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Research Paper

CLEANING POTENTIALITIES OF SOME THERMAL COALS OF ODISHA ON ITS BURNING BEHAVIOR

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Out of the total Indian coal reserves, the non-coking coals of Odisha constitute about 23%. The coals are spread in two major coal fields namely: Talcher and Ib Valley. The coals contain high ash wherein the extraneous material was intimately mixed in the coal matrix during the formation stage, causing a high level of impurities in the Run-of-Mine (ROM) material. These coals possess difficult to very difficult washability characteristics. Beneficiation of high-ash non-coking coals of India has become the prerequisite for improving the overall economics and efficiency of power generation. To meet the stipulations laid by environmental gazette notification of the Government of India, the non-coking coals are to be beneficiated before they are fed to thermal power stations. Keeping this in view detailed washability studies were carried out on three major coal sources of Odisha and based on the data clean coal at three different ash levels were generated. Combustion studies of the raw and clean coal have been conducted in a Drop Tube Furnace basically to observe the change in the burning behavior with the level of cleaning. From the combustion behavior of the washed fraction, it was found that, for two coal samples, Burnout Efficiency (BE) has improved compared to that of the raw coal, while for another sample, it was observed that at 34% clean coal ash level the BE has reduced compared to that of raw coal. The studies concluded that for the coals of Odisha, it is better to fix the level of washing a particular coal based on combustion properties of the clean coal rather than taking an arbitrary value.

Keywords: Non-coking, Washability, Drop Tube Furnace, Burnout efficiency, etc.

INTRODUCTION

All fossil fuels including coal, which have taken three million years to form, have limited availability. Fossil fuels are the main source of energy world-over. Today 85% of primary energy comes from fossil sources (coal, oil, etc.), and their reserves are continually diminishing. The relative abundance of coal in India compared to other fossil fuels makes it a natural choice as the primary source of fuel, be it for steel making, power generation or for other uses. India has significant coal reserves 285 billion tons, out of which about 85% constitute non-coking coal and the energy requirement is heavily dependent on the non coking coal reserves. Although alternative

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sources of energy are being thought of on a large scale, coal is expected to remain the dominant fuel for power generation for decades to come. The power history of India reveals its dependence on coal. Around 70% of total domestic electrical energy is generated by coal-fired thermal power plants today (Geological Survey of India Report, 2012).

The state of Odisha contains approximately 23% of India's reserves of non-coking coal (Biswas *et al*., 1996), and the major supplier is Mahanadi Coalfields Limited (MCL). The state has two major coalfields, namely Talcher coalfields and Ib Valley coalfields. The state is the main supplier of coal to the various thermal power stations in the Southern part of India, which are at a distance upto 1,000 km and in case of some plants even more. The coal of Odisha are characterized as high ash, the raw coal ash levels vary from 40 to 55%, the washability characteristics are poor and falls under difficult-to-wash. The stipulation laid by the Ministry of Environment and Forest (MOEF), Govt. of India for the use of non-coking coals in Thermal Power Plant, as coal ash not exceed 34% transport to urban areas or beyond 1,000 km, is posing problems to all the coal suppliers of the state of Odisha. This has prompted the coal suppliers and coal users to take initiatives on reducing the ash by washing high ash non-coking coals (Gouri Charan *et al*., 2007).

Beneficiation of such coal of Odisha is therefore obvious in priority level provided the process is cost effective and the benefits obtained can overcome the enhanced price of washed coal. However, the only guidelines available to them are the limiting overall 34% ash, irrespective of nature of the coal, combustible: non-combustible ratio, moisture content, and washability characteristics. The limit to which a coal needs washing or preparation has to be justified not from the ash content but from the specific quality parameters, like calorific value, burn-out efficiency of the raw and clean coal, etc., that have a relation with the total combustible reactive and, therefore, may govern the actual combustion behavior of the prepared coal (Sen *et al*., 2002).

