Evaluation of Optimum Composition of Starch as a Binding Material for Square Coal Briquettes

Muhammad Babar[1], Mansoor Ul Hassan Shah[2]

[1, 2]University of Engineering and Technology Peshawar, Pakistan

Abstract: ***Various coal samples from Darra Adam Khel (KPK province of Pakistan) region were collected for making the square shaped coal briquettes. Starch solutions of different concentrations were used as organic binding material. Coal briquettes were made using an indigenously designed and fabricated lab scale apparatus. Firstly the calorific values of these coal briquettes were evaluated using Bomb calorimeter. The strength of the prepared samples was analyzed by compression test carried out by Universal Testing Machine (UTM) respectively. This resulted in data generation for determining strength of these briquettes. The set of results obtained for these square coal briquettes were then compared among themselves to find the optimum performance value of starch solution as a binding material. The results in terms of strength and combustion calculation of this research work will help in gaining concentration of implementing bodies for application on a pilot scale. This project is aimed to reduce load on the current trend of extensive deforestation by providing an alternative energy source. Proper utilization of this project will help our country in overcoming current energy crisis.***

Keywords: Coal briquettes, starch solution, binding materials.

1. Introduction

Energy crisis is one of the major problems throughout the world. In the 20th century it has reached the alarming situation. The energy problem can be solved by utilizing different energy sources. Like other countries Pakistan is also a victim of energy crisis. The present research work is an effort to find out any possible solution for the energy shortage. The economic value of coal deposits in Pakistan was highlighted in 1980 when large reserves of coal were discovered in the Sind Province. The total coal resources of Sind have been estimated to 184.6 billion tones. The total coal reserves of Baluchistan are about 217 million Tones. The total coal resources of Punjab are estimated to be 235 million tones. The coalfields of KPK are not yet fully explored. The total coal resources of AJK are estimated at 0.06 million tones. Pakistan is now the 2nd richest nation of the world in respect of coal resources [1].

Coal resources of Pakistan are estimated to be 185.5 billion tones [2]. "Pakistan has sufficient coal reserves which can be utilized to produce electricity and gas, for 700 to 800 hundred years [3]. Coal gasification was already producing 50,000 MW around the world, as the cost of electricity per unit is relatively low [4]. The energy problem of Pakistan can be solved by using only few percent of these coal reserves. There are two main ways of utilization of coal. One is the coal gasification and coal briquetting. The present work is only about coal briquetting.

For improving the coal ranking, ease of combustion, ease of transportation and increasing its efficiency coal briquettes are made. The manufacturing of coal briquettes is aimed to increase the surface area of coal available for combustion. Coal is a cheap fuel because of its abundant reserves, but it emits harmful gases and particulates, leaves ash when it burns, and contaminates the environment during transportation. It is also hard to ignite as compared to gas or petrol fuels. Since long time people all over the world are trying to overcome these problems and to make it convenient and clean fuel. There are two main ways of utilization of coal. One is the coal Briquetting and the other is coal gasification. The later one requires large scale factory, big investment and may produce secondary pollution. Briquetting is receiving high attention in developing countries where oil and gas are scarce and wood fuel supply is diminishing.

2. Literature Survey

Several attempts have been reported from time to time regarding the selection of binders and its cost in the manufacturing of coal briquettes. Early research in this regard suggests the use of different types of pitch which includes coal-tar and petroleum. Coal-tar is considered to be the most economical however the later is the best for consolidating small coal into a coherent form. Mehmat et al. (1997) reported Production of Ammonium Nitro Humate. They also proposed its use in coal briquetting as a binding material. Aluminum hydroxide and lignite are used to produce cheap Ammonium Nitro Humate. Experimental work of Mehmat and Gulhan showed that Ammonium Nitro Humate possesses good binding properties and can be used as a binding agent for making coal briquettes. The author focused the effect of the proposed binder on the mechanical strength only however its effect on thermal properties was not discussed [5]. An increase in pitch content within the range tested (10–25 wt %) improves significantly the impact and compressive resistance of the briquettes. Whatever the amount of pitch used, the mechanical resistance of the briquettes decreases during burning. In both cases (before and after activation) the mechanical resistance of the briquettes depends on the starting char and the pitch content used [6].

