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THE EFFECT OF PYROLYSIS TEMPERATURE ON THE HEAT VALUE OF PYRO-OIL USING PLASTIC WASTE

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Abstract. *This work primarily investigated the pyrolysis of smalls scale fixed bed reactor using plastic wastes type LDPE during slow pyrolysis (non-isothermal) in a batch reactor to assess the effect of different temperatures on the product yield and heating value. The calorie bomb of Parr Instrument was performed to investigated heating value of pyro-oil product at different temperatures 250, 275, 300oC. The pyro-oil obtained at higher product yield of 300 °C while the increased temperature will affect to increase the product yield of pyro-oil. The highest heating value of pyro-oil produced at a reactor temperature of 300oC is 9,769.78 cal/gr. From the results of pyro-oil using plastic waste type LDPE, the characteristics of the heating value are equivalent to diesel fuel.*

Keywords: fixed bed reactor, slow pyrolysis, plastic waste LDPE, heating value.

1. INTRODUCTION

Pyrolysis is a process of decomposition of organic material with heat without containing oxygen. The products that can be produced can be in the form of gas (H2, CO, CO2, H2O, CH4), tar and charcoal. Charcoal formed during the pyrolysis process can be used as fuel or used as activated carbon. While the liquid oil produced from the pyrolysis process can be utilized as an addictive substance or used for fuel mixtures [1]. The advantages of pyrolysis as an alternative technology including having a high conversion ratio, its products have a high energy content, the resulting products can be increased into basic materials for other purposes as well as controlling an easier process when compared to the incineration process [2].

Plastic waste is a polymer compound with a very large molecular shape in which the main element is carbon. The term plastic, in a chemical sense, includes synthetic or semi-synthetic polymerization products. One type of plastic waste that is very easy to find is Low Density Polyethylene (LDPE). The derivative of this type of plastic is crackle plastic whose use is still very massive in the community so that its existence is quite abundant and is considered to have no economic value. Its main characteristics are that it is easy to process, easy to shape using heat, and is formed from petroleum-based materials.

A lot of works have been developed on pyrolysis in traditional reactors such as fluidized-bed [4],[5], fixed bed [6], [7], rotary kiln [8] reactors etc. Regarding product distribution at different operating conditions. Whilst recently the pyrolysis of terrestrial biomass has received a great deal of attention at various experimental conditions from rice husk and rice straw [9], palm [10], orange peel [11], and coconut leaf's [12]

Research on pyrolysis oil has begun to be developed, especially its characteristics. Pyrolysis gases from agricultural waste were investigated at different temperatures. The result of the rape straw residues pyrolysis conversion demonstrated that high temperatures determine an important increase of H_2 content in the gas phase, this strongly affecting the energy potential of the pyrolysis gas [13]. The physical properties of the liquid production from pyrolysis of waste plastic bag compared favorably with diesel oil, which shows that it can be used as diesel oil substitution [14]. The results and quality of the pyrolysis product using plastic waste are highly dependent on the parameter setting such as temperature, reactor type, residence time, pressure, different catalysts usage and type of fluidizing gas with its flow rate [15]. Furthermore, the TGA experiment showed when the heating rate increases, the decomposition temperature of the plastics samples also increases [16]. The aims of this paper to study the effect of pyrolysis reactor temperature on the yield and heating value of pyro-oil obtained from LDPE type plastic waste which are immensely available in Indonesia.

2. METHODS

2.1 Experimental Method

The reactor pyrolysis (diameter:260mm and high:250m) was made from stainless steel having the fuel feeder (header heigh:100mm, diameter:50mm) at top of reactor. A LDPE plastic waste was transfer into reactor by fuel feeder. Operating temperature at reactor was investigated at three different by 250 C, 275 C and 300 C. Non-circulating water condenser unit was setup with reactor and did not add of catalyst or extra chemical during process. Experiment was batch process fully closed system setup.

Temperature distribution of the reactor assessed by digital recording measurements on the reactor. Type K thermocouple installed on the reactor wall with 3 (three) measurement points to obtain the average temperature distribution that occurs. Temperature variations are carried out by controlling the valve on the heating furnace to achieve the required temperature setting.

Figure 1. Setup pyrolysis of LDPE plastic

The amount of LDPE plastic waste is put into the reactor is 0,7 kg. The batch type experiment was operating for up to 200 minutes until it reaches the set temperature. When the temperature inside the reactor reaches the pyrolytic temperature, the product gas is passed through the condenser where cooling water temperature is 30-35 ºC which causes the condensed gas to produce a pyro-oil. Then the liquid is collected from the reservoir and weighed. The product yield of condensate oil were determined by the following Eq. (1) respectively:

$$\text{Pyro} - \text{oil yield (wt\%)} = \frac{m.condensate}{m.feedstock} x\ 100\% \quad (1)$$

2.2 Heating Value Analysis

The 1341 Calorimeter is an improved version of a plain, static jacket, oxygen bomb calorimeter that has been made by Parr for any solid or liquid material. The calorimeter requires no permanent connections. It can be set up and ready to operate in a few minutes and, when not in use, can be disassembled easily and stores on a s helf.

Figure 2. Standardization of bomb calori using benzoid acid.

