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COAL BENEFICIATION

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ABSTRACT

In India, for power generation we mainly depend upon coal, which is imported from other countries due to their fine grade. Our Indian coal is of low grade as it is having more ash content and moisture content. These factors may affect the performance of the boiler. Hence to increase the boiler performance by using the Indian coal we need to decrease the ash and moisture content. This can be achieved by following the coal beneficiation process which is presented in this paper.

Keywords: ash content, boiler performance, coal beneficiation, moisture content.

I.INTRODUCTION

Coal is a complex combination of organic matter and inorganic mineral matter formed over eons from successive layers of fallen vegetation. Coals are classified by rank according to their progressive alteration in the natural metamorphosis from lignite to anthracite. Coal rank depends on the volatile matter, fixed carbon, inherent moisture, and oxygen; although no single parameter defines a rank. Typically, coal rank increases as the amount of fixed carbon increases and the amount of volatile matter, ash content and moisture decreases. In the US, the American Society of Testing and Materials (ASTM) standardizes methods to analyze coal for chemical and physical characteristics pertinent to industry use and coal bed science. An ASTM procedure to classify coal by rank (low to high) approximates the heating value, fixed carbon, moisture content and volatile matter in coal. Given the various characteristics and origins of coal, knowing the coal rank provides insight into coal behavior during extraction and conversion. Based on that they are classified into:

Grade A – Anthracite
Grade B – bituminous
Grade C – sub bituminous
Grade D – Lignite

Since coal is abundant in earth's crust, it contains many elements such iron ferrites, sulphur dioxide (SO_2), moisture, volatile matter, ash content, fixed carbon.

1.1Moisture

Moisture is an important property of coal, as all coals are mined wet. Groundwater and other extraneous moistureare known as adventitious moisture and is readily evaporated. Moisture held within the coal itself is known as inherent moisture and is analyzed quantitatively. Moisture may occur in four possible forms within coal:

1. Surface moisture: water held on the surface of coal particles or macerals
2. Hydroscopic moisture: water held by capillary action within the micro fractures of the coal
3. Decomposition moisture: water held within the coal's decomposed organic compounds
4. Mineral moisture: water which comprises part of the crystal structure of hydrous silicates such as clays

1.2 Volatile matter

Volatile matter in coal refers to the components of coal, except for moisture, which are liberated at high temperature in the absence of air. This is usually a mixture of short and long chain hydrocarbons, aromatic hydrocarbons and some sulfur. The volatile matter of coal is determined under rigidly controlled standards. In Australian and British laboratories this involves heating the coal sample to 900 ± 5 °C (1650 ±10 °F) for 7 min.

1.3 Ash

Ash content of coal is the non-combustible residue left after coal is burnt. It represents the bulk mineral matter after carbon, oxygen, sulfur and water (including from clays) has been driven off during combustion. Analysis is fairly straight forward, with the coal thoroughly burnt and the ash material expressed as a percentage of the original weight. It can also give an indication about the quality of coal. Ash content may be determined as air dried basis and on oven dried basis. The main difference between the two is that the latter is determined after expelling the moisture content in the sample of coal.

1.4 Fixed carbon

The fixed carbon content of the coal is the carbon found in the material which is left after volatile materials are driven off. This differs from the ultimate carbon content of the coal because some carbon is lost in hydrocarbons with the volatiles. Fixed carbon is used as an estimate of the amount of coke that will be yielded from a sample of coal. Fixed carbon is determined by removing the mass of volatiles determined by the volatility test, above, from the original mass of the coal sample.

II.COAL BENEFICIATION

India ranks third in world coal production, producing 608 million tons (10%), after china (3650MT, 46%) and United States of America (922.1MT, 11%).The majority of this production, approximately 85%, is used for thermal power generation. Electricity from coal currently accounts for 71% of India’s total 67 gigawatts of power generated. Total power generation for coal is projected to increase to 161 gigawatts by 2030.Indian coals are of poor quality contain 23-30%when shipped to power stations. In addition, over time the calorific value and the ash content of thermal coals in India have deteriorated as the better quality coal reserves are depleted and surface mining and mechanization expand.A low-quality, high-ash coal also creates problems for power stations, including erosion in parts and materials, difficulty in pulverization, poor emissivity and flame temperature, low radiative transfer, and excessive amounts of fly ash containing large amounts of unburned carbons. The use of beneficiated coal

(Low ash coal) can reduce erosion rates by 50-60% and maintenance costs by 35%. Hence we are importing coal from Australia (9%) although we are having plenty of coal reserves. If we can utilize our coal by removing the ash content, moisture up to a maximum extent.