Coals of Odisha have poor washability characteristics due to high proportion of inherent ash, and it is often impractical to wash these coals economically down to a low-ash level. The ash content and also washability characteristics of the two major coalfields of Odisha vary drastically both seam and area wise, blending of coals from different coalfields fed to the washeries pose critical problems in obtaining the desired washed product. Moreover, free silica (a-quartz) present in minerals is detrimental to the operation of power stations and cause frequent shutdowns. Thus, because of the nature of associated minerals, the thermal coals deserve a suitable beneficiation circuit different from that followed for the coking coals. This article deals with the methodology that may be followed to develop a beneficiation strategy for the coals of Odisha, at different ash levels and linking the level of cleaning with the burning behavior of the coals for effective combustion.

Experimental

The samples were collected from Mahanadi coal fields, a subsidiary of Coal India Ltd. The samples were collected from working benches with the help of a Haul pack and pay loader, by scraping the entire cross section of the bench at various places. After proper and thorough mixing, about 10 tons of sample from each colliery were collected and brought to the laboratory for further studies.

The raw coal first screened at 75 mm and the plus 75 mm fraction was crushed in a single roll crusher. The overall combined fraction of the product below 75 mm was subjected to screen analysis. The size distributions of coal crushed to minus 75 mm are shown in Table 1.

The crushed coal was subjected to screen analysis at 50, 25, 13, 6, 3 and 0.5 mm. Each of the individual size fractions were subjected to float and sink tests, and the relative density range was 1.40 to 2.00. The washability data of the combined fraction (75-0.5 mm) for each sample is shown in Table 2. The minus 0.5 mm coal fractions were not subjected to float-and-sink tests. The Washability curves on the whole coal basis for the raw coal were plotted for all the samples and depicted in Figures 1-3.

Representative samples from the overall combined fraction of the product below 75 mm was taken for studies like raw coal characterization, size analysis and size wise float and sink tests. The raw coal was characterized with respect to proximate, ultimate, ash fusion, HGI and GCV and the data is shown in Table 2.

Table 1: Size Analysis of Coal Crushed to 75 mm

Size, mm	Tal-I		Tal-II		IB-I	
	Wt. %	Ash%	Wt. %	Ash%	Wt. %	Ash%
75-25	67.9	42.6	63.8	38.5	63.3	54.0
25-6	17.4	36.3	19.7	41.7	22.8	46.3
6-0.5	12.1	26.8	12.6	37.6	10.1	41.4
–0.5	2.6	34.0	4.0	40.2	3.8	44.6
	100.0	39.4	100.0	39.1	100.0	50.6

Note: Ash% is calculated on dry basis

Table 2: Float and Sink Data of the Samples Collected from the Different Mines

Rel. Density Fraction	Tal-I		Tal-II		IB-I	
	Wt.%	Ash%	Wt.%	Ash%	Wt.%	Ash%
<1.40	32.1	19.25	33.1	19.62	13.21	15.7
1.40-1.50	21.8	28.7	15.5	30.7	10.43	30.3
1.50-1.60	9.7	38.6	13.7	38.9	12.61	38.5
1.60-1.70	9.8	48.5	9.9	45.3	8.73	46.4
1.70-1.80	4.8	53.6	10.9	54.3	7.89	52.7
1.80-1.90	6.2	64.4	4.7	60.7	10.92	61.5
1.90-2.00	5.3	69.4	3.4	68.2	6.39	71.2
>2.00	10.3	78.8	8.9	79.7	29.82	82.9
	100.0	39.3	100.0	39.2	100.0	54.3

Table 3: Detailed Characterization of the Raw Coal

	Tal-I	Tal-II	IB-I
Proximate Analysis			
Moisture%	8.4	7.7	8.2
Ash%	37.1	37.3	50.8
VM%	26.4	25.6	20.4
FC%	28.1	29.4	20.6
GCV(kcal/kg)	3750	3990	2025
HGI	51	56	81
Ultimate Analysis (Air dried basis)			
Carbon%	38.9	43.7	28.73
Hydrogen%	2.0	2.7	2.24
Nitrogen%	0.9	0.8	0.58
Sulphur%	0.4	0.5	0.33
Ash Fusion, Temperature, °C			
ID	>1360	>1400	>1400
HEMP	>1400	>1400	>1400
FLUID	>1400	>1400	>1400

