World Journal of Advanced Engineering Technology and Sciences
eISSN: 2582-8266
Cross Ref DOI: 10.30574/wjaets
Journal homepage: https://wjaets.com/

(RESEARCH ARTICLE)

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Effect of heat exchanger pipe diameter on the conversion of polypropylene plastic waste

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World Journal of Advanced Engineering Technology and Sciences, 2023, 08(02), 339–343

Publication history: Received on 01 March 2023; revised on 11 April 2023; accepted on 13 April 2023

Article DOI: https://doi.org/10.30574/wjaets.2023.8.2.0114

Abstract

The purpose of this study was to determine the effect of the diameter of the heat exchanger on the formation of fuel oil from plastic waste. The raw material for plastic is polypropylene (PP), which is used to package mineral water. The research method used is an experiment to make plastic oil by pyrolysis. The procedure uses a kilogram of polyethylene. The raw material is cut into small pieces before being put into the pyrolysis tube. The result of this study is that the maximum temperature of the reactor (Tmax) is inversely proportional to the diameter of the heat exchanger used. The average volume of fuel oil produced in each variation of heat exchanger diameter is 0.625 L, 0.8 L, and 1 L, respectively. The average calorific value of the fuel produced in pyrolysis with a heat exchanger diameter of 1/2 inch, 3/4 inch, and 1 inch, respectively, is 10899.67 cal/gr, 10945.33 cal/gr, and 11062.33 cal/gr.

Keyword: Pyrolysis; Heat exchanger; Plastic; Calorific value

1. Introduction

Plastic production has increased dramatically around the world over the past 60 years. Plastic is currently recognized as a serious threat to the environment because it is difficult to decompose, so it can last a long time in the environment [1]. So far, the majority of people only think about the short-term benefits of plastic materials, namely that they are light weight, easy to carry, durable, strong, and more economical than other raw materials such as paper or cloth, without thinking much about the long-term impact on environmental sustainability. To realize environmental sustainability, a concept is needed that can be a breakthrough in overcoming environmental problems in resource management, namely the concept of sustainable development.

The potential for environmental damage from plastic waste is quite large. The Indonesian government has started to commit to reducing plastic waste through the 3R (reduce, reuse, recycle) program, and the government is targeting a reduction of up to 70% by 2025 [2]. This is done because Indonesia is the second largest producer of plastic waste after China [3]. Integrated Sustainable Waste Management (ISWM) states the need for collaboration between stakeholders, final disposal units, and waste processors [4]. Policies limiting the use of plastic bags to reduce plastic waste can also be implemented, as has been done by several countries, including Denmark, China, Bangladesh, South Africa, and Belgium, through prohibition and the implementation of taxes [5].

The cracking process is one way to convert plastic waste into oil. Cracking is the process of breaking down polymer chains into compounds with lower molecular weights. The result of this plastic cracking process can be used as a chemical or fuel. There are three kinds of cracking processes, namely: 1. Hydrocracking Hydrocracking is a cracking process that involves reacting plastic with hydrogen in a closed container equipped with a stirrer at a temperature

