Development of Lab Scale Pyrolysis Setup to Convert Waste Plastic into Oil

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Abstract: Utilization of waste effectively and efficiently is one the major concern of the world. The depleting natural resources (like fossil fuels) add further to this concern. If we continue to use and exploit fossil fuels at the existing rate, then after another 150 years or so they would be no longer available for our use. Therefore, it is the duty of present generation to use fossil fuels judiciously to ensure sustainable development. The need of the hour is to adopt some measures which can help to manage wastes and at the same time to generate some alternate fuels out of it to conserve the precious fossil fuels. The process known as "Pyrolysis" which can be a possible solution for conversion of waste to fuel. In pyrolysis, wastes like plastic, polythene, tyres and biomass etc. can be converted to fuel oil, chemicals and gas, using heat in absence of air. Thus, pyrolysis these days is catching everybody's attention due to its potential to utilize variety of waste feedstocks to generate combustible products and may prove to be potential technology for society in the times to come. Based upon this idea, an effort is made in this study to produce oil from the pyrolysis of waste plastic. In the present work, plastic waste was converted into pyrolytic oil using self fabricated pyrolytic reactor at Energy Lab in DCRUST, Murthal and vapour condensing unit. Various properties like calorific value, kinematic viscosity and density were measured and compared with diesel.

Keywords: Pyrolysis, fossil fuels, Viscosity, Calorific value and density

I. INTRODUCTION

Pyrolysis is a thermo-chemical decomposition of organic materials from larger molecules to the smaller molecules at elevated temperatures in the absence of oxygen. Pyro-means (heat) and lysis-means (breakdown) [1]. During pyrolysis, the object molecule is subjected to very high temperature which allow the molecules to move faster and they start vibrating, these vibrations depends or proportional to the temperature given. In pyrolysis process the temperature is very high and due to this high temperature, the molecules start breaking down in tiny molecules, which is pyrolysis. The chemical bonds present get split up in the absence of oxygen thus leaving the energy stored in the organic substance. The term "waste plastic" refers to discarded products made from plastic material, which is any of a wide range of synthetic or semi-synthetic organic solids that are moldable. It consists of various household or industrial items such as PET bottles, plastic shopping bags, toys, containers, packaging materials, etc. Those items come in different forms and types of plastic. Among six main plastics, low density polythene (LDPE) is used in various field such as grocery bags, water hoses, garbage cans, film, containers etc. At present the annual consumption of plastic in India is about 12 Million Tones and is expected to touch 20 million metric Tonnes by the year 2020[1]. The plastic packaging industry is growing at a rate of 18% per annum and it will touch USD 73 billion by 2020 [3]. According to CPCB, India is annually generating about 5.6 million metric tonnes of plastic waste, with Delhi producing the most at 689.5 metric tons every year [3]. These statistics indicates India's hunger for plastics has been growing tremendously despite some legal curbs on some items like polythene. Plastics are simply synthetic or semi-synthetic long chain polymers. They are made from inorganic and organic materials like C (carbon), Si (silicon), H (hydrogen), N (nitrogen), O (oxygen), and chloride. Due to presence of these long chain inorganic and organic materials they are not easily degradable and that's why their disposal become a serious problem. The technique of recycling the waste plastics through pyrolysis started some 20 years back. Recycling of waste plastics is very important by seeing the increasing amount of these polybags.