The quantity of energy evolved by combustion of Parr Instrument Company benzoic acid, when burned under standard bomb conditions* is given below [17], where the mass is against brass weights in air ** **26454 J/g, 6318.4 IT cal/g**, **11373 Btu/lb.** This value is based on a comparison of the combustion energy with NIST Standard Reference Material (SRM) 39j benzoic acid under identical experimental conditions. The results of at least 20 paired tests using an equal number of interleaved Parr samples and 39j control samples demonstrate no significant difference (95% CF) between the two heat of combustion values.
*) Certificate of Analysis SRM 39j Benzoic Acid, National Institute of Standards and Technology.
**) The reduction of weight in air to weight in vacuum results in a heat of combustion value of 26434 J/g for benzoic acid. This value uses the following assumptions:

- The density of benzoic acid at 25C is 1.320 g/cc.
- The density of dry air (1 atm and 20 C) is 0.0012 g/cc.
- The density of brass is 8.4 g/cc.

The heating value for the combustion that occurs in the bomb can be written with the following equation [17]

$$Q = \frac{W.\Delta T}{m} \quad (2)$$

Where:
Q = Heating value of the sample (cal/gr)
W = Calorimeter Heat Coefficient (cal/^{o}C)
ΔT = Different Temperature (^{o}C)
m = Mass of sample (gr)

3. RESULTS AND DISCUSSION

3.1 Pyro-oil production yield

The test is carried out for up to 200 minutes to ensure the pyrolysis process runs to completion. The resulting bio-oil product shows physical differences in the form of differences in color, level of turbidity and sedimentation. Figure 3 shows visual observations, namely differences in color, level of turbidity and the resulting precipitate. The higher the operating temperature, the cleaner and brighter bio-oil

Figure 3. Pyro-oil product with different pyrolysis temperature

The effect of reactor heating temperature on the pyrolysis process affects the amount of pyro-oil produced. Figure 4 shows the bio-oil yield increasing along with the increase temperature in the reactor. At a temperature of 250^{o}C, the yield was 22,4%wt, then increased to 35%wt at a temperature of 275^{o}C and the highest bio-oil yield 45,3%wt at a temperature of 300^{o}C.

Low heating rates (slow pyrolysis) such as 10 and 20 C/min was found to produce oil with low or no wax formation due to the high residence time of volatiles inside the heating zone for further cracking to produce low range hydrocarbons. At low temperature and heating rate, the dissociation mainly causes the formation of aliphatic olefins and paraffin [18]

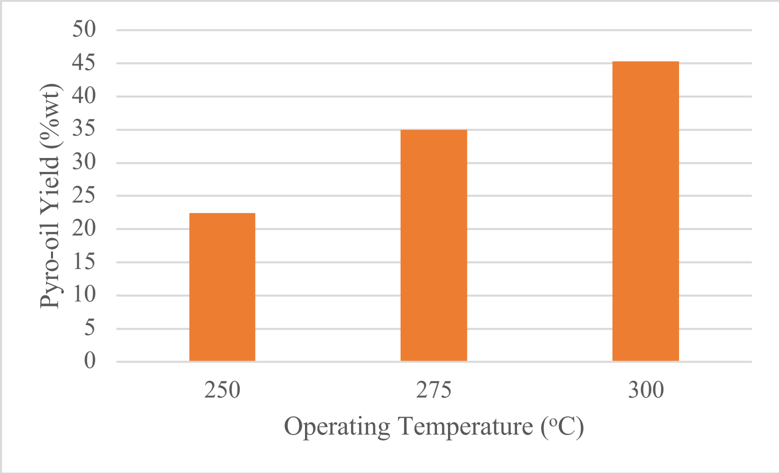

Figure 4. Average pyro-oil yield on pyrolysis of plastic LDPE

3.2 Heating Value of Pyro-Oil

The heating value was investigated repeated twice to provide a comparison of test results and reduce the risk of invalid data. Pyro-oil samples at a temperature of 250°C were tested twice and labeled A1, A2, 275°C with labels B1, B2, and 300°C with labels C1, C2. Bomb calorimeter test begins with standardizing procedure using a standard sample of benzoic acid. The weight of the samples tested in each is ± 1 gram. The temperature difference was measured in the water (water jacket) which was recorded in a stable condition, shortly before the bomb, and the highest temperature after doing the bomb. The comparison of the heating value presented in Table 1 where the resulting calorific value is an increase in line with the increase in the reactor temperature

No	Calorimeter Heat Coefficient (cal/°C)	Sampel	Massa	ΔT (°C)	HHV (calgr)	Average
1	**1804,09**	A1	1,0147	5,41	9613,50	**9612,85**
2		A2	1,0154	5,41	9612,21	
3		B1	1,0219	5,54	9780,48	**9674,80**
4		B2	1,0341	5,49	9569,14	
5		C1	1,0162	5,45	9676,03	**9769,78**
6		C2	1,0142	5,55	9863,53	

Table 1. High Heating Value (HHV) of pyro-oil from different temperature of reactor

4. CONCLUSION

The results showed that pyrolysis product are highly dependent on parameter temperature setting. The highest temperature reactor at 300oC showed maximum pyro-oil yield of 45,3 %wt. Visual observation of the pyro-oil shows that there are differences in color degradation, where the higher of the reactor temperature, the brightness of the pyro-oil also increases. The highest calorific value of the bio-oil product is that which is produced from the highest operating temperature of 9.76.78 cal/g.

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