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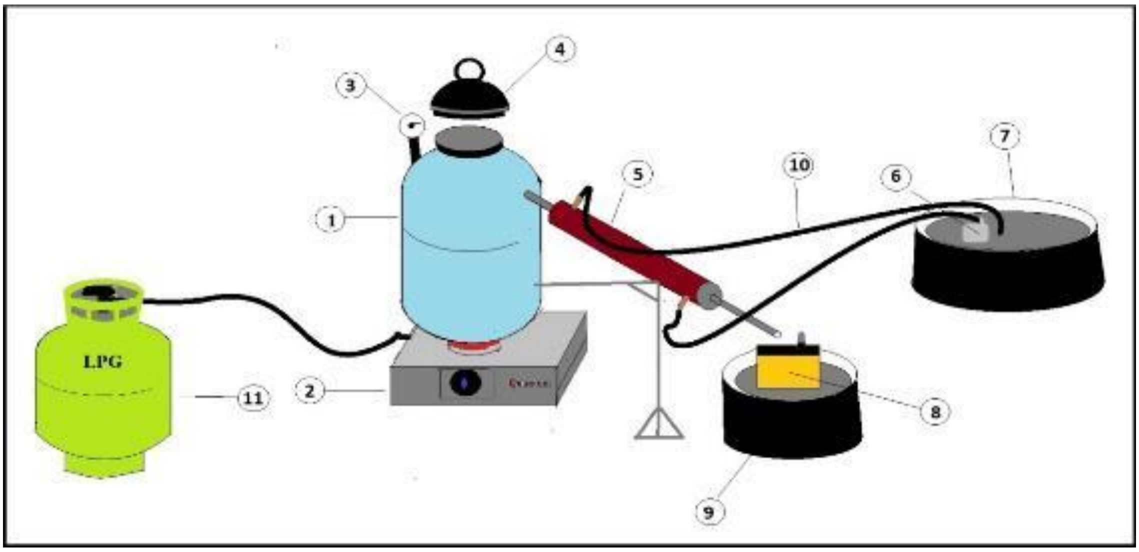
between 423 K and 673 K and a hydrogen pressure of 3–10 MPa. This hydrocracking process is assisted by a catalyst. To assist mixing and reactions, solvents such as 1-methyl naphthalene, tetralin, and decalin are usually used. Some of the catalysts that have been studied include alumina, amorphous silica alumina, zeolite, and zirconia sulfate. 2. Catalytic Cracking in this way uses a catalyst to carry out the fracture reaction. In the presence of a catalyst, it can reduce the temperature and reaction time. 3. Thermal cracking Thermal cracking is a pyrolysis process, namely, heating polymer materials without oxygen [6]. This process produces charcoal, oil from gas condensation such as paraffin, isoparaffin, olefin, naphthene, and aromatics, as well as gases that cannot be condensed. In plastic thermal cracking, the macromolecular structure of the polymer is broken down into smaller molecules. Thermal cracking reactions can be carried out with or without a catalyst. Several pyrolysis reactors have been developed and tested, such as batch and semi-batch reactors [7], fixed bed, fluidized bed, and spouted bed reactors [8].

The use of plastic waste as fuel has also developed, such as the process of making plastic oil using a catalyst [9]. The catalyst used in his research was ZSM-5 using a batch reactor. manufacture of oil from LDPE plastic waste by the pyrolysis method with variations in temperature [10]. This study did not use a catalyst in the manufacturing process. Operating temperature 150⁰C and 420⁰C. The result is a plastic oil that is equivalent to kerosene, which is about 30% of the pyrolysis product and contains a high element of sulfur. Making oil from LDPE plastic materials using pyrolysis techniques without a catalyst [11]. The experiment was carried out at atmospheric pressure with a temperature range of 150–420 ⁰C. The result is that the oil obtained is a type of kerosene. The composition of the sulfur content and calorific value was determined using the ASTM method and analyzed using gas chromatography. Making plastic oil by the pyrolysis method has also been carried out using two different types of plastic, namely LDPE and PP. The result is that the volume of fuel from PP type plastic is higher and has a higher calorific value when compared to oil from LDPE type plastic. In this research, oil will be made from plastic mineral water (PP) bottle waste using the pyrolysis method with variations in the diameter of the heat exchanger pipe. The results will be tested for physical properties including density, viscosity, and heating value. This test was carried out to be able to compare the properties of the oil produced against other fuels [12].

2. Material and Methods

The research method used is experimental. Plastic fuel oil is made by the pyrolysis method. Variations in the diameter of the heat exchanger used are 1/2" (D1), 3/4" (D2), and 1" (D3). The oil obtained was then tested for its physical properties. The raw material for making plastic oil is mineral water from glass bottles (polypropylene, or PP).



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

Before use, PP type plastic waste is first cleaned and then cut into pieces. The feedstock is then placed in a 1 kg pyrolysis reactor and heated. The steam leaving the pyrolysis reactor is then fed to the heat exchanger and cooled. Water is used as a coolant, which flows in the opposite direction to the flow of the pyrolysis steam. The vapor condenses and then settles in the tank. As a result, the volume and weight of the oil is measured to determine the density of the resulting oil. Viscosity test with a viscometer (ASTM D88). Test the calorific value with a bomb calorimeter (ASTM D78 3).

3. Result and Discussion

Making fuel from plastic waste by the pyrolysis method for each type of plastic by varying the diameter of the heat exchanger, the reactor temperature is increased slowly until it reaches the maximum temperature.

