Extraction of Fuel from Waste Plastic using Pyrolysis Method

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Abstract— There has been an ever increasing global demand for energy in recent years. The demand especially from liquid fuels is very high and the limited resources of fuel production has created bottleneck leading to an energy crisis. This has led to exploring other resources for fuel production, one of which is plastic. Being a non-degradable source, plastics disposed off in the open environment as wastes pose a threat to the environment. Most of the waste plastics end up as landfills. It can instead be used as a source for making fuel. The work describes an attempt to use the waste plastic to synthesize potential fuel called 'Pyrolysis Oil' since the process used in order to obtain the oil is Pyrolysis. The obtained oil from different grades of waste plastics is analyzed so as to validate its use as fuel. Waste Plastic from municipal solid waste were collected and were sorted based on their types like PET bottles, Polypropylene, Polystyrene, HDPE and LDPE. These Plastic wastes are graded and shredded and then heated in a closed chamber (Similar to a process called Pyrolysis) to attain temperatures up to 450-5500C. The Plastic waste is melted and gases produced at this temperature are condensed to liquid state. Both, Condensed and Uncondensed gases can be used as fuel to engines. The Fuel produced is tested for Calorific Value, Density, Viscosity and Fire point, and is compared with Gasoline and Diesel Fuel.

Keywords: Waste Plastic, Pyrolysis Method

I. INTRODUCTION

Plastics have become in indispensable part in today's world. Due to their light-weight, durability, energy efficiency, coupled with a faster rate of production and design flexibility, these plastic are employed in entire gamut of industrial and domestic areas.

Plastic are non-degradable polymers of mostly containing carbon, hydrogen and few others elements such as chlorine, nitrogen etc. Due to its non-biodegradable nature, the plastic waste contributes significantly to the problem of municipal waste management.

1) Plastic are natural / synthetic materials.
2) They are produced by chemically modifying natural substances or are synthesized from inorganic and organic raw material. On the basis of their physical characteristics, plastics are usually divided into thermo sets, elastomers and thermoplastics.
3) These groups differ primarily with regard to molecular structure, which is what determines their differing thermal behavior. The following table lists the characteristics of the various types of plastics.

A. Types of plastics:

1) PET (Polyethylene Terephthalate)
2) HDPE (High Density Polyethylene)
3) PVC (Polyvinyl Chloride)
4) LDPE (Low Density Polyethylene)
5) PP (Polypropylene)

B. Pyrolysis:

It is a process of thermal degradation in the absence of oxygen. Plastic & Rubber waste is continuously treated in a cylindrical chamber and the pyrolytic gases are condensed in a specially-designed condenser system. So here we will convert waste plastic into diesel, plastics are shredded and then heated in an oxygen-free chamber (known as pyrolysis) to about 400 degrees Celsius. As the plastics boil, gas is separated out and often reused to fuel the machine itself. The fuel is then distilled and filtered. Because the entire process takes place inside a vacuum and the plastic is melted - not burned, minimal to no resultant toxins are released into the air, as all the gases and or sludge are reused to fuel the machine.

II. PROBLEM STATEMENT

The demand for plastic is increasing day by day which possess a tremendous threat to the environment. Around 5.6 million tons per annum of plastic waste is generated in India which is about 15,342 tons per day. In the coming few years the waste amount will still enlarge to an extent, so there should be ways and means to get rid of these huge amounts and transform it into useful and highly demanded applications. Hence, by pyrolysis process we can convert waste plastics into fuel. From the previous projects and reports it was found that external heating was used.

As a result, the heat loss was very high leading to low conversion efficiency. In this project we are using electric heater as source of heat enclosed in a ceramic blanket insulator which reduced the heat loss and increased the efficiency.

III. LITERATURE REVIEW

The energy crisis is remarkable bottleneck in the supply of energy resources to an economy. There has been an ever increasing global demand for fuel in recent years. The demand of the fuel especially from liquid fuels is very high and the limited resources of fuel production have created bottleneck and which in results an energy crisis. There is a ringing a bell of conventional fuel. This has led to exploring alternative resources for fuel production, one of which is waste plastic. Being a non-degradable source, plastics disposed off in the open environment as wastes pose a threat to the biosphere. The fuel can be manufactured from the waste plastic.

The waste plastic is melted and gases produced at near about 350^0C temperature are condensed to liquid state. The Fuel produced is tested for Viscosity and Calorific Value, and is compared with Gasoline and Diesel Fuel.

A. Concluding Remarks:

1) Waste plastic can be converted into useful oil by pyrolysis process.

2) The fuel obtained by pyrolysis process has similar properties that of diesel.
3) Use of catalyst will enhance the process and will decrease the total process time.
4) The oil yield can be manipulated by adjusting the pressure and temperature; however the higher temperature will result in higher gas yield.