Figure 1 : Washability Curves for the Coal Sample Tal-I

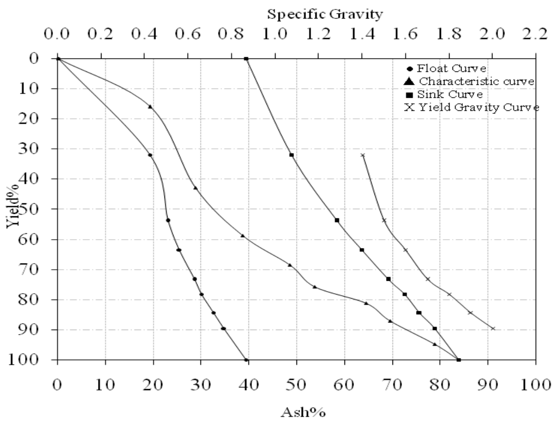


Figure 2: Washability Curves for the Coal Sample Tal-II

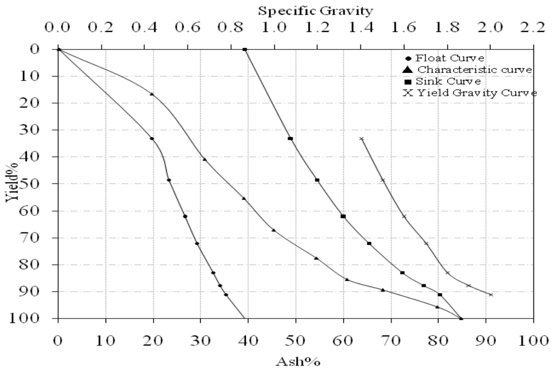
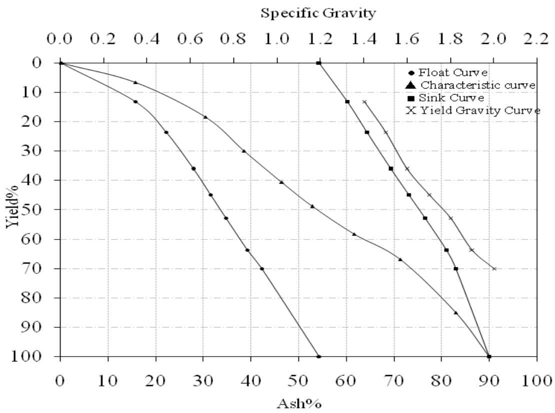


Figure 3 : Washability Curves for the Coal Sample IB-I



STUDIES ON COMBUSTION BEHAVIOR OF RAW AND CLEAN COAL

Generation of Clean Coal and Sample Preparation

From the washability data generated for all the three different samples, the specific gravity of cut was graphically evaluated and clean coal was generated at three different ash levels, viz., 25%, 30% and 34%. For combustion test in Drop Tube Furnace (DTF) the raw coal and the clean coals were crushed to 3 mm size followed by batch grinding under standard condition for a fixed time to ensure >80% passing through 72 micron. The clean coals were characterized with respect to ash analysis and petrographic studies and the data is shown in Tables 4 and 5.

Drop Tube Furnace

The DTF used in the study consists of a vertical ceramic tube of length 2500 mm and ID 100 mm

