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OPTIMIZING THE QUALITY OF CHAR BRIQUETTE PYROLYSIS PRODUCTS OF PLASTIC WASTE

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Abstract: Recycling process of the plastic waste into fuel in the concept of Waste to Energy is a technology that began to popularize the pyrolysis method. In addition to liquid fuels as the main product , which is produced from the above method is solid and non - condensable gases. Generaly, the residual gas is burned directly , while the solids can be processed into solid fuel (char briquettes) . To process the solids into a char (fixed carbon + ash) then it should be the beginning of a process to remove moisture and reduce levels of volatile matter . Despite a volatile fuel but large levels indicate that the pyrolysis process has not been good , besides the burning application will cause soot . Initial research has resulted in the burning of 8 quality test data sample of 13 samples char briquettes obtained by pyrolysis of polyethylene plastic material with an operating temperature variation between 450-500 ° C , as well as mass variations and types of catalysts Zeolite Y and Natural Zeolite . In addition, the variation was also performed by mixing the PE material with the type of Polystyrene , Polypropylene , Polyethylene Terephthalate , and Other . Char characteristics are known through the proximate test include moisture content , ash , volatile matter and fixed carbon , calorific value is tested through the bomb calorimeter . Combustion quality tested in the furnace at a temperature of 230 ° C ± walls and constant air flow of 0.7 m / s , and the measured emission levels .The problem is in the application note that burning briquettes are not optimized , long heating periods indicated , as well as varying levels of CO . Therefore, it is necessary to the optimization of combustion quality will be analyzed through the ultimate test and the effect of porosity.

Keywords: *pirolisis, char, ultimate, proximate, porosity*

1. INTRODUCTION

Global plastics production has increased over the years due to the many applications of plastics in many sectors (Sunaryo, et. al 2021). Plastic is also an essential material for modern existence. Plastics make up many products for everyday use, and the packaging encases a wide variety of products. As the economy continues to expand, production and consumption of plastics have increased to meet the needs of a growing market (Behzadi et., al; 2013).

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The concept of plastic recycling is the preferred method because plastic waste is considered a cheap and abundant raw material. Processing it into oil as a liquid fuel is an interesting way to produce an energy source while improving the quality of plastic waste handling. A popular recycling technique for processing plastic into liquid fuel is pyrolysis (Jung et., al.; 2010). Pyrolysis is the chemical decomposition and thermal decomposition of molecules in conditions without oxygen. Plastic pyrolysis products actually do not only produce oil, there are other products, namely in the form of non-condensable gas, a few percent of soft precipitate (wax), and the rest is charcoal (char). The percentage of each pyrolysis product depends on several factors including the temperature of the reactor, the use of the reformer, and the type of catalyst (Lee et. al. ; 2012).

Until now, the utilization of plastic pyrolysis is more focused on the use of liquid fuel products for further processing into several types of fuel oil (BBM). In general, by-products in the form of non-condensable gas and char have not been processed to be put to good use (Cantrel et al.; 2010). These non-condensable gases can actually be used, for example, to help heat a reactor, or to be processed to obtain useful compounds. Likewise, char which has a high carbon content allows it to be processed into fuel besides being used as fertilizer (biochar). When compared to products in the form of gas, char is a product that is easier to process and store as a fuel reserve. In the plastic pyrolysis process as mentioned in the previous description, several factors affect the resulting product. Variations in the reactor temperature setting can affect the volume of char, gas, and liquid fuel produced (Sharobem, et. al; 2010). The higher the temperature of the reactor, the more oil will be produced and less char, but if the temperature is too high, the oil will decrease and gas production will increase. On the other hand, the percentage of char and solids will be higher at lower reactor operating temperatures (Mulgaonkar, et. al ; 2013). Likewise, the use of catalysts affects the character of the types of compounds formed during the process.

