Conversion of Waste Plastics Into Fuel

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Abstract- *The ever increasing quantity of plastic wastes generated in the modern world has posed several social and health problems.Over a several million tonnes of plastics are produced annually worldwide and the used products has become a common feature at overflowing bins and landfills. Though work has been done to make futuristic biodegradable plastics, there have not been many conclusive steps towards cleaning up the existing problem. Here, the process of converting waste plastic into value added fuels is explained as a viable solution for recycling of plastics. Thus two universal problems such as problems of waste plastic and problems of fuel shortage are being tackled simultaneously. In this study, plastic wastes are used for the pyrolysis to get fuel oil that has the same physical properties as the fuels like petrol, diesel etc. Pyrolysis runs without oxygen and in high temperature, which is why a reactor is fabricated to provide the required temperature for the reaction. Converting waste plastics into fuel hold great promise for both the environmental and economic scenarios. Thus, the process of converting plastics to fuel has now turned the problems into an opportunity to make wealth from waste.*

Keywords- Waste plastics, Pyrolysis, Calorific value, Viscosity.

I. INTRODUCTION

Plastics play an important role in day today life, as in certain application they have an edge over conventional materials. Indeed, their light weight, durability, energy efficiency, coupled with a faster rate of production and more design flexibility, have allowed breakthroughs in fields ranging from non-conventional energy, to horticulture and irrigation, water-purification systems and even space flight. However one has to accept that virtues and vices co-exist. Plastics are relatively cheaper and being easily available has brought about use and throw away culture. Plastics waste management has become a problem world over because of their non-degradable property. A majority of landfills, allotted for plastic waste disposal, are approaching their full capacity. Thus recycling is becoming increasingly necessary.

Economic growth and changing consumption and production patterns are resulting into rapid increase in generation of waste plastics in the world. Due to the increase in generation, waste plastics are becoming a major stream in solid waste. After food waste and paper waste, plastic waste is the major constitute of municipal and industrial waste in cities. Even the cities with low economic growth have started producing more plastic waste due to plastic packaging, plastic shopping bags, PET bottles and other goods/appliances which uses plastic as the major component. This increase has turned into a major challenge for local authorities, responsible for solid waste management and sanitation. Due to lack of integrated solid waste management, most of the plastic waste is neither collected properly nor disposed of in appropriate manner to avoid its negative impacts on environment and public health and waste plastics are causing littering and chocking of sewage system. On the other hand, plastic waste recycling can provide an opportunity to collect and dispose of plastic waste in the most environmental friendly way and it can be converted into a resource. In most of the situations, plastic waste recycling could also be economically viable, as it generates resources, which are in high demand. In general, the conversion of waste plastic into fuel requires feed stocks which are non-hazardous and combustible.

In 21st century due to the fossil fuel crisis in past decade, man- kind has to focus on developing the alternate energy sources such as biomass, hydropower, geothermal energy, wind energy, solar energy, and nuclear energy. The developing of alternative fuel technologies are investigated to deliver the replacement of fossil fuel. The focused technologies are bio-ethanol, bio-diesel lipid derived biofuel, waste oil recycling, pyrolysis, gasification, dimethyl ether, and biogas On the other hand, appropriate waste management strategy is another important aspect of sustainable development since waste problem is concerned in every city. The waste to energy technology is investigated to process the potential materials in waste which are plastic, biomass and rubber tire to be oil. Pyrolysis process becomes an option of waste-to-energy technology to deliver bio-fuel to replace fossil fuel. Waste plastic is investigated in this research as it is the available technology. The advantage of the pyrolysis process is its ability to handle unsort and dirty plastic. The pre-treatment of the material is easy. Plastic is needed to be sorted and dried. This paper describes main aim to find a solution to the mountings problem of plastic disposal, for which the plastic are converted into useable fuel.