II. LITERATURE REVIEW

Recycling of waste plastics has become very important as they are non-biodegradable and pose a threat to our environment. Among six main plastics, low density polyethylene (LDPE) is used in various field such as grocery bags, water hoses, garbage cans, film, containers, plastic bottles etc [12]. As per the report from United Nations Environment Program (UNEP), it is advisable to dispose the waste plastic by some suitable alternatives, the report suggested that the Pyrolysis process under suitable conditions of feedstock and temperature conditions is the best method so far. They have also mentioned that it is safe to produce liquid fuel from polyethenes and waste plastics [13] The research carried out by various researchers after carefully observing the various properties of conventional fuels in comparison to plastic derived oil it is established that plastic derived oil can be used as an alternate fuel to suffice our needs. With the help of pyrolysis process, plastic waste substances can be decomposed into three different fractions which are solid, liquid and gas [14]. There are high boiling point hydrocarbons in liquid products. There is a requirement of fractional distillation inorder to obtain useful gasoline ranged hydrocarbons. There are other products of pyrolysis like benzene, toluene and other aromatic hydrocarbons. Studies conducted on waste plastic pyrolytic oil have suggested that this oil can be used as a substituent to both petrol and diesel [7].

III. DESIGN AND FABRICATION OF LAB SCALE PYROLYSIS SETUP

For carrying out this research work Semi-Batch kind of reactor was used. In this kind of reactor, the feedstock is added initially before the start of pyrolysis process and the products are removed continuously once they are generated. The Pyrolysis set up consists of two main parts i.e. the reactor and the condensing unit. The reactor has an inner cylinder and an outer cylinder which are made concentric on a base plate. Pyrolysis reactor is mainly made up of three materials namely mild steel, stainless steel and iron. Glass wool and Asbestos ropes are used as insulating mediums to reduce heat losses due conduction and convection. The materials that is opted to produce this Lab scale setup was mild steel, stainless steel and Glass wool. The outer cylinder and the top cover of the setup are made up of mild steel. The reason for selecting mild steel was greater tensile strength then low carbon steel and good machining qualities and suitability for welding. To ensure that it is completely leak free this flange is tightened with the help of nuts and bolts with a close packing in between. As the thermo-chemical conversion, will take place in the inner cylinder, thus to bear the maximum temperature inside the cylinder, stainless steel is used because it has high temperature resistance. In addition to that, an insulation of glass wool between the stainless-steel cylinder and mild steel cylinder is provided that does not allow the heat to transfer outside as it is light in weight and has high tensile strength and exceptional resilience which make it a better insulating material. Table-1 shows the dimensions of the lab scale pyrolysis setup which can be calculated based on the capacity of the cylinder used in the experimental setup.

Table 1: Dimensions of reactor

Particulars	***Dimensions***
Height of reactor	430mm
Diameter of outer cylinder	203mm
Diameter of inner cylinder	127mm
Diameter of base plate	203mm
Thickness of base plate	2.032mm
Thickness of inner (SS) cylinder	1.219mm
Thickness of outer (MS) cylinder	1.219mm
Diameter of gas outlet pipe	12.7mm

B. Fabrication of the Pyrolysis Setup

First step is welding of stainless steel cylinder on an iron plate so that iron plate is facing bottom position and stainless steel cylinder is welded on it because the iron plate comes in direct contact to heat and after that due to conduction heat is transferred inside the cylinder. For casing of the stainless-steel cylinder another cylinder is used which is of mild steel and it also welded on the base iron plate. Dimensions are illustrated in the table-1. The gap between the inner stainless steel cylinder and outer mild steel cylinder is filled with glass wool which acts as an insulation between two cylinders, as temperature and heat inside the inner cylinder is going to be very high, to prevent that transfer of heat in outward direction. Last step is to close the top of the cylindrical portion, for that a flange type arrangement is made with small outlet for exhaust and a bolt arrangement to fed into the reactor and to pull out the residues left after pyrolysis.

Then the sub assembly-1 is fitted to a self-fabricated water cooled condenser which is used to convert the gases coming out into fuel simply by cooling it. The other appliances and equipment that are used in Pyrolysis set up are Burner, L.P.G. gas cylinder and the Sensors and gauges. The burner used in this process is high pressure burner, which can throw flames with high pressure, it located direct under the reactor with a stand mounted on it. Liquefied petroleum gas cylinder is used because it does not create any pollution while burning of gas, it has high octane rating that allows it to mix better with air and to burn more completely then does gasoline, generating less carbon. Furthermore, a pressure gauge is mounted on top of reactor where gas outlet takes place and for temperature there is a sensor, wherever temperature you want to measure just touch the probe of the sensor on that region and the estimated value of temperature will be shown by the digital meter.

