World Journal of Advanced Engineering Technology and Sciences

eISSN: 2582-8266

Cross Ref DOI: 10.30574/wjaets

Journal homepage: https://wjaets.com/

WJAETS

(RESEARCH ARTICLE)

Check for updates

Characteristics physical and chemical properties of fuel from plastic waste for mineral water glasses

Ida Bagus Alit * and I Made Mara

Department of Mechanical Engineering, Faculty of Engineering, University of Mataram, Jl. Majapahit No. 62 Mataram-Nusa Tenggara Barat 83125, Indonesia.

World Journal of Advanced Engineering Technology and Sciences, 2024, 11(01), 268–273

Publication history: Received on 30 November 2023; revised on 13 February 2024; accepted on 15 February 2024

Article DOI: https://doi.org/10.30574/wjaets.2024.11.1.0050

Abstract

This research aims to convert plastic waste, especially plastic cups for packaging mineral water, into fuel oil through a pyrolysis process. The experimental method used is with the following stages: first, 1kg of plastic raw material is chopped before being put into a pyrolysis tube. Next, the tube is heated to change the plastic into a liquid form which then evaporates. The hot steam from this plastic is channeled to a heat exchanger to be condensed. Cooling is carried out using water flowing in the opposite direction to the direction of the steam. The results of plastic vapor condensation are collected to analyze their physical and chemical properties. Testing of physical and chemical properties includes specific gravity, heating value, kinematic viscosity, flash point, ash, lead and sulfur content. The result is that fuel from plastic bottle waste has a density value of 742 kg/m3, kinematic viscosity of 1.76 cSt, lower heating value of 43.28 MJ/kg, flash point of 1^{0}C, ash, lead and sulfur content respectively of 0.003905%, 0.0000231%, and 0.000462%.

Keywords: Plastic waste; Pyrolysis; ; Heat exchanger; Physical and chemical properties

1. Introduction

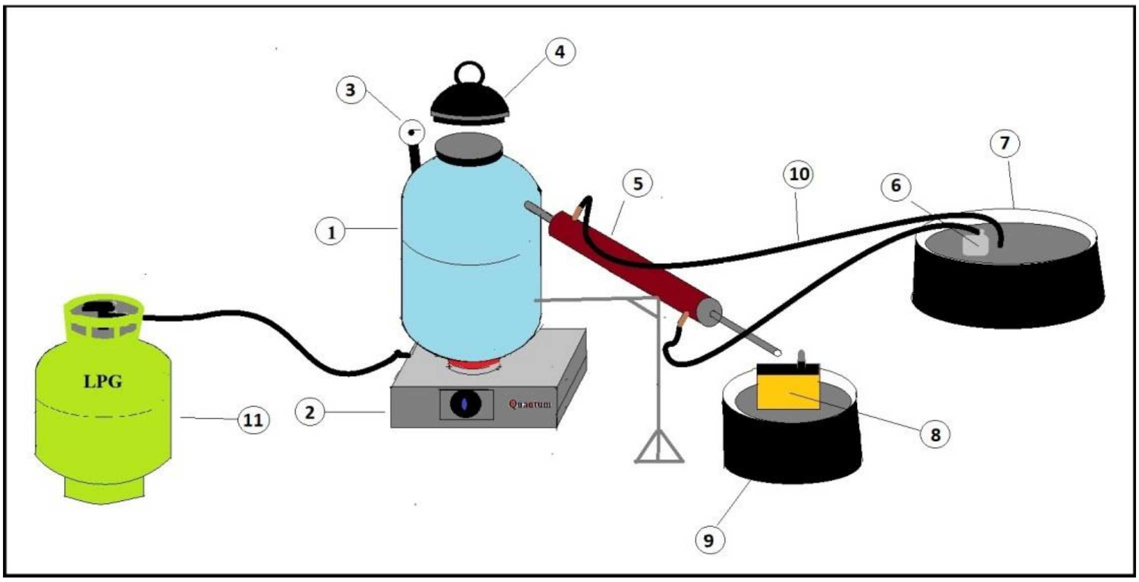
Plastic is a type of polymer that has unique and extraordinary characteristics. Polymers themselves are materials formed from molecular units known as monomers [1]. The use of plastic is generally widespread in society because of its advantages, such as the ability to be shaped according to needs, easy to carry, and affordable prices. However, plastic has weaknesses, especially in that it is difficult to decompose by soil, which can cause environmental pollution. Plastic can be divided into two types, namely thermoset plastic and thermoplastic plastic. Thermosetting plastic cannot be recycled because its polymer structure forms a three-dimensional network. Examples of thermosetting plastics include PU (Poly Urethene), UF (Urea Formaldehyde), MF (Melamine Formaldehyde), polyester, epoxy, and so on. Meanwhile, thermoplastic plastic can be molded repeatedly by heating. Thermoplastic plastics involve PP, PE, PS, ABS, SAN, nylon, PET, BPT, Polyacetal (POM), PC, and others [2]. Indonesia is ranked second as a producer of plastic waste after China [3], indicating the potential for significant environmental impacts. The Indonesian government has committed to reducing plastic waste through the 3R (Reduce, Reuse, Recycle) program, with a target of reducing it by 70% by 2025 [4]. Several studies have been carried out in an effort to contribute to plastic waste management. The Integrated Sustainable Waste Management (ISWM) model highlights the importance of collaboration between stakeholders, landfills, and waste processing facilities [5]. Reducing plastic waste can also be achieved through policies limiting the use of plastic bags, as has been implemented by several countries such as Denmark, China, Bangladesh, South Africa and Belgium, either through bans or taxes [6]. Tertiary recycling involves the conversion of plastic waste into fuel oil, which can be achieved through a cracking process. This cracking process aims to break down plastic polymer chains into compounds with lower molecular weights. The results of plastic cracking can be used as chemicals or fuel, and there are three types of cracking processes that are commonly used [7]: a. Hydro Cracking: Hydro cracking involves the reaction

