Global Journal of Engineering and Technology Advances

eISSN: 2582-5003

Cross Ref DOI: 10.30574/gjeta

Journal homepage: https://gjeta.com/

Global Journal of Engineering and Technology Advances

eISSN 2582-5003

Global Scholar Press, INDIA

(RESEARCH ARTICLE)

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Liquid fuel production from high density polyethylene plastic waste

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Global Journal of Engineering and Technology Advances, 2023, 16(02), 086–091

Publication history: Received on 21 June 2023; revised on 29 July 2023; accepted on 01 August 2023

Article DOI: https://doi.org/10.30574/gjeta.2023.16.2.0149

Abstract

This research aims to determine the effect of heat exchanger diameter variations on the volume and physical properties of fuel derived from plastic waste. The plastic waste is converted using the thermal cracking method, which involves heating the raw material without oxygen. This process produces charcoal and oil from the gas condensation in the heat exchanger. The type of plastic used is High-Density Polyethylene (HDPE) waste. The variations of heat exchanger diameter used are 1/2inch, 3/4 inch, and 1 inch. The physical properties investigated include density, viscosity, and heating value. From the test results, it was found that density of the oil fuel produced from plastic waste decreased with increasing heat exchanger diameter. However, the volume and heating value of the fuel produced increased. Generally, the physical properties of plastic pyrolysis oil produced from the thermal cracking process of plastic waste resemble those of gasoline

Keywords: Plastic; Pyrolysis; Heat exchanger; Heating value

1. Introduction

Plastic is a synthetic material that has become ubiquitous in our daily lives. From packaging to electronics, from clothing to medical devices, plastic has become an integral part of modern society. However, the production and disposal of plastic have raised significant environmental concerns. Plastic is made from petroleum, a non-renewable resource, and its production requires a significant amount of energy and releases greenhouse gases. Furthermore, plastic waste is a major contributor to ocean pollution, with an estimated eight million metric tons of plastic entering the oceans each year. This not only harms marine life, but also affects the entire ecosystem and can potentially harm human health. The durability of plastic is both a blessing and a curse. On one hand, it allows for long-lasting products and packaging that can protect goods during transportation. On the other hand, it also means that plastic can persist in the environment for hundreds of years, leading to accumulation and pollution. To address the environmental impact of plastic, there have been efforts to reduce plastic usage, increase recycling rates, and promote the use of biodegradable alternatives. Many countries have implemented plastic bag bans or taxes, and companies are exploring more sustainable materials for their products. Consumers can also play a role by choosing to use reusable bags, water bottles, and straws. While plastic has undoubtedly brought convenience to our lives, it is important to recognize its environmental impact and take steps to reduce its negative effects. By working together, we can find sustainable solutions that balance our needs with those of the environment. High-Density Polyethylene (HDPE) is a type of plastic that is resistant to leakage, chemical substances, and has high strength and rigidity. HDPE is commonly used in various applications, including milk bottles, food containers, water pipes, cleaning products, and more. The advantages of HDPE include its corrosion resistance, ability to maintain the cleanliness and safety of food materials, and its recyclability. HDPE can be recycled and reused for various products, including plastic bottles, pipes, construction materials, and various household items. Additionally, HDPE is resistant to UV radiation, making it suitable for outdoor applications that are directly exposed to sunlight. HDPE plastic has high density, which provides good physical strength and durability, making it a popular choice for various

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industrial and consumer needs. However, it is important to note that while HDPE has long-lasting properties and is recyclable, excessive use and improper disposal can cause environmental issues. Therefore, it is important to reduce the sustainable use of HDPE plastic and recycle it to minimize negative impacts on the environment.

Indonesia is ranked second as the world's largest producer of plastic waste after China [1], which can cause significant environmental damage. The Indonesian government has committed to reducing plastic waste through the 3R program (Reduce, Reuse, Recycle), targeting a reduction of up to 70% by 2025 [2]. Various studies have been conducted to contribute to plastic waste management. The Integrated Sustainable Waste Management (ISWM) model emphasizes the need for collaboration between stakeholders, final disposal, and waste processing units [3]. Reduction of plastic waste can also be achieved through policies that limit the use of plastic bags, as implemented by several countries including Denmark, China, Bangladesh, South Africa, and Belgium, through bans or the imposition of taxes [4].

