Sustainability of Using Low-Rank Coal as Energy Source through The Upgrading Brown Coal (UBC) Process by Adding Waste Cooking Oil

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Abstract. The use of coal which is dominated by hard coal is projected as the main energy source (± 25%) in 2050 according to the Indonesian Government Regulation No. 79 of 2014. The use of low-rank coal as a substitute for hard coal through the Upgrading Brown Coal (UBC) process is supported by the Indonesian Government Regulation No. 77 of 2014 concerning the obligation to increase the added value of mining products. The use of UBC products can reduce the amount of coal consumption by up to 50% of the use of low-rank coal. The UBC process is still being developed, as in this study, a mixture of low-rank coal and waste cooking oil is used as a coating material to cover the coal pores after the watering process. The variation in the mixing ratio of low-rank coal and waste cooking oil is 1:1; 1:2; and 1:3, with a variation of the heating temperature and mixing mixture of 100°C; 125°C; 150°C; 175°C; and 200°C. The analysis showed that the best conditions are found at a ratio of 1:3 with a temperature of 175°C, wherein the results of the inherent moisture showed a decrease of 21.95% with a calorific value of 7462.82 cal/g. The high calorific value obtained was proven by the flame that occurred for 14 minutes for 50 g of the UBC product sample in the best variable with ash content of 2.92%, and volatile matter by 64.77%.

Keywords: Upgrading Brown Coal, Waste Cooking Oil, Environmentally Friendly Energy

1. Introduction

Based on Government Regulation of The Republic of Indonesia No. 79 of 2014 concerning National Energy Policy, some achievement of national energy policy targets is needed to meet the supply and utilization of energy as a target for the provision and utilization of primary energy and final energy. This energy policy is aimed at achieving an optimal energy mix, namely the increase in the role of renewable energy, as well as natural gas, followed by the target of reducing the use of oil and coal as an energy source. Based on the data below, the role of coal as an energy source in 2050 is targeted to reach 25%, replacing the role of oil which is targeted to decrease to 20%, which was previously the main energy source [1]. The policy is based on the high coal production that has existed so far. This can be seen from the export demand for mining commodities, especially coal demand, from abroad increasing from year to year. The volume of coal exports increased, from 287 million tons (2011) to 343.5 million tons (2016) [2]. The coal demand is also met from imported coal, which is projected to increase from 4 million tons in 2016 to 11 million tons or 2% in 2050 [3].

Coal production in Indonesia is expected to continue to increase along with the addition of coal contracts and an increase in the need for national coal. This is because coal is still a cheap and very
necessary type of fossil fuel to meet the needs of steam power plants as a basic burden and the needs of several industries, such as cement, textile, steel, and others. National coal production is targeted to continue to increase to reach 648 million tons in 2050 which will certainly deplete national coal reserves, especially the much-needed coal with calorie content above 5,100 kcal/kg [3]. Based on coal reserves data as of January 1, 2016, the proven reserves of medium to high-quality coal (> 5,100 kcal/kg) reached 9.9 billion tons, while the total coal reserves reached 14.3 billion tons [4].

Types of medium quality coal to the top (hard coal) are needed by many power plants and industries. Therefore, it is estimated that coal reserves and total medium to high-quality coal reserves will be exhausted in 2038 and 2048 respectively [2]. This condition needs attention from the government by promoting coal exploration, encouraging the use of low-quality coal (<5,100 kcal/kg) as fuel for coal power plants at the mouth of the mine, increasing efficient use of technology, and encouraging the use of coal upgrading. One of the uses of low-quality coal is the utilization of the Upgrading Brown Coal (UBC) process. Previous research mentioned that the net annual cash flow (ACF) has a positive value, this UBC commercial plant is considered to be economically feasible [5].

This condition needs attention from the government by promoting brown coal exploration. The limitations of old coal energy sources in Indonesia, encourage the use of low-quality coal (<5,100 kcal/kg) as an export resource and fuel for the coal power plant at the mouth of the mine, increase efficient use of technology, and encourage the use of coal upgrading [4]. From previous research, it was found that the use of UBC product use can reduce the amount of coal consumption by 50% of the use of low-quality coal. This is due to the quantity of high humidity and the low heating value of low-quality coal (brown coal) which causes the amount of fuel needed by the boiler to be 3 to 4 times more than the use of high-quality coal (hard coal) to produce the same amount of electricity [6].

