Characterization and Utilization of Jhama Coal

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Abstract— Natural coke is a kind of fossil fuel with calorific value of 18–28 MJ/ kg. There are abundant natural coke reserves in the world, but at present it is abandoned and needs research and development for its utilization. Thermogravimetric analysis (TG) can be done to investigate pyrolysis characteristics of natural coke. The effects of the heating rate, the final pyrolysis temperature, the particle diameter, and the operating pressure on the pyrolysis process of natural coke can be examined with pressurized thermogravimetry. Scan electron microscopy show that the natural coke at higher temperature has better porous structure, which is beneficial to volatilization, and a better reduction activity. Decrease in the particle size leads to more volatile release. The pressure has less effect on pyrolysis under lower temperature, while the effect becomes stronger when the temperature is higher than a given point. In Indian coalfields huge amounts of natural coke have been produced due to magmatic intrusions. Jharia Coalfield in eastern part of India alone contains approximately 2000 Mt of baked coking coal as a consequence of these intrusions in the form of discordant and concordant bodies. Natural coke is characterized by the presence of low volatile matter and high ash contents and organic constituents showing isotropy and anisotropy. Natural coke is smokeless because the volatile matter escaped off, it can be processed for gasification or can be used directly for domestic ovens and in blast furnace. Natural Coke may be used to make synthesis gas, a mixture of carbon monoxide and hydrogen. Syngas; Water gas: a mixture of carbon monoxide and hydrogen, made by passing steam over red-hot coke (or any carbon-based char), Producer gas: a mixture of carbon monoxide, hydrogen, and nitrogen, made by passing air or air-steam blast over red-hot coke (or any carbon-based char). Natural coke is also used for heat shielding in space craft's when mixed with other materials. Jhama coal or Natural coke is excluded resources due to difficulty in mining and its low calorific value. Natural coke coexists with coal in the coal bed, but is discarded or left in the mine without scheduled exploitation because of lack of effective utilization technology, which would cause tremendous energy waste and harm to the environment. Therefore, considering the challenge of energy crisis sources, it is necessary to utilize it for power generation. But it can be used into blast furnace with blending it, in formation coke from bituminous coal in coke ovens. Gasification of Natural coke can be done in fluidized bed reactor with using suitable catalyst, to increase yield and heating value of product gas. Characterization of natural coke can be done by-proximate analysis, ultimate analysis and H.G.I (hardgroove grindability index), ash fusion temp, G.C.V. (gross calorific value), swelling index no. , dilation etc.

Keywords: Jhama Coal

I. INTRODUCTION

The intrusion of igneous rocks into coal seams is a common feature of Indian coalfields. Natural coke or "jhama" or special low volatile(SLV) fuel, as it is commonly known in india, is the result of carbonization of coal in situ by igneous intrusion. Jhama occurs in many coalfields of India, for example, at Raniganj, Jharia and Bokaro. Its estimated reserve in Jharia coalfields are 400 MTs. It is a material of extremely variable composition and physical characteristics. The variation depends on nature of the intrusion, its proximity to coal seam and extent of its effect.

With increasing demand of steel as a sign showing countries growth, the demand of coke is also increased and if use this discarded natural coke ,as a blender with carbonized coke, this can help not only to maintain economy but also we can conserve energy of coals which may be unused due spontaneous combustion or magmatic energy. Technologies like P.C.I (pulverized coal injection) may be used for natural coke to utilize it in blast furnace.

Another utilization of natural coke is gasifcation. Due to high prices of gases and ample reserves of jhama, we can gasified them with advanced technologies like fluidized bed reactor with catalyst, and then by methanization we can get pipe line substitute natural gas for clean burning with high calorific value.

Natural coke is a by-product during the process of coal mining and is also a kind of high metamorphic grade coal. It is a solid combustible fossil fuel and formed from coal by a relatively local elevated heat flow caused by an intrusive igneous rock. The volatile matter is released in short periods when the magma intrudes into coal. Natural coke has pores which are empty or filled with mineral matter. The textural features, such as the size, shape, distribution and orientation of pores are variable. The immediate contact between the igneous intrusive body and the coal may be sharp and planar or it may be diffuse and irregular. It becomes porous and penetrable and it is suitable for gasification. Calorific value of natural coke is about 18–28 MJ/kg.

