EFFECT OF VACUUM RESIDUE AND PETROLEUM BENZINE AS THE ADDITIVE CALORIFIC VALUE AND MOISTURE OF COAL

PENGARUH VACUUM RESIDUE DAN PETROLEUM BENZINE SEBAGAI ZAT ADITIF PADA KADAR AIR DAN NILAI KALOR BATUBARA

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ABSTRACT

Upgrading the coal is a process that increases the calorific value of low-rank coal through decreasing the moisture content of the coal. This method usually uses mixed heavy oil to close the opened pores after coal upgrading. The additives have a molecule structure like heavy oil. The aim of this study is to determine the effect of additives on the moisture content and calorific value after coal upgrading process. Coal upgrading in this study applies several variations i.e., coal particle size and coal mass mixed with an additive which is a mixture of vacuum residue and petroleum benzine with a ratio of 0.005 g: 1 mL as a coater. Before upgrading process, the moisture content and calorific value of the coal is 13.39 %adb and 6,663 cal/g db. After the process, the lowest moisture content of the coal in the ratio of coal (b/v) and additives was 4:3 with 21.75% ad. The highest calorific value of the coal was shown in the ratio of coal (b/v) and additives 1:1 with 7,189 kcal/kg. The lowest moisture content is indicated by the particle size of -120 mesh. The highest calorific value of coal is shown by the particle size of -120 mesh.

Keywords: coal upgrading, additives, coal, moisture content, calorific value.

ABSTRAK

Coal upgrading *merupakan proses peningkatan nilai kalor batubara peringkat rendah melalui penurunan kadar air dalam batubara. Metode ini biasanya menggunakan minyak berat yang dicampurkan untuk menutup pori-pori yang menggalami pelebaran setelah dilakukan* coal upgrading*. Penelitian ini bertujuan untuk mengetahui pengaruh zat aditif terhadap kadar air dan nilai kalor.* Coal upgrading *pada penelitian ini dilakukan dengan beberapa variasi ukuran partikel batubara, zat aditif, dan massa batubara menggunakan zat aditif yang merupakan campuran* vacuum residue *dan* petroleum benzine *dengan rasio 0.005 gr: 1 mL sebagai* coater*. Sebelum proses* upgrading*, nilai kadar air dan nilai kalor batubara dalam penelitian ini adalah 13,39% adb dan 6.663 kal/g db. Setelah proses* upgrading*, nilai kadar air batubara terendah ditunjukkan pada rasio batubara (b/v) dan zat aditif 4:3 dengan nilai kadar air 21,75%. Nilai kalor batubara tertinggi ditunjukkan pada rasio batubara (b/v) dan zat aditif 1:1 dengan nilai kalor 7.189 kcal/kg. Nilai kadar air batubara terendah ditunjukkan oleh ukuran partikel -120 mesh sedangkan nilai kalor batubara tertinggi ditunjukkan oleh ukuran partikel -120 mesh.*

Kata kunci: coal upgrading*, zat aditif, batubara, kadar air, nilai kalor.*

INTRODUCTION

Indonesia is a country that has a lot of energy resources, one of which is coal. Coal is a combustible organic sedimentary rock with carbon, hydrogen and oxygen as the main composition which is formed from plant remains over a long period of time (tens to

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hundreds of millions of years). In 2021, Indonesia's coal resources were estimated at 110,069.91 million tonnes and coal reserves were estimated at 36,278.85 million tonnes with around 34% of the total reserves is low-rank coal or lignite, around 59% is medium rank or sub-bituminous coal, around 5% is high-rank coal or bituminous, and about 2% is very high-rank coal or anthracite, coal inventory were estimated at 24,365.84 million tonnes, and coal exploration target was estimated at 6,141.12 million tonnes (Pusat Sumber Daya Mineral Batubara dan Panas Bumi, 2022).

According to the GeoRIMA (2020), Jambi is one of the third largest coal producing areas in Sumatra after South Sumatra and Riau. Jambi has 2,224 million tonnes of low-rank coal with <5100 kcal/kgdb calorific value. Low-rank coal generally has a high moisture content which around 40% and a low calorific value so its utilization is still limited compared to the other rank coals.

There are several methods to reduce water content that have been introduced since the 1920s in the United States, Australia, Japan, and others (Suwono, 2005). One of them is Upgrading Brown Coal (UBC) technology, which is a technology for upgrading low-rank coal by reducing the total moisture content developed by Kobe Steel Ltd., Japan. The advantage of this technology is that the process is done by low temperatures and pressures. To prevent the coal from reabsorbing water, residual oil is added in the process to coat the pores of the coal particles (Badan Litbang ESDM, 2012).