Based on Government Regulation of The Republic of Indonesia No. 77 of 2014 concerning the Implementation of Mineral and Coal Mining Business Activities that require the process of adding value to low-quality coal (brown coal). This regulation that demands coal processing for added value includes quality improvement (upgrading), briquetting, cokes making, liquefaction, gasification, and coal slurry/coal water mixture [7].

The process of adding value with the Upgrading Brown Coal (UBC) method is a solution to improve the quality of low rank coal before it is used or converted in other forms of energy so that the energy and heating values obtained are more important and can minimize environmental pollution. Brown coal with low characteristics is difficult to compete with and has an adverse impact on the environment. Low-quality coal consists of many pores and the moisture trapped between the pores is removed by evaporation to be further mixed with asphalt. Asphalt function to fill the pores of coal after the evaporation process and prevent the re-absorption of water content into coal [8]. In this research, the use of used cooking oil as waste oil is expected to be a substitute for asphalt which is added as a mixture in the UBC process to fill coal pores after the dewatering process. The use of waste cooking oil will also save costs so that the process of upgrading coal can be maximized.

2. Experimental methods

The use of research methodology was experimental by taking low-rank coal sample at the mine site of PT Bukit Asam while waste cooking oil was from the seafood restaurant in South Sumatera, and tested in the laboratory of the Research Center of Universitas Sriwijaya. The stages of the UBC process are carried out as follows [7]:

a. Coal preparation: low–rank coal was crushed and then sieve to size up to 32 mesh.

b. Slurry dewatering: low-rank coal was mixed with waste cooking oil in different composition: 2:1, 1:1, 1:2, and 1:3 (w/w) total of the mixed ingredients is 300 g. The mixture was mixed and heated with the various temperature 100°C, 125°C, 150°C, 175°C, and 200°C for about 1 hour in magnetic stirrer. This stage is used to evaporated the water.

c. Coal-oil separation: The mixture was dried in the oven about 1 hour. The slurry at every composition were filtered to separated coal and waste cooking oil.

d. Coal briquetting: The mixture was pressed to separate coal at 7000-10.000 psi. The briquette was leaved at open space for 24 hours.
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Coal Preparation

Slurry Dewatering

Coal Briquetting

Coal-Waste Cooking Oil Separation

Figure 1. Upgrading Brown Coal (UBC) process block diagram

The product analysis stage of UBC product such as inherent moisture, gross calorific value, ash content, and volatile matter would be examined at Laboratorium Dinas Pertambangan, South Sumatera. The next step is to see the correlation between the inherent moisture content value and the calorific value of the UBC product. This correlation is done to see whether the addition of waste cooking oil in the UBC process which has the main purpose to reduce water content can increase the calorific value of the UBC product or not.

3. Results and discussion

Raw material from PT. Bukit Asam is coal which is not sold commercially because of the quality carried by the standards set by the company. Therefore, even though the heating value is above 5000 cal/gr, this coal still categorized as low-rank coal because only used for the company's internal needs. Table 1 shows the results of the raw material analysis in more detail.

| Table 1. Raw material analysis |
|--------------------------------|
| Inherent Moisture (%) | Calorific Value (cal/gr) | Ash Content | Volatile Matter |
|-------------------------|--------------------------|-------------|----------------|
| 8.2                     | 6242                     | 4.6         | 42.32          |

In this experiment, focus the study is the effect of the composition of briquettes given different heating temperatures with different compositions. The UBC product produced in this experiment has a denser texture due to the low-rank coal section coated with waste cooking oil.

3.1. Moisture Content

The decrease in moisture content is the main target of this experiment considering that the basis of the UBC process is the slurry dewatering process so that it can be a supporting factor in increasing the quality of low-rank coal [7]. The temperature of the heating and variations in the mixture between coal and oil affect the moisture content in UBC products. The value of the moisture content of UBC products is presented in Figure 2.
Each heating temperature in various mixed variations shows different results. From the graph, it can be seen that the decrease in moisture stops when the heating temperature reaches 200°C. Heating to a temperature of 200°C causes an increase in the moisture content of the previous variable because oil is defect or degraded by temperature which causes defect to the oil structure [9]. This defect causes the presence of oil on briquettes to not have much influence on the quality of briquettes. The UBC product in this condition has not been well coated by oil and allows water to re-enter after the pores in the product UBC open with the dewatering process in the early steps of the UBC process.

