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Effect of Heating Temperature on Quality Improvement of Lignite in the Process of Upgrading Brown Coal

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Abstract:- Lignite is known as low rank coal. As a result, it has less demand and limited in utilization. Because lignite has a low calorific value of combustion, high sulfur and water content, accordingly it is necessary improving the quality of that coal. One of the efforts that can be done is through the process of Upgrading Brown Coal (UBC) with a heating technique. This study aims to determine the effect of heating temperature on the UBC process conducted by using a solution of benzene and low sulfur wax residue (LSWR), so as to increase the minimum 50% lignite calorific value with inherent moisture content of a maximum of 5% and may decrease the value of volatile matter. Lignite with a particle size of 8 mesh are mixed with LSWR as additive and solution of benzene with a ratio of 1 g : 0.5 mL. Then, it was heated with heating temperature of 100ºC, 125ºC, 150ºC, 175ºC, 200ºC for 1 hour. Lignite that had been treated were then analyzed for parameters of inherent moisture, ash content, volatile matter, fixed carbon and calorific values. The analysis shows the heating temperature of 125ºC can produce coal with the highest improvement of calorific value namely 54.23% with a calorific value that is 5,735 cal/g, inherent moisture is 4.02%, ash content is 8.13%, volatile matter is 44.27% and a fixed carbon is 43,55%. This treatment can raise the rank of brown coal into sub-bituminous coal rank.

Keywords:- *Benzene; Brown Coal; Lignite; LSWR; Temperature; Upgrading.*

I. INTRODUCTION

British Petroleum has been released the report inform that the total low rank coal reserves (including brown coal) in Indonesia amounted to 10,878 million tons in 2018 [1].

The utilization of lignite (also called as brown coal) is still limited compared to the type of bituminous or anthracite coal because lignite has a low calorific value (less than 5,100 cal/g) also relative high sulfur and water content. Besides that this coal is also generally flammable when transporting or in stock-pile, so it is not easy to handle. As a result, this type of lignite coal cannot be sold or must be sold at very cheap prices. This is an example of lignite characteristics that obtained from coal mining in Samarinda city-Indonesia, i.e. calorific value is 4,789 kcal/kg, moisture content is 18.91%, fixed carbon content is 26.07%, ash content is 7.79%, and volatile matter content is 47.23% [2].

Upgrading Brown Coal (UBC) technology can be used to improve the quality of lignite. After the UBC process is implemented, the quality of lignite will increase equivalent to the sub-bituminous coal rank [3] or higher so that it can be used as a better fuel.

The Upgrading Brow Coal (UBC) process has been carried out with a variety of techniques. Dewatering method is one of upgraded brown coal (UBC) technology which has been developed by Kobeco steel since the early 1900s. In this method crushed lignite is dispersed in light oil containing heavy oil and then dewatering at temperature of 130 to 160ºC under a pressure of 400 to 450 kPa [4]. Zou et al. have developed multi-stage fluidized bed pyrolysis to upgrade lignite but this method still needed additional of excess heat, N_2, O_2 and steam to made partial gasification [5]. Meanwhile Feng et al. have used hydrothermal and thermal method to upgraded lignite which has high ash and volatile matter content with the result that increasing lignite fixed carbon content with the relatively high temperature thermal process namely 500ºC [6].

In this research, UBC technique was executed with mixing lignite and low sulfur wax residue (LSWR) which dissolved in benzene subsequently those materials simple heated at atmospheric pressure. Addition of benzene beneficial as substance to enhance moisture vaporizing and at the same time LSWR dissolved in benzene will covered the pore which formation due to evaporation of moisture from lignite. Usually it was used light oil such as kerosene to accelerate evaporation of moisture, but in this time used benzene to prevent increasing of volatile matter at the final product. Benzene more stable than light oil if heated at high temperature because it has cyclic structure meanwhile light oil only composed in straight chain structure.