Vacuum Residue

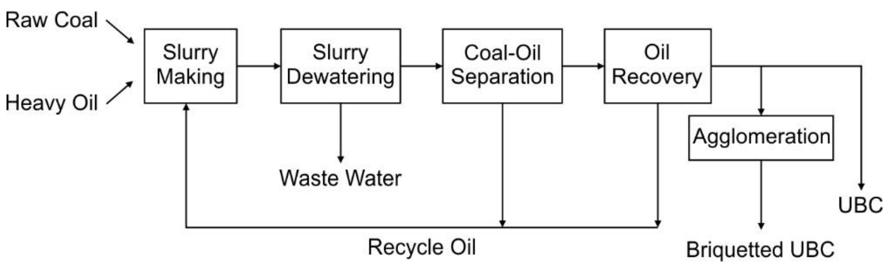
Vacuum Residue or short residue according to (Budhiarto, 2015), is one of the residual products obtained from the Vacuum Distillation Unit (VDU) which can be reprocessed in the Visbreaking and Thermal Cracking unit by breaking the hydrocarbon chains from long-chain into higher chain hydrocarbons with heat to produce products such as gas, gasoline, naphtha, LPG, residue, coke, and diesel oil.

Petroleum Benzine

According to (Merck, 2019), Petroleum benzine is a suitable solvent and is often used for classical applications in the laboratory. Petroleum benzine has an explosion limit of 1.0–7.4% (V), flash point ≤21°C, combustion temperature 260°C DIN 51794, melting point ≤80°C, vapor pressure 370 hPa (25°C), and kinematic viscosity 0.45 mm^2 / s (20°C). This material is a clear, colorless liquid, obtained from refined petroleum with a concentration of unsaturated, volatile hydrocarbons and aromatic hydrocarbons so that petroleum benzine can be used as an additive. Petroleum benzine is a mixture of hydrocarbon solvents with a predominantly carbon number in the range C4 to C11.

Upgrading Brown Coal (UBC)

Upgrading Brown Coal according to Deguchi (1999) is a process that increases the calorific value of low-rank coal by decreasing the moisture content in the coal. UBC process was first introduced by Kobe Steel Ltd., Japan. The process is basically divided into 4 main stages: slurry making, slurry dewatering, coal-oil separation, and oil recovery. The flow diagram of the process is shown in Figure 1.



Source: Deguchi (1998)

Figure 1. UBC process flowchart

Compared to other upgraded technologies, such as hot water drying (HWD) or steam drying (SD) which require high pressure and temperature, the UBC process is very simple because the pressure and operating temperature are low which can cause imperfect water removal from coal. Therefore, it is necessary to add the additives to reduce the water content in the coal pores and form hydrophobic coal to make the water doesn't bond with the coal (Umar, 2010).

The UBC process is carried out at a temperature around 150°C so that the tar removal from the coal is not yet complete. As a result, it is necessary to add additives to cover the surface of coal, such as starch, molasses, concentrated slope (fuse oil), and residual oil (Deguchi, 1998). For UBC process, the residual oil is used as an additive, which is an organic compound that has several chemical properties similar to coal. Based on Figure 2, the surface of the coal before the quality improvement process is still coated with surface water and after the quality improvement process is carried out using oil that has the same chemical properties as the coal. The residual oil will enter the coal pores to replace the surface water and will dry out, then unite with the coal. This oil layer is strong enough and can stick for a long time so that the coal can be stored in the open for quite a long time (Couch, 1990).

METHODS

Coal Sample Preparation

The coal sample used in this study came from PT Tebo Prima Jambi. Before coal upgrading, the raw coal was analyzed for its moisture content and calorific value first at the Laboratory of Energy & Environment – LPPM Institut Teknologi Sepuluh November, Surabaya as shown in Table 1 and categorized as a High Volatile C Bituminous coal according to the Institut Teknologi Sepuluh November ASTM D388-12 with the calorific value of 6393 – 7227 kcal/kg, the water content of 12-18%, and volatile matter 46-54%. The coal sample's size was then reduced into -25+40 mesh, -40+60 mesh, -60+120 mesh, and -120 mesh as shown as in Table 2.

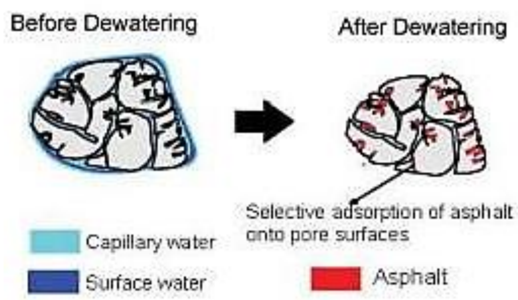
Table 1. Proximate analyze and calorific value before coal upgrading

Parameter	Nilai
Total Moisture (%, adb)	13.39
Volatile Matter (%, adb)	53.1
Ash Content (%, db)	2.76
Calorific Value (kal/g, db)	6,663

One of the additives used to increase the calorific value of the coal in this research is the vacuum residue (Figure 9) which is a product of vacuum distillation. This material has a paste-like shape with a calorific value of 9,785 kcal/kg and a moisture content of 0.02%. The method used in the calorific value and water content test is ASTM D5865/D5865M-19 and ASTM D3173/D3173 M-17.