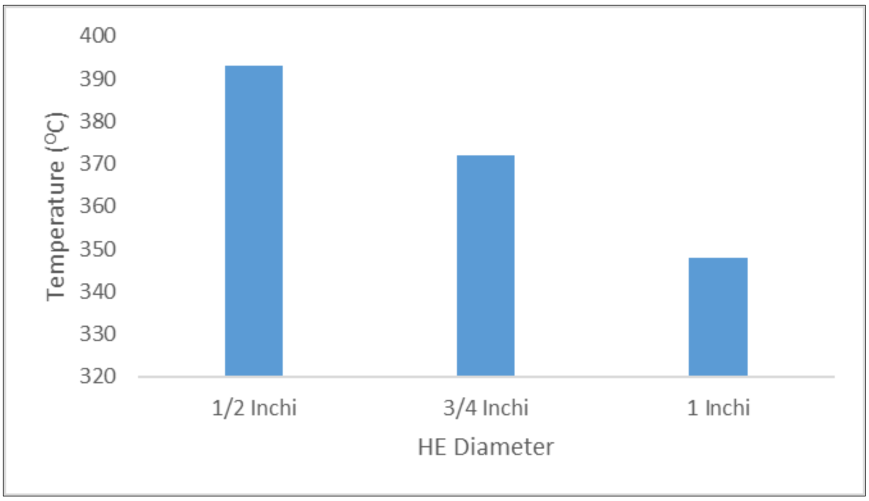


Figure 2 Pyrolysis temperature for HE diameter

The maximum temperature of the reactor (Tmax) is inversely proportional to the diameter of the heat exchanger used. The larger the heat exchanger diameter, the lower the Tmax. The average maximum temperature for each heat exchanger diameter variation is 393 ^{0}C, 372^{0}C and 348 ^{0}C respectively.

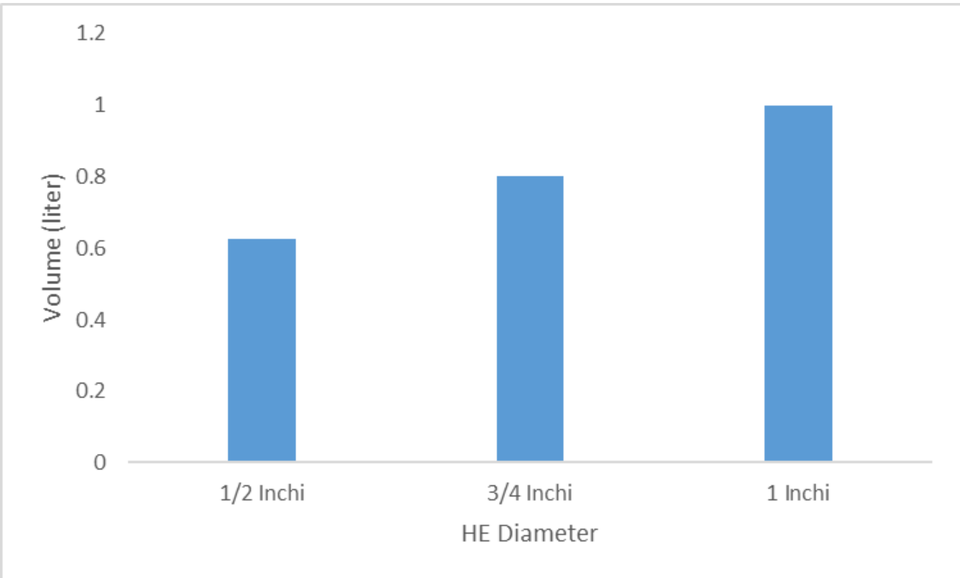


Figure 3 Volume of plastic waste fuel

Figure 3 shows the volume of fuel oil (BBM) produced from the pyrolysis process of PP type plastic waste at various heat exchanger diameters. The average volume of fuel produced in each heat exchanger diameter variation is 0.625 L, 0.8 L and 1 L respectively. Variations in heat exchanger diameter cause the volume of fuel oil produced to be different for each type of plastic. This is because the larger the diameter of the heat exchanger, the greater the cooling water contact area. So the heat transfer process is getting better and more gas can be condensed. Meanwhile, the smaller the diameter of the heat exchanger, the smaller the cooling water contact area. Thus, the process of heat transfer is getting smaller and less gas can be condensed.

