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Experimental Study of Coal Washability using Float and Sink Test

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Abstract

Pakistani coal is characterized by large amount of mineral matters especially pyrite, which restricts its use in power generation and process industry. High ash contents in coal create problems in terms of slagging, fouling, clinker formation and environmental pollution. High ash content of the coal will affect the coal applications, in order to reduce ash the contents of coal, there is need to clean the coal. In this experimental study effect of dense medium, specific gravity, settling time and particle size on coal washability have been carried out. Experimental study showed that maximum clean coal float fraction was separated out at particle size of 60 mesh. The maximum yield of clean coal is 86.1 % obtained in float and sink test. Settling time also influenced directly on float fraction, float and sink fraction became almost constant at 16 hours. In present research lowest ash contents of clean coal is reduced from 36.38 % to 11.1% which is acceptable for further utilization of process industry.

Keywords: Salt Range Coal, Coal Cleaning, Float and Sink Analysis, Proximate Analysis, Run of Mine (ROM)

1. Introduction:

Coal is a natural fossil fuel, heterogeneous mixture of organic and inorganic matters. The composition of the coal varies from mine to mine and coal physical properties also change horizontally and vertically within the same mine. Coal is mostly used for power generation in the world. The different state is explained by the different origin of such three fuels. Whereas oil and natural gas come from the rests of microscopic organisms living in water (plankton, seashells, coral, etc.) deposited in the depth of ocean. Coal is formed from the decay of trees and plants. The structure and form of which, albeit modified, can still be identified by means of a microscope [1]. Carbon is the major element of coal after the other main components of the original living things such as (nitrogen, oxygen and hydrogen) gradually decomposed during chemical and physical operations. The energy of the sun stored in the trees produced as a result of combustion: therefore it is an invaluable container of "fossil" solar energy.[2]

There are enormous coal reserves of (185.175 billion ton) have been identified in all provinces of Pakistan. The vast coal reserves of Pakistan, estimated at around 186 billion ton have finally started to attract foreign investment, the most prominent being China interested to setup a coal-based power generation plant by end this year at Thar, the area that houses the largest reserves of over 175 billion ton. Though many other countries including Bosnia, also have shown interest in coal

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exploration. This article primary highlights the Chinese interest.

A pre-feasibility study of the Thar coal reserves has already being conducted by the Shinhua Group. Coal assumes a critical job as the essential and cheap source for the production of electricity. For example, half of the power in the US is being generated from coal it may increase up to 54% by 2020. Coal is primarily used as a fuel for power generation in many other countries.

The policy makers have also realized the importance of coal as inexpensive power generation resource and that explains the government's interest to produce 20 % of energy demand from the coal. The plant at Thar, funded by China would provide half a million dollars soft credit for the proposed 600 MW plant. It would be one of many other coal-powered plants across the country generating a total of 3,000 MW under the plan that envisages meeting energy requirement from coal as planned. [3]

There is no similarity between two similar coals due to the fact that every coal has its own physical and chemical properties. The lignite rank coal found in Pakistan to be used in power generation with certain restrictions. It contains high sulphur and also high ash content. Furthermore, that type of coal may be processed and washed to force it for the use of electricity production. Salt Range mine coal has high ash content and to be found suitable for washing purpose.

There are two types of impurities associated with coal.1) Fixed or Inherent 2) Free or Extraneous. First type of impurity associated during the formation period of coal while second category is associated during mining, transportation and storage. It is not easy to remove the fixed impurity by using simple technique but it can be removed by using some special technique like acid and alkali treatment to purify the coal. On the other hand free or extraneous impurity can be removed easily by using simple technique. As we know that run of mine (ROM) coal contains many impurities such as clay, rock, non-combustible matters, ash content and sulphur. Coal is mainly used as fuel when it is burnt in the furnace the emissions of the burnt coal have negative effect on the environment as well as on human health. NO_x and SO_x emissions from the coal combustion will affect human lungs and will pollute the environment also.

To reduce the emissions from coal burning there is need to clean the coal. There are many coal cleaning technologies such as based on physical and chemical cleaning. Chemical cleaning is restricted lab scale due to its cost and low efficiency. Physical cleaning method consists of dry and wet cleaning process, among all these process dense medium separation technique is most suitable for coal washing. First of all run of mine (ROM) coal should be washed to reduce sulphur, ash content and transportation cost.[4, 5]

In the present research I have selected Salt Range Coal sample for experimentation because it has high ash content as compared to Makarwal coal and other coal mines in Pakistan, objectives of my study is to decrease the ash contents of coal by using float and sink analysis. Float and sink analysis through which the ash contents removed from actual amount to consumable amount. Prepared the solution of $ZnCl_2$ under different specific gravity and observe the behavior of which solution of salt range coal with $ZnCl_2$ has highest capacity to settle down the impurities. This coal mine is located in the province of Punjab near Khewra. Around 213 million ton coal reserves have been found in the Salt Range and its quality according to analysis is reported to be sub-bituminous. [6]

2. Materials And Method:

It is clear from the literature review that series of Glass Beakers, Scoops, Glass Agitators, Tongs, Balance and Muffle Furnace are used for Float and Sink Analysis. Jaw Crusher and Ball Mill are used for required size coal sample preparation. Experimental setup is available in Research & Development lab at NFC-IEFR Faisalabad.