Berowitz (2002) reported that practical size of raw material has a great influence over the mechanical strength of coal briquettes. From his experimental work he showed that the mechanical strength is inversely related to particles size of raw coal i-e greater the size lower will be the strength and vice versa. The increase in strength using raw material of small particles is due to low porosity and high cohesive power [7]. Taylor (1988) proposed the use of pitch as a binding material for making coal briquettes. Their experimental work showed that mechanical properties of briquettes can be determined by the binder used. Clark and Marsh proved that the use of pitch as a binding agent can affect the characteristics of pores of the coal briquettes i-e pore size, pore shape etc. and hence affect the mechanical strength of the coal briquettes [8]. Thomas (1999) reported that resins can also be used as a binding material. The author first noticed the synthesis of resin and their use as a binding material. He showed that low temperature carbonization of coal oil produces a mixture of alkyl substituted phenols, which can further be used for producing resole. Author used resole solutions of different compositions i-e 7-10% and showed that briquettes having low concentration of binding material have much more better combustion performance. They also observed that the briquettes retain their shape even up to 70% weight loss [9].

3. Problem Statement

To overcome the energy problems in the modern world the expertise decided to take benefit from the coal reserves. There were many problems in using simple coal. Therefore some technologies like coal gasification and coal briquetting were discovered for the ease of combustion. Due to extensive use of coal briquetting technology different attempts were made to make some advancement it this field. Low strength is one of the major problems observed in the existing coal briquette designs. This research is an attempt to minimize the strength problems as much as possible.

The main objective of this study is to utilize the power of coal efficiently, to reduce the energy shortfall and the combustion problems which are observed in the existing coal briquettes. This research work also helps to investigate the strength using starch solution of different concentration as a binding material, and to find the optimum concentration of starch solution for the square coal briquettes.

4. Materials and Methods

In this research work coal of Darra Adam Khel region of Khyber PukhtoonKhwa province was under consideration. Binder selected for making the square shaped coal briquettes is starch solution of different composition. Coal samples were taken from Darra Adam Khel to make the square shaped coal briquettes. First we passed the raw coal through proximate analysis to find out the Moisture level, Volatile matter, Ash content, Fixed Carbon, and Calorific value. Table 1 shows the result of proximate analysis.

Coal sample	**Darra Adam Khel**
Moisture level (%)	1.10
Volatile matter (%)	10.66
Ash content (%)	19.2
Fixed Carbon content (%)	69.02
Calorific value	29840

Table 1: Proximate analysis of raw coal

Briquettes were then manufactured from each sample of the coal.

Figure 1 show the steps involved in the briquetting process.

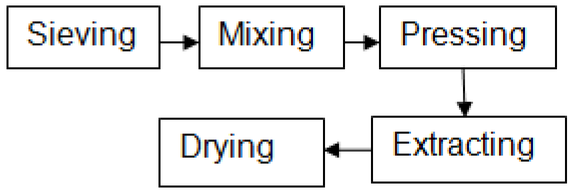

Figure 1: Briquetting process steps

In the first step the raw coal was screened in order to remove coarse particles. Five samples each of mass 800 grams were then taken for making the square shaped coal briquettes. Starch solutions having different concentrations were then thoroughly mixed with the screened coal samples. The mixed material is then put into the square mould of the locally designed equipment and pressed with the help of the upper lever. The coal briquettes so made were then extracted by the lower lever. The briquettes are then allowed to dry. Table2 shows the coal briquettes specifications.

Briquette No.	Coal Mass(gm)	Solvent(ml) (Water)	Starch mass(gm)
1st	800	250	10
2nd	800	250	15
3rd	800	250	20
4th	800	250	25
5th	800	250	30

Table 2: Coal briquettes specification

Surface Area of the square coal briquettes were 16in^2 having each dimensions equal to 4inches. Nine circular holes each having diameter equal to 0.5 inches is left in the coal briquettes for primary air. The equipment used for the coal briquettes is shown in figure 2.