Table 2. Research matrix

Coal Mass (grams)	Coal Size (mesh)	Additive Variations* (mL)
Raw Coal		0
100	-20+40	25
		50
50		75
		100
100	-40+60	25
		50
50		75
		100
100	-60+120	25
		50
50		75
		100
100	-120	25
		50
50		75
		100



Source: Shigehisha (2006)

Figure 2. Coal surface before and after UBC process

Coal Upgrading

The first thing to do coal upgrading is making a slurry. Coal with sizes of -25+40, -40+60, -60+120, and -120 mesh is mixed with 25, 50, 75, and 100 ml of additives and stirred for 3 minutes in which the research matrix can be seen in Table 1. The additive used is a mixture of vacuum residue and petroleum benzine with a 0.005gr: 1ml ratio. Then the coal is put into the autoclave and heated at ±150°C for ±60 minutes and then cooled at room temperature for ±60 minutes. This process is called as the slurry dewatering process. The upgraded coal was analyzed for moisture content and calorific value at PT Surveyor Indo, Jambi.

RESULTS AND DISCUSSION

Figure 3 and 4 show the graphs of the effect of coal and additives ratio (g/v) and particle size on the moisture content of coal. The lowest moisture content of coal in Figure 3 is the ratio of ½ coal and additives and the particle size is -120 mesh with 24.05 %ad moisture content, while the highest moisture content of coal is found at a ratio of 1/1 of coal and additives and the particle size is -25+40 mesh with 32.46 %ad moisture content. The lowest moisture content of coal in Figure 4 is found at a ratio of 4/3 coal and additives and the particle size is -120 mesh with 21.75 %ad moisture content, while the highest moisture content of coal is found at a ratio of 4/1 coal and additives and the particle size is -40+60 mesh with 36.55%ad moisture content. The ratio of coal and additives that produces the lowest moisture content is found at a ratio of 4/3 with particle size passed through 120 mesh screens. According to Suraputra (2011), the adsorption process can be influenced by the contact area of the adsorbent and adsorbate, the larger the surface area of the adsorbent in contact with the adsorbate, the higher the adsorption rate will be. The surface area of the adsorbent is influenced by the particle size of the adsorbent, the smaller the coal particle size, the larger the surface area, which means the smaller the particle size, the smaller the moisture content will be.

In this study, the moisture content of coal after the upgrading process of the calorific value increases which was not matched with the initial hypothesis. According to Sari, Handayani and Syarifudin (2014), the waiting time of coal after the upgrading process affects the ability of coal to reabsorb the water content in which the longer the waiting time, the higher the coal reabsorbs the moisture content. As Aswan *et al.* (2019) also stated that the waiting time is a factor that affects the upgrading process. In this study, the upgrading process and testing had a fairly long waiting time of about ±3 months, making it possible for coal to re-absorb the moisture. In this study, after the heating process in coal upgrading, the coal is left in the autoclave for ± 1 hour and immediately transferred into the sample bottle/plastic which caused evaporation in the sample bottle/plastic. According to Permadi, Pulungan and Solihin (2015), before the analysis, it is necessary to pay attention to the humidity of the air in the storage area so that the quality of the stored coal can be maintained because air humidity can affect the quality of coal. According to Ningsih *et al.* (2020), the process of heating coal can cause pores in coal to open or fractures to occur on the surface of the coal which can cause coal to tend to absorb water quickly because the adsorption capacity of coal in dry samples is greater than that of the moist samples coal.

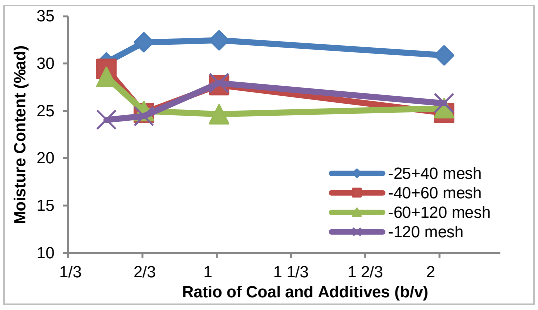


Figure 3. The effect of coal and additive ratio (b/v) and particle size on moisture content (coal mass = 50 grams)

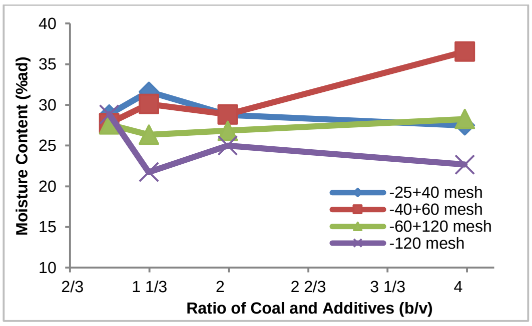


Figure 4. The effect of coal and additive ratio (b/v) and particle size on moisture content (coal mass = 100 grams)

