17.2	59.1	4.4	59.2
>2.00	25.1	75.5	30.0	79.5	18.5	76.3	29.4	81.3	31.0	78.5	24.9	80.6
	100.0	46.7	100.0	52.2	100.0	44.9	100.0	50.6	100.0	54.3	100.0	43.8

should be kept in consideration while selecting the ideal process for a coal washing plant to meet the required deliverables. Every designer is expected to keep these parameters in his/her consideration while selecting the optimum process as both the processes has its own pros and cons.

It should be noted that a heavy media cyclone has the ability to beneficiate almost all the types of mature coal including the extremely difficult to wash coal. However, jigging has its own limitation and can effectively wash mature coals up to an NGM of 20% for non-coking type. Hence, the NGM percentage should be one of the important factors that should be considered while selecting the optimum washing process. The cut density of separation is another major consideration while deciding the best technology for washing coal.

Based on the extensive studies carried out on the coal sources from different coalfields, it may be concluded that for achieving 34% clean coal ash, the suitable equipment may be jigs, which are easy to operate, maintain and controlled [12].

State-of-art technologies for washing high ash Indian non-coking coals

Most of the non-coking coal washeries in India concentrated mainly on partial beneficiation, i.e., coarse coal beneficiation the finer fraction (generally, of lower ash content but prone to higher moisture take up), is allowed to bypass the washing circuit. Since most of the free dirt and banded materials are included in the coarser fraction, beneficiation of this fraction only and mixing of the washed product with the untreated smaller fraction gains first acceptance for maintaining presently desired ash at 34%. The washing of coal may be a dry or wet process. The state-of-art technologies available vis-à-vis their advantages and disadvantages are outlined below:

Dry beneficiation

So far Indian coals are concerned; most of the separation processes are based on difference of relative density between coally matter and shale particles/other impurities present in the coal and the processes are either wet or dry methods: Five known forms of coal dry beneficiation are the rotary breaker, ore sorters, air jig, fluidized bed air dense medium separator and the FGX separator.

Rotary breaker utilizes selective breakage principle to remove large, unbroken pure rock pieces while providing better coal liberation for subsequent cleaning processes. The rotary breaker repeatedly lifts the feed material, whose size is larger than the screen aperture, and drops it against the strong perforated screen plates. Two products are generated: one being large unbroken high-ash tailings and the other being broken product having better liberation characteristics. Rotary breaker has proven to be a robust machine having very low operating costs, and a high capacity up to 2000 tph. It may be noted that some of the private washeries in Maharastra, Chattisgarh installed rotary breakers for partial beneficiation (KEMTA existing Dry Beneficiation Plant at Integrated Baranj OCM near Nagpur).

Ore sorting through radiometric technologies have emerged as a viable option and recently few industrial installations were seen in South Africa and China. Radiometric techniques are of two kinds – gamma ray plus laser height profiling technology and multi-energy X-ray differential attenuation technology. What differentiates radiometric from earlier dry beneficiation techniques is that separation is based not on physical form, colour or friability of the particle but on its inherent properties. In India a deshaling plant based on X-ray sorting was commissioned and tested at Madhuband Wahery.

Small capacity all mineral dry air jigs are installed mostly in Odisha and in Chattisgarh. The air jig's limitation is that separation efficiency is low, target ash in clean coal is difficult to obtain and cross-migration is on the higher side apart from high power consumption and dust pollution caused. The latter can be addressed with some change in the design related to enclosure of the equipment, but other limitations persist. On the plus side, air jigs do not need water and cost of beneficiation is a fraction of wet technologies. Given the levels of efficiency, air jigs may at best be a transient phase, till better dry beneficiation technologies replace them.

Fluidized bed air dense medium separators are widely being used in China for both coarse and fine coal beneficiation. In India, one plant was installed based on this technology but it did not work efficiently, limitations are the difficulty in maintaining specific gravity of media which can be affected by a whole host of variables- particle size and specific gravity variation in magnetite, nozzle clogging, drop in air pressure and moisture content in raw coal. Other grey areas are: capacity limitations of modules, power consumption and recovery of magnetite.

The FGX dry separator is a special type of air table that consists of a perforated separating deck, three air chambers, a vibrating mechanism, and a hanging support mechanism. The separating deck, having riffles on its surface, is suspended inclined both in longitudinal and transverse directions. Airflow supplied from a blower fluidizes feed material on the deck and the vibration mechanism imparts a helical turning motion to particles as they slide in the longitudinal direction. In a relatively broad particle size range (top-to-bottom size ratio of 10:1), a density-based particle stratification takes place on the separating deck under the action of the vibration force, the upward fluidizing force of the air flow, and the downward gravity force of the solid particles. Commercial plants in US, South Africa and China are in operation, however this technology is to be tested for Indian coals. CSIR-National Mineral Laboratory, Jamshedpur is installing a pilot scale FGX separator and results are awaited.