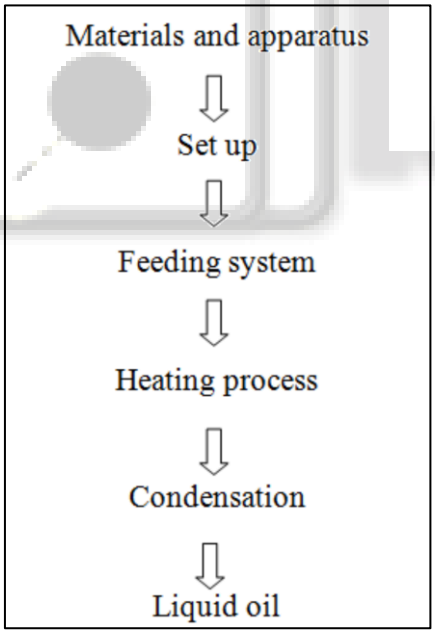
IV. METHODOLOGY

A. *Pyrolysis:*

Pyrolysis is generally defined as the controlled heating of a material in the absence of oxygen. In plastics Pyrolysis, the macromolecular structures of polymers are broken down into smaller molecules or oligomers and sometimes monomer units. Further degradation of these subsequent molecules depends on a number of different conditions including (and not limited to) temperature, residence time, presence of catalysts and other process conditions. The Pyrolysis reaction can be carried out with or without the presence of catalyst. Accordingly, the reaction will be thermal and catalytic Pyrolysis. Since majority of plastic used are polyolefin, so extensive research has been done on this polymer which is summarized as below.

B. *Thermal Pyrolysis of Polyolefin:*

The non-catalytic or thermal Pyrolysis of polyolefin is a high energy, endothermic process requiring temperatures of at least 350–500 °C.



At different temperatures the oil will be collected by the pyrolysis process.

V. MATERIAL SELECTION

Selection of the material depends upon factor of safety, which depends upon the following factors such as reliabilities of properties, reliability of applied load, the certainty as to exact mode of failure, the extent of simplifying assumptions, the extent of localized, the extent of initial stresses set up during manufacturing.
The material used is Mild Steel (45C8) and Copper (Cu).

VI. COMPONENTS OF SETUP

The setup of Extraction of fuel from waste plastic using pyrolysis method consists of number of elements. But main components of setup are: 1. Reactor 2. Condenser

A. *Reactor:*

The type of reactors has an important impact in the mixing of the plastics and catalysts, residence time, heat transfer and efficiency of the reaction towards achieving the final desired product. So considering the modes required for the pyrolysis setup, the reactor is selected as follows.

Mode of operation	Semi-batch
Phases present	Heterogeneous
Process	Fluidized bed
Operating pressure	Internal medium pressure (0.2MPa)
Operating temperature	High temperature (500°C)
Operating condition	Closed
Geometrical Shape	Cylindrical
Orientation	Vertical
Wall thickness	Thick walled
Heating method	Electrical
Location	Field equipment

Table 6.1: Selection of Reactor

Fig. 6.1: Reactor

B. *Condenser:*

Condenser is a device or unit used to condense a gaseous substance into a liquid state through cooling. In so doing, the latent heat is released by the substance and transferred to the surrounding environment. Condensers are used for efficient heat rejection in many industrial systems. A condenser is designed to transfer heat from a working fluid to a secondary fluid or the surrounding air. The condenser relies on the efficient heat transfer that occurs during phase changes, in this case during the condensation of a vapor into a liquid. The vapor typically enters the condenser at a temperature above that of the secondary fluid.

Fig. 6.2: Condenser

C. Fabrication of Setup:

The need of different components was determined by layout and based on holding capacity of the heating camber. The parts have been marked according to parts list.

Sr. No.	Part name	Quantity
1	Frame	1
2	Heating Chamber	1
3	Heating Coil (2 kW)	2
4	Insulation	1
5	Gasket	1
6	Nut, Bolt & Washer	8
7	Copper pipe (2m)	1
8	Direction Valve	1
9	Pressure Gauge	1
10	Thermocouple (K type)	1
11	Temperature Indicator	1
12	Pump	1
13	Tank	1
14	Collecting Unit	1

Table 6.2: Parts list for the setup

VII. EXPERIMENTAL PROCEDURE

1) 1 Kg of weighed plastic granules are fed into the modified pressure cooker. The pressure cooker is modified by attaching a pressure gauge to maintain pressure and a thermocouple is attached to measure temperature.
2) Heat is provided by using Nichrome coil heater which may be between 350^0C-400^0C. It is the temperature at which plastic begins to melt and vaporize.
3) These vapors are passed through copper tubes which are connected to shell and tube heat exchanger. At the end of the heat exchanger, the distillate is collected. The amount of distillate obtained is measured.
4) The color of the distillate is noted. The time and temperature at which the distillate is obtained is also noted.
5) This experiment is repeated with different plastics such as LDPE, HDPE, PP, PS, plastic wastes (mainly plastic carry bags, CD case etc.).