In Indian coalfields huge amounts of natural coke have been produced due to magmatic intrusions. Jharia Coalfield in eastern part of India alone contains approximately 2000 Mt of baked coking coal as a consequence of these intrusions in the form of discordant and concordant bodies. Collieries of Jharia Coalfield. Natural coke is derived from coking coal under in-situ conditions due to intense magmatic induced heat and overburden pressure. Natural coke is characterized by the presence of low volatile matter and high ash contents and organic constituents showing isotropy and anisotropy. Through physical, petrographic and chemical properties of natural coke or 'jhama' as determined by various methods it has been established that the reactives in the unaltered coals (vitrinite, liptinite, pseudovitrinite, reactive semifusinite, etc.) are b25.0 vol.%, moisture b2.5%, volatile matter b15.0% and hydrogen b4.0%. The temperatures attained in the coal seams have been deciphered using some standard models, which indicate that a temperature ~1000 °C was attained. This produced huge amount of anisotropic and deposited carbons. An attempt has been made to understand the factors that influence the genesis of natural coke and heat altered maceral products in coals in Indian coalfields.

II. LITERATURE REVIEW

There are very some attempt to characterize the jhama coal in previous literature. Its utilization is also not explored so much. Some work like S.E.M(Scanning Electron Microscopy) on Jhama coal has been done The organic petrography was carried out using DM4500 advanced polarizing microscope, while scanning electron micrography was performed on a JEOL-840A JSM. The coal and natural coke samples were pulverized and beneficiated, and fractions of different sizes (50–0.50 mm) at varying specific gravities (1.4 to >1.8) were subjected to this study with a view to expose the concentrations of microstructures and microtextures of natural coke in different specific gravity fractions.

In addition, an effort was made to compare the variety of textures as seen with the help of optical microscopy with those as revealed under scanning electron microscope. SEM photographs revealed some textural features of natural coke, which remained unexposed in optical microscopy. This may be due to the use of unpolished samples and greater depth of focus achieved by SEM. The features which were studied through these two microscopy methods are characterization of carbonized matrix, mosaics, flow textures, micro, meso and macropores and cracks formed due to escape of volatiles including properties of mineral matter or their altered products (glassy matrix). The different washability fractions of Burragarh natural coke have shown that there is gradual decrease of reactive macerals and increase of anisotropic mosaics, flow textures and deposited carbons up to specific gravity of 1.70. The approach thus enabled a combined maceral–mineral analysis, which bears good implications on academic and industrial use of natural cokes.

The pyrolysis products were analyzed with the VECTOR 22 infrared analyzer. The effects of the heating rate, the final pyrolysis temperature, the particle diameter, and the operating pressure on the pyrolysis process of natural coke were examined with the Thermax500 pressurized thermogravimetry. The pyrolysis process of the natural coke can be divided into two different degasification stages, different from that of coal, which includes three stages—drying, semi-char forming and degasification. The results show that TG curve shifts to the higher temperature region as the heating rate increases. The heating rate has almost no effect on the ultimate volatile release. The final pyrolysis temperature has a strong impact on the ultimate volatile release. The higher the final pyrolysis temperature is, the more the ultimate volatile yield is. SEM pictures show that the natural coke at higher temperature has better porous structure, which is beneficial to volatilization, and a better reduction activity. Decrease in the particle size leads to more volatile release. The pressure has less effect on pyrolysis under lower temperature, while the effect becomes stronger when the temperature is higher than a given point.

An effort to investigate the effect of carbonization in two intrusive affected coal seams of Ena (seam XIII) and Alkusa (seam XIV) collieries of this coalfield has been done.

Through petrographic studies by microscopy, characterization of normal and heat-affected coals was carried out. The microstructures and microtextures produced due to extraneous heat have been related to nature and extent of heat, location of heating source, and quality and quantity of natural coke produced. Based on the results of this study and earlier studies, an effort has been made to study the classification scheme for microtextures of natural cokes generated through in-situ carbonization of the coal seams. It has been observed that in case of such heat effects under overburden pressure, the anisotropy is much more pronounced as compared to laboratory-carbonized cokes. In the mildly carbonized coals (pre-plastic phase, b300 °C) the vitrinite attained higher reflectance than normal vitrinite, liptinite started disappearing, and inertinite remained unaffected. In the moderately affected coals (plastic phase, 300–500 °C), mesophase spheres and fused natural cokes were generated from the reactives (vitrinite and liptinite maceral groups), the liptinites disappeared, and structurally, the inertinites remained almost unchanged with slight increase in the reflectance value. In the severely heat-affected coals (post plastic phase, N500 °C) the identified microtextures were mesophase spheres, different shapes and sizes of natural cokes, graphitic sphaeroliths, pyrolytic carbons, inerts with morpho structural changes and slightly higher reflectance values, and altered and unaltered mineral matters. A gradual change in the heataffected coals with increasing temperature was observed with respect to location of intrusive body.