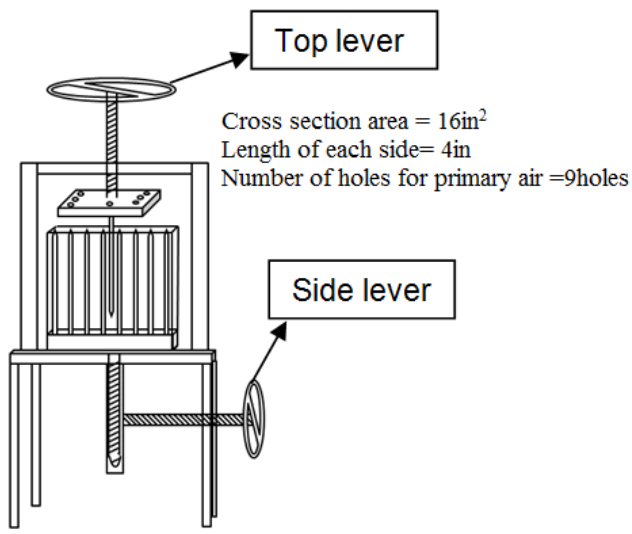

Figure 2: Designed coal briquetting equipment

The top lever is used for pressing the mixed material in the mould, while the side lever issued for extracting the coal briquette from the mould. Then the square coal briquettes prepared by the above mentioned equipment was then passed through Calorific value test, Compression test (UTM) in order to determine their strength. The result obtained for calorific value and strength were noted for the square shaped coal briquettes having different concentration of starch binder. The results obtained for these different binder dilutions were then compared among themselves in order to select an optimum concentration of starch solution.

5. Results and Discussions

After passing the prepared coal briquettes samples through calorific value test through bomb calorimeter the following results were obtained.

Briquette Sample	*Calorific Value (J)*
Sample 1	27893
Sample 2	26268
Sample 3	30463
Sample 4	22251
Sample 5	28354

Table 3: Calorific value results

When the coal briquette sample one having composition 800gm coal, 250 ml solvent, and 10gm starch was combusted completely in the bomb calorimeter it was found that it has the calorific value of 27893 J. When the same test was repeated for sample no.2 having composition 800gm coal, 250 ml solvent, and 15gm starch, its calorific value was found 26268. Sample no.3 containing 20gm of starch and same amount of coal and solvent has the highest value of calorific value which was 30463.

After increasing the amount of starch in the binder solution it was found that the calorific value started decreasing. The calorific values obtained for the sample no.4 and sample no.5 having 25gm and 30gm of starch in the binder solution, was 22251J and 28354J respectively.

From the above results of the calorific value we suggest that the sample no.3 having composition "800gm coal, 250 ml solvent, and 15gm starch" has the highest value and hence it is the optimum value of starch for calorific value. For calculating the strength of the prepared coal briquettes, these briquettes were passed through Compression test a in the Centralized Resource laboratory (CRL) University of Peshawar the following results are obtained.

Table 4 shows the results of area, diameter, energy, stress, strain and young modulus obtained from the UTM analysis of the sample no.1 of the square shaped coal briquette. From the table we observe that the value of stress at the break point is 0.0776N/mm^2, at peak point it is 0.1311 N/mm^2 while at the yield point it is 0.0775 N/mm^2. Deformation produced by this stress is known as strain. The strain at the break point is 10.800, while at peak it is 5.9753 and at yield point it is 1.2974.

Area (mm^2)	100
Def @ break (mm)	8.3160
Def @ Peak (mm)	4.6010
Def @ Yield(mm)	0.9990
Dia (mm)	101.00
Energy @ break (N.m)	8.3113
Energy@ peak (N.m)	4.3052
Energy @ yield (N.m)	0.4676
ISO 9969Ring stiffness (N/mm^2)	0.0704
Load @ Break (N)	792.00
Load @ Peak (N)	1337.0
Load @ yield (N.)	791.00
Outer Diameter (mm)	101
Strain @ break (%)	10.800
Strain @ peak (%)	5.9753
Strain @ yield (%)	1.2974
Stress @ break (N/mm^2)	0.0776
Stress @ peak (N/mm^2)	0.1311
Stress @ yield (N/mm^2)	0.0775
Young's modulus (N/mm^2)	5.0401

Table 4: UTM result for sample no.1

The load on the briquette at the break point was 917N. When the load on the briquette was increased up to 1890N cracks appeared in the briquette further more with a small change of load the deformation was greater and at yield point the value of load was 703N.