Figure 5 and 6 show the graphs of the effect of the ratio of coal and additives (b/v) and particle size on the calorific value of coal, the highest calorific value in Figure 5 is in the ratio of 2/3 of coal and additives and the particle size is -25 +40 mesh with 6739 kcal/kg db calorific value, while the lowest calorific value of coal is found at a ratio of 2/1 of coal and additives and the particle size is -60+120 mesh with 6362 kcal/kg db calorific value.

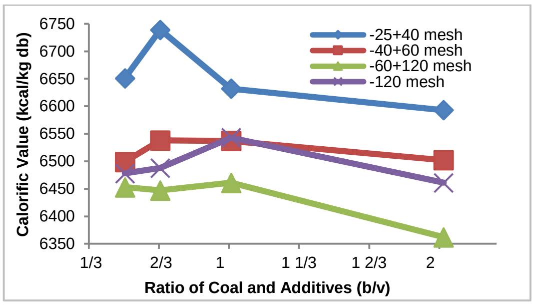


Figure 5. The effect of coal and additives ratio (b/v) and particle size on the calorific value (coal mass = 50 grams)

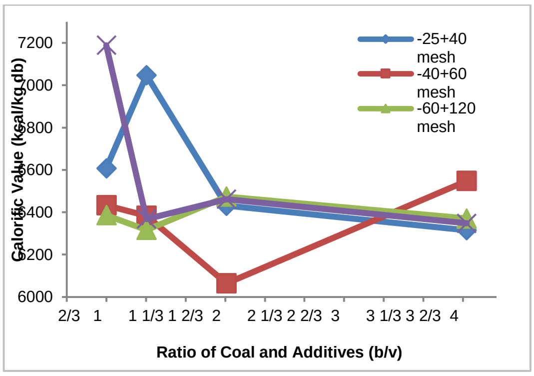


Figure 6. The effect of coal and additives ratio (b/v) and particle size on the calorific value (coal mass = 100 grams)

The highest calorific value of coal in Figure 6 is found in the ratio of 1/1 of coal and additives and the particle size is -120 mesh with 7189 kcal/kg db calorific value, followed by a ratio of 4/3 of coal with additives and the particle size is -25 +40 mesh, while the lowest calorific value of coal is at a ratio of 2/1 of coal with additives and the particle size is -40+60 mesh with 6064 kcal/kg db calorific value. The ratio of coal and additives that produces the highest calorific value is found at a ratio of 1/1 with particle size passed through 120 mesh screens. According to Jaya *et al.* (2017), this is because the greater the ratio of coal and additives and the small particle size causes more additives to enter the coal pores. The presence of additives can help the process of evaporation of moisture so that more moisture can be evaporated from the coal. The more moisture that can be evaporated, the increase in the calorific value of coal will be even greater.

The data obtained in this study after the process of upgrading the calorific value with this method was dominated by the decreasing calorific value from the results of the initial analysis of coal where the characteristics of the coal before and after upgrading process is shown in Table 3. According to Nursani, Handayani and Bahrin (2020), the process of upgrading coal is done by heating the coal for 1 hour and then the heavy oil (additive) is mixed with coal which aims to cover the empty pores due to water that has been removed through the heating processor which is also called the coating process so that water cannot re-absorb the coal pores, while in this study the coal upgrading process is conducted by mixing the coal and the additives first and then heating for 1 hour so that the coating process is unperfect.

Table 3. Characteristics of the coal before and after upgrading process

Parameter	Before	After
Total Moisture	13.39 %adb	Increased
Calorific Value	6,663 cal/g db	Decreased
Coal	Slurry	Powdery

According to Deguchi (1998), the UBC process have the process to filter the used oil which called oil recovery, but in this study, the oil recovery process was not carried out. Figure 7 shows a comparison before and after the heating process where after the heating process, the coal is no longer in the form of a slurry but in the form of a powder so that no oil recovery process is carried out. In addition, the ratio of vacuum residue and petroleum benzine is too small to allow the coating process to be imperfect.

Figure 7. Comparisons between before and after heating process

CONCLUSIONS

The ratio of coal and additives that produce the lowest water content is in a ratio of 4/3 coal and additives with particle size passed through 120 mesh screens where the smaller the coal particle size, the larger the surface area, which means the smaller the particle size, the smaller the moisture content will be. The ratio of coal and additives that produce an increase in calorific value compared to the calorific value of the initial analysis of coal is found in a ratio of 1/1 coal and additives with particle size passed through 120 mesh screens.

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