Coal beneficiation is a low-cost solution that can

(1) Produce higher quality coals that can be burned more cleanly and with greater efficiency,
(2) Reduce the amounts of emitted fly ash and associated hazardous air pollutant precursors,
(3) Minimize capital, operating and maintenance costs associated with coal fired power generation,
(4) Reduce the need to import higher-quality coals,
(5) Improves health and safety.

Coal beneficiation is the process of cleaning of coal before combustion to remove SO_2, ash content, moisture content, NO_x etc... In this paper we are conducting beneficiation of coal by removing

- Moisture content
- Ash content

2.1 Removal of Moisture

If the moisture content of coal is more, then the boiler efficiency decreases and upon combustion the unburnt coal increases leads to more pollution.

Moisture can be removed by the process of drying. Different driers are used such as

2.1.1 Fluidized Bed Dryers (FBD)

Fluidized bed drying is ideal for a wide range of particulate or granular solids and has found wide spread usage in various industries, including those dealing with chemicals, pharmaceuticals and bio-chemicals, food and dairy products, and polymers. This is mainly due to very high heat and mass transfer rates as a result of vigorous gas-solid mixing. Fluidized bed dryers can compete successfully with more conventional dryer types (e.g. rotary, tunnel, conveyor) in the drying of powders, granules, agglomerates and pellets, with particles averaging between 50–5000 μm. Both heat sensitive and non-heat sensitive products can be dried using one or more of the FBD variants, among which, the most common are: Batch FBD, Well-Mixed Continuous FBD (WMFBD), Plug-Flow FBD (PFFBD),

Vibrated FBD (VFBD), Mechanically-Agitated FBD, Centrifugal FBD, and Spouted Bed Dryers (SBD). Each variant design has its strengths and weaknesses and their implementation is highly dependent on feed and product requirements. Other advantages include smaller foot print, relatively lower capital and maintenance cost, and ease of control. However, FBD is not without its limitations. Among the major issues in fluidized bed drying are high power consumption, increased gas handling requirements, high tendency to cause product attrition, and low flexibility in terms of feed type (size and shape) that can be handled. Here we will focus on novel designs that have potential for drying LRC.

2.1.2 Screw Conveyor Dryers (SCD)

When there is need for simultaneous conveying and heating or cooling, a screw conveyor can be easily converted to a dryer or heat exchanger by providing the necessary heat to the moving solids either directly or indirectly and by removing the evaporated moisture by gentle gas flow or by application of vacuum. Typically, a screw conveyor dryer consists of a jacketed vessel (generally cylinder or U-trough) in which material is simultaneously heated and dried as it is conveyed. The heating medium, usually hot water, steam, or any thermal fluid, may also flow through the hollow flights and shaft to provide high heat transfer area without the need for additional space or material.

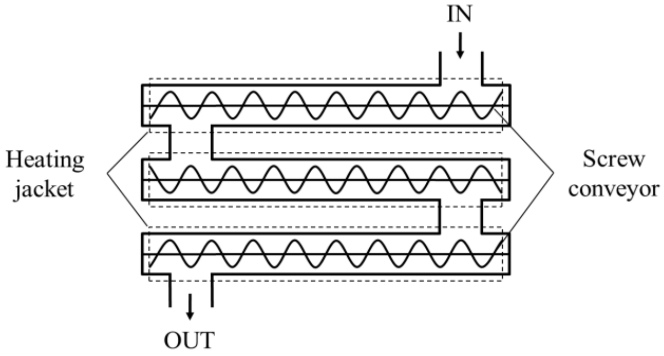

Fig.1 Schematic diagram of a multi-stage screw conveyor dryer

2.1.3 Solvent Displacement

Treatment of coal and coal fines in a variety of organic liquids, as a means of enhancing the stability of coal, while reducing energy requirements during drying has been around since 1926. One example is hot oil drying whereby raw coals are dried in hot oil after which most of the oil is recovered, a method also known as fry drying and used extensively for foods and sludge drying. Oil that is absorbed into the coal pores supposedly results in greater stability of the processed coal.