The application of this pyrolysis technique is of course not solely aimed at producing more liquid fuels, but the potential contained in by-products also needs attention (Paraschiv et. al ; 2009). Char is a result that is more easily processed than gaseous products, even though it is a very small amount but has the potential to be further processed into an energy source. The content of chemical elements in it is mostly carbon (solid carbon) so it is possible to process it into the form of solid fuel (briquettes). Something that will be a question is the performance of these briquettes when used as fuel (Saiki et. al ; 2013). Preliminary research has produced combustion quality test data for 8 samples of briquettes from 13 samples of char obtained by pyrolysis of polyethylene plastic materials with variations in operating temperature between 450-500 °C, as well as variations in mass and type of Zeolite Y and Natural Zeolite catalysts. In addition, variations were also made by mixing the PE material with the types of Polystyrene, Polypropylene, Polyethylene Terephthalate, and Others (Shadaka et. al ; 2013). Characteristics of char are known through proximate tests including moisture content, ash, volatile matter, and fixed carbon, the calorific value is tested through a bomb calorimeter. Combustion quality was tested in a furnace with a wall temperature of ± 230°C and a constant airflow of 0.7 m/s, and emission levels were measured. The problem is that in the application it is known that the combustion of briquettes is not optimal, characterized by long heating periods, and varying levels of CO. Therefore it is necessary to optimize the quality of combustion which will be analyzed through ultimate testing and porosity effects (Smoot et al; 1985).

The application of this pyrolysis technique is, of course, not solely aimed at producing more liquid fuels, but the potential contained in by-products also needs attention. Char is a result that is more easily processed than gaseous products; even though it is a very small amount but it has the potential to be further processed into an energy source (Saptoadi et al. ; 2008). The content of chemical elements in it is mostly carbon (solid carbon), so it is possible to process it into the form of solid fuel (briquettes). Something that will be a question is the performance of these briquettes when used as fuel. The quality of the briquettes will be affected by the quality of the material used to form the briquettes. Furthermore, the proximate and ultimate tests become the basis for determining the quality of plastic pyrolysis residue.The aim of the study was to investigate the pyrolysis of residual char from plastic waste into briquettes.

2. MATERIALS AND METHOD

The materials used in this study were 13 samples of char from the pyrolysis of plastic waste with several different treatments during the process. Variations in the process include reactor temperature, type and composition of raw materials, and use of catalysts (Table 1).

Table 1. Variation of treatment in the pyrolysis process of plastic waste

No sample	Material	Composition (%)	Operating Temperature (°C)	Zeolite Type	Weight (gram)
1	PE	100	450	Natural Zeolite	300
2	PE	100	500	Natural Zeolite	100
3	PE+Other	50-50	450	Natural Zeolite	100
4	PE	100	450	Natural Zeolite	0
5	PE	100	450	ZeoliteY	100
6	PE+PS	50-5-	450	Natural Zeolite	100
7	PE+PS+Other	50-25-25	450	Natural Zeolite	100
8	PE	100	450	Natural Zeolite	400
9	PE+PP+PS	50-40-10	450	Natural Zeolite	300
10	PE+PP+PET+PS+Other	50-30-10-5-5	450	Natural Zeolite	300
11	PE	100	450	Natural Zeolite	100
12	PP+PE	40-60	450	Natural Zeolite	300
13	PE	100	450	Natural Zeolite	200

The reactor used for the pyrolysis process is a batch reactor type with a slow pyrolysis concept as shown in Figure 1. The pyrolysis process carried out is intended to produce the main product liquid fuel so that each process will be stopped if very little liquid is known to be produced even though gas products are still possible. generated. Behavior during the process is predicted to affect char characters.