* Corresponding author: Ida Bagus Alit.

of plastic with hydrogen in a closed container equipped with a stirrer at a temperature between 423K – 673K and a hydrogen pressure of 3 – 10 MPa. This process uses catalysts and solvents such as 1-methyl naphthalene, tetralin, and decalin to facilitate mixing and reaction. Some of the catalysts used include alumina, amorphous silica alumina, zeolite, and zirconia sulphate, b. Catalytic Cracking: Catalytic cracking uses a catalyst to facilitate the cracking reaction. Catalysts help reduce the temperature and reaction time required, c. Thermal Cracking: Thermal cracking, including the pyrolysis process, involves heating polymer materials without oxygen. This process produces charcoal, oil from the condensation of gases such as paraffin, isoparaffin, olefin, naphthene, and aromatics, as well as non-condensable gases. The thermal cracking reaction can be carried out with or without a catalyst. Several types of pyrolysis reactors that have been developed include batch/semi batch reactors, fixed bed reactors, fluidized beds, and spouted beds. Utilizing plastic waste as fuel also involves developing a process for making oil from plastic. For example, research uses the ZSM-5 catalyst in making oil from LDPE type plastic waste using the pyrolysis method. This process is carried out without a catalyst at a temperature range of 150-420^{0}C, producing plastic oil equivalent to kerosene of around 30% of the pyrolysis results, with a high elemental sulfur content. Other research also includes making oil from LDPE plastic using a pyrolysis technique without a catalyst, with the result being kerosene type oil. The composition of sulfur content and heating value were analyzed using the ASTM method and gas chromatography [10,11,12].

2. Material and Methods

The research methodology used is experimental, namely the production of plastic oil through the pyrolysis method followed by evaluation of the physical properties of the oil produced. The main ingredient for plastic oil production is Polypropylene (PP) which is sourced from mineral water bottle packaging.



Pyrolysis reactor; 2. Heater; 3. Thermometer; 4. Cover; 5. Heat exchanger; 6. Pump; 7. Cooling bucket; 8. Condensate container; 9. Condensate cooling bucket; 10. Hose; 11. LPG cylinder;

Figure 1 Pyrolysis apparatus [13**]**

Before being used, plastic waste is thoroughly cleaned, cut into pieces, dried in the sun, then weighed (1 kg of plastic waste for each fuel oil production). The raw material is then put into the pyrolysis reactor and heated. The steam released from the pyrolysis reactor is directed and cooled in a heat exchanger, with water serving as a cooling medium that flows in the opposite direction to the pyrolysis steam. The condensed steam is collected in a container. The results are measured based on the volume and weight of the oil to determine its density. Viscosity testing uses a Viscometer (ASTM D88), while testing the flash point and fire point uses a Flash & Fire point Tester (ASTM D93). Calorific value testing was carried out using a Bomb Calorimeter (ASTM D7843). Measurement of lead content in ash was carried out using Atomic Absorption Spectrophotometry (AAS) ASTM D 3335 type AA 55. The results obtained were then compared with the results for gasoline and diesel.