Table 5 displays the results of area, diameter, energy, stress, strain and young modulus obtained from the UTM study of the sample no.2 of the square shaped coal briquette. From the table we can see that the value of stress at the break point is 0.0899N/mm^2, at peak point it is 0.1853 N/mm^2 while at the yield point it is 0.0689N/mm^2.

Area (mm^2)	101
Def @ break (mm)	9.7030
Def @ Peak (mm)	5.0000
Def @ Yield(mm)	2.6900
Dia (mm)	101.00
Energy @ break (N.m)	10.357
Energy@ peak (N.m)	3.7024
Energy @ yield (N.m)	0.6787
ISO 9969Ring stiffness (N/mm^2)	0.0560
Load @ Break (N)	917.00
Load @ Peak (N)	1890.0
Load @ yield (N.)	703.00
Outer Diameter (mm)	101.00
Strain @ break (%)	12.601
Strain @ peak (%)	6.4935
Strain @ yield (%)	3.4935
Stress @ break (N/mm^2)	0.0899
Stress @ peak (N/mm^2)	0.1853
Stress @ yield (N/mm^2)	0.0689
Young's modulus (N/mm^2)	3.6284

Table 5: UTM result for sample no.2

Deformation produced by this stress is known as strain. The strain at the break point is 12.601, while at peak it is 6.4935 and at yield point it is 3.4935. The ratio of stress to strain i.e. young modulus for the given data is found to be 3.6284 N/mm^2.

UTM analysis of the sample no.3 of the square shaped coal briquette is shown in Table 4.4.The load on the briquette at the break point was 3915N. When the load on the briquette was increased up to 4503N cracks appeared in the briquette further more with a small change of load the deformation was greater and at yield point the value of load was 901N. From the table we can see that the value of stress at the break point is 0.3838N/mm^2, at peak point it is 0.4414N/mm^2 while at the yield point it is 0.0883N/mm^2.

Deformation produced by this stress is known as strain. The strain at the break point is 6.8613, while at peak it is 3.7950 and at yield point it is 0.3913. The ratio of stress to strain i.e. young modulus for the given data is found to be 21.610 N/mm^2.

Area (mm^2)	101.00
Def @ break (mm)	5.4890
Def @ Peak (mm)	3.0360
Def @ Yield(mm)	0.3130
Dia (mm)	101.00
Energy @ break (N.m)	19.456
Energy@ peak (N.m)	9.1203
Energy @ yield (N.m)	0.1575
ISO 9969Ring stiffness (N/mm^2)	0.2838
Load @ Break (N)	3915.0
Load @ Peak (N)	4503.0
Load @ yield (N.)	901.00
Outer Diameter (mm)	101.00
Strain @ break (%)	6.8613
Strain @ peak (%)	3.7950
Strain @ yield (%)	0.3913
Stress @ break (N/mm^2)	0.3838
Stress @ peak (N/mm^2)	0.4414
Stress @ yield (N/mm^2)	0.0883
Young's modulus (N/mm^2)	21.610

Table 6: UTM result for sample no.3

Table 7 shows the results obtained from the UTM analysis of the sample no.4 of the square shaped coal briquette. The load on the briquette at the break point was 3029N. When the load on the briquette was increased up to 4457N cracks appeared in the briquette further more with a small change of load the deformation was greater and at yield point the value of load was 1464N.