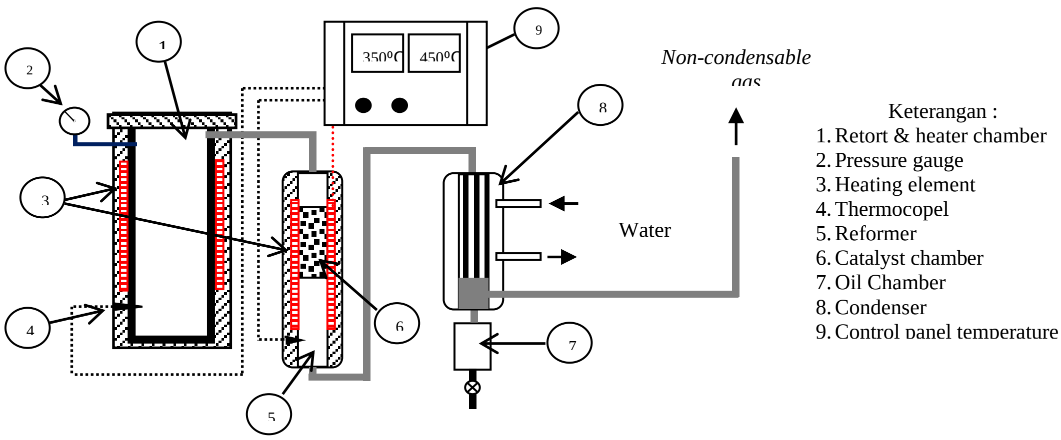

Figure 1. Schematic of a batch reactor

The pyrolysis reactor (Figure 1) used is in the Energy Conversion Laboratory, Faculty of Engineering, UGM. In the test, the proximate test will be carried out at the PSPG PAU UGM Laboratory.

a. Testing the water content (moisture content)
   With reference to ASTM D 3137-03, the sample will be heated for 1 hour at 107°C. Based on the FAO reference (1993), the initial sample (M1) is heated in a drying oven until there is no change in mass (Me), then the moisture content (m) can be calculated using Equation 1.

$$m = \frac{M_1 - M_e}{M_e} x\ 100\% \quad (1)$$

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b. Volatile matter testing
Volatile testing through the process stages of 1 gram sample is heated to a temperature of 950 ± 20°C with a holding time of 10 minutes. Furnace conditions without oxygen usually flow nitrogen or helium gas which is stable and does not easily react with the sample. The calculation formula according to ASTM D 3175 standard can be seen in Equations 2 and 3 below.

$$C = \left[\frac{A - B}{A}\right] x\ 100\% \tag{2}$$

$$Volatile\ matter = C - D \tag{3}$$

Information from the above equation, A is the weight of the sample in grams, B is the weight of the sample after heating in grams, and C is the weight loss in percent (%). D is the moisture content in percent obtained in the previous test.

c. Testing ash (ash)
The 1-gram sample will be heated to a temperature of 750°C with a heating rate of 3.3°C/minute and a holding time of 120 minutes. The calculation formula according to ASTM D 3174 standard can be seen in Equation 4 below.

$$\text{Ash}\ (100\%) = \left[\frac{A - B}{C}\right] x\ 100\% \tag{4}$$

Information from the equation above, A is the weight of the ashes and cup in grams, B is the weight of the empty cup in grams, and C is the weight of the initial sample in grams.

d. Calculation of fixed carbon
After the water content, ash content, and volatile matter are known, the fixed carbon content can be calculated using the ASTM D3172 standard. After the water content, ash content, and volatile matter are known, the fixed carbon content can be calculated using the ASTM D3172 standard.

e. Calorific value
The calorific value test will refer to the ASTM 2015 standard, using bomb calorimeter equipment.

f. Ultimate Test
The ultimate test is to determine the levels of C, H, O, N, and S. If the research has used the bomb calorimeter method, the ultimate test will not be carried out.

g. Porosity Test
To find out the porosity, a particle size test of char in briquettes will be carried out beforehand.

3. RESULT

Characteristics of char which is known through the proximate test, has shown various data as presented in Table 2. The data shows that each char sample has a ratio between ash content (ash), moisture, volatile, and fixed carbon content at different percentages. different.

