IOP Conference Series: Materials Science and Engineering

PAPER • OPEN ACCESS

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To cite this article: E Yustanti *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **478** 012025

IOP Conf. Series: Materials Science and Engineering 478 (2019) 012025 doi:10.1088/1757-899X/478/1/012025

The effects of hot briquetting on the coke strength in the biocoke making process with coal blending method

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Abstract. The biomass waste of rice husk and coconut shell in Indonesia reaches more than 15.8 million tons/year. In addition, the utilization of biomass waste has not been performed optimally. Rice husk and coconut shell are the biomass that can be processed as briquette material. This research aims to find the maximum temperature of hot briquette to generate the maximum coke strength from blending. First, the biomass waste was performed by a carbonization process at 400^{o}C with a coal composition of biomass 95:5 wt%. The production of coke briquette used molasses binder 15 wt%. The hot briquette temperature variation was at 100 and 150^{o}C with a briquette pressure of 200 kg/cm^2. Coke briquette then was carbonized at 1100^{o}C for 4 hours and followed by water quenching. The result indicates that hot briquette temperature depends on the type of biomass used. Coke briquette with a rice husk blend at 100^{o}C and 150^{o}C hot briquette temperature, respectively produced coke strength of 11.5 and 20.9 kg/cm^2. Meanwhile, coke briquettes with coconut shell charcoal blend at 100^{o}C and 150^{o}C hot briquette temperature respectively produced coke strength of 15.8 and 10.8 kg/cm^2.

1. Introduction

Coking coal limited availability limitation in Indonesia provides an opportunity for blending with biomass to produce biocoke. Biomass is a solid or liquid waste that can be utilized as a fuel source in blast furnace. This energy source contains the lowest sulfur relativity so it does not cause a huge air-pollution. Generally, biomass densification has several advantages, for example, it can increase the calories score per volume unit, is easily stored and transported, and has similar size and quality [1]. The availability of diverse biomass becomes a good alternative, especially the coconut shell and rice husk biomass. This condition occurs because the position of Indonesia as an agricultural country with a wide beach area. Obviously, both of coconut shell and rice husk availability are very abundant.

Based on the data from the Indonesian Agency for Agricultural Research and Development (2017), rice husk from rice milling in Indonesia in 2016 reached 15.8 million tons. Coconut shell is found almost in all areas of Indonesia [2]. The coconut shell is a part of coconut in the form of endocarp. It is hard and located inside the coconut after the husk containing a lot of lignin decreases about 30%. As biomass waste, coconut shell as a fuel is widely used either directly or indirectly as the carbonization process first [3]. When compared to other biomass charcoal, coconut shell charcoal has the highest carbon content.

Rice husk and coconut shell blending with coking coal is expected to overcome the limited coking coal in Indonesia and utilizing the abundant biomass as an alternative raw material in coke industry. Generally, using biomass directly as a fuel is less efficient. Therefore, a carbonization process is required. Biomass carbonization plays a very important role because it is related to the calories score produced. Agricultural waste can be processed with carbonization followed by briquetting to produce a good fuel. One of the ways to process agricultural waste [4]. Variation of briquette pressure affects the briquette thermal characteristic. The additional pressure will increase the value of coke compressive strength. In addition, the effect of briquetting temperature is the higher temperature will decrease the residual moisture content in coke briquette. The higher temperature has a positive effect on briquette strength [5].

2. Materials and methods

2.1. Coal Pulverizing and Sieving
The production of coke briquette in this research used a blend of coking coal from Central Borneo with rice husk and coconut shell biomass from Kebondalem, Cilegon. The size reduction process was conducted on coarse coal using pulverizer mill followed by sievin*g* to obtain the size fraction of -40#. The more dominant use of point fraction -40 # will produce more compact coke briquettes because finer grains will fill in the cavity grains, so that it can increase density [6].

2.2 Biomass Carbonization
Biomass carbonization was conducted at temperature of 400^{o}C and produced charcoal. Then, charcoal was followed by grinding and sieving (-60#). The process of biomass carbonization aimed to increase the calorific value and fixed carbon.The biomass carbonization process was conducted by using a mini rotary kiln and resulted about 20-30 %yield. The process of coconut shell carbonization in the temperature of 600^{o}C with total bait of 1,946.6 gram produced 547 gram charcoal or about 28 %yield.

2.3 Coal Blending and Hot Briquetting Process
Blending between coal and biomass was conducted with the addition of adhesive in the form of molasses by 15 wt% of the total blend. Molasses as a binder composed with hydrocarbon bonds. It produced the higher fixed carbon by hot briquetting. In order to produce higher fixed carbon and increase the coke strength, it was compacted the briquetting pressure at 200 kg/cm^2. The suitable temperature of briquetting process for biomass was below 100^{o}C and not more than 150^{o}C. However, the temperature is also based on the type of biomass properties.