2.1 Sample Preparation

For sample preparation run of mine (ROM) coal is crushed by using Jaw crusher. Jaw crusher consist of two plane jaws moving to and fro ,one jaw is fixed and other is moving by a cam. The moving jaw is

also known as sing jaw. These two jaws are made of cast steel and the frame outside these jaws is usually made of cast iron. The space between these jaws is called crushing chamber. The coal sample which is to be crushed is placed between the jaws and swing jaw moves with low speed and breaks the particle into pieces. The weighted flywheel is used to provide the inertia that moves the shaft and causes to close the gap between the jaws. A compression force is used to break the large particle into small pieces in the jaw crusher. Required particle size was not achieved by single stroke of jaw crusher it was repeated in order to achieve the desired results. Jaw crusher is used to convert the run of mine (ROM) coal lump

s into small pieces.[7]

The ball mill is used to convert these crushed particles into fine particles. It contains cylindrical shell which revolves around its own axis. Some portion of the empty shell is filled by the grinding media the remaining is filled with material which is to be crushed. The grinding media is usually the ball which is made of steel, chrome steel, stainless steel, rubber or ceramic. The inside of hollow shell lined with rubber or any other abrasion material which reduces the wear and tear. The material in the ball mill which is to be grinded into fine particle are surrounded by the balls and converted into fine particles due to impact action between ball and particle as ball mill revolves around its axis. The working principle of the ball mill is based on the impact or attrition between the fast moving ball and powder material. After the jaw crusher where the large particles of the coal are crushed into small particles then ball mill is used to convert these small coal particles into fine particles for further size reduction. [8]

2.2 Float and Sink Test

Salt Range run of mine (ROM) coal lumps were first crushed, grinded and then screened into different particle size like, 10, 60, 100, 140 and 200 mesh through screen analysis. The aqueous solution of $ZnCl_2$ was prepared and used as dense medium. The liquid solutions of different specific gravity 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8 and 1.9 were prepared. In order to perform the experiment 500 ml glass beakers have been used and beakers are placed in such a way that it starts from specific gravity 1.2 to 1.9. 100 gm salt range coal of specific particle size placed in the aqueous solution of different relative density. It was settled for certain time such as 10,12,14,16, 18 hrs after that clean coal particle having low density will float and remaining coal with impurity will settle down. Now these float fractions and sink fractions were separated out. These fractions in china dish were placed in furnace and heated for certain time to dry.[9, 10]

Table-1: Experimental Results of Float and Sink Test

Specific Gravity	Float Fraction (%)	Ash Contents (%)	Sink Fraction (%)
1.2	38.9	14.7	61.1
1.3	46.8	12.5	53.2
1.4	57.9	12.2	42.1
1.5	65.5	11.8	34.5
1.6	65.5	11.5	27.5
1.7	72.5	11.3	17.6
1.8	82.4	11.1	17.6
1.9	82.4	11.1	17.6

3. Results And Discussions:

In the present research the run of mine (ROM) Salt Range coal is the feedstock. Coal sample was initially crushed and then screened into different particle size such as 10, 60, 100, 140 and 200 mesh. The samples of different particle size were studied by changing the operating parameters of float and sink analysis and optimum results were observed at which maximum yield was obtained.

3.1 Proximate Analysis of Salt Range Coal:

In proximate analysis the coal sample of particle size 60 mesh and one gram was placed in Muffle Furnace which has maximum temperature range 1200 °C results have shown in following table-2.

Table-2: Proximate Analysis of Salt Range Coal

Parameters	Experimental Values	Reference Values [11]
Moisture (%)	4.9	3.2-10.8
Volatile Matter (%)	23.3	21.5-38.8
Ash Contents (%)	36.3	12.3-44.2
Fixed Carbon (%)	35.3	25.7-44.8
Heating Value (Btu/lb)	10,570	9472-15,801

3.2 Moisture Content:

Analytical techniques are used to measure the properties of the coal. It is very important to determine that for what purpose coal is being used such as for coking, electricity production and steel manufacturing etc. As we know that when coal is mined it contains moisture contents. There are two types of moisture. (i) Inherent moisture (ii) Free moisture Inherent moisture is a type of moisture which penetrates through the structure of coal it is difficult to remove the inherent moisture from the coal by using conventional method. Another type of moisture is free moisture which is available outside at the external surface of the coal and it is easy to remove as it exposed to the environment. The percentage of moisture contents varies as geological structure, age, location and other condition varies. When coal is transported from mine to the plant some part of moisture may be evaporated. The moisture content will vary from location to location for the same coal as when and where it is being used. The amount of moisture will decide that how much heat is required to dry the coal before feeding to the furnace in the power plant.