Table 2. Proximate Test Results

No. Sample	PROXIMATE TEST				
	Calori value (Cal/gr)	Ash (%)	Water content (%)	Volatile matter (%)	Fixed Carbon (%)
1	6562,852	23,577	5,808	55,460	15,155
2	3840,142	41,059	9,284	24,681	24,976
3	4229,475	36,508	4,689	6,238	52,565
4	6538,229	25,019	6,743	49,787	18,451

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5	7583,171	21,577	4,712	60,942	12,769
6	7525,232	22,033	4,399	63,672	9,896
7	7124,590	22,550	2,524	49,378	25,548
8	4128,476	38,346	6,020	24,727	30,907
9	4216,112	29,503	10,369	17,128	43,000
10	4263,257	32,526	7,173	10,947	49,354
11	7531,748	19,774	1,995	64,594	13,637
12	3575,075	39,765	10,354	13,204	36,677
13	7169,702	22,645	5,512	60,321	11,522

The burning characteristics of the briquettes will be analyzed through the burning rate graph data. Combustion data for char from 100% PE can be seen in Figure 2 and Table 3, while for char from mixed materials can be seen in Figure 3 and Table 4.

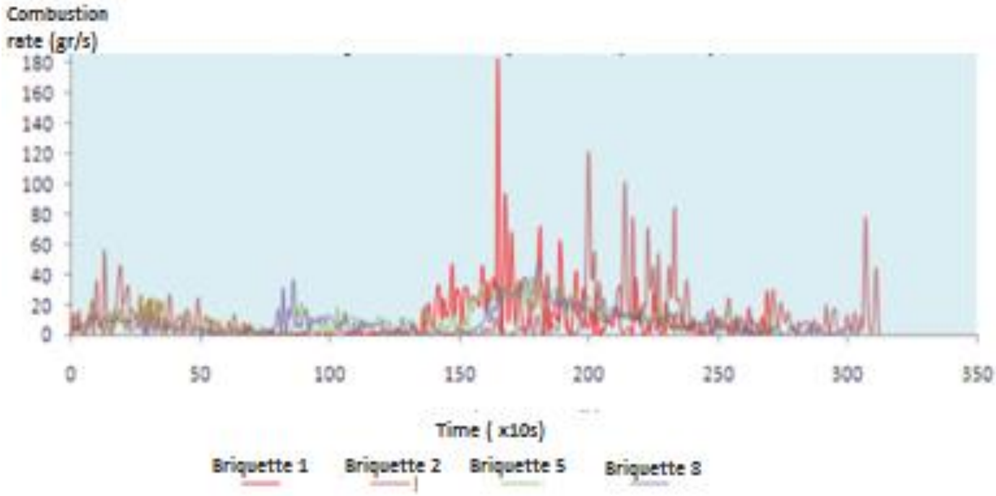

Figure 2. Graph of burning rate (100% PE briquette char)

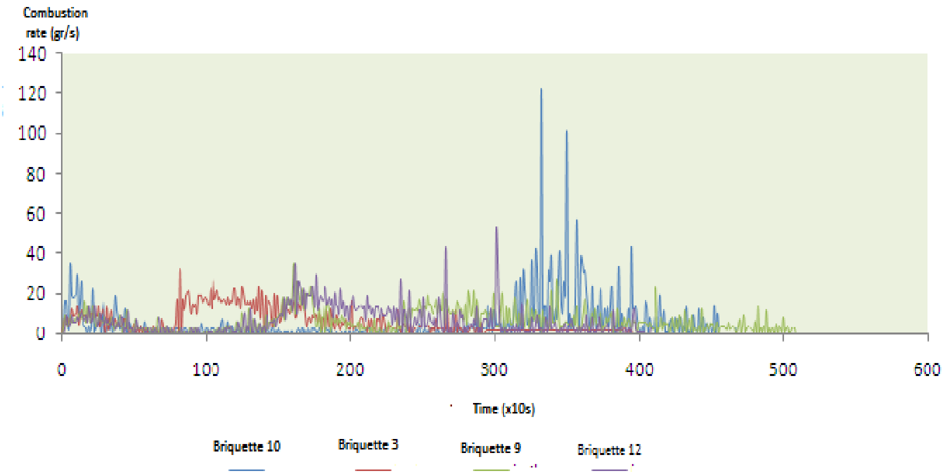

Figure 3. Graph of combustion rate (briquettes from pyrolysis char mixed materials)