1.1 OBJECTIVES

- Plastics waste management has become a problem world over because of their non-degradable property. A majority of landfills, allotted for plastic waste disposal, are approaching their full capacity. Thus recycling is becoming increasingly necessary.
- Plastic waste recycling can provide an opportunity to collect and dispose of plastic waste in the most environmental friendly way and it can be converted into a resource. Most suitably plastic waste recycling could also be economically used for conversion into fuel, which is in high demand.
- This can fulfil the energy demands of our nation to much extent.

II. METHODOLOGY

2.1 Pyrolysis

Pyrolysis is the chemical decomposition of organic substances by heating, the word is originally coined from the Greek- derived elements pyro "fire" and lysys "decomposition". Pyrolysis is usually the first chemical reaction that occurs in the burning of many solid organic fuels, cloth, wood, and paper, and also of some kinds of plastic. Anhydrous pyrolysis process can also be used to produce liquid fuel similar to diesel from plastic waste. Pyrolysis technology is thermal degradation process in the absence of oxygen. 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.

2.2 Thermal Degradation of Plastics

The non-catalytic or thermal pyrolysis of polyolefin is a high energy, endothermic process requiring temperatures of at least 350–500 °C. In some cases, high temperature as 700–900 °C is essential in achieving decent product yields. The extent and the nature of these reactions depend both on the reaction temperature and also on the residence of the products in the reaction zone, an aspect that is primarily affected by the reactor design. In addition, reactor design also plays a fundamental role, as it has to overcome problems related to the low thermal conductivity and high viscosity of the molten polymers.

2.3 Catalytic Cracking (De-Polymerization)

Addition of catalyst enhances the conversion and fuel quality. As compared to the purely thermal Pyrolysis, the addition of catalyst in Pyrolysis significantly lowers Pyrolysis temperatures and time. A significant reduction in the degradation temperature and reaction time under catalytic conditions results in an increase in the conversion rates for a wide range of polymers at much lower temperatures than with thermal pyrolysis. Moreover Narrows and provides better control over the hydrocarbon products distribution. Also increases the gaseous product yields. Under similar temperatures and reaction times, a much higher gaseous product yield is observed in the presence of a catalyst for polyethylene.

2.4 Condensation

It is the process of cooling the entire heated vapour coming out of the reactor. The condenser has an inlet and an outlet for cold water to run through the outer area. This is used for cooling of the vapour. The gaseous hydrocarbons emitted at a temperature of about 350°C are condensed to about 30 – 35°C.

III. EXPERIMENTAL SET UP AND PROCEDURE

Thermal cracking process without catalyst is used in converting waste plastic into liquid fuel. Various batches of waste plastic are selected for this particular experiment. In first batch, by weight 50% of each Low density polyethylene and polypropylene are selected for the experiment. Both waste plastic are solid hard form. Collected waste plastic is cleaned using liquid soap and water. For experimental purpose we use sample of Polypropylene (PP) and Polyethylene (PE). A reactor used for thermal cracking and temperature used ranges from 100° C to 400° C. The experiment is carried out under a closed air system with no vacuum process applied during this thermal cracking process. We use low density polypropylene plastics in a batch process system because conversion temperatures for these plastics are relatively low. Waste plastics are converted into liquid slurry when heat is supplied. Due to gradual increase in heat supply, temperature is increases, as a result liquid slurry turns into vapour and the vapour then passes through a condenser unit. The process of converting the waste plastic to alternative energy begins with heating the solid plastic without the presence of cracking catalyst to form liquid slurry, condensing the vapour with standard condensing column to form liquid hydrocarbon fuel. During the thermal cracking process plastic portions are not broken down immediately because plastics have short chain hydrocarbon to long chain hydrocarbon. For every individual waste plastic, melting to fuel production experiment requires time 3-4 hours, first stage of heat applied breaks down only the short chain hydrocarbon. When temperature increases the plastic carbon-carbon bond breakdown slowly. As the temperature increases the long chains are breakdown step by step. During this thermal cracking process some light gases such as methane, ethane, propane and butane are produced. These compounds are unable to condense because they have negative boiling point. These light gases could be alkane or alkene group and it can also contain CO or CO_2 emissions. After experiment is concluded some solid black residue is collected from the reactor.