Table 4: Ash Analysis of Different Samples Collected from Mines

Ele-ments	Tal-I				Tal-II				IB-I			
	Raw Coal	Cleans (Ash)			Raw Coal	Cleans (Ash)			Raw Coal	Cleans (Ash)		
		34%	30%	25%		34%	30%	25%		34%	30%	25%
SiO_2	63.5	55.8	59.9	60.8	60.2	58.3	58.8	58.2	59.68	58.16	59.21	48.2
Al_2O_3	24.9	29.7	31	28.4	28.4	32.3	31.1	32.6	33.21	31.07	27.3	34.71
Fe_2O_3	4.4	3.2	1.2	2.0	6.6	3.6	5.0	3.6	3.19	5.59	8.97	10.7
TiO_2	1.1	1.1	1.4	1.4	1.6	1.8	1.2	1.1	2.24	1.4	1.94	1.09
P_2O_5	1.1	1.1	0.2	1.1	0.7	0.6	0.6	0.7	0.11	0.29	0.42	0.73
SO_3	0.2	0.5	0.2	0.3	0.03	0.1	0.03	0.05	0.28	0.29	0.09	0.24
CaO	2.7	4.3	2.7	2.5	1.02	1.5	1.3	1.8	0.09	1.22	0.74	2.21
MgO	1.0	1.6	0.8	0.8	0.5	0.4	0.6	0.6	0.08	0.73	0.37	0.75
Alkali	1.1	2.7	2.6	2.7	0.95	1.4	1.37	1.35	1.12	1.25	0.96	1.37

Table 5: Petrographic Analysis of Samples Collected from Different Mines

	Tal-I				Tal-II				IB-I			
	Raw Coal	Cleans (Ash)			Raw Coal	Cleans (Ash)			Raw Coal	Cleans (Ash)		
		34%	30%	25%		34%	30%	25%		34%	30%	25%
Vitrinite %	50.6 (66.6)	61.1 (72.9)	56.5 (68.7)	60 (73)	27.4 (36.7)	24.8 (31.9)	23.2 (28.1	27.5 (32.6	21.1 (35.6)	49.4 (61.5)	52.3 (60.6)	58.3 (66.17)
Liptinite %	9.6 (12.7	6.9 (8.2	7.3 (8.9	5.3 (6.5	14.6 (19.5	17.9 (22.9	22.9 (27.5	22.4 (26.6	11.4 (19.2	9.9 (12.2	14.7 (17	11.3 (12.83
Inertinite %	15.7 (20.7)	15.9 (18.9)	18.5 (22.4)	16.8 (20.5)	32.8 (43.9)	35.1 (45.2)	37.1 (44.4)	34.3 (40.8)	26.9 (45.2)	21.1 (26.3)	19.3 (22.36)	18.5 (21)
Mineral Matter%	24.1	16.1	17.7	17.9	25.2	22.2	16.5	15.8	40.6	19.6	13.7	11.9
Mean, Ro%	0.45	0.45	0.45	0.44	0.41	0.41	0.41	0.41	0.48	0.48	0.48	0.48

Note: Results in the parenthesis are on dry mineral matter free basis.

having five zones. All the five zones were heated electrically by externally heated canthal wire and the temperature in all the five zones could be raised upto 1100 ^{0}C. In each zone there were provisions of sample (solid and gases) collection through water-cooled probe, which was connected through cyclone and vacuum pump. In each zone temperature of wall of DTF and inside gas, could be measured. The rate of coal feeding in DTF was 1-3 kg/h. Pulverized coal was first dried at 110 ^{0}C separately in air oven for 1 h and fed through the vibratory feeder at the rate of 1.5 kg/h when the temperature of the combustor was about 850 ^{0}C. The primary air (30%) and preheated (180 ^{0}C) secondary air (70%) considering 20% excess air was fed into the combustor and all the relevant parameters including air flow were kept more or less the same in DTF for the set of experiments. The char sample from the fifth port was collected for each run. The velocity of gas inside the combustor was 2.8-3.0 m/s and velocity at which samples were collected by probe was in the range of 3.5 to 3.6 m/s.

The chemical analyses of the char and coal were determined to calculate the unburnt combustibles which is an indicator of Burnout Efficiency (BE), where

$$BE = \{1 - A_O (100 - A_C) / A_C * (100 - A_O)\} * 100 \quad ...(1)$$

where A_O is the dry ash% of the parent coal and A_C is the dry ash% of the char.