The technology used to convert plastic waste into fuel oil is through the process of thermal pyrolysis. Several studies on the conversion of plastic waste into high-quality liquid fuel products have been conducted and have shown promising results for further development [5].

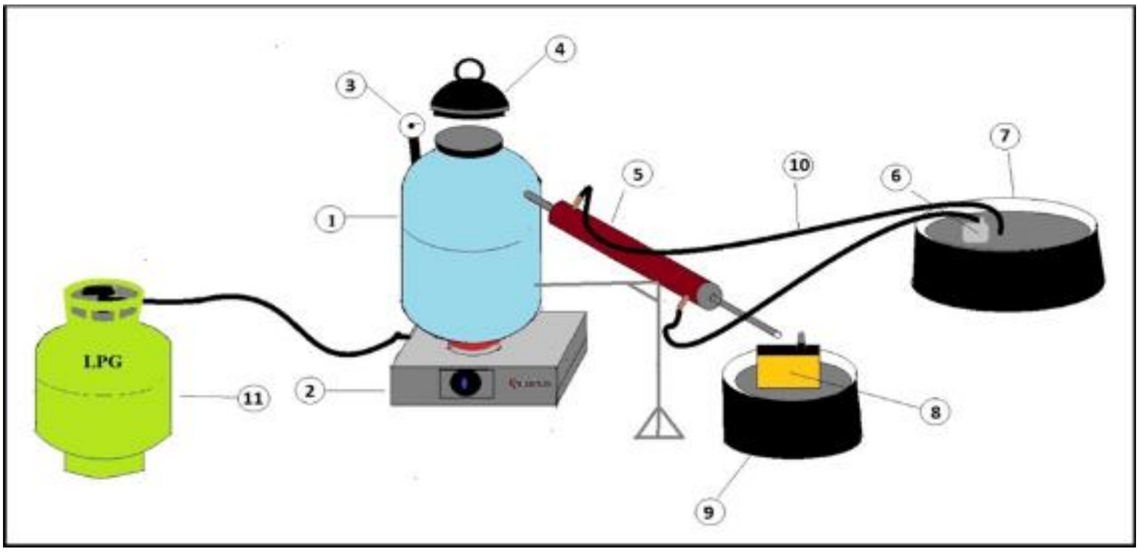
Chemical recycling methods like pyrolysis have the potential to significantly increase recycling rates by enabling the use of mixed waste plastics that cannot be processed through mechanical recycling. Pyrolysis offers an environmentally friendly alternative to incineration and inefficient landfilling, and it can also handle waste materials that are not efficiently collected separately, such as novel materials including composites, particularly during their early market stages when their volumes are low.

The pyrolysis process is defined as the thermal degradation of materials in a closed chamber without the presence of air. This process is suitable for processing various types of materials, including plastic waste, and is environmentally friendly. The main principle of pyrolysis is to heat the material at high temperatures without involving oxygen. During the pyrolysis process, high-molecular-weight substances are broken down into simpler substances such as gases, liquids, and solid carbon [6]. Various literature provides information on the typical temperature range used for materials; for example, a temperature range of 300-1000 °C has been published for the pyrolysis of plastic waste. The products of the pyrolysis process are typically referred to as pyrolysis oil, pyrolysis coke (charcoal), and pyrolysis gas. In addition to the chemical composition, the quantity and quality of pyrolysis products are also influenced by the moisture content of the substrate, particle size of the material, process temperature and pressure, heating rate, and catalytic properties of the substances used during the process [7]. Chemical recycling methods like pyrolysis have the potential to significantly increase recycling rates by enabling the use of mixed waste plastics that cannot be processed through mechanical recycling. Pyrolysis offers an environmentally friendly alternative to incineration and inefficient landfilling, and it can also handle waste materials that are not efficiently collected separately, such as novel materials including. However, there are several challenges that need to be addressed for effective implementation of plastic waste pyrolysis. These challenges include the limited availability and inconsistent quality of feedstock, inefficient and costly sorting processes, the absence of markets due to a lack of standardized products, and unclear regulations pertaining to plastic waste management. Overcoming these challenges will be crucial for the successful adoption and scale-up of pyrolysis as a plastic waste recycling solution [8]. The utilization of plastic waste as fuel has seen various developments, including the production of plastic oil using a catalyst. The research employed ZSM-5 as the catalyst in a batch reactor. Another study focused on manufacturing oil from LDPE plastic waste through pyrolysis, with different temperature variations [9]. This particular research did not involve the use of a catalyst in the process. The operating temperatures ranged between 150°C and 420°C. The outcome was a plastic oil comparable to kerosene, comprising approximately 30% of the pyrolysis product and containing a significant amount of sulfur. Similarly, oil production from LDPE plastic materials using pyrolysis techniques without a catalyst was explored [10]. The experiment was conducted under atmospheric pressure, with temperatures ranging from 150°C to 420°C. The resulting oil was identified as a type of kerosene. The sulfur content and calorific value were determined using ASTM methods and analyzed using gas chromatography.