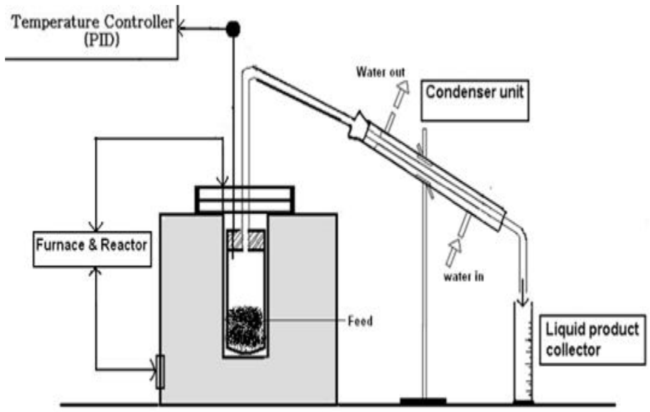

Fig. 3.1 Pyrolysis Setup

The above Fig. 3.1 shows the experimental setup of the pyrolysis process, which contains main units such as reactor vessel, condenser unit and an oil collector.

The reactor which has been designed for the solid waste pyrolysis is a cylindrical shell. It is made up of an aluminium alloy with a radius of 14cm and height of 30cm. Thermal degradation of plastics is caused by furnace from the bottom of the vessel. The top side is open through which solid wastes are fed at the beginning and the solid residue is removed after pyrolysis. During the reaction, the top side is kept closed by a lid tightly not allowing the gases to escape from the vessel. This prevents ingression of atmospheric air into the reactor, there by achieving proper pyrolysis. An exit is provided at the top of lid using a ball valve of 0.75 inches allowing the vapours to escape through the extended copper pipe of 0.625 cm in diameter.

The condenser is provided to cool and condense the gases evolved out from the pyrolyser. As a result of cooling, the condensable gases become liquid which is called pyrolytic oil. The condenser used here is made of borosilicate glass and it is tube in tube type. It is mounted at an angle at the end of the copper tube, coming out of the reactor vessel. The evolved gases from the pyrolyser pass through the glass tube and the cooling water is circulated in the outer tube of the condenser. As the evolved gases may contain particulate matter and tar, they are passed on the tube side, so that cleaning would be easier after completion of the experimental work. However, a certain fraction of gases cannot be condensed and they are termed as non-condensable gases.

IV. RESULTS AND DISCUSSIONS

This experiment is mainly conducted to convert the waste plastics into fuel. Performing the pyrolysis process on different types of plastics in various batches i.e. Polyethylene (PE), Polypropylene (PP) and mixture of both. After obtaining the oil from various plastics, several tests are performed to evaluate the properties of these oils and the values obtained are compared with the values of conventional fuels such as Petrol, Diesel etc.

4.1 Colour and Odour

The oils obtained from various plastics are investigated and can be differentiated based on the colour and odour. Based on odour, the oils obtained from various plastics cannot be differentiated, as they have similar unpleasant odour.

Table 4.1.1 Colour Investigation

Sample	Colour
Petrol	Reddish Orange
Diesel	Yellow
Polyethylene	Brown
Polypropylene	Pale yellow
Polyethylene + Polypropylene	Brown

Fig 4.1Oil from Plastic Pyrolysis

4.2 Density

Investigations are carried on density of the samples. Density of a substance is defined as its mass per unit volume. The volume of 50ml of sample is measured in a measuring flask and mass of the same is obtained using a digital weight balance.

