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Factors Influencing the Performance of Coal Briquettes

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Abstract

The continuous supply of energy resources is essential for the development of any nation. The economic and social life of any nation depends enormously on the energy resources. Over the past few years the energy crisis is becoming a major issue in developing countries as Pakistan. Oil, Natural gas and hydro are the three major energy resources of the Pakistan. These conventional energy resources were being exploited in the past leading to an issue of energy crisis in the country. Replacing expensive imported energy resources with coal briquettes made from indigenous coal reserves can provide fuel for the local residential and commercial markets. Coal briquettes formation is a process to convert coal powder into a specific shape with the help of a binder. An external force is applied to the coal binder mixture to make a firm body of desired shape. The briquettes formed this way will not disintegrate under normal conditions of transportation and use. Coal briquettes are preferred over raw coal because they are a smokeless, strong and low emissive fuel that can be used in numerous domestic and commercial applications. The performance of coal briquettes formed is dependent largely upon its thermal properties and the mechanical strength. Nowadays an environmentally safe briquettes formation process is also included in the performance criteria of coal briquettes. The mechanical strength of coal briquettes affects its storage and transportation to the intended market. The studies on coal briquettes show that coal briquettes quality depends on many factors like the type of binder, quantity of binder, grade of coal, moisture level, coal particle size and its distribution etc. These factors along with some of the factors as time of compaction, compaction temperature, and compaction pressure and moisture level are discussed in this paper to evaluate the performance of briquetting technology in future.

Keywords: Coal briquettes, strength of coal briquettes, binders, alternative energy source

Introduction

It is definite that energy is an essential need of humanity. The development of any country can be measured by its energy consumption. Coal is an essential energy source. Most of the developed countries of the world have utilized their coal sources for industrial development in the 19th century. Coal is still an important energy source and can replace conventional fuel sources like petroleum and natural gas to meet the current rise in energy demand [1]. Coal is present abundantly in the world, it is estimated that 2.870 million tones (~700 million tonnes of crude oil equivalent) of proven coal reserves are currently available in the world [2]. The present energy crisis can be contained by harnessing the power of indigenous coal reserves.

The use of raw coal for industrial and power generation is being used throughout the world particularly in developing countries. However the handling and burning of raw coal for domestic, light industrial and commercial applications poses a challenging problem mainly due to its high ignition temperature, varying coal quality, ash, particle emission, and smoke generation. Also using raw coal emits harmful greenhouse gases which are offensive and is a major contributor towards the environmental pollution [3,4]. In addition the raw coal in the process of mining, transportation, and handling and on exposure to the weather is prone to disintegration. The amount of disintegrated coal and/or flakes form a considerable percentage of the mined coal in comparison to lumped coal and are sold at considerably low rates. However, by briquetting and carbonizing if required, coal can be converted into a comparatively clean, condensed, and stable form to use. The resultant fuel is also inexpensive. The use of coal briquettes and improved performance stoves are encouraged in the developing world especially in countries where coal is found in abundance in comparison to other fuel sources [5]. The environmental and health impact that result due to the low efficiency burning of raw coal can be addressed by using coal briquettes [6], also the conversion of flaked coal into briquettes upgrades the value and is often sold at greater prices than that for lumped coal.

Coal briquettes in Pakistan

In the last few years an energy shortage has been faced by many developing countries especially Pakistan. The use of conventional fuels like animal dung, wood and charcoal are extensively used in rural areas of many developing countries. In Pakistan they are also used for cooking, heating and other purposes. These conventional fuels can be easily replaced by coal briquettes. The use of coal and coal products are also useful for developing countries like Pakistan because firewood and charcoal use in Pakistan has led to extensive deforestation. The country has rich resources of low ranked indigenous coal which can be utilized in the form of coal briquettes to heat the residential, commercial, and industrial space and processes [7].