It has been concluded that, barring the effect of pressure, the changes due to heat effect on coking coals, whether in situ or laboratory carbonization, are almost similar. Organic and inorganic constituents undergoing changes at a particular temperature are nearly similar in both conditions. In case of pronounced overburden pressure, flow structures develop in the natural coke groundmass. Higher reflectance and very strong anisotropy, as evidenced in completely baked coking coals with fine to very coarse mosaic structures, may be a good criterion to explore these heat altered coals for the carbon artifact industry and further efforts are required to be made in this line.

III. PRESENT WORK AND MATERIAL

The following experimental work are being carried out as a part of this research project.

A. SAMPLE COLLECTION AND PREPARATION:

For experiment lumpy jhama coal is collected from chasnala open cast project and then to feed to jaw crusher, it is hammered to suitable size.

1) For proximate analysis, coal was then intermixed thoroughly and sampling was done by coning and quartering. This was meant to attain further uniformity in the obtained coal sample. Some amount of coal was kept aside for proximate analysis.
2) Rest of the coal was subjected to roll crusher and grinder for crushing to finer size. Small quantity of

coarser coal was found; those were screened, crushed again and mixed in the obtained powdered coal.

B. *PROXIMATE ANALYSIS:*

Determination of moisture, volatile matter, ash and fixed carbon in coal comprises its proximate analysis. It suggests us the overall composition of coal without incorporating elemental analysis. It also gives a picture of uniformity in the coal sample.

1) *Determination of Moisture Content:*

Approximate 1 g fine coal(72#) was taken in a weighed porcelain crucible and was placed in a hot air oven at 100 – 110 degree C for 1 hour. Then the loss in weight of the coal due to this heating gave us the moisture per cent of coal used.

% Moisture in Coal = Loss in weight of coal/Weight of coal initially taken *100

Impact, Interpretation and use of moisture data:

- Moisture values are very important due to the influence they have on other measured and calculated values used in jhama coal analysis and, ultimately, they play an important part in buying and selling of jhama coal,although it has low moisture content.
- The total moisture is used in calculating the as received calorific value of jhama coal, which is often used as the basis for contracts. When thousand of tons of jhama coal are involved in a contract, an error that may appear insignificant under normal situation may cause serious monetary loss.
- It is used to determine the amount of drying needed to reach the required value.
- Jhama coal with high moisture content requires more heat for vaporization, which leads to longer cycle and decreased production of steel in blast furnace.
- The total moisture of jhama coal used must be accurately known to allow for proper charging of coke ovens and overall control of coking process.
- Drying, pulverizing, dust proofing and general handling of jhama coal all depends on moisture data.

2) *Determination of Volatile Matter in Coal:*

It is the loss in weight of moisture free powdered coal (72#)when heated in a crucible fitted with a loosely fitting cover in a muffle furnace at 950 degree C for exactly 7 minutes.

% Volatile Matter in Coal= Loss in Weight of Moisture Free Coal/Initial Weight of
Moisture Free coal*100

Impact, Interpretation and use of volatile matter value:

- Volatile matter values are used as an indication of the amount of smoke that may be emitted furnaces or other type of coal burning equipment.
- Volatile matter values are important in the selection of jhama coals and in determining blending proportions of jhama coal for blast furnace.
- The volatile matter of jhama coal is used as mean of evaluating the extent of coking, depending on the intend use of natural coke.
- Volatile matter value will be useful in identifying the process for gasification.

3) *Determination of Ash in Coal:*

It is the weight of residue left in a crucible after complete combustion of a previously weighed quantity of powdered coal in an open crucible (i.e. in the presence of air) at 750 degree C in a muffle furnace for duration of 90 minutes.