Table 4.2.1 Density of Samples

Sample	Density, gm/cc
Petrol	0.745
Diesel	0.832
Polyethylene	0.752
Polypropylene	0.742
Polyethylene + Polypropylene	0.749

From the above table 4.2.1, it is observed that density of the fuel sample obtained from plastics and conventional fuels are nearly equal**.**

4.3 Viscosity (at 40 °C)

Investigations on viscosity of the samples are also conducted. Viscosity of fluid is a measure of its resistance to gradual deformation by shear stress or tensile stress. Shear resistance in a fluid is caused by inter molecular friction exerted when layers of fluid attempts to slide by one another. Dynamic viscosity is the tangential force per unit area required to move on one horizontal plane with respect to other plane at a unit velocity when maintaining a unit distance apart in the fluid. It can be expressed in poise. Kinematic viscosity is the ratio of dynamic viscosity to density. It is expressed in stokes.

Table 4.3.1 Dynamic and Kinematic Viscosities

Sample	Dynamic Viscosity, poise	Kinematic Viscosity, stokes
Petrol	0.0074	0.010
Diesel	0.0247	0.0298
Polyethylene	0.0157	0.021
Polypropylene	0.0188	0.0254
Polyethylene + Polypropylene	0.0166	0.0223

From table 4.3.1 it is observed that the viscosities of plastic oil samples are in a feasible range nearer to the values of conventional fuels.

4.4 Flash and Fire Point

Flash and fire point of various samples are also investigated. The flash point of a volatile material is the lowest temperature at which vapours of a liquid will ignite. The fire point of fuel is the temperature at which the vapour produced by that given fuel will continue to burn for at least 5 seconds. Flash and fire point values for different samples are shown in table 4.4.1.

Table 4.4.1 Flash and Fire Point Temperatures

Sample	Flash point °C	Fire point °C
Petrol	43	54
Diesel	52	63
Polyethylene	34	44
Polypropylene	23	32
Polyethylene + Polypropylene	28	37

4.5 Calorific value

The calorific value or heat of combustion is the total energy released as heat when a substance undergoes complete combustion with oxygen under standard conditions. The chemical reaction is typically a hydrocarbon or other organic molecule reacting with oxygen to form carbon dioxide and water and release heat. The heat of combustion is conventionally measured using Bomb's calorimeter. It is generally expressed in terms of kJ/kg or kJ/mol.

Table 4.5.1 Calorific Values

Sample	Calorific Value, kJ/kg
Petrol	48000
Diesel	43400
Polyethylene	32300
Polypropylene	34800
Polyethylene + Polypropylene	32800

Table 4.5.1, shows the calorific values of various samples of oil and conventional fuels. We see that the samples of oil have a good range of calorific valve nearer to those of conventional fuels.

V. CONCLUSIONS

Plastics present a major threat to today's society and environment. Over several million tons of plastics are dumped into the oceans annually, killing about many species of oceanic life. Though mankind has awoken to this threat and responded with developments in creating degradable bioplastics, there is still no conclusive effort done to repair the damage already caused. In this regard, the pyrolysis studied here presents an efficient, clean and very effective means of removing the debris that we have left behind over the last several decades. By converting plastics to fuel, we solve two issues, one of the large plastic seas and the other of the fuel shortage. These dual benefits, though will exist only as long as the waste plastics last, but will surely provide a strong platform for us to build on a sustainable, clean and green future. By taking into account the financial benefits of such a project, would be a great boon to our economy. So, from the studies conducted we can conclude that the properties of the fuel obtained from plastics are similar to that of petrol and further studies on this field can yield better results.

After analysing and comparing all above properties of fuels and samples of oil from plastic pyrolysis, we can say that oil from plastic pyrolysis can become a substitute for fuel. This oil cannot be used directly but after some more processing like distillation, addition of additives, etc. it can be used as fuel. For now,

- This oil can be used as a feedstock to oil refineries.
- It can be used as a Bio-Diesel with appropriate blending ratio.
- It can be used to run diesel power plant and produce electricity.
- It can also be directly used as furnace oil as it has good calorific value.

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