Based on the data in Table 3, it can be seen that the longest burning period for Sample 8 briquettes is 50.5 minutes with the highest fixed carbon of 30.907% (proximate). Meanwhile, based on the data in Table 4, it can

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be seen that the highest combustion rate of 122 milligrams/second is owned by Sample 10 briquettes, and the lowest is 32 milligrams/second owned by Sample 3 briquettes.

Sample 9 briquettes had the longest burning period, namely 84.80 minutes with the highest moisture content of 10.369% (proximate).

Table 3 Characteristics of burning briquettes (char 100% PE)

No. Sample	Weight (gram)	Highest Burn Rate (gr/s)	Air Flow Speed (m/s)	Burning Period (minute)	Ash Mass (gram)
1	4,381	0,183	0,7	44,83	1,60
2	4,463	0,121	0,7	50,17	1,82
5	4,382	0,039	0,7	45,83	1,37
8	4,378	0,049	0,7	50,50	1,75

Table 4 Characteristics of burning briquettes (mixed char materials)

No. Sample	Weight (gram)	Highest Burn Rate (gr/s)	Air Flow Speed (m/s)	Burning Period (minute)	Ash Mass (gram)
10	4,441	0,122	0,7	78,00	1,924
3	4,377	0,032	0,7	65,80	1,981
9	4,298	0,035	0,7	84,80	1,272
12	4,291	0,053	0,7	67,80	1,779

The test was carried out to measure the emission of briquette combustion using the MRU OPTIMA 7 gas analyzer model. Overall the emission test data for the 13 briquette samples is shown in Table 5 which can show the relatively low levels of measured emissions (CO, NO, NOX, and SO2). The emission values contained in the research samples when compared with the Regulation of the Minister of Energy and Mineral Resources No. 47 of 2006 stipulates that the maximum emission limits for CO (626 ppm), NO, and NOx (78 ppm), and SO2 (50 ppm) can be said to be within safe limits. However, the different emission test conditions make it inappropriate to compare. The limitations of the obtained char samples made it impossible to make briquettes in large quantities, in some samples a maximum of 3 to 4 briquettes with small dimensions. For this reason, combustion tests cannot be carried out in a briquette furnace, so the emission results that are measured are limited to the procedures carried out.

Based on the characteristics of char and after it becomes char briquettes, several problems can be used as guidelines for determining combustion optimization steps, namely;

a. The char particles are soft in the 100 mesh scale, so the products made do not have variations in porosity.
b. The low porosity of briquettes causes problems, namely inhibiting oxygen diffusion in the combustion process, so it is necessary to choose a combustion strategy including excess air or printing briquettes on small dimensions.
c. Based on the proximate test, it is known that there is a lot of water content in the particles, so it is necessary to dry them first.
d. Optimization of briquette combustion is inseparable from the quality of the briquettes as fuel, in this case, the storage of briquettes must be airtight to avoid the adsorption of water by carbon.

4. CONCLUSION

The conclusions that can be drawn from the research that has been achieved are;

a. Characteristics of char are known that the particle size is very fine so that the average porosity of the sample is very low. Some of the samples have high levels of volatility, including their calorific value.
b. Combustion optimization can be carried out by further drying the briquette raw materials to remove moisture content. In addition, briquettes with low porosity will be optimal if they are made in small dimensions and with holes.

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