% Ash in Coal= Weight of Residue Ash Formed/ Initial Weight of Coal taken *100

Impact, Interpretation and use of Ash data:

- The value obtained for ash content is not a true indication of noncombustible material occurring in jhama coal. The ash value is an empirical quantity, but is quite useful for many practical applications.
- Ash is one of the parameter normally specified in coal contracts for marketing.
- In combustion, high ash content reduces the amount of heat obtainable from a given quantity of jhama coal.
- High ash content leads to problem of handling and deposing of ash produced during combustion.
- The composition of ash is considered in the amount of clinkering and boiler tube slagging that may take place in boiler. Most of the boilers are designed on the basis of specified ash content.
- natural Coke which is used in blast furnace requires more fluxing limestone to compensate for the ash, and the greater volume of natural coke to obtain the require amount of usable carbon.
- In commercial pulverization of jhama coals, the amount and the nature of ash is carefully considered before selecting pulverizing equipment or setting up the grinding process.

4) *Determination of Fixed Carbon:*

It was mathematically calculated and was determined indirectly by deducting the sum of total of moisture, volatile matter and ash percentage from 100.

% Fixed Carbon= 100-(% moisture+ % volatile matter+ % ash)

Impact, Interpretation and uses of fixed carbon value:

- It is a measure of solid combustible material that remains after the volatile matter in jhama coal has been removed.
- It give the information about the amount of carbon to be gasified after the removal of volatile matter
- It is use to estimate the Fuel Ratio with volatile matter

BASIS	FIXED CARBON (%)	VOLATILE MATTER (%)	MOISTURE (%)	ASH (%)
As Recieved	61.871	10.925	2.944	24.26
Dry	63.74	11.25	--------	25
D.A.F	84.99	15	--------	-------
D.M.M.F	87.92	12.08	-------	-------

BASIS	FIXED CARBON (%)	VOLATILE MATTER (%)	MOISTURE (%)	ASH (%)
As Recieved	63.32	9.11	3.89	23.68
Dry	65.882	9.47	--------	24.63
D.A.F	54.99	12.57	--------	-------
D.M.M.F	90.37	9.62	-------	-------

Table 1: Proximate Analysis Results Table

The proximate analysis was carried out for 3 specimens from the same sample to check the correctness and to ensure uniform result throughout. It was reported in tabulated manner and average value of Ash % and Fixed Carbon % were obtained.

C. *ULTIMATE ANALYSIS-*

Ultimate Analysis is done to know the elemental composition of jhama coal and its calorific values to its usefulness in combustion and gasification process.

1 gm of jhama coal sample is placed in Bomb- Calorimeter to determine its elemental composition .We get the following results-

N (%)	C (%)	S (%)	H (%)	O (%)	MOISTURE(%)	ASH (%)
1.533560	62.911922	1.111047	1.701923	5.481548	3	24.26

Table 2: Ultimate Analysis Results Table

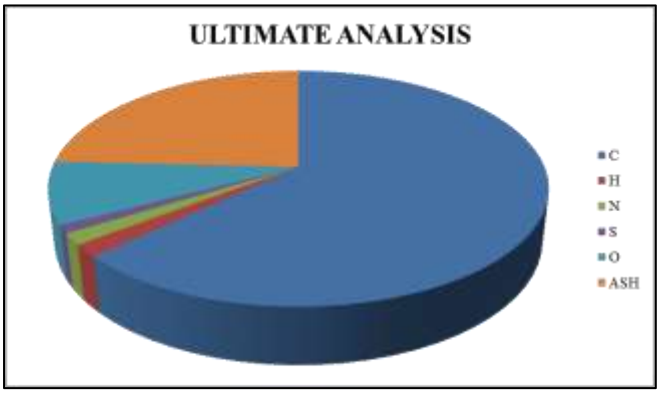

Fig. 1: Pie chart showing the percentage of elements in Jhama coal

Impact, Interpretation and uses of carbon and hydrogen value:

- Carbon and hydrogen values give the information about the combustibles in jhama coal.
- Carbon and hydrogen values are used in calculation of heat values.
- It's used for calculating heat balance in boiler efficiency test.
- Carbon and hydrogen values used in establishing the amount of air required for combustion.
- The most important use of Carbon and hydrogen values is for basic research.

Impact, Interpretation and uses of nitrogen value:

- Nitrogen data are primarily used in research. These values are needed so that oxygen from can be estimated by difference.
- Jhama coal nitrogen value is useful in predicting the amount of nitrogen in the products of jhama coal liquefaction and jhama coal gasification process.
- Nitrogen value is also useful from the point of view of combustion product.

Impact, Interpretation and uses of Total sulphur value: Sulphur is one of the most important constitute of jhama coal and no one would like to have the coal with high sulphur content.