Furthermore, the pyrolysis method has been employed to produce plastic oil using two different types of plastic: LDPE and PP. The research showed that the volume of fuel derived from PP plastic was higher and exhibited a higher calorific value compared to oil from LDPE plastic. In another study, plastic oil was manufactured from discarded PP water bottles using the pyrolysis method, with variations in the diameter of the heat exchanger pipe [11]. The resulting oil was subjected to physical property tests, including density, viscosity, and heating value. These tests aimed to compare the properties of the produced oil with other fuels.

2. Material and methods

The research method used is experimental. Plastic fuel oil is produced through the pyrolysis technique. Different sizes of heat exchangers were employed, including 1/2" diameter (D1), 3/4" diameter (D2), and 1" diameter (D3). Subsequently, the obtained oil underwent testing to assess its physical characteristics. The type of plastic used is HDPE (High-Density Polyethylene) waste.



1.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 [12]

HDPE plastic waste is first cleaned and then cut into small pieces. The prepared raw material is then fed into a pyrolysis reactor weighing 1 kg and heated. The vapor produced from the pyrolysis process is passed through a heat exchanger and then cooled using water as a coolant. The flow of pyrolysis vapor is counter to the flow of water. As a result, the vapor condenses and accumulates in the tank. The volume and weight of the oil produced are measured to determine its density. To assess viscosity, a viscometer (ASTM D88) is used, while the heating value is tested using a bomb calorimeter (ASTM D783).

3. Results and discussion

The production of oil from plastic waste through the pyrolysis method involves adjusting the diameter of the heat exchanger. The temperature of the reactor is gradually raised until it reaches the maximum temperature.

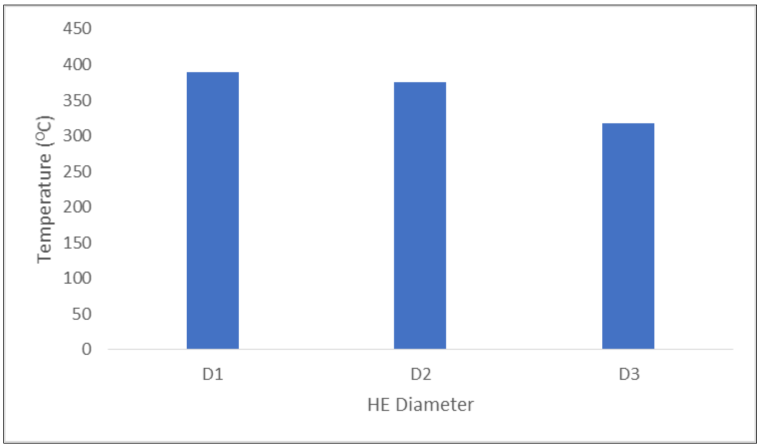


Figure 2 pyrolysis reactor temperature

The maximum temperature (Tmax) of the reactor exhibits an inverse relationship with the diameter of the heat exchanger employed. A larger diameter heat exchangers result in a lower Tmax value. Specifically, the average maximum temperatures recorded for each variation of heat exchanger diameter are 390°C, 375°C, and 317°C, respectively. The reactor temperature will produce a significant amount of oil fuel at temperatures above 300°C [13].