A very important parameter for the coal mining is moisture all the mined coal are wet as it received from the mine. Environmental condition and ground water are the main sources of moisture in the coal. Moisture presence in the coal will increase the transport cost and lower the efficiency of the combustion process. That is why it is very important to remove moisture from the mined coal before its effective use. Coal sample was placed in the furnace at 105 °C for 1 hour. After that moisture is being calculated by loss of mass and 4.90 % moisture was found in the coal sample.[12]

3.3 Volatile Matter

Volatile matters are considered as a part of coal which released at high temperature when oxygen is not present. Presence of volatile matters in the coal is not considered good as it directly influence on the rank of towards decreases. It usually contains mixtures of water, carbon dioxide, fixed carbon, aromatics and hydrocarbons. In the applications of activated carbon volatile matters are very important. It can be calculated by using ISO standard which elaborate that coal sample was placed in muffle furnace closed with cover heating at 950 °C for exactly 7 minutes and 23.34 % volatile matters of coal were calculated. Volatile matters have important aspects as the formation of product, comparatively experimental value below from reference value that is why not effected the calorific value, if value is high then dual parameters would be refer to control.[13]

3.4 Ash Content:

Ash contents represent the quality of coal; presence of ash contents in the coal is not desirable at all as ash content in the coal increases the quality of coal decreases. Ash content in the coal is due to the presence of mineral matters as mineral matter in coal increases ash content also increases. Ash produced as a result of combustion when coal is burnt. There are two types of ash one is fly ash and second is bottom ash. Bottom ash can be directly disposed off and fly ash is treated before disposing off. It can be calculated on air dry basis or on oven dry basis. Salt Range coal has high ash content which decreases the calorific value of coal. Ash mainly consists of oxides which melt at high temperature. Coal sample was placed in the furnace and heated at 750 °C for four hours and 36.68 % ash contents were calculated in the ROM Salt Range Coal. This is the main reason that I have selected Salt Range coal because it has high ash contents due to which it is not suitable for power generation. Ash

exist in form of fly and bottom ash, fly ash obtained after the processing, but in present case bottom ash exist which is under consideration to mitigate into the lowest level. [14, 15]

3.5 Fixed Carbon

Fixed carbon obtained from the proximate analysis of coal sample which is 35.35 %. As the amount of fixed carbon in the coal increases the calorific value also increases. When fixed carbon in the coal is low then coal rank is categorized according to heating value of coal. It indicates the rank of coal. Proximate analysis of salt range coal is given in table-2. Fixed carbon contents exist in two types, bound and surface carbon. The bound carbon need substantial amount of energy to convert into useful product. On the contrary the carbon contents on the surface of coal no more energy required to convert them into desired products. Initially surface carbon formed the undesired product such as carbon oxides and carbon with sulfur. [16]

3.6 Calorific Value

Calorific value is defined as the amount of heat liberated by the combustion of unit mass of fuel. It expressed in terms of kJ/kg or Btu/lb. Calorific value is the indicator of coal which indicates the grade of coal if coal has high calorific value then its quality will be high. The cost of high calorific value coal will be high as compared other types of coal. There are two types of calorific value one is known as high calorific value and second is known as low calorific value [17]. As we know that moisture is present in the coal when we burn the coal heat released and water vapor evaporates if all products of combustion and water vapor condensed then this is called high calorific value if Products of combustion condensed except water vapor then this are called low heating value. Coal is used as a fuel in the power production. The amount of coal used in the power plant for the production of electricity per hour will be determined by the calorific value if coal has high calorific value then low quantity of coal will be used for the same duty. The bomb calorimeter is used to calculate the calorific value of the coal. Coal sample is placed in the crucible of bomb calorimeter. 6 volt battery is connected with electrodes and current is flowing through circuit. The combustion will start initially temperature is noted and heat released will increase the temperature of water and again temperature is noted and calorific value is recorded. The calorific value of Salt Range coal was calculated as 10,570 Btu/lb. [18]

3.7 Effect of Operating Parameters on Yield of Clean Coal

Settling time is the most important parameters in coal washability by float and sink analysis. In float and sink analysis coal sample of particle size 60 mesh number was placed in the aqueous solution of $ZnCl_2$ having 1.8 specific gravity. was settled for different time then float fraction and sink fraction were separated. It is clear from the experiment that the maximum float fraction was it obtained at 20 hrs but optimum float fraction was obtained at 16 hrs because there is minute change in the float fraction after 16 hrs settling time. After performing the experiment it was observed that as we increased the settling time float fraction percentage also increased then a point came when it became constant as shown in the fig.1.

