LOGIC
Journal of Engineering Design and Technology
Vol. 21 No.3 November 2021; p. 179 - 183

p-ISSN : 1412-114X
e-ISSN : 2580-5649
http://ojs2.pnb.ac.id/index.php/LOGIC

DESIGN AND FABRICATION OF A FIXED BED PYROLYSIS WITH LDPE PLASTIC WASTE

1,2,3) Mechanical Engineering,Politeknik Negeri Bali, Jimbaran, Badung, Indonesia
4) Mechanical Engineering, Udayana University, Jimbaran, Badung, Indonesia

Correponding email [1)]: agusputrawan@pnb.ac.id

I Made Agus Putrawan[1)], I Ketut Gde Juli Suarbawa[2)], I Made Rajendra[3)], I N S Winaya[4)]

Abstract.
This paper presents the design of a fixed bed reactor pyrolysis to convert plastic waste type LDPE into condensate oil. The dimensions of the batch type pyrolysis reactor are adapted to household needs and are designed to be easy to operate and transport. From the results at three different pyrolysis temperature variations; 250 °C, 275 °C and 300 °C shows that reactor yields a maximum condensate oil of 45,3wt% at temperature of 300 °C. In addition, the weight of charcoal also decreased along with the increase in operating temperature.

Keywords: design and fabrication, fixed bed pyrolysis, plastic LDPE, condensate oil

1. INTRODUCTION

Currently, the waste problem has become a common problem in various places, especially in big cities which have relatively dense population with relatively limited waste disposal sites and almost all waste disposal sites in cities in Indonesia only apply open dumping which is considered not to be appropriate as a systematic way of handling waste [1]

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. Conversion of plastic waste into fuel has several advantages, as well as being one of the main alternatives for processing plastic waste, because landfill and incineration methods have a negative impact on the environment.

Pyrolysis technology is an alternative for municipal solid waste treatment which is considered quite prospective to be developed because it has several advantages 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].

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 [3].

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]

Plastic based on its type consists of two, namely thermoplastic and thermoset plastic, thermoplastic is a plastic that has been shaped to soften by heat treatment and can be reshaped repeatedly, until it loses its constituents. Thermoset plastics are plastics that have been molded and cannot be softened by heat treatment. Excess heat will burn the constituents. 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.

Knowledge of the thermal properties of various types of plastics is very useful for the plastic recycling process which includes the thermal properties of melting point (Tm), transition temperature (Tg) and decomposition temperature. The transition temperature is the temperature when the plastic undergoes structural stretching so that there is a change from a rigid state to a more flexible state. Above the melting point, the plastic experiences an increase in volume so that the molecules move more freely which is indicated by an increase in their flexibility. The melting temperature is the temperature at which the plastic begins to soften and turn into a liquid. The decomposition temperature is the limit of the liquefaction process. If the temperature is raised above the melting temperature, the plastic will flow easily and the structure will decompose. Decomposition occurs because the thermal energy exceeds the energy binding the molecular chains.

Based on the above description it is deemed necessary to research the effect of working temperature by design of the pyrolysis system on the oil yield product.

2. MATERIALS AND METHODS

2.1 Feed stock

Plastic waste used as fuel for this experiment was collected from household production which is usually dominated by LPDE types such as plastic bags for dry-cleaning, newspapers, bread, frozen foods, fresh produce and garbage. Thus, maintaining uniform characteristics, the plastic is separated from the impurities and cropped into equal sizes.

2.2 Reactor design

The application of fixed bed pyrolysis equipment with batch reactor type is designed for household scale with a maximum capacity of 0.01 m3 which can treat crackle waste produced by households on average for 4 days. 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. Design and sign is made to carry a compact concept with m that is easy to move and operate. The preheating source comes from a heating furnace using LPG fuel. Crackle-type plastic waste can be inserted into the feeder nut located at the top of the reactor. The system pyrolysis was designed as the Fig.1 bellow

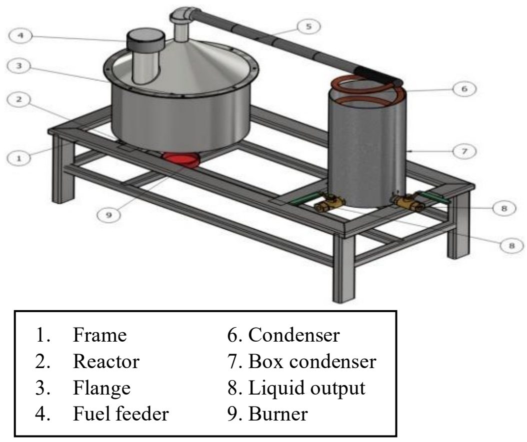

Figure1. The schematic design of fixed bed pyrolysis system

2.3 Experimental Method

A LDPE plastic waste was transfer into reactor by fuel feeder. A waste plastic to fuel production process was applied at three different temperature by 250 C, 275 C and 300 C. During fuel production process vacuum system did not apply and catalyst or extra chemical did not added. Condensation unit was setup with reactor and no water circulation system was added. Experiment was batch process fully closed system setup.