- Total sulphur information are necessary for effective control of emissions of oxides of sulphur during combustion process. Emission of sulphur oxides leads to the corrosion of equipment/machinery and slagging of combustion or boiler equipment.
- Sulphur oxides contribute to major atmospheric pollution and environmental damage.
- Sulphur data are therefore necessary for the evolution of jhama coal to be used for combustion purposes.
- Sulphur knowledge is immensely important from the point of blending process. As the coke used in metallurgical process require low sulphur content.
- It's also important from jhama coal beneficiation point of view.

Impact, Interpretation and uses of oxygen value:

- It is useful in combustion process or boiler application. Its data are used for determining the suitability of jhama coals for blending,P.C.I, or gasification process.
- In general jhama coal with higher oxygen content are unsuitable for blending in blast furnace, as they are believed to more reactive and are more easy to gasify .

D. *CALORIFIC VALUES-*

C.V BASED ON PROXIMATE ANALYSIS

G.C.V for M>2% is-

GCV= 85.6 {100 – (M + 1.1 A)} – 60 M,
=85.6{100-(2.944+1.1*24.26)}-60*2.944
= 5847.032 Kcal/Kg

Where,

FC: Fixed carbon, V: Volatile Matter, A: Ash, and M: Moisture

C.V BASED ON ULTIMATE ANALYSIS—

GCV = 80.8 C + 345 (H – O/8) + 22.2 S
= 80.8*62.911922+345(1.701923-8.481548/8)+22.2*1.111047
= 5329.3452 Kcal/Kg

Where,

C= Total carbon, H= Total hydrogen, O= Oxygen, and S= Total Sulphur.

NET CALORIFIC VALUE—

N.C.V= G.C.V- 53*H
=5329.3452-(53*1.701923)
= 5239.143281 Kcal/Kg

USEFULL HEAT VALUE(U.H.V)—

V.M< 19% SO,

U.H.V= 8900 – 138(M+A) – 150(19-V)
= 8900 – 138(2.944+24.26) – 150(19-10.925)
= 3934.598 Kcal/Kg

E. *Grindability Index:*

The grindability of jhama coal is a measure of the ease with which jhama coke can be ground fine enough for use as a pulverized fuel, and as such it reflects some of the physical properties of natural coke, like hardness, strength, tenacity and fracture.

Hardgrove Grindabilty test is usually used to measure the grinding or pulversing property of jhama coal. Number of new surface generated per unit time per unit area serves as the basis for the design of hardgrove grinadability test (IS: 4433-1979).

Method of determination: 50 g of –16 +30 mesh size jhama coal is placed into grinding bowl having 8 steel ball having 25.4 (+/-) 0.003 mm diameter. The grinding machine is rotated to 60 revolutions. The grounded sample is sieved through 75-micron sieve. HGI value is calculated using the relation;

HGI = 13 + 6.93 M

Where,

M= mass of sample passed through the 75 micron sieve.

Lower value suggests that it is difficult to grind.

Grindability data are greatly affected by the moisture content and temperature, and may also influenced by the plastic deformation of small particle, which adhere strongly and difficult to separate.

H.G.I= 13+6.93W

Where,

W= weight passing through 200 mesh sieve

W(gm)	H.G.I
8.86	74.399
7.9	67.747
8.7	73.291

Table 3: Data Related to H.G.I(Hardgrove Grindability Index)---

Result: So Nearest value of H.G.I= 74

F. CAKING INDEX

Caking index is defined as whole number ratio in a mixture of sand to coal of 25 gm when heated under specified condition produces a coherent mass capable of withstand a load of 500 gm and at same time does not produce loose grains more than 5%.

Desirable Properties of Sand:

1) Size-212 to 296 micron meter
2) Unreactive
3) Should not fuse when heated to 950 degree C for 3 hrs.

To perform the test we assume the cakink index of jhama coal to 14.Then calculated the wt of coal and corresponding wt of silica sand. After mixing uniformly in a glass tube , we put the mixture in muffle furnance at 900 degree C for 7 min.We found that jhama coal of sample does not form coke button till 3 assumed caking index. At assumed caking index of 2, jhama coal forms button which is capable of with sat and 500 gm load without showing loose grains more than 5% of jhma coal.

RESULT: No caking property is shown by sample of jhama coal.

G. SWELLING INDEX:

For determining swelling index we have taken 1 gm of 72# air dried jhama coal and put in a V.M crucible with lid and heated at a temperature of 850 dergee C for 7 minutes. After that we found that powdered jhama coal is remained.

So the result is- Sample shows zero swelling index.