Apart from oil, drying of coal in other hydrocarbons has also been demonstrated with success. Murphy described a two-fold improvement in drying time when methanol was used as the drying liquid. Similarly, Cantu et al. described the use of alcohols with 1–3 carbon atoms to facilitate the drying of coal. Grounded coal immersed in hot molten paraffin (104–163 ºC) was also shown to be another effective dehydration method. Dean showed that coal treated from such a process displayed a dramatic increase in calorific value (originally 22,300 kJ/kg, upgraded up to 34,900 kJ/kg), low final moisture content (around 3%), and inhibited rehydration due to paraffin displacement of water in coal cavities. Drying in organic solvent was found to be less energy intensive than conventional evaporative means since the latent heat of vaporization of volatile solvents is significantly lower than that of water. Nevertheless, some thermal energy is still required for heating and the solvent recovery processes—which could be energy intensive. An attempt to further reduce this energy requirement is described by Yoon et al. through a process that claims to spontaneously displace surface moisture under sufficient pressure, with little or no heating, and using a gas that can be converted into a non-polar, hydrophobic liquid (e.g. butane). This concept is illustrated in the following figure.

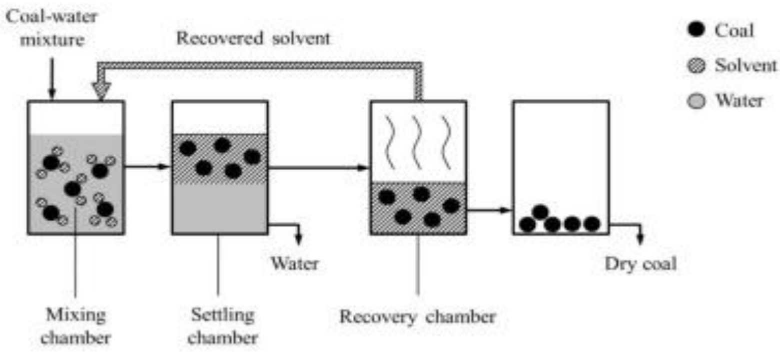

Fig.2 Dewatering of coal through solvent displacement of water

2.2 Removalof Ash from Coal

Coal purification process first started in U.S.A., Japan and other European countries. The coal extract knows as solvent refined coal which can be used as such for various purposes or further processed to obtain impurities and host of chemicals.Cleaning of coal mainly divided into two processes

(a) Mechanical process

1) Conventional method
2) Density based method

(b) Chemical process

2.2.1 Mechanical process

a) Convectional Method

The coal from mines is stored in form of stock piles at plant. The cleaning process is done by first washing plants are typically preceded by single or two-stage crushing to reduce the raw coal to a top size of 100, 75 or 50 mm.The smaller fraction of raw coal (-13, -10 or -6.5 mm) that typically contains low ash (20-30%) is usually not washed. The specific size selected for washing or direct consumption would depend upon the ash content and effectiveness of screening. The coarser fraction is washed by jig, heavy medium bath or heavy medium cyclone to the extent that the combined ash of the washed coarse coal and the unwashed small (<10 mm) and fine (<3 mm) coal is within the stipulated limit. In some washery plants, inefficient barrel washers and spirals are used for small and fine coal, respectively, in which case the fraction finer than approximately 0.5 mm would normally be discarded. In some cases, the extent of coarse coal cleaning is limited to rock removal by hand picking, which is labor intensive and highly inefficient.

b) Density Based Method

The coal cleaning is done based on the density differences of various composites in coal. It is done by two ways

1) Water based separation
2) Air dense medium fluidized bed system

2.2.2 Air dense medium fluidized bed system

The fine coal particles are mixed with magnetic power and passed through the secondary air distributed fluidized bed system (SADFBS) and the pure coal is collected at the bottom of the distributed layer.