2.4 Re-carbonization Process of Briquette
The last process was briquette re-carbonization at 1100^{o}C for 4 hours and followed by water quenching through giving a splash of water to a hot biocoke at room temperature. The variable for re-carbonization process was based on previous research [6]. Water quenching after 1100^{o}C re-carbonization process led to the bond formation among the particles in coke briquette. The burn shrinkage of quenched coke was about 37-45%.

2.5 Proximate and Ultimate Analysis
The proximate analysis of coal and biomass charcoal was conducted to determine the content of fixed carbon to compare the difference between raw material and biomass charcoal. Proximate analysis was conducted in the Research Center for Geotechnology, Indonesian Institute of Sciences (LIPI), Bandung and ultimate analysis was conducted in Research Center and Development for Mining and Coal (TEKMIRA), Bandung.

IOP Conf. Series: Materials Science and Engineering 478 (2019) 012025 doi:10.1088/1757-899X/478/1/012025

3. Results and discussion

Biomass utilization provides many benefits such as renewable resources, relatively contain the lowest sulfur, provide an energy-efficiency and decrease the cost saving of waste treatment handling. Table 1 shows the results of raw materials proximate analysis. Preliminary analysis was performed after drying process of biomass at 110^{o}C, which intended to facilitate the size reduction process using mini jaw crusher. Proximate analysis was performed to determine raw material quality and the content inside. The components based on proximate analysis consist of moisture, ash, volatile matter, and fixed carbon. Proximate analysis in this research was performed by applying LECO TGA 701 instrument based on ASTM D3172 standard.

Table 1. Proximate Analysis of Raw Material

Analysis (Air dried basis)	Coking Coal (%)	Rice husk (%)	Coconut shell (%)
Moisture	1.18	9.37	10.10
Volatile Matter	29.26	54.38	57.02
Ash	2.21	22.20	14.10
Fixed Carbon	67.36	14.05	18.60
Total Sulfur	0.69	0.02	0.03

In Table 1, we can see fixed carbon content of raw material. Rice husk contained lower bound carbon by 14.05% compared to fixed carbon of coconut shell by 18.60%. The biomass carbonization process can increase carbon content as shown in Table 2.

Table 2. Proximate Analysis of 400^{o}C Charcoal

Analysis (Air dried basis)	Rice husk charcoal (%)	Coconut shell charcoal (%)
Moisture	7.44	5.03
Volatile Matter	7.73	33.09
Ash	45.85	1.33
Fixed Carbon	38.99	60.55
Total Sulfur	0.01	0.02

The biomass carbonization process aims to increase the carbon content. The carbon content is the amount of pure carbon contained in charcoal. The increasing temperature in carbonization process greatly affect the charcoal quality, including the carbon content [7]. The results of proximate analysis in Table 2 shows that the fixed carbon of rice husk charcoal increased by 278% from 14.05% to 38.99%, while the fixed carbon of coconut shell increased by 326% from 18.6% to 60.55%.

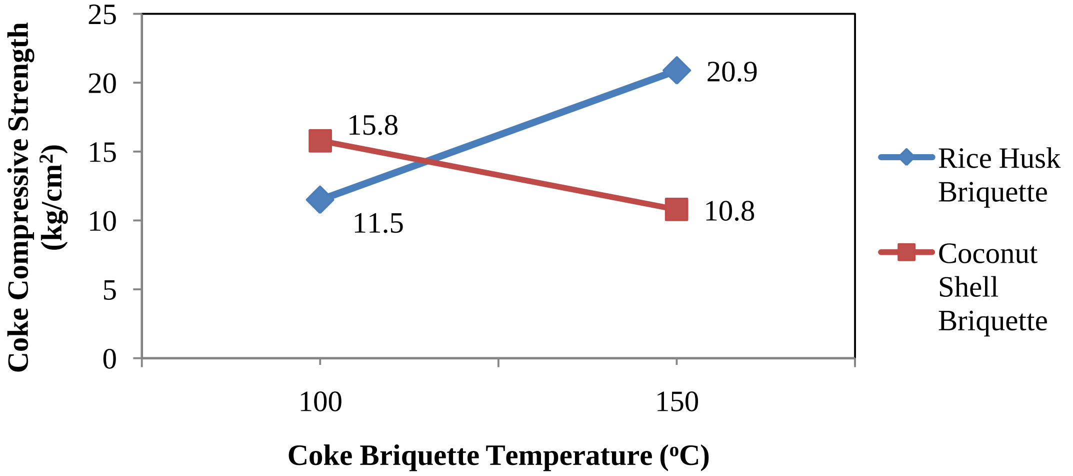

Figure 1. The Relationship between Hot Briquetting and Coke Strength

Next, we will discuss the effect of hot briquetting temperature on coke strength. Hot briquetting process in this research used a temperature variation of 100 and 150°C. Blending method was performed to blend between coking coal and biomass charcoal. The hydrothermal coal heating process can be performed through hot briquetting.