3. Result and Discussion

The plastic waste pyrolysis process produces 1215 ml (0.9 kg) from 1 kg of raw material.

The maximum temperature of the pyrolysis reactor is 305^{0}C for waste plastic pyrolysis oil. The pyrolysis fuel was then tested and compared with gasoline and diesel fuel.

Figure 2 (a) row material (b) plastic pyrolysis oil

Figure 3 shows the results of plastic pyrolysis oil density testing. Density shows how much mass is contained in a certain volume. The density of plastic oil is 742 kg/m^3, this value is equivalent to gasoline fuel. Similar results were also obtained in plastic oil testing research [14] with a density range of 668 – 740 kg/m^3.

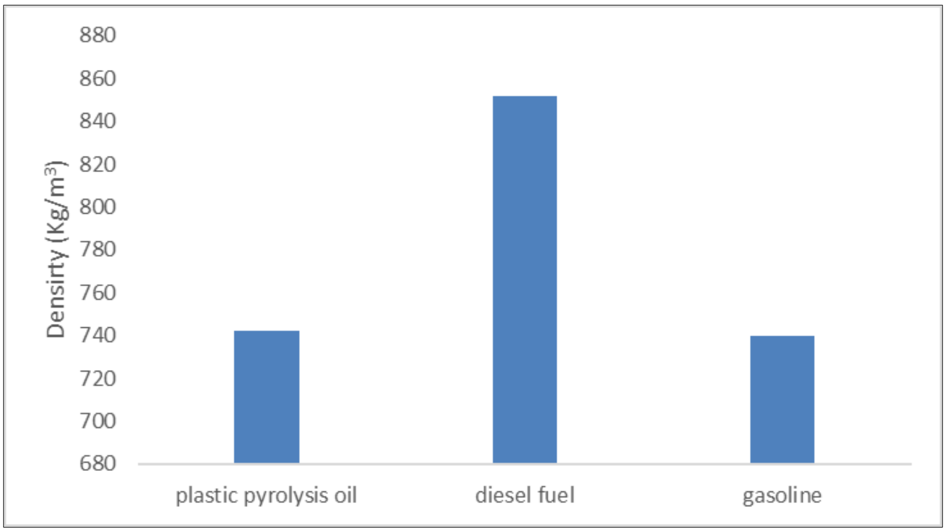


Figure 3 Density of pyrolysis fuel compared to diesel and gasoline fuels

The kinematic viscosity of plastic oil was obtained at 1.76 cSt, as shown in Figure 4. Kinematic viscosity is a measurement used to describe the ability of a fluid to flow and move relative to changes in temperature. The kinematic viscosity value of plastic pyrolysis oil is between the viscosity of gasoline and diesel.

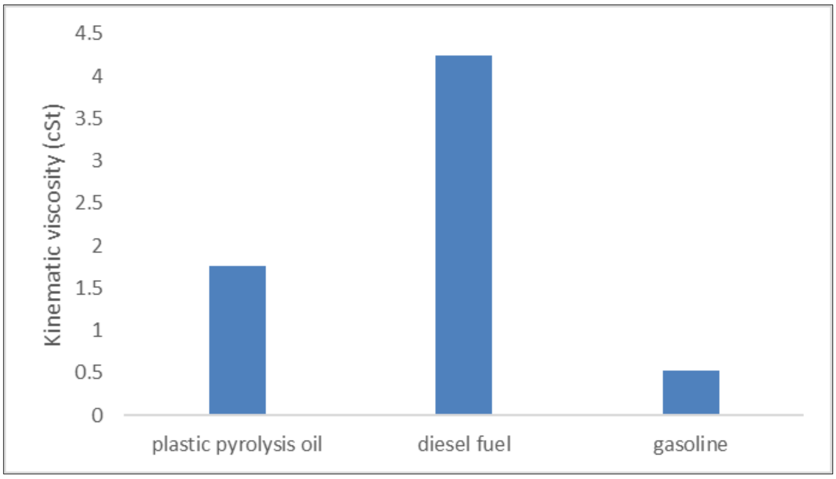


Figure 4 Kinematic viscosity of pyrolysis fuel compared to diesel and gasoline fuels

The flash point of plastic pyrolysis oil is 1^{0}C, as shown in Figure 5. This flash point value indicates that plastic pyrolysis oil is very flammable, so the storage process must be safer. The flash point value of plastic pyrolysis oil is much higher than gasoline fuel and lower than diesel fuel.