Gammage *et al*. [8] studied the burning characteristics of different fuels used in Pakistan. Comparison of different fuels and coal briquettes was conducted on a typical indoor stove in-use in Pakistan. The results depicted that coal briquettes emit less harmful gases as compared to raw coal and other conventional fuels. Glenn highlighted the social acceptance of coal briquettes in the Pakistani domestic market. He suggested that coal briquettes can easily replace the traditional wood burning in the urban areas of Punjab and NWFP (now KPK) [8]. However, the acceptance of coal briquette burning in the industrial sector was welcomed with little hesitation indicating for a slow adoption in this sector [8]. Burring characteristics of coal briquettes such as ignition temperature, steady state burning, smoke and ash content along with non-burning characteristics such as mechanical strength and moisture resistance will affect the adoption in the domestic and industrial markets.

Strength of coal briquettes

Mechanical strength of prepared coal briquettes affects its storage and transportation to the intended market. The studies show that the strength of coal briquettes depends on many factors such as moisture content, coal particle size and its distribution, time of compaction, compaction temperature and pressure, binder type and amount and grade of coal etc. Among these factors it can be shown from the experimental work that the compressive strength of briquettes is greatly affected by the amount of binder, curing temperature, size of coal, a type of coal and the ash content on burning. Parameters like moisture content, briquetting pressure and time for briquetting does not affect the briquetting strength significantly [9]. The work on these factors that affect coal briquette strength are discussed below.

Size and shape of coal briquettes

The size of the coal powder affects the mechanical properties of coal briquettes. Berkowitz and Gregory in their studies found that the coal particle size and its distribution affect the strength of coal briquettes. They showed that the strength of coal briquettes decreases with an increase in particle size [10,11]. The durability of coal briquettes is enhanced when fine coal powder is used for making briquettes [12].

The size and shape of resulting coal briquettes also affect the product strength. The size and shape affect was studied by applying stress on cylindrical and pillow shaped briquettes. The results showed that the pillow shaped briquettes are stronger than the cylindrical shaped briquettes because there was a density difference cylindrical shape briquettes with maximum density in the upper portion of the briquettes [13]. The size of briquettes and position of stress applied on pillow shaped briquettes does not affect its strength significantly. The experiments on cylindrical briquettes showed that the dimensions of briquettes and the position of the applied stress define the strength of coal briquettes [13].

Curing temperature

The heat treatment and the temperature also affect the coal briquettes quality. Blesa *et al*. [14] looked into the mechanical characteristics of heat cured coal briquettes made from molasses and suggested that curing brings a uniform morphology to the resulting structures. Blesa *et al*. [14] also verified that low rank coal after pyrolysis can be used for producing high strength briquettes. The favorable temperature of pyrolysis was 600 °C in their work. The briquettes formed this way showed a higher calorific value and lower volatile matter upon combustion. The mechanical properties like strength and water resistance of fuel were also enhanced by heat treatment. The strength of heat cured briquettes can further be increased by the high temperature carbonization process. As the temperature of carbonization increases so does the strength but it makes the process uneconomical. So high temperature carbonization processes should only be followed when the strongest briquettes are required [15].

Compaction pressure

Moreover Gregory observed that briquette density is directly related to the pressure applied during the formation of coal briquettes. The maximum density can be obtained by applying pressure up to 150 MPa [11,16]. Miller recognized that abrasion resistance and density of coal briquettes increases largely up to pressure of 70 MPa further increasing the pressure only slightly increases the density and abrasion resistance [16].

Grade of coal

The importance of the type of coal used for coal briquetting can be assessed by the experimental work of Moghaddam *et al.* Bituminous coal fines from three different fields were used for their work. The results showed that the type of coal affects the compressive strength and water resistance of coal briquettes. The quantity of mineral matter present in different amounts in various types of coal is the cause of this behavior [17]. Burchill *et al*. [18] demonstrated that the difference in the surface and bulk compositions of the coal briquettes causes the deposition of large mineral content at some points and the formation of microscopic pores in the whole structure. Some other factors like refining, mining process and the physical properties of the coal also create minute spaces in coal. The deposition of mineral matter and pores weakens the structure of briquettes and the resulting briquettes break under stress.