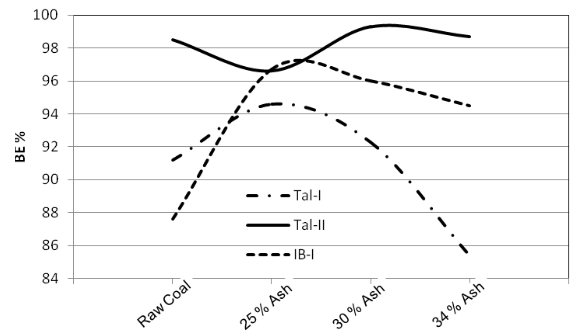
RESULTS AND DISCUSSION

Characterization tests on the raw coal samples revealed that the ash percentage (on air dried basis) of IB-I was high, around 50%. Coals of Tal-I and Tal-II contained lower ash contents, around 37%. Moisture percentage (on as-received basis) of the coals was in the range 7.7 to 9%. The characterization results for all samples (Tal-I, Tal-II and IB-I) are presented in Table 1. Coals from all these sources are friable in nature (HGI 51 to 81). Gross calorific value (GCV) varies from 2025 to 3990 kcal/kg. Sulphur contents of the coals are in the range 0.3% to 0.5%, which are within the accepted limit for thermal coal. The Initial deformation temperature or ash fusion temperatures of coals from all sources are around 1400 ^{0}C, which also satisfy the requirement of combustion properties. The ash analysis of the raw coal samples as shown in Table 4 indicates that the major ash forming minerals are silica and aluminum. Petrographic studies on the samples from each source were carried out as this might play an important role in the combustion of coals and the data as shown in Table 5, indicates that the vitrinite content of the raw coal varied from 21.0% to 50.0%. In case of Tal-I and Ib-I it was noticed that as the ash content in the clean coal reduced, the vitrinite content increased. However, in case of Tal-II the vitrinite content of the clean coal did not increase when the ash content reduced, this may be due to the fact that the clean coal was enriched with other materials like liptinite and inertenite.

From Table 2 it may be noticed that about 63.0% of the crushed material was above 25 mm. The –0.5 mm fraction of all the sources were 2.6 -4.0% and its ash percentage varied from 34.0 to 44.6%. From the washability curve as depicted in Figures 1 to 3, it may be seen that the theoretical yield% for the sample Tal-I at 34%, 30% and 25% ash levels were 88%, 77.5% and 63% respectively. For the sample Tal-II the theoretical yield% at 34%, 30% and 25% ash levels were 88%, 74% and 54% respectively and for the sample IB-I the theoretical yields at 34%, 30% and 25% ash levels were 52%, 41.5% and 30% respectively. The basic objective of washing should be the optimum rejection of non combustibles and not merely to achieve a prefixed ash limit (Singh *et al.*, 2010). 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 it is an outcome of the initiatives taken by different statutory bodies to reduce the existing level of pollution, the load on transportation, etc. (Chattopadhyay *et al.*, 2012).

The BE of the samples was estimated in DTF from the chemical analysis of the original coal and the char samples collected from the middle port of DTF using the ash constancy approach. During run in DTF, char samples collected from different ports and fly ash and bottom ash were also collected. The BE of the coal samples are depicted in Figure 4.

Figure 4: Burnout Efficiency of Raw and Washed Coal Fractions for all the Three Samples



As may be seen from Figure 4 in the case of combustion of raw coal of Tal-I the BE of the raw coal is 91.2% but once the ash content was lowered to 34%, ash level the BE had fallen down to 86.4%, but at 25% and 30% ash level the BE is significant amounts to 94.6 and 92.3% respectively. The lowering of BE at 34% ash level may be due to the difference in the petrographic mix of the said coal, and anomalous behavior in the distribution of the mineral matter in the washed fractions. Further, during combustion of washed fraction clinker was observed in the first port of the DTF, which may be due to the increase in the CaO content in the washed fraction (Biswas *et al.*, 2007).