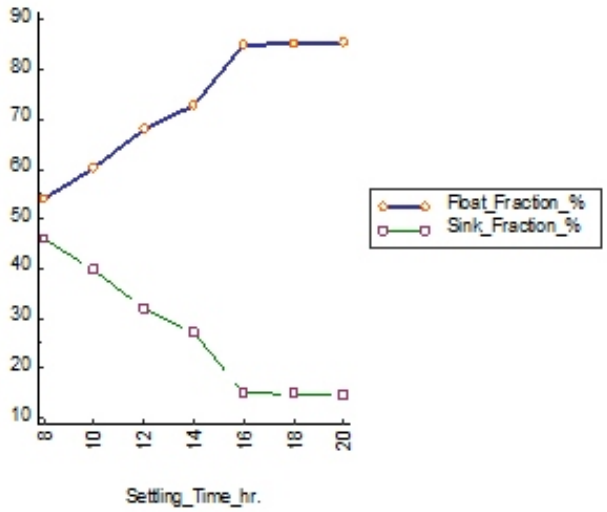

Figure 1: Settling time vs float/sink fraction

3.8 Effect of Specific Gravity on Float Fraction:

The aqueous solution of $ZnCl_2$ having different specific gravity such as 1.2, 1.3, 1.4, 1.5,

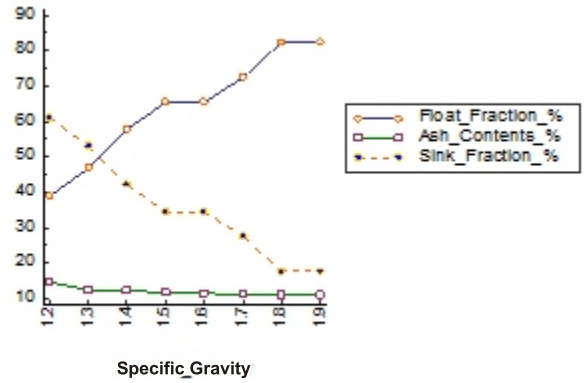

Figure 2: Specific gravity vs float/sink and ash fraction

1.6, 1.7, 1.8 and 1.9 was prepared at different specific gravity. It was observed from the results that maximum float fraction of washed coal was obtained at 1.8. This shows that impurities of salt range coal having density less than 1.8 sink down and clean coal particles have density greater than 1.8 moved in upward direction. Experiments were performed float and sink fraction separated out at different specific gravity then it was dried in the oven at 105 °C for one hr and weight of float fraction was measured by using balance.

Samples of different specific gravity were placed in muffle furnace and heated up to 750 °C for four hrs then ash contents of salt range coal having different specific gravity was calculated. It was observed from the experiments that minimum ash contents 11.1 % of washed coal found at 1.8 specific gravity. It is clear from the graph that as we increased the specific gravity of solution ash content of coal decreased as shown in the fig.2.

3.9 Effect of Particle Size on Float Fraction

Salt Range coal samples of different particle size such as 10, 60, 100, 140, and 200 mesh numbers were prepared. Float and sink test was performed against the different particle size having other parameters remains constant. Float fractions were separated out small coal particles floated and larger particles settled down. The maximum float fraction 86.1 % was separated at 60 mesh number particles as shown in the fig.3.

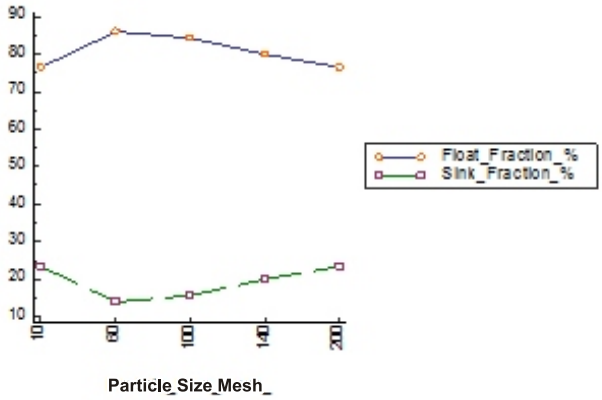

Figure 3: Particle size vs float/sink and sink fraction

4. Conclusion:

The maximum product of clean coal is 82.4% at relative density of 1.8.The yield of clean coal increases as the settling time increases but the optimum yield is 85.1% at settling time of 16 hr. The maximum yield of clean coal 86.1% is obtained at particle size of 60 meshes. The lowest ash content of clean coal 11.1% is obtained at specific gravity of 1.8.

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