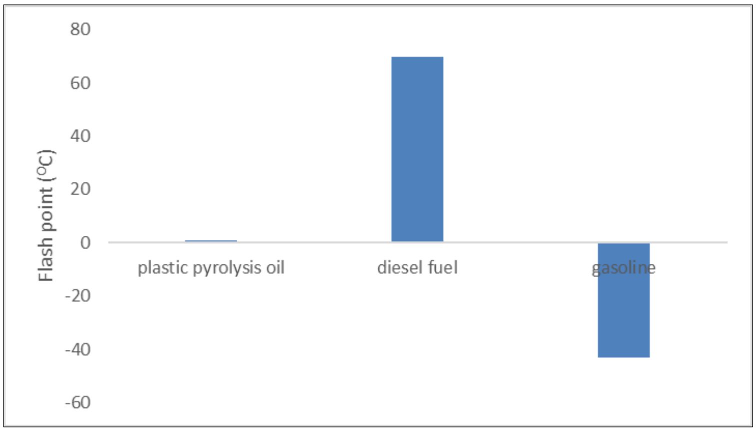


Figure 5 Flash pont of pyrolysis fuel compared to diesel and gasoline fuels

Figure 6 shows the lower heating value of plastic oil produced using the ASTM D 7843 Adiabatic Bomb calorimeter is 43.28 MJ/kg. The heating value of pyrolysis oil shows the amount of energy that the fuel can release when it goes through a combustion reaction. The calorific value of plastic pyrolysis oil is equivalent to gasoline, so the energy that this fuel can release is close to gasoline fuel. As a comparison, the results of testing the upper heating value in research [15] obtained the highest value of 44.3 MJ/kg.

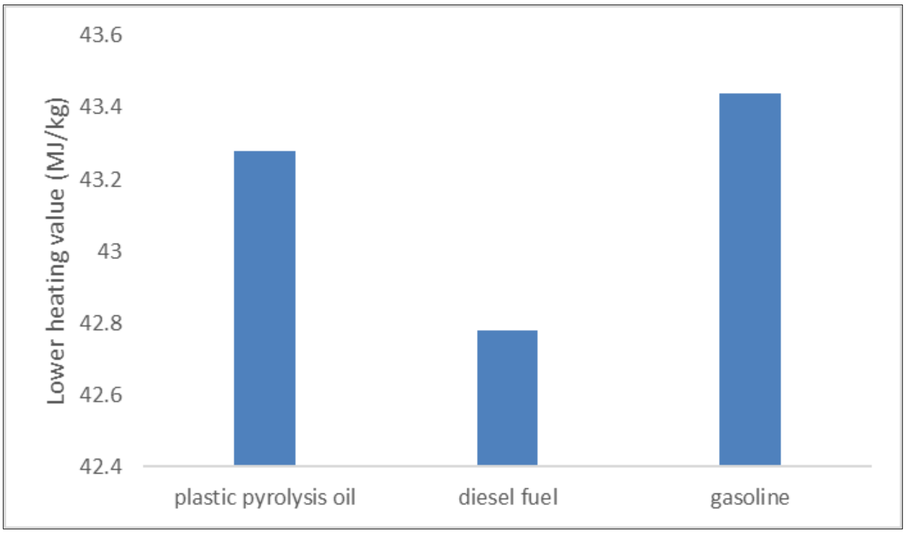


Figure 6 Lower heating value of pyrolysis fuel compared to diesel and gasoline fuels

Table 1. Shows the test results for ash content, sulfur content and Pb content of plastic pyrolysis oil compared to gasoline and diesel fuel. The results of plastic pyrolysis oil testing showed that the sulfur and lead content values were below the lower limit value for gasoline.