In the case of combustion of raw coal of Tal-II sample the BE of the raw coal was 98.5% and during combustion with washed fractions at 25%, 30% and 34% ash level the BE are 96.6%, 99.3% and 97.5% respectively which indicates a definite trend with washing of Tal-II coal.. There is no marked improvement in the burnout efficiency of the fraction having 25% ash as the sample collected from the first port show poor burnout compared to the other fractions. Moreover, presence of clinker was observed in the burnout residues of this fraction. Ash compositional analyses show that there is increase from 1.02% to 1.8%, in the CaO content in the washed fraction. The presence of these inorganic components could contribute to the clinker formation at the early stage of burning leading to relatively poor burnout.

In the case of combustion of raw coal of IB-I sample the BE of the raw coal is very low amounts to 87.0%, which is due to the fact that the raw coal contains high ash and during combustion with washed fractions at 25%, 30% and 34% ash level the BE are 97%, 96% and 94% respectively which showed very good improvement when the raw coal was washed. Moreover, presence of clinker was not observed in the burnout residues of these fractions, which is evident from the ash compositional analyses data where it shows marginal increase in the CaO content in the washed fractions.

From the combustion behavior of raw coal and washed fractions it may be seen that in case of Tal-I there is no marked improvement in the BE when the ash content was lowered, where as for Tal-II and IB-I a definite trend was observed. Hence, it may be suggested that before fixing the level of washing it is important to study the combustion behavior of both raw and washed coals, with detailed characterization test for supportive data rather than taking an arbitrary value.

CONCLUSION

The laboratory studies revealed that the overall characteristic of Ib-1 was poor with respect to that of Tal-1 and Tal-2.

Detailed washability studies revealed that the theoretical yield for Tal-1 at 34%, 30% and 25% ash levels 88%, 77.5% and 63% respectively.

Similarly the washability studies on Tal-II revealed that the theoretical yield at 34%, 30% and 25% ash levels were 88%, 74% and 54% respectively.

The washability studies revealed on Ib-I that the theoretical yields at 34%, 30% and 25% ash levels were 52%, 41.5% and 30% respectively.

The combustion studies revealed that for the sample Tal-I, there is no improvement in the burnout efficiency when the ash content was lowered, where as for Tal-II and Ib I, the burnout efficiency improved once the ash was reduced.

It may be concluded that for the coals of Odisha, it is imperative to fix the level of washing a particular coal based on the detailed combustion studies using drop tube furnace rather than taking an arbitrary value.

REFERENCES

1. Biswas S, Das N S and Kalyan S (1996), *Beneficiation of Non-Coking Coal for Power Generation*, BIMI 96, Int.Conf., New Delhi, December 16-19.

2. Biswas S, Choudhury N, Ghosal S, Mitra T, Mukherjee A, Sahu S G, and Kumar M (2007), “Impact of Petrographic Properties on the Burning Behavior of Pulverized Coal Using a Drop Tube Furnace”, *Energy and Fuels*, Vol. 21, No. 6, pp. 3130-3133.

3. Chattopadhyay U S, Singh K M P, Gouri Charan T and Haldar D D (2012), “Effect of Washing High Ash Indian Non-Coking Coals on Combustion”, *International Journal of Coal Preparation and Utilization*, Vol. 32, No. 2, pp 69-79

4. Geological Survey of India Report (2012), Government of India. Inventory of Indian Coal Resources.

5. Gouri CharanT, Jha G S P.C.Chattopadhyay, Haldar D D and Sen K (2007), “Cleaning Potential of Samleshwari Noncoking Coal by Washability Investigation”, *International Journal of Coal Preparation and Utilization*, Vol. 27, No. 1, pp. 138-148.

6. Sen K, Choudhury A, Das N S, Chattopadhyay P C and Jha G S (2002), “Quality Coal for Efficient Power Generation”, *International Conference & Business Meet on ‘Fossil Fuel Power Generation’*, March 21-23, New Delhi

7. Singh K M P, Chattopadhyay U S, Gouri Charan T and Haldar D D (2010), “A Modified Godbert Apparatus for Determining Optimum Level of Beneficiation for Indian Non-Coking Coal for Power Generation”, *International Journal of Coal Preparation and Utilization,* Vol. 30, pp. 310-321.

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