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Green and Sustainable Pyrolysis: Conversion of Plastic Solid Waste into Liquid Fuel

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Abstract

Excessive use of fossil fuel like gasoline and increasing number of automobiles has led to extensive scientific research in the field of alternative fuel sources. Also due to the vast range of uses of plastics across many industries, Plastic Waste in landfills and global production of plastic increased over time. The conversion of Waste plastic into liquid and gaseous fuels and value-added chemicals by pyrolysis followed by fractional distillation is explained as a practical and sustainable solution for recycling plastics because the calorific value of plastic is almost identical to that of hydrocarbon fuel. This research work is focused on converting high density plastic into liquid fuel by pyrolysis at temperature 200-400°C. The obtained liquid fuel was subjected to distillation at different temperature ranges. The density and viscosity of distilled sample was measured and was found to be close to that of petrol.

Keywords: Pyrolysis, Liquid Fuel, Sustainable Solution

1. Introduction

Plastics are an integral part of our modern life and are used in almost all daily activities. Since plastics are synthesized from non-renewable sources and are generally not biodegradable, waste plastics are the cause of many of the serious environmental problems the world faces today. However, waste plastics can become a source of enormous energy with the correct treatment. In recent years, huge amounts of waste plastic are available in municipal solid waste (MSW) and many places. Since the 1970s, the rate of plastic production has grown faster than that of any other material. If historic growth trends continue, global production of primary plastic is forecasted to reach 1,100 million tons by 2050 (Visual Feature | Beat Plastic Pollution, 2021). Kathmandu alone uses around 4,700,000 to 4,800,000 plastic bags daily. In Nepal, 16 percent of urban waste is comprised of plastic, which is 2.7 tons of daily plastic garbage production. In the global context, the found to be close to that of pure gasoline. The 10% WPO and 90% RON90 blend produces optimal engine performance at 3500 rpm (Khairil et al., 2020).

This research work aims to develop a system for pyrolysis of HDPE plastic to convert it into liquid fuel and then perform characterization of the obtained fuel based on their physical characteristics. The output of pyrolysis process gives liquid fuel along with different value-added chemicals. Also, the residue in the reactor which is rich in carbon content can be studied to be used as fuel for other processes. This is a part of ongoing research in which the pyrolysis of 2.5 kg of HDPE has been performed to obtain 1900 ml of liquid fuel which has been distilled further to determine its compliance with existing fossil fuels that are used to power CI and SI engines.

2. Material and Methods

The process of pyrolysis requires a reactor where the plastic is subjected to high temperatures in absence of oxygen. The gas from the reactor then goes through the condenser pipes where gaseous fuel condenses into liquid fuel which is finally collected in the collection tank. The process of pyrolysis is shown in Figure 1.

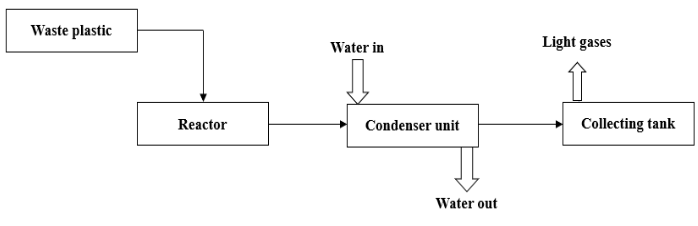

Figure 1: Block diagram for the pyrolysis process

The reactor is made of cast iron in which 2.5 kg of shredded HDPE plastic was fed and heated at temperature of 300-400℃**.** Liquid plastic fuel was produced in 28.27 liters batch reactor at temperature of 373℃. Some char can be found in the plastic fuel. The specification of the reactor is shown in Table 1.

Table 1: Specifications of reactor

Specifications	Value (in mm)
Outer Diameter	306
Inner Diameter	300
Height	400
Thickness	3
Flange Outer Diameter	385
Flange Inner Diameter	300

Figure 2: Pyrolysis Setup

HDPE plastic when subjected to high temperature inside the reactors produces gaseous fuel which is then passed into heat exchanger pipe for condensing and the liquid fuel is collected in the collection tank as shown in Figure 2. The plastic oil is permitted to pass through a conical flask setup with filtration paper to remove unwanted char from the plastic oil as shown in Figure 3.