Wet beneficiation

The most widely accepted technologies for washing through wet processes are jigging and heavy medium separators considering the coarse coal fraction only however barrel washer is also being used for wet beneficiation in few washeries.

Jigging

The washability characteristics of feed coal are very important for selection of a jig washer. After detailed washability studies and computer simulation of the washability data, considering the Ep value of the washing unit feasible washing circuit, is to be carried out. In view of large production of non-coking coals and demand of consistent quality of power coals at less than 34% ash content, jig may be considered as suitable washer to solve the problem of power industries.

Hence jigs (Baum, Batac and ROM) may be used as a washing unit. Jigs are low cost, adaptability to wide size range of coal and simple technique, easy operation and large capacity jigs are available.

The obvious dirt, stone and high ash content shale can easily be removed in pithead washery or adjacent to power plants. The availability of ROM jig opens the possibility of using a simple and economic process of beneficiating the ROM coal of size as large as 400mm at pit head. The saving in railway freight due to elimination of rejects to the tune of 10 to 15% may complement the washing cost. Of the two non-coking coal washeries constructed so far, Bina (NCL) uses ROM jig (size 250-30mm) and Piparwar (CCL) installed BATAC jig (size 100-13mm) supplied by Humbolt Wedag India ltd.

Dense medium separation

Experience with the existing washeries shows that the characteristics of raw coal feed changes considerably and gradually deteriorates over the years. Keeping in mind the difficult situations, we should design a flow sheet, which can tackle the possible variation of feed coal at optimum yield at desired ash level. Dense medium bath is a highly efficient method for separation of difficult to wash Indian coals (coarse size, >10-15mm) having high near gravity materials at separation density and can be operated effectively between 1.30 and 1.80 density of cut with separation efficiency (Ep) in the tune of 0.025 - 0.06. But the process is costly and required skilled manpower for its operation. One of the drawbacks of the process is that it cannot beneficiate coals below 15/10mm because of high settling time taken by the particles in viscous liquid.

From the experience gained in the beneficiation of Indian coals it has been realized that static dense medium coal cleaning process is effective for comparatively coarse sized coal having bottom size limit around 6mm. Below this size, the separation becomes progressively ineffective due to higher settling time taken by the small particles in viscous separating liquids. Gravity process other than static dense medium bath is also not effective for cleaning of small size particles. Dense medium cyclone washer using centrifugal force instead of gravitational force, hold much promise for beneficiation of smaller size coal with high order of performance (Ep 0.025 - 0.04) and high capacity. Dense medium cyclone is the most effective tool for treatment of Indian coal having high near gravity material.

Even though, H. M. washer is efficient in producing low ash cleans with better yield, it is not desirable to use this circuit for producing washed coal of ash 34% as the cost and availability of magnetite plays a vital role and it may be difficult to operate with media having sp.gr. more than 1.8, mainly due to viscosity of the media. The H.M. circuit may produce deep cleaned washed coal having ash as low as 25% or even less suiting for sponge and cement industries.

Barrel washer

The barrel washer is a combination of cylindrical and conical construction. In the barrel the beneficiation takes place based on the principles of hindered settling. Coal and water are fed into the cylindrical portion of the barrel which rotates at a certain predetermined speed. The spiral inside the barrel creates waves in the water in which the pulsation of coal takes place. The lighter coal moves with the top layer of the wave and is discharged at the conical end as low ash coal or clean coal. The high ash coal that settles in the bottom is carried by the spirals to upper cylindrical portion and discharged at the top end as rejects. The rejects and clean coal move in the opposite directions inside the barrel. The Aryan Coal Beneficiation Company had installed few barrel washers for washing high ash non-coking coals (RKP washery, Manuguru, SCCL, Telengana).

Conclusions

The economic as well environmental benefits of using beneficiated coal in power sector have been established but the need of more and more washeries is yet to be met. Washability characteristics of the raw coal should be prime criteria in selecting the washing circuit. Considering the poor liberation characteristics, Indian non-coking coals should be washed, preferably, at larger sizes.

Dry beneficiation techniques may be adopted where the ash reduction required is not much and for low capacity plants this seems to be ideal. Coal jigs are best suited for washing high ash Indian coals due to the fact that they are cheap and easy to operate and more effective if the separation cut point is above 1.80 specific gravity. Heavy medium baths/ cyclones are the most efficient separator for deep washing of high ash Indian coals having high near-gravity material at separation point.

CIMFR has undertaken R&D studies in a broad spectrum on indigenous non-coking resources. Samples have been collected from most of the major sources/projects of different coalfields of the country. The study would help in identification of suitable coals and in projecting most economically viable washing circuit for power industries.

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