There for it was necessary to investigate effect of heating temperature because pressure treatment under atmospheric condition and additional of benzene into lignite will effect on vapor pressure of water in lignite and influence the boiling temperature of water-benzene mixture.

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II. METHOD

Before experiencing UBC treatment, the lignite samples were analyzed its proximate parameters which included inherent moisture content (% M) analyzed by ASTM D-3173 method, ash content (% A) were analyzed by ASTM D-3174 method, volatile matter content (% VM) analyzed by the ASTM D-3175 method, the fixed carbon content (% C) calculated by formula

$$\% C = 100\% - \% M - \% A - \% VM \quad (1)$$

Meanwhile the calorific value was analyzed by the method of ASTM D-5865-10a.

Lignite samples, which obtained from coal mining in Samarinda City-Indonesia, were crushed and sieved to obtain a uniform size of ± 8 mesh. The UBC process was done by mixing a sample of 1 gram of lignite with 0.5 mL of additive (a mixture of LSWR-benzene with 1 : 0.005 volume ratio). The mixture was placed in a porcelain crucible, then heated in an oven at 100°C for 1 hour. So that the oven pressure is in the atmosphere, the air regulator button was set on the opening maximum. After being heated the sample was cooled in a desiccator and then the characteristics of the coal were analyzed as an analysis of the characteristics of the coal prior to the UBC treatment. The UBC process was carried out for other temperature variation namely, 125°C, 150°C, 175°C, and 200°C.

III. RESULT AND DISCUSSION

In this study the sample used was lignite with the results of the raw coal analysis can be seen in table 1.

Parameters [a]	**Value**
Inherent Moisture (%)	27.6917
Ash Content (%)	6.1082
Volatile Matter *(%)*	51.0483
Fixed Carbon *(%)*	15.1518
Calorific Value (cal/g)	3,718.68

Table 1:- Parameters Analysys of Lignite Raw Material

[a.]air dried basis

Based on table 1., it can be seen that the characteristics of coal before undergoing treatment are categorized as low rank coal or lignite (brown coal) because it has a calorific value of less than 5,100 cal/g, low fixed carbon content and high inherent moisture content. Therefore, it is necessary to improve the quality of lignite through a process (UBC) by adding additives in the form of LSWR mixture dissolved in benzene. Furthermore, the coal heating process is carried out at various temperature variations for one hour so as to improve the quality of lignite coal into coal which is equivalent to sub-bituminous coal type, as presented in table 2.

From the research results that presented in table 2. shows that heating at a temperature of 100°C to 125°C occured decreasing in the inherent moisture value. This is due to the addition of Low Sulfur Wax Residue (LSWR) which fills the void from the coal pores and coats the coal surface during the heating process. So that after the heating process, the bound water which was originally contained in the coal has been evaporated and the water contained in the surrounding air cannot re-enter then inherent moisture value increase again at temperature of 150°C to 200°C.

Parameters [a]	**Values at Various Temperature**				
	100°C	125°C	150°C	175°C	200°C
Inherent Moisture (%)	6.2356	4.0272	4.1271	4.2970	4.6995
Ash Content (%)	8.8200	8.1384	9.0546	8.8778	8.5266
Volatile Matter (%)	43.3894	44.2790	43.7685	43.8937	42.9957
Fixed Carbon (%)	41.5550	43.5554	43.0498	42.9315	43.7782
Calorific Value (cal/g)	5,379.85	5,735.42	5,707.22	5,623.91	5,608.51

Table 2:- Parameters Analysys of Lignite after UBC Treatment

[a.]air dried basis

However, at temperature variation of 150ºC to 200ºC the percentage of inherent moisture returns to rise, this is due to changes in the surface structure of coal which becomes smoother, so that LSWR which is an additive decomposes and is released due to overheating, making it easier for water that has been evaporated re-filling coal pores.