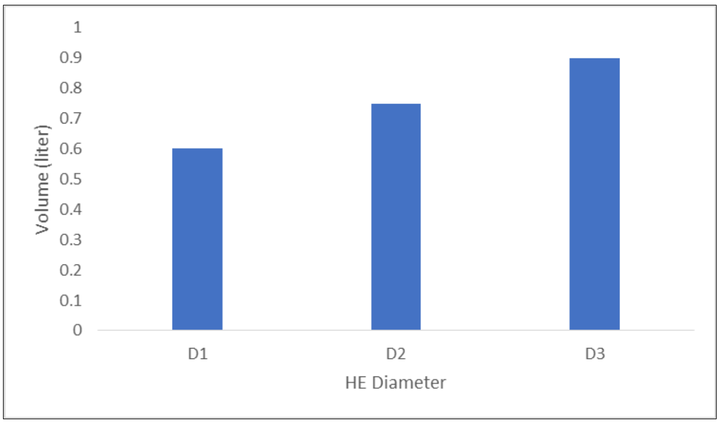


Figure 3 volume of HDPE plastic pyrolysis oil

In Figure 3, the graph illustrates the quantity of fuel generated through the pyrolysis process of HDPE plastic waste at different heat exchanger diameters. The average fuel volume produced for each heat exchanger diameter variation is 0.6 L, 0.75 L, and 0.9 L, respectively. The variations in heat exchanger diameter influence the volume of HDPE plastic pyrolysis oil. This is due to the larger diameter of the heat exchanger facilitating a greater contact area with the cooling water, resulting in an improved heat transfer process and increased condensation of gas. Conversely, a smaller heat exchanger diameter corresponds to a reduced contact area with the cooling water, leading to a diminished heat transfer process and lower gas condensation.

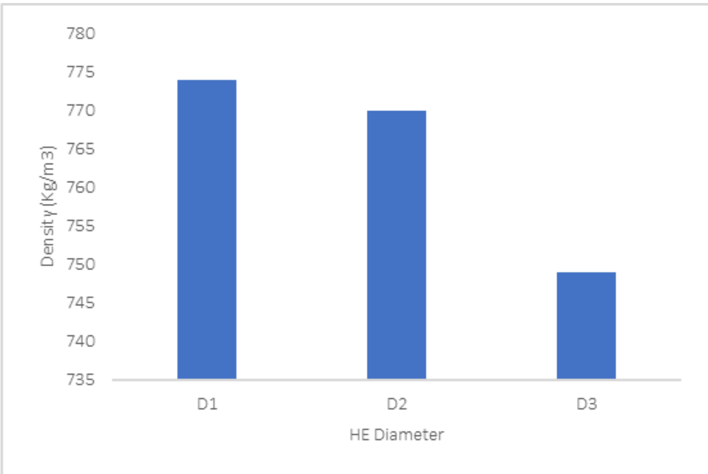


Figure 4 Density of HDPE plastic pyrolysis oil

The thermal cracking process in a heat exchanger with a diameter of 1/2 inch yielded the highest fuel density, averaging at 774 kg/m^3. Conversely, the lowest density was observed in the 1inch diameter heat exchanger, with an average value of 749 kg/m^3. The density of HDPE plastic pyrolysis oil produced in this study is lower than the density of the oil reported in the previous study [14], which was 799 kg/m^3. In general, the density of the produced oil is lower than that of the raw materials. The density of the resulting fuel is influenced by the density of the material used, where lower density materials yield lower density fuels. The density of the fuel oil is closely associated with the temperature maintained in the reactor during the plastic waste-to-fuel conversion process. Higher reactor temperatures correspond to higher fuel density, while lower reactor temperatures result in lower oil density.