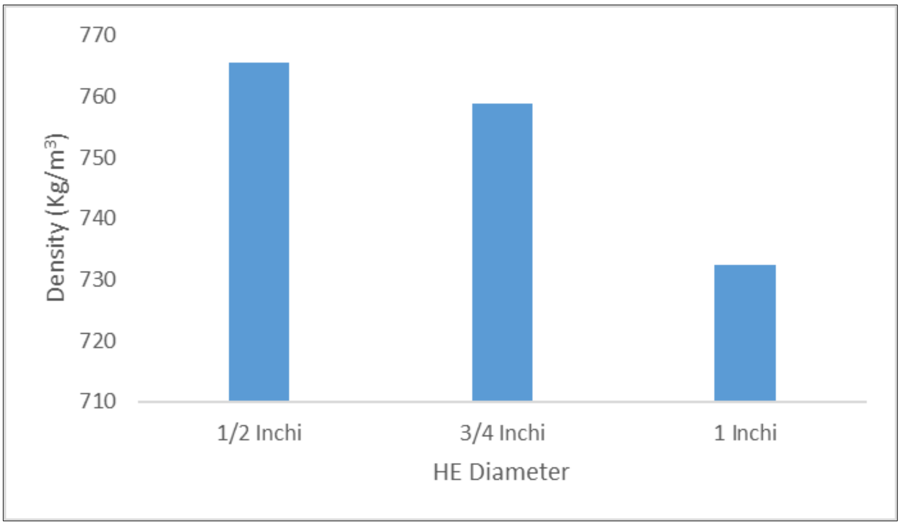


Figure 4 Density of plastic waste fuel

The highest fuel density was produced by the thermal cracking process in a 1/2 inch diameter heat exchanger with an average value of 765.57 kg/m^3, and the lowest in a 1 inch diameter heat exchanger with an average value of 732.33 kg/m^3. In general, the density of the resulting oil is lower than that of the basic ingredients. The lower the density of the material used, the lower the density of the resulting fuel. The resulting fuel oil density value is closely related to the reactor temperature during the process of making fuel from plastic waste. The higher the reactor temperature, the higher the resulting fuel density. Meanwhile, the lower the reactor temperature, the lower the density of the oil produced.

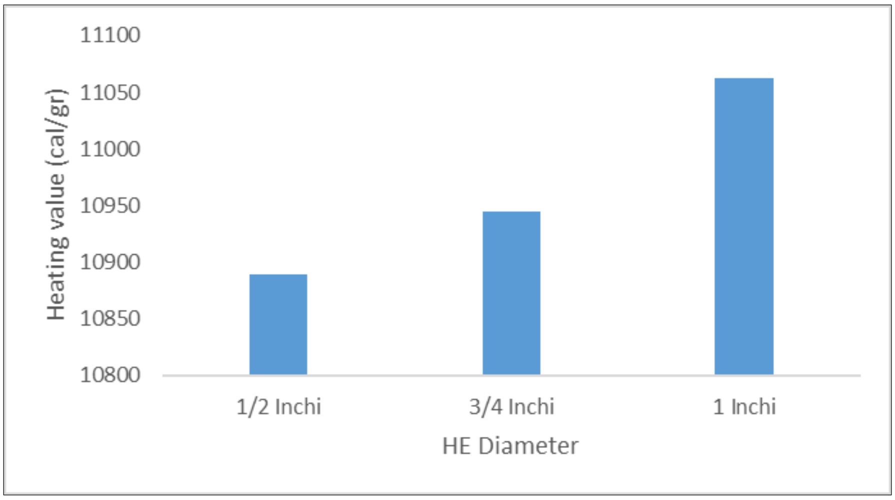


Figure 5 Heating value of plastic waste fuel

Figure 5 shows the heating value of fuel produced in the pyrolysis process with heat exchanger diameters of 1/2 inch, 3/4 inch and 1 inch, the results are 10899.67 cal/gr, 10945.33 cal/gr and 11062.33 cal/gr. Heating value of fuel is closely related to its density, the calorific value of fuel oil is inversely proportional to its density. The higher the density of the fuel, the lower the heating value.

4. Conclusion

Fuel oil produced by the pyrolysis method is a maximum of 1 liter per 1 kg of raw material. The larger diameter of the heat exchanger, the lower the reactor temperature. The average temperature of the pyrolysis process is 375^{0}C. Density of fuel oil is inversely proportional to the heating value. The calorific value obtained is close to the calorific value of gasoline.

Compliance with ethical standards

Acknowledgments

The author also wishes to thank the Department of Mechanical Engineering University of Mataram for facilitating the implementation of this research

Disclosure of conflict of interest

The authors declare no conflict of interest.

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