Table 1 Ash, Pb and Sulfur content

characteristics	Plastic pyrolysis oil	Diesel fuel	Gasoline
Ash content (%)	0.003905	-	0.01(Maks)
Pb content (%)	0.0000231	0.04 (Maks)	-
Sulfur content (%)	0.0004620	0.2 (Maks)	0.5 (Maks)

4. Conclusion

Pyrolysis of plastic waste produces 1215 ml (equivalent to 0.9 kg) from every 1 kg of initial raw material. The pyrolysis reactor reaches a maximum temperature of 305^{0}C during the conversion of plastic waste into pyrolysis oil. The results of the analysis of physical and chemical properties include measurements of density of 742 kg/m^{3}, kinematic viscosity of 1.76 cSt, lower heating value of 43.28 MJ/kg, flash point of 1^{0}C, ash, lead and sulfur content respectively of 0.003905%, 0.0000231%, and 0.000462%.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Kumar S, Panda, AK dan Sing RK, (2011), A review on Tertiary Recycling of High – Density polyethylene to Fuel, resources, Conservation and Recycling, 55, 893- 910

[2] Hendiarti, N. 2018. Combating Marine Plastic Debris in Indonesia, Science to Enable and Empower Asia Pacific for SDGs

[3] Jambeck. J.R., R. Geyer, C. Wilcox, T.R. Siegler, M. Perryman, A. Andrady, R. Narayan, K.L. Law. (2015), Plastic waste inputs from land into the ocean. Science 347(6223): 768-771. Doi: 1126/science.1260352.

[4] Guerrero, L.A., G. Maas, W. Hogland. (2013), Solid Waste Management Challenges for Cities in Developing Countries. Waste Management, 33, 220-232

[5] Nielsen, T.D., K. Horlmberg, J. Stripple. (2019), Need a Bag? A review of public policies on plastic carrier bags Where, how, and to what effect? Waste Management, 87, 428-440.

[6] Panda, A.K., (2011), Studies on Process Optimization for Production of Liquid Fuels from Waste Plastics. Thesis, Chemical Engineering Department National Institute of Technology, Rourkela.

[7] Miskolczi N, Nagy R. (2012), Hydrocarbons obtained by waste plastic pyrolysis: Comparative analysis of decomposition described by different kinetic models. Fuel Processing Technology , 104, 96-104

[8] Hussain Z, Khan KM, Perveen S, Hussain K, Voelter W. (2012), The conversion of waste polystyrene into useful hydrocarbons by microwavemetal interaction pyrolysis. Fuel Processing Technology, 94, 145-150

[9] Mohamad S, Saptoadi, Norsujianto, Cheng S, Zainal, Yoshikawa K, (2014), Fuel Oil Production From Municipal Plastic Waste in squential Pirolisis and catalytic Reforming reactors, Energi Procedia 47, 180-188.

[10] Sarker, M., Rashid, M.M., Rahman, M.S., dan Molla, M., (2012), Envirnmentally Harmful Low Density Waste Plastic Conversion into Kerosene Grade Fuel, Journal of Environmental Protection, 3, 700 – 708.

[11] Moinuddin, S., Mohammad Mamunor, R., Muhammad Sadikur, R., & Mohammad, M. (2012). Environmentally harmful low density waste plastic conversion into kerosene grade fuel. *Journal of Environmental Protection*

[12] Alit, I. B., Susana, I. G. B., & Mara, I. M. (2022). Conversion of LDPE and PP plastic waste into fuel by pyrolysis method. *Global Journal of Engineering and Technology Advances*, *10*(03), 073-078.

[13] Alit, I. B., & Sutanto, R. (2023). Effect of heat exchanger pipe diameter on the conversion of polypropylene plastic waste. World Journal of Advanced Engineering Technology and Sciences, 08(02), 339–343.

[14] Prurapark, R., Owjaraen, K., Saengphrom, B., Limthongtip, I., & Tongam, N. (2020). Effect of temperature on pyrolysis oil using high-density polyethylene and polyethylene terephthalate sources from mobile pyrolysis plant. *Frontiers in Energy Research*, *8*, 541535.

[15] Fulgencio-Medrano, L., García-Fernández, S., Asueta, A., Lopez-Urionabarrenechea, A., Perez-Martinez, B. B., & Arandes, J. M. (2022). Oil production by pyrolysis of real plastic waste. *Polymers*, *14*(3), 553.