Area (mm^2)	101.00
Def @ break (mm)	14.311
Def @ Peak (mm)	4.5420
Def @ Yield(mm)	0.3130
Dia (mm)	101.00
Energy @ break (N.m)	46.214
Energy@ peak (N.m)	9.6639
Energy @ yield (N.m)	0.8522
ISO 9969Ring stiffness (N/mm^2)	0.1872
Load @ Break (N)	3029.0
Load @ Peak (N)	4457.0
Load @ yield (N)	1464.0
Outer Diameter (mm)	101.00
Strain @ break (%)	18.830
Strain @ peak (%)	5.9763
Strain @ yield (%)	2.2092
Stress @ break (N/mm^2)	0.2969
Stress @ peak (N/mm^2)	0.4369
Stress @ yield (N/mm^2)	0.1435
Young's modulus (N/mm^2)	10.744

Table 7: UTM result for sample no.4

From the table we can see that the value of stress at the break point is 0.2969 N/mm^2, at peak point it is 0.4369 N/mm^2 while at the yield point it is 0.1435N/mm^2. Deformation produced by this stress is known as strain. The strain at the break point is 18.830, while at peak it is 5.9763 and at yield point it is 2.2092. The ratio of stress to strain i.e. young modulus for the given data is found to be 10.744 N/mm^2.

Table 8 gives us the results of area, diameter, energy, stress, strain and young modulus obtained from the UTM analysis of the sample no.5 of the square shaped coal briquette. From the table we can see that the value of stress at the break point is 0.1274N/mm^2, at peak point it is 0.3652 while at the yield point it is 0.2594N/mm^2.

Area (mm^2)	100.00
Def @ break (mm)	8.0900
Def @ Peak (mm)	2.5290
Def @ Yield(mm)	0.8790
Dia (mm)	100.00
Energy @ break (N.m)	19.135
Energy@ peak (N.m)	7.1113
Energy @ yield (N.m)	1.7305
ISO 9969Ring stiffness (N/mm^2)	0.2215
Load @ Break (N)	1287.0
Load @ Peak (N)	3689.0
Load @ yield (N.)	2620.0
Outer Diameter (mm)	101.00
Strain @ break (%)	10.286
Strain @ peak (%)	3.2155
Strain @ yield (%)	1.1176
Stress @ break (N/mm^2)	0.1274
Stress @ peak (N/mm^2)	0.3652
Stress @ yield (N/mm^2)	0.2594
Young's modulus (N/mm^2)	99.528

Table 8: UTM result for sample no.5

Deformation produced by this stress is known as strain. The strain at the break point is 10.286, while at peak it is 3.2155 and at yield point it is 1.1176. The ratio of stress to strain i.e. young modulus for the given data is found to be 99.128 N/mm^2. The load on the briquette at the break point was 1287N. When the load on the briquette was increased up to 3689N cracks appeared in the briquette further more with a small change of load the deformation was greater and at yield point the value of load was 2620N.

Table 9 shows the comparison of the strength for the five samples of coal briquettes.

Briquette Sample	Strength (N)
First sample	1337
Second sample	1890
Third sample	4503
forth sample	4457
Fifth sample	3689

Table 9: Strength value comparisons

From the above comparison it is clear that third sample of coal briquette having composition "20gm starch + 250ml water + 800gm coal" has highest calorific value and highest strength.

6. Future Outcomes

- This project will help peoples in selecting suitable coal briquettes for their use as a replacement of oil and gas.
- This research work will provide a cheap and efficient source of energy for industrial and domestic use. Industries of National level like PTB (Pakistan Tobacco Board) and industries of Multinational level like PTC (Pakistan Tobacco Corporation) both will take benefit from this project by adopting this project for tobacco curing.
- In the same way the local barns and local factories could also be beneficialized by this project. Using the square coal briquettes will be helpful in drying purposes e.g. wood drying and fruits drying. It will also help in cooking and heating purpose.
- This project will also help in reducing global warming, and were improve the quality of our environment. From research point of view this project were also be helpful in comparing starch and other binders like PVA and Molasses; it were also be helpful in comparing different designs among themselves.

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Author Profile

Engineer Muhammad Babar has completed BSc Chemical engineering from University of Engineering and Technology Peshawar (Pakistan) in 2009. In his BSc he worked on the project under the title of “Designing & Evaluating a Solar Tobacco Barn”. In 2010 he started MS chemical engineering from the same university and in 2014 he completed his MS degree in chemical engineering. His area of research was coal briquettes. During his MS he worked on a project under the title “Evaluation of optimum concentration of starch solution as a binding material for square coal briquettes”. He has practical experience of working in process industries as well as teaching experience in different Universities and colleges.