Moisture content and the time of compaction

Berkowitz showed that coal briquettes can be formed easily by the addition of water up to a certain optimum value [10]. Gregory revealed that optimum moisture content required for making high strength coal briquettes is between 50 to 100 percent of the actual moisture content found in the coal. Water helps to increase the strength of coal briquettes because water increases the adhesive forces of coal particles and decreases the free surface energy of coal particles. Rapid compaction can be done only if the optimum moisture content is provided [11]. On the other hand the amount of water added during briquettes formation affects the drying time and the drying mechanism of the coal briquettes. So the cost of the product is increased because of the extra effort required for the drying process. Gunnink and Li suggested that the required briquettes strength can be achieved if the time of compaction is increased instead of increasing the moisture content [19]. The time required for briquetting is an important parameter for coal briquettes strength [10]. Miller observed that increasing duration of compaction significantly increases the strength of coal briquettes [16].

Binder selection

Altun *et al*. [20] looked into the burning characteristics of coal briquettes from a combustion kinetics point of view. They suggested that coal briquettes ignition efficiency and effectiveness of combustion reaction was considerably dependent on the binder type, amount of binder agent and water addition. Coal tar pitch and petroleum residues are the common binders used for the coal briquetting process. These binders give high strength briquettes but they have a hazardous effect on human beings and are also involved in environmental pollution. Environmentally safe binders like molasses etc. gave briquettes of comparatively low strength. Mehmet and Gulhan showed that using humic acid as a binder can solve these problems to some extent. In their work the optimum conditions required for high strength briquettes were found to be heat treatment of 1 h at 165 °C, 5 % humic acid as a binder and a moisture content of 10.50 % [21].

The type of binder used for making coal briquettes not only affects the strength but also has an effect on the burning properties of coal briquettes. Altun *et al*. [22] studied the burning properties of coal briquettes by using different binders. They used different binders like molasses, sulfide liquor, sodium silicate, corn starch, lime, peridur, polyvinyl acetate, bentonite and carboxyl methylcellulose. The results of revealed that the heating value of briquettes is increased by using binders of sulfide liquor, corn starch and heavy crude oil while the molasses and carboxyl methylcellulose decreased the ash content of briquettes on burning [22].

The cost of the binder is another important parameter in binder selection for the briquetting process. Taulbee performed an economical and technical investigation of briquettes by using different binders in combination with the coal and saw dust. Out of the 50 binders used for briquette making, guar gum, wheat starch and lignosulfate (lime) were found to be the most cost effective binders [9]. Ellison and Stanmore have looked into producing high mechanical strength coal briquettes without the addition of any binder [23].

Briquettes with reduced emissions

The combustion of all types of coal produces CO_2 emissions and other hazardous gases like SO_2 etc. The use of high grade coal such as anthracite coal for briquette makes an environmentally friendly fuel. The anthracite coal is a naturally occurring clean fuel but the cost and limited reserves of anthracite coal restricts its use for the briquette formation. Environmentally safe briquettes can be produced by applying various techniques during manufacturing. De-volatilisation is the most common technique applied for producing low smoke briquettes. De-volatilization can be done by a heat treatment process involving the inclusion of chemicals like calcium hydroxides. Heat treatment and additives decrease the emissions of harmful gases by fixing the sulfur and nitrogen content in the coal [14]. Novel techniques used for the reduction of pollutants in the air is the utilization of biomass in combination with coal to make bio-coal briquettes [24]. Biomasses are naturally occurring organic materials that help to complete the combustion of the coal with liberation of less poisonous gases [24]. Large amounts of fine coal powder are made from coal cleaning and other coal processing. These fine coal powders can be combined with agricultural waste like exhausted mushrooms for making environmentally safe briquettes [25].

Conclusions

In light of the above it can be concluded that future compositions of coal briquettes should have their combustion and mechanical strength properties investigated. The desired result of better quality briquettes includes high calorific value, ease of burning, high mechanical strength, low ignition temperature and less ash and smoke emission. This research work looks into the factors that influence the above stated properties of coal briquettes. The results show that briquettes performance is greatly affected by the amount of binder, curing temperature, size of coal, type of coal and ash content on burning, while the briquetting quality is not significantly affected by parameters like moisture content, briquetting pressure and time.

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