The operating temperature of the reactor will be assessed by recording the temperature measurements on the reactor. Type K thermocouple will be 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.

LDPE (700g) plastic waste is put into a fixed bed pyrolysis reactor. The reactor admires 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 C which causes the condensed gas to produce a liquid. Then the liquid is collected from the reservoir and weighed. The product yield of condensate oil were determined by the following Eq. (1) respectively:

$$\text{Condensate oil yield (wt\%)} = \frac{m.\,condensate}{m.\,feedstock}\,x\ 100\%$$

3. RESULTS AND DISCUSSION

3.1 Temperature Distribution

The temperature distribution in the pyrolysis reactor is controlled by 3 type K thermocouples mounted on the reactor with a height distance of 30mm at each point. Real time data recording using 4 channel digital temperature display. The heating rate control is done by manually adjusting the valve opening on the stove. The temperature of the cooling water in the condenser is also recorded to display the condition of the cooling water. The temperature distribution obtain by 250ºC showed as Fig 2. below

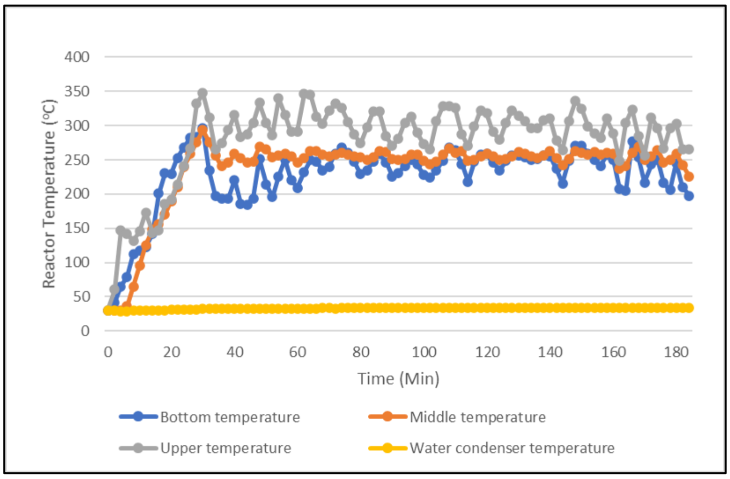

Figure 2. Temperature distribution 250ºC

3.2 Condensate oil yields

The effect of reactor heating temperature on the pyrolysis process affects the amount of oil produced. Table 1 shows an increase in the volume of condensate oil production along with the increase in temperature in the reactor. At a temperature of 250ºC, the volume of condensate oil produce was 182 ml, then increased to 310 ml at a temperature of 275ºC and the highest volume was 526.5 ml at a temperature of 300ºC.

Table 1. Pyrolysis product with different temperature

Reactor temperature (ºC)	Feed mass of LDPE (gram)	Volume of condensate oil (ml)	Condensate oil yields (%wt)
250	700	182	22,4
275	700	310	35
300	700	526,5	45,3

From the results of the volume of condensate oil, it shows that the increased temperature has an effect on the increase in the volume of condensate oil. A reactor temperature of 250ºC showed a volume of condensate oil of 182ml, an increase temperature to 275°C results in an increased the volume of condensate oil to 310ml and at a temperature of 300ºC produced the highest condensate oil, which is 526.5ml. This is influenced by the decomposition process of the plastic that has entered the melting temperature phase (Tm) of 330ºC to release the molecular bonds that form plastic into gas.

3.3 Char product

Fig. 3 shows the mass of charcoal produced during the pyrolysis process. At a temperature of 250ºC, the amount of charcoal is 175 grams, an increase in temperature to 275ºC indicates a decrease in the amount of charcoal, which is 122 grams and the lowest mass of charcoal is 70 grams, which is produced at a reactor temperature of 300ºC. The increase in reactor temperature will reduce the amount of charcoal produced in the pyrolysis system.

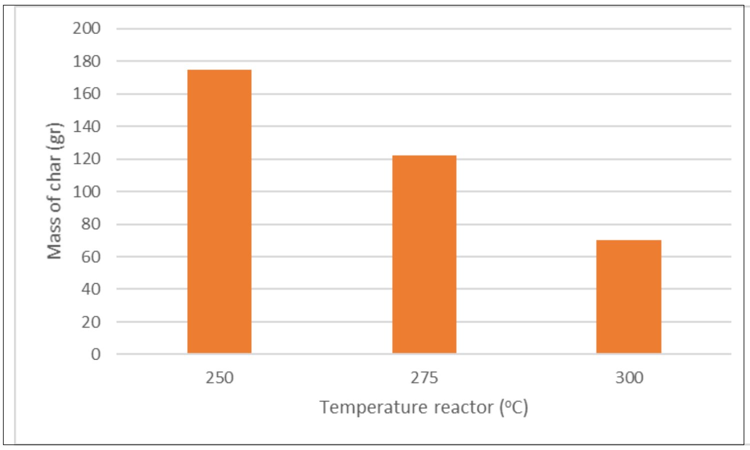

Figure 3. Char product with different temperature

4. CONCLUSION

From the results obtained, it can be concluded that the highest amount of condensate oil production is produced at a reactor temperature of 300C, which is 45.3%wt. The amount of charcoal produced decreased as the pyrolysis temperature increased.