Figure 3: Filtration of plastic oil

Distillation is then carried out in round bottom flask as shown in Figure 4. The temperature at which the first drop of condensed vapor seen coming from the lower end of condenser tube is noticed is known as the initial boiling point. A lower initial boiling point indicated that the sample contains less hydrocarbons. The temperature at which the thermometer reads a reduction in temperature despite increased heat is known as the final boiling point. Three samples at different temperature ranges were taken as shown in the Figure 5.

Figure 4: Distillation of plastic oil

Figure 5: Sample of different temperature

3. Results and Discussion

Thermal pyrolysis of waste plastic was done at 373°C. 1900 ml of plastic fuel was obtained from pyrolysis of 2.5 kg of high-density plastic. The density and viscosity of plastic oil was tested and found to be 783.2 kg/m^3 and 0.02 poise respectively. The density of the distilled oil was found to be between the range of 730 to 788 kg/m^3. The density of petrol lies between 710 to 770 kg/m^3 whereas the density of diesel is around 830 kg/m^3. The density of liquid fuel obtained from pyrolysis seems to be closer that of petrol. The density and viscosity of different temperature ranges distilled sample are shown in Table 2.

Table 2: Density and viscosity of samples

Temperature ranges (in °C)	Density (in kg/m^3)	Viscosity (poise)
50-100	730	0.005
100-140	760	0.008
150-172	788	0.018

3.1 Running Cost

The running cost for production of liquid fuel is mainly dependent on the cost of electricity consumed by the heater. The plastic used can be obtained from waste due to which its cost is not considered. The running time of coil heater was 3 hours 8 minutes. Total energy consumption can be calculated as

Total kilowatt hour = (2500÷1000) × (3+8÷60) = 7.83 units

Considering average per unit cost of electricity to be Rs. 10, total running cost for production of 1.9 liters of liquid fuel can be calculated as

Total cost of 7.83 unit = Rs. 10×7.83 = Rs. 78.33

Running cost per liter of liquid fuel can be calculated to be Rs 41.22

4. Conclusions

The pyrolysis of HDPE plastic was performed to produce liquid fuel. 2.5 kg of shredded plastic was fed to the reactor and 1900 ml of liquid fuel was obtained as output which was further filtered and distilled at different temperature ranges to obtain fuels of different density and viscosity. The density of the fuel was found to be between the range of 730 to 788 kilograms per cubic meter (kg/m^3) which is similar to that of petrol. The dynamic viscosity of the fuel was found to be between the range of 0.005 to 0.018 poise. The running cost for production of one liter of liquid fuel was calculated to be Rs 41.22.

The fuel obtained at the output can be characterized by performing fractional distillation and performing tests to determine the properties of fuel. The obtained fuel can further be mixed with existing fuels used in CI and SI engines and engine performance analysis can be performed to determine the potential of liquid fuel from pyrolysis to replace or substitute existing fossil fuels.

References

A plastic world - ICIMOD. (2018). Retrieved January 16, 2023, from https://www.icimod.org/article/a-plastic-world/

Fakhrhoseini, S. M., & Dastanian, M. (2013). Predicting pyrolysis products of PE, PP, and PET using NRTL activity coefficient model. *Journal of Chemistry*. https://doi.org/10.1155/2013/487676

Khairil, Riayatsyah, T. M. I., Bahri, S., Sofyan, S. E., Jalaluddin, J., Kusumo, F., Silitonga, A. S., Padli, Y., Jihad, M., & Shamsuddin, A. H. (2020). Experimental study on the performance of an si engine fueled by waste plastic pyrolysis oil–gasoline blends. *Energies*, *13*(6). https://doi.org/10.3390/EN13164196

Visual Feature | Beat Plastic Pollution. (2021). Retrieved January 16, 2023, from https://www.unep.org/interactives/beat-plastic-pollution/

Williams, P. T., & Williams, E. A. (1998). Interaction of Plastics in Mixed-Plastics Pyrolysis.