The hot briquetting process aims to increase coke strength. During this process, the release of volatile matter occurred, although it was just a little due to the heating. During the briquetting process, the molasses binder in the briquette burnt, so that the hydrocarbon chains inside were released. Consequently, the carbon content was expected to increase significantly. This condition allows for an increase in coke strength. Carbonized biomass charcoal at 400°C as blending material may provide effect on coke strength [8]. Figure 1 shows coke briquette with blended rice husk charcoal generates higher strength in hot briquetting process with temperature of 150°C equal to 20.9 kg/cm^2. In contrary, coke briquette with coconut shell charcoal generates higher strength in hot briquetting process with temperature of 100°C that is equal to 15.8 kg/cm^2. The metallurgical coke compressive strength for blast furnace was at the range of 28.12-103.34 kg/cm^2 [9]. For the next experiment, we suggest to increase compacting pressure when process briquetting until 4000 kg/cm^2 to reach more metallurgical coke compressive strength. The high pressure and temperature simultaneously act upon the mass, the cellular structures within the material release lignin, which binds individual particles into a compact unit-briquette. Strength of briquettes increases with the increase of the pressure to the strength limit (approx.150-250 MPa) of the compacting material. Increased strength causes low absorption of atmospheric humidity and thus increases the briquette durability [10].

Coke briquette with coconut shell charcoal blend has greater strength than briquette with rice husk charcoal blends, because the coconut shell charcoal generates tar during carbonization. With the carbonization process, wood tar resulted at temperature more than 400° C. It also has functions as a binder. Therefore, tar on coconut shell charcoal clearly provides the effect of increasing the strength value on coke briquette. On the hot briquetting effectiveness at 100°C on the blended biocoke with coconut shell charcoal, it was assumed that it occurred due to the tar from carbonization process. If hot briquetting temperature is increased to 150°C, then the vaporized tar may be much more than the hot briquetting at 100°C.

Table 3. The Nature of Proximate Coke

Material	M (%)	VM (%)	Ash (%)	FC (%)
BSP (HB 100°C)	0.7	2.15	12.14	85.01
BSP (HB 150°C)	0.38	1.77	11.93	85.92
BTK (HB 100°C)	0.89	3.02	20.75	75.34
BTK (HB 150°C)	1.27	1.69	19.06	77.98

BSP: Rice Husk Briquettes; BTK: Coconut Shell Briquettes; HB = Hot Briquetting

Coke is obtained from re-carbonization process of blending briquettes at high temperatures of 1100°C without oxygen, and it depends on the amount of carbon for 4 hours [11]. Stage of coal changes into coke starting at 375–475°C, briquettes experiencing decompose forms plastic layer around the wall. When the temperature reaches 475–600°C, tar fluid and hydrocarbon compound (oil) appear and it is followed by compaction of plastic mass into semi-coke. However, the re-carbonization process at temperature 800-900°C only produced semi-coke. And the suitable temperature for re-carbonization process was at 1100°C to produce the stabilized coke. Coking stage is strongly affected by the contraction of coke period, development of coke structure, and evolution of hydrogen at the end of coking.

As shown in Table 1, coke briquettes with a rice husk charcoal blend that had experienced hot briquetting process at 150°C generated fixed carbon of 85.92%, 0.91% higher compared to hot briquetting at 100°C that generated fixed carbon by 85.01%. Meanwhile, coke briquettes with the coconut shell charcoal blend that had experienced hot briquetting process at 150°C generated fixed carbon of 77.98%, 2.6% higher compared to hot briquetting at 100°C generating fixed carbon of 75.34%.

4. Conclusions

Based on the research results, it can be concluded that the hot briquetting depends on the type of biomass. Rice husk charcoal produced the coke strength 20.9 kg/cm^2 by hot briquetting at temperature 150°C, while coconut shell charcoal is more suitable with hot briquetting at 100°C with the coke strength of 15.8 kg/cm^2. The highest strength of coke briquette from blending with rice husk has not met the minimum metallurgical coke standard of 28.12 kg/cm^2. The quenching process may fix the proximate characteristic of briquette coke by increasing the density level.

Acknowledgment

The authors gratefully acknowledge the support of Reseacrh Center for Geotechnology Indonesian Institute of Sciences (LIPI) and Research Center and Development for Mining and Coal (TEKMIRA), Bandung for the research facilities. Research work is partially funded by the Ministry of research, technology and higher education under the research grant PDUPT with contract number: 095/SP2H/LT/DRPM/2018.

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