5. ACKNOWLEDGEMENT

The author would like to thank the board and reviewer of LOGIC Journal. Logic is a peer-reviewed research journal aiming at promoting and publishing original high quality research in all disciplines of engineering and applied technology. All research articles submitted to Logic should be original in nature, never previously published in any journal or presented in a conference or undergoing such process across the world. All the submissions will be peer-reviewed by the panel of experts associated with particular field. Submitted papers should meet the internationally accepted criteria and manuscripts should follow the style of the journal for the purpose of both reviewing and editing. And Acknowledgments also to colleagues for all the support and assistance provided in this study

6. REFERENCES

[1] Damanhuri, Enri. Damanhuri, Tri Padmi. 2003. Pengelolaan Sampah. Bandung

[2] Himawanto, D.A., Indarto, Saptoadi, H. Rohmat, T.A. 2010. Pengaruh Heating Rate Pada Proses Slow Pyrolisis Sampah Bambu dan Sampah Daun Pisang. Prosiding Seminar Rekayasa Kimia dan Proses, Jurusan Teknik Kimia Fakultas Teknik Universitas Diponegoro, Semarang.

[3] Savira, F. L., & C., O. H. (2018). Pirolisis Sampah Plastik Sebagai Bahan Bakar Alternatif Dengan Penambahan Sampah Ranting. Jurnal Envirotek, 9(2), 32–40. https://doi.org/10.33005/envirotek.v9i2.966

[4] Ly, H. V., Kim, S. S., Choi, J. H., Woo, H. C., & Kim, J. (2016). Fast pyrolysis of Saccharina japonica alga in a fixed-bed reactor for bio-oil production. Energy Conversion and Management, 122, 526e534.

[5] I. N. S. Winaya and T. Shimizu, "Reduction of the volatile matter evolution rate from a plastic pellet during bubbling fluidized bed pyrolysis by using porous bed material," Chem. Eng. Technol., vol. 30, no. 8, pp. 1003–1009, 2007, doi: 10.1002/ceat.200600309.

[6] Islam, M. R., Tushar, M. S. H. K., & Haniu, H. (2008). Production of liquid fuels and chemicals from pyrolysis of Bangladeshi bicycle/rickshaw tire wastes. Journal of Analytical and Applied Pyrolysis, 82(1), 96–109. doi:10.1016/j.jaap.2008.02.005

[7] Swamardika, I. B. A., Winaya, I. N. S., & Hartati, R. S. (2019). Utilization plastic waste using pyrolysis fixed bed. IOP Conference Series: Materials Science and Engineering, 539, 012021. doi:10.1088/1757-899x/539/1/012021

[8] A. Li et al., "Investigation of pyrolysis of waste plastics in a rotary kiln - influence of final pyrolysis temperature on pyrolysis products," J. Fuel Chem. Technol., vol. 27, no. 4, p. 346, 1999.

[9] Fu, P., Yi, W., Bai, X., Li, Z., Hu, S., & Xiang, J. (2011). Effect of temperature on gas composition and char structural features of pyrolyzed agricultural residues. Bioresource Technology, 102(17), 8211–8219. doi:10.1016/j.biortech.2011.05.08

[10] Abnisa, F., Arami-Niya, A., Daud, W. M. A. W., & Sahu, J. N. (2013). Characterization of Bio-oil and Bio-char from Pyrolysis of Palm Oil Wastes. BioEnergy Research, 6(2), 830–840. doi:10.1007/s12155-013-9313-8

[11] Aguiar, L., Márquez-Montesinos, F., Gonzalo, A., Sánchez, J. L., & Arauzo, J. (2008). Influence of temperature and particle size on the fixed bed pyrolysis of orange peel residues. Journal of Analytical and Applied Pyrolysis, 83(1), 124–130. doi:10.1016/j.jaap.2008.06.009

[12] Rajendra, I. M., Winaya, I. N. S., Ghurri, A., & Wirawan, I. K. G. (2019). Pyrolysis study of coconut leaf's biomass using thermogravimetric analysis. IOP Conference Series: Materials Science and Engineering, 539, 012017. doi:10.1088/1757-899x/539/1/012017

[13] Bajus, M. dan Hajekova, E. (2010). Thermal Cracking of The Model Seven Components Mixed Plastiks into Oils/Waxes. Petroleum and Coal.

[14] Isahak, W. N. R. W., Hisham, M. W. M., Yarmo, M. A., & Yun Hin, T. Y. (2012). A review on bio-oil production from biomass by using pyrolysis method. Renewable and Sustainable Energy Reviews, 16(8), 5910–5923. https://doi.org/10.1016/j.rser.2012.05.039

[15] Mokhtar, A., Jufri, M., & Supriyanto, H. (2018). Perancangan Pirolisis Untuk Membuat Bahan Bakar Cair Dari Limbah Plastik Kapasitas 10 KG. Seminar Nasional Teknologi Dan Rekayasa 2018, 126–133.

[16] Budiyantoro, C., 2010. Thermoplastik dalam Industri. Teknika Media, Surakarta.