The figure below shows the experimental set-up used to obtain the Liquid fuel from plastic waste:

Fig. 7.1: Working Experimental Setup

The different polymers that are used as the feed for waste plastics are:

1) High Density Polyethylene (HDPE)
2) Polypropylene (PP)
3) Polystyrene (PS)

The figure below shows Plastic samples used for Pyrolysis

Fig. 7.2: Samples of Shredded Plastic Waste Saline Bottles

A. Steps Involved in the Experimental Procedure:

1) Feeding: Feed the feedstock‘s to reactor through feeder and closes the feeder inlet.
2) Heating: To increase the temperature of reactor, heat the product of reactor inside by using heating source.
3) Condensing: The plastic get evaporated at high temperature, this vapor is condensed to atmospheric temperature by using straight and spiral tube condensers.
4) Liquid collection: Out coming product from the condenser is collected at liquid collector. At the end of condenser provide a cyclone separator to separate the plastic liquid fuel and non-condensable gases. These non-condensable gases are reuses to heat the Pyrolysis unit.

VIII. CHARACTERIZING OUTPUT

The characteristics which are studied as follows:

A. Calorific Value:

INSTRUMENT USED: BOMB CALORIMETER
VALUE OBTAINED = 46,050 kJ/kg

Fig. 8.1: Bomb Calorimeter

B. Viscosity:

INSTRUMENT USED: SAYBOLT VISCOMETER
VALUE OBTAINED = 2.1 Centi-Stokes

Fig. 8.2: Saybolt Viscometer

C. Fire Point:

INSTRUMENT USED: FIRE POINT APPARATUS
Value: FIRE POINT = 42^0C.

Fig. 8.3: Flash and Fire point Test Apparatus

D. Density:

INSTRUMENT USED: GRADUATED BEAKER
VALUE OBTAINED = 693.666 kg/m^3

Fig. 8.4: Plastic fuel in a Beaker/Flask

IX. RESULT

Pyrolysis process of shredded Polystyrene resulted in production of Bio-Oil obtained contained the following constituents by % Volume:

1) Pyrolytic oil – 48.6%
2) Wax- 40.7
3) Pyrogas-10.1%
4) Char- 0.6%.

The Operating Temperature during the entire process is 375^0C and was carried out in a modified pressure cooker of capacity 1 Liter (Approx 1.2Kg of Polystyrene by mass) without Catalyst. Use of Catalyst increases the yield of Pyrolytic Oil and Pyrolytic Gases.

A. Tests for Characterizing Output:

Different tests have been carried out to study and compare the fuel characteristics of different samples and those of petrol and diesel which are used as the standard reference. The characteristics which are studied are shown below:

Sr. No.	Properties	Plastic Oil	Gasoline	Diesel
1	Calorific Value (kJ/kg)	46,050	48,000	42,000
2	Density(kg/m^3)	693.67	719.7	812
3	Viscosity	2.1	0.71	3.05
4	Fire Point (^{0}C)	42	40	74

Table 8.1: Comparison of Properties of Plastic oil with conventional fuels

X. CONCLUSION

1) It would also take care of hazardous plastic waste and reduce the import of crude oil.
2) Without emitting any pollutants 1 kg of Waste plastics is converted into 75% of useful liquid hydrocarbon fuels.
3) The properties of produced plastic liquid fuel are almost similar to that of Diesel fuel, hence plastic fuel represents a good alternative fuel for diesel engine and therefore it can be used for diesel engine vehicles.
4) This method is both Ecological and Economical.

REFERENCE

[1] Pawar Harshal R., "Waste plastic Pyrolysis oil Alternative Fuel for CI Engine – A Review", Research Journal of Engineering Sciences, ISSN 2278 – 9472,Vol 2(2), Feb 2013.
[2] Kanika Mathur, "Extraction of pyrolysis oil waste plastics", IRJET Vol. 3, Issue 4, Apr 2016.
[3] Faisal Abnisa, "A review on pyrolysis of plastic wastes", Energy Conversion and Management 115,308–326,2016.
[4] Antony Raja, "Conversion of Plastic Wastes into Fuels", Journal of Materials Science and Engineering, ISSN 1934-8959, 2011.
[5] Rajaram T. Karad, "Waste plastic to fuel- Petrol, Diesel, Kerosene", IJEDR Vol. 5, Issue 3, ISSN: 2321-9939.
[6] Aditya Machiraju, "Extraction of Liquid Hydrocarbon fuel from waste plastic", IJCRT, National Conference Proceeding NTSET, Feb 2018.
[7] Ahmed I. Ahmed, "Conversion of plastic waste to liquid fuel", IJTRA Vol. 2, Issue 3, May-June 2014.
[8] Dr. B. J. Patil, "Extraction of Liquid from waste plastic", IJERTSR Vol. 4, Issue 8, August 2017.
[9] Stella Bezergianni, "Alternative Diesel from Waste Plastics", Chemical Process & Energy Resources Institute, Centre for Research & Technology Hellas, 2017.
[10] B. M. Patil, "Fuel from Plastic Waste", IJET, Special Issue on NCRIET 6(2): 121-128, 2015.