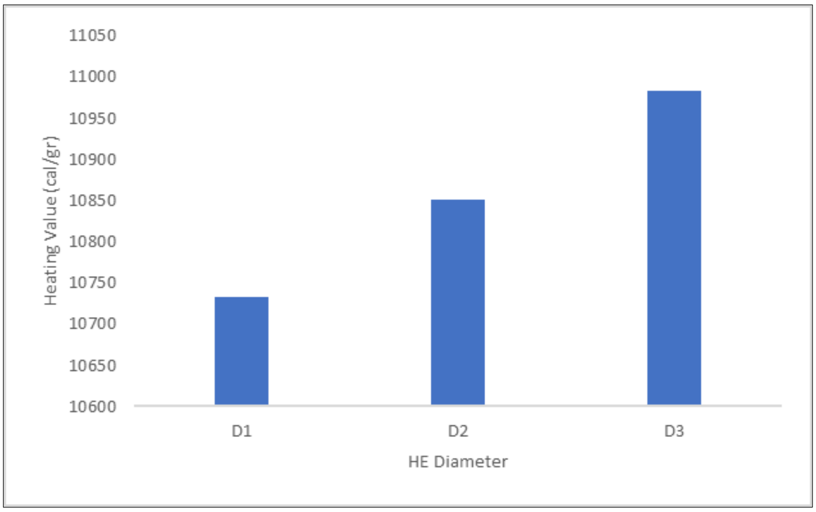


Figure 5 Heating value of HDPE plastic pyrolysis oil

Figure 5 shows the heating values of the fuel produced through the pyrolysis process using heat exchangers with diameters of 1/2 inch, 3/4 inch, and 1 inch. The recorded values are 10733cal/gr, 10851cal/gr, and 10983cal/gr, respectively. The heating value of the fuel is strongly connected to its density, with the calorific value of the fuel oil exhibiting an inverse relationship with its density. As the density of the fuel increases, its heating value decreases.

4. Conclusion

The maximum temperature of the reactor and the density of plastic oil pyrolysis will decrease with increasing heat exchanger diameter. However, the volume and calorific value of the resulting fuel increase. This research is expected to be one of the solutions to overcome the problem of plastic waste and the results can be used as fuel

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] 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.

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

[3] 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.

[4] 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.

[5] Iswadi, D., Nurisa, F., & Liastuti, E. (2017). Utilization of LDPE And Pet Plastic Waste To Become Fuel Oil With The Pyrolysis Process. Jurnal Ilmiah Teknik Kimia UNPAM, 1(2)

[6] Bridgwater, A. V., Meier, D., & Radlein, D. (1999). An overview of fast pyrolysis of biomass. Organic Geochemistry, 30(12), 1479–1493. https://doi.org/10.1016/S0146-6380(99)00120-5

[7] Honus, S., Kumagai, S., Fedorko, G., Molnár, V., & Yoshioka, T. (2018). Pyrolysis gases produced from individual and mixed PE, PP, PS, PVC, and PET—Part I: Production and physical properties. Fuel, 221, 346–360. https://doi.org/10.1016/j.fuel.2018.02.074

[8] Qureshi, M. S., Oasmaa, A., Pihkola, H., Deviatkin, I., Tenhunen, A., Mannila, J., ... & Laine-Ylijoki, J. (2020). Pyrolysis of plastic waste: Opportunities and challenges. Journal of Analytical and Applied Pyrolysis, 152, 104804.

[9] Mohamad Syamsiro, 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, pp. 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, 2012, 3, 700 – 708.

[11] 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

[12] Alit, I. B., & Sutanto, R. (2023). Effect of heat exchanger pipe diameter on the conversion of polypropylene plastic waste. Word Journal of Advanced Engineering Technology and Sciences, 8(02), 339-343

[13] Wajdi, B., Sapiruddin, S., Novianti, B. A., & Zahara, L. (2020). Processing Plastic Waste Into Fuel Oil (BBM) Using the Pyrolysis Method as an Alternative Energy. Kappa Journal, 4(1), 100-112.

[14] Syamsiro, M., Saptoadi, H., Norsujianto, T., Noviasri, P., Cheng, S., Alimuddin, Z., & Yoshikawa, K. (2014). Fuel oil production from municipal plastic wastes in sequential pyrolysis and catalytic reforming reactors. Energy Procedia, 47, 180-188.