The percentage of ash content after the UBC process tends to increase compared to coal before the UBC process. The escalation ash content after the UBC process is caused the addition of additives which is a mixture of LSWR and benzene. The LSWR used contains 0.1% ash content [7] which can increase the ash content of coal processed. The results of this study indicate that the effect of heating temperature on the value of the obtained ash content does not indicate a fixed trend, however, the difference in the value of the ash content is not too high with a standard deviation of 0.3591. It can be said the value of ash content remains with an average value of 8.6835%.

From the results of the volatile matter (VM) analysis that shown in table 2., it can be seen that the VM value has decreased after the UBC process to around 41% -44% if compared with the initial coal VM, namely 51.0483% . The decrease in volatile matter is due to utilization of benzene as solvent which is a hydrocarbon compound with a cyclic-shaped molecular structure so that will be more difficult to degrade at high heating temperature, as consequence it does not increase the VM content of coal. The decrease in VM is also caused by the initial volatile matter contained in coal partly evaporated along with benzene and water during the heating process. The results of this study indicate that the effect of heating temperature on the value of volatile matter does not indicate a constant tendency, but the difference from the value of the volatile matter is not too high with a standard deviation of 0.4909. It can be said that the VM value is fixed with an average of 43.6650%.

The value of fixed carbon produced is strongly influenced by the decreasing of value of inherent moisture and also ash content as well as volatile matter, because the value of fixed carbon is not the result of analysis but the result of calculations.

The heating temperature affects the calorific value of coal. The results in table II., show that the highest calorific value occurs at 125ºC, but after heating temperature be increased at 150ºC to 200ºC the calorific value has decreased. It is caused by raise in moisture content again. The high inherent moisture content will cause some of the heat possessed by the coal to be used to evaporate the water contained and reduce the calorific value of the coal. Otherwise, if the inherent moisture value is low, then the heat used to evaporate the water is smaller so that the calorific value of the coal is higher. The calorific value at a temperature of 125ºC increased from 3,718 cal/g to 5,735 cal/g and is the highest calorific value obtained in this research.

The percentages of calorific value increasing are more than 50% at heating temperatures of 125ºC to 200ºC as figured from graph below.

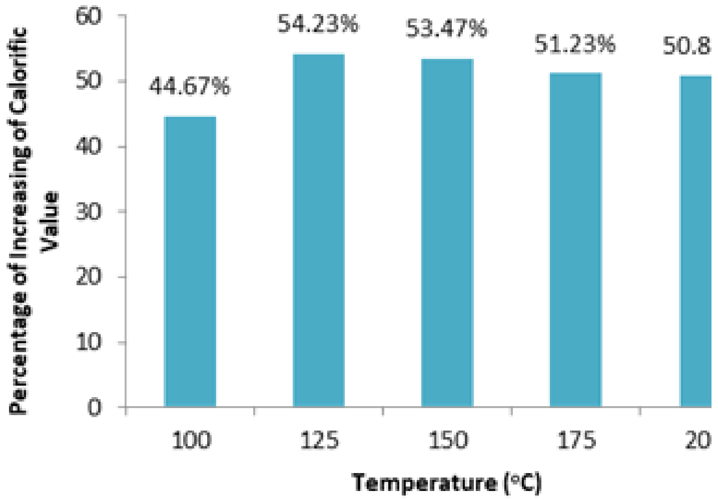

Fig 1:- Percentage of Calorific Value Increasing at Various of Heating Temperature.

IV. CONCLUSIONS

From the results of research conducted with variations in temperature of 100ºC, 125ºC, 150ºC, 175ºC and 200ºC can be concluded as follows:

- At the heating temperature of 125ºC, obtained coal with the highest calorific value, which is 5,735 cal/g with inherent moisture content of 4.02%, ash content of 8.13%, volatile matter 44.27% and fixed carbon of 43.55% so increased to sub-bituminous coal rank.
- Heating to the temperature of 125ºC gives the effect of the smallest percentage of moisture, high fixed carbon percentage and the highest calorific value of coal, while the percentage of volatile matter has decreased from the percentage of initial coal volatile matter.

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