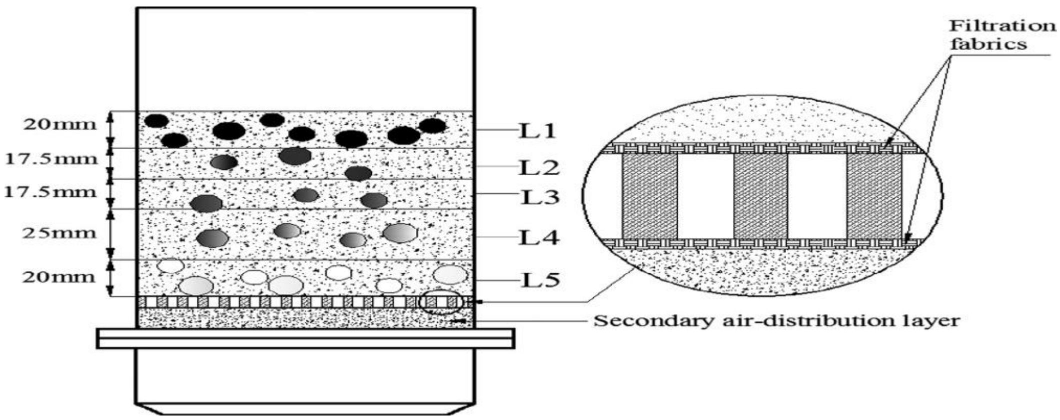

Fig.3 Secondary Air Distributed Fluidized Bed System

a) Chemical process

Removal of ash from coal by various chemical and solvents like

a) Mixture of calcium fluoride and sulphuric acid

b) Anthracene oil

c) Sulphuric acid

d) Hydrochloric acid

e) Sodium Hydroxide

f)Mixture of NMP and Ethylene-di-oxide

g) NMP N-Methyl-2-pyrolidine (C_5H_9NO)

h) Aniline ($C_6H_5NH_2$)

i) Furfural –Heterocyclic aldehyde (OC_4H_3CHO)

j) Acetic acid (CH_3COOH)

K) Toluene as an extractant (C_7H_9)

III.METHODS AND RESULTS

3.1Preparation of Samples

Four types of coal samples have been collected from different mines having different percentages of ash. The samples are leveled A, B, C and D and their ash contents are 4.7%, 26%, 37% and51.1% respectively. The samples are properly grinded and have been passed through 72 meshes.

3.2 Experimental Procedure

Five solvents such as NMP, Furfural, Aniline, Acetic acid and Toluene have been selected based on literature survey to remove ash from coal samples. Initially four samples, leveled A, B, C, and D are mixed with individual solvents in four different containers having same solvent to coal ratio. The coal added solvents has been heated at 120o C where a mechanical starrier has been used as shown in figure1 to ensure proper mixing for half an hour. After that the mixture has been sent to thermal distillation unit as shown in figure 2 to recover the solvents. Approximately 65% solvent has been recovered by this process the remaining part of solvent of mixture is removed by drying it in hot air oven and again the ash content of solvent refined coal has been determined using proximate analysis. The same procedure has been repeated taking different solvent to coal ratio.

3.3 Calculated Ash Percentages of Different Grade Coal

Several experiments have been done using different solvents such as NMP, Aniline, Furfural, Acetic Acid and Toluene with their different concentrations to remove ash content of coal leveled A , B, C, and D.

3.3.1 Removal of ash of Sample leveled D.

concentration of coal	percentage removal of ash			
Coal : Solvent	NMP	ANILINE	ACETIC ACID	TOLUENE
1:06	8	6	1.3	1.25
1:10	18	8	1.5	1.55
1:15	17.9	8	1.5	1.55
1:20	18	8	1.5	1.65
1:25	18.5	8.2	1.6	1.69

3.3.2 Removal of ash of Sample leveled C

concentration of coal	percentage removal of ash			
Coal : Solvent	NMP	ANILINE	ACETIC ACID	TOLUENE
1:06	4%	5.4	5	1.3
1:10	5	6.7	6.4	1.55
1:15	5.5	8.1	7.5	1.55
1:20	8.6	10.3	10.5	1.54
1:25	8.9	12.3	13.5	1.56

3.3.3 Removal of ash of Sample leveled B

concentration of coal	percentage removal of ash			
Coal : Solvent	NMP	ANILINE	ACETIC ACID	TOLUENE

1:06	10%	7.7	1.7	1.67
1:10	26	14.7	1.8	1.9
1:15	26	19	1.8	1.9
1:20	26	19	1.8	1.8
1:25	25.96	18.5	1.73	1.78

3.3.4 Removal of ash of Sample leveled A

concentration of coal	percentage removal of ash			
Coal :Solvent	NMP	ANILINE	ACETIC ACID	TOLUENE
1:06	23%	25	1.75	1.6
1:10	72.34	70.6	1.8	1.8
1:15	72.34	71	1.8	1.8
1:20	73.2	71	1.798	1.9
1:25	72	69.9	1.77	1.79

IV.CONCLUSION

This study shows that NMP is the best solvent to remove ash from coal compare to other four solvents such as Aniline, furfural, Acetic Acid and Toluene. Highest ash removal by NMP is 72.34% when coal and solvent ratio is 1:10. But there is a limitation to increase the concentration of NMP. Experimental result shows that after a certain value of concentration of NMP the ash removal rate is decreasingby increasing the concentration of NMP. By following the driers systems we can remove the maximum moisture content. Hence by decreasing these two contents the fixed carbon percentage increases and hence the boiler efficiency also increases.

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