If viewed from moisture content, the best heating temperature is 175°C in each composition of coal and wasted cooking oil shows the smallest value. In addition, the graph shows that the greater the composition of the oil from the mixture, the lower the moisture content. The composition of the oil content in the briquettes determines the quality of coal, especially the value of inherent moisture. The presence of oil in coal affects the attractiveness (cohesive force) between coal materials. Increasing the cohesive force will strengthen the pores so that is become smaller and prevent the entry of impurities. The cohesiveness of coal will increase if the moisture content in coal decreases [10]. The presence of pores can cause a decrease in the quality of briquettes because many impurities that can enter fill the pores. The more oil that fills the pores, the fewer impurities that enter the pores of the briquettes. From the explanation above, the lowest moisture content was obtained at 175°C and 1:3, when compared to low-rank coal, decreased to reach 1.8% of the overall composition of UBC.

3.2. Calorific Value

Calorific value influenced by a decrease in moisture in UBC product, it can be seen in the lowest moisture content in the composition of 1:3 briquettes with a temperature of 17°C there is an increase in calorific value up to 7552.55 cal/g (figure 3). Calorific value is also affected by water content because of the lower the water impurity, the higher the calorific value. These results, when compared with the low-rank coal before going through the addition of waste cooking oil, have increased the calorific value of more than 1000 cal/g.
The increase in the lowest calorific value occurs in the ratio of coal and oil 2:1 at a temperature of 100°C which is 6,777.4 cal/g. The water at that temperature has not been completely evaporated due to the reason (the water has not been evaporated at 100°C). In addition, the amount of coal that is more than oil causes not all low-rank coal pores that have undergone a dewatering process to be filled with used cooking oil.

3.3. Ash Content

The ash content of coal in each variation in composition and temperature is shown in figure 4.

The ash content is an undesirable impurity in the process of making UBC products and in the coal itself. Most of the ash content in each composition decreases with increasing temperature and affects the calorific value of the UBC product [11,12]. The higher the ash value will reduce the calorific value because the calories burned become decreased when there is impurity ash. The high calorific value was obtained (conditions 175°C and 1:3) were proven for 14 minutes for 50 g of the UBC product samples in the best variable with ash content of 2.92%.

3.4. Volatile Matter

The level of the fly substance in briquettes is one of the impurities that can trigger the initial combustion. Gas content such as H2, CO, CO2, CH4, and steam affect the ease of briquettes to ignite and affect the amount of smoke produced [9]. The greater the level of volatile matter, the easier the UBC products to light up with side effects that will produce a lot of smoke. The substitution of waste cooking oil in coal can increase volatile matter levels in UBC products, resulting in an increase of up to 65.77% from 42.32%. The results of volatile matter analysis are presented in the graph below.
3.5. Inherent Moisture Content – Calorific Value Correlation

The attachment between inherent moisture (IM) and calorific value (CV) is displayed by comparing the composition between the low-rank coal composition and used cooking oil to show the effectiveness of adding wasted cooking oil in the UBC process.

In figure 6 the graph shows that the greater the composition of oil contained in UBC products will bind the material so that the coal material will be increasingly bound. UBC product with a composition of 2:1 shows that oil does not have a big enough role because the attachment between CV and IM reaches 44.30%, but with the addition of binding oil between these qualities the greater, this is shown in the ratio 1:3, the relationship between the two is bound to 94.5% and are not bound by 0.055%. This indicates that the presence of oil plays an active role in increasing the CV contained in the UBC product.

4. Conclusion

UBC process can manufactured upgraded coals with better combustion characteristics compared to those of raw coals. The process of improving the quality of low-rank coal decreases the water content of UBC products, this is evidenced by the decrease in water reaching 1.8% at the composition of 1:3 and 175°C. In the composition of the lowest moisture content, the highest calorific value is more than >1000 cal/g reached 7552.22 cal/g. The quality of UBC products increases with increasing temperature with the best temperature of 175°C and decreases in quality at 200°C due to damage caused by the degradation of wasted cooking oil. The composition of the mixture affects the cohesion of the UBC
products marked by the more oil added, it will eliminate the impurities, is indicated by the composition 1:3 which has the best value. The presence of ash content and the volatile matter has an effect on the calorific value, the lower the ash content and the higher the level of volatile matter, the higher the heating value. The attachment between the value of the inherent moisture content and the calorific value decreases as the composition of wasted cooking oil increases, as evidenced by the value of the binding (regression) in the composition of 1:3 of 94.48%.

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