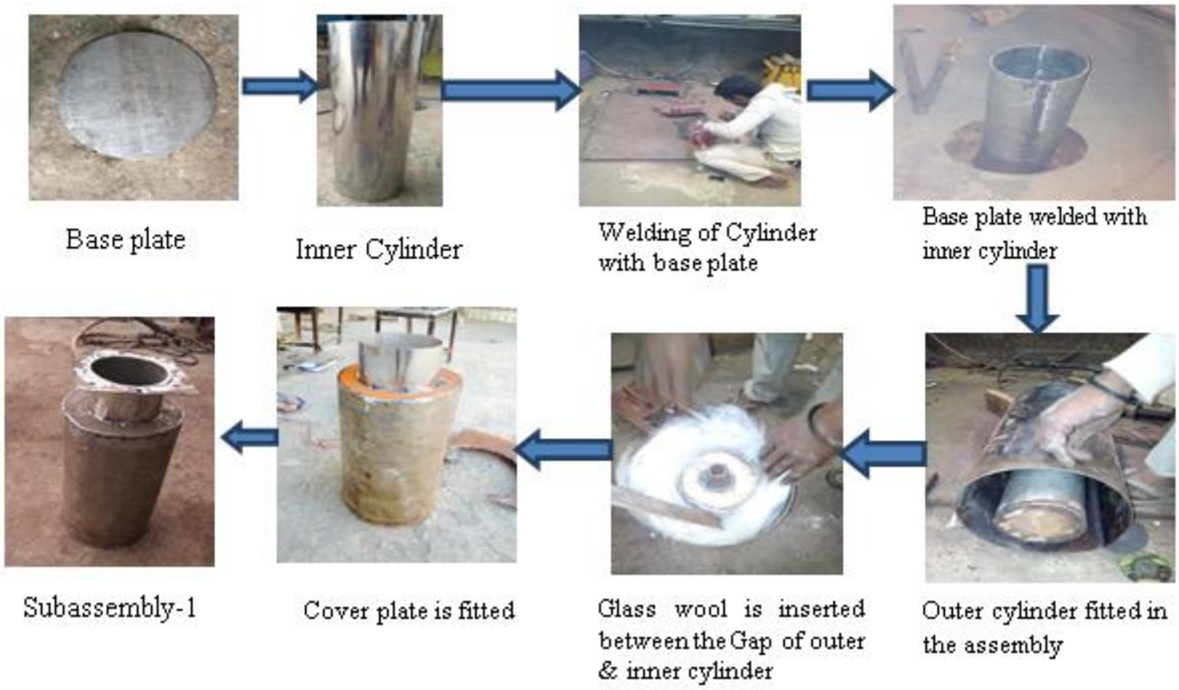

Figure 2: Assembly of the components to for sub-assembly 1 of pyrolysis.

Figure 3: Fabricated Pyrolysis setup

IV. PRODUCTION OF PYROLYTIC OIL

The procedure for converting waste plastic into pyrolytic oil is carried out in a pyrolysis reactor. The feedstock i.e. plastic waste is cleaned up by washing. They are then dried up completely and weighed initially. The bigger size plastics are reduced to smaller size by using cutting snips before feeding them into the reactor. Equal proportion of plastic and polythene waste, about 600gms are taken and fed into the reactor from the upper side, by opening the flange of the reactor. The amount of fed material depends upon the size of reactor. After feeding the raw materials the reactor is closed with help of nuts and bolts on the flange, this does not allow any type of leakage. Now place the reactor on the stand which is mounted on burner and burner is connected to LPG gas cylinder. Fill the condenser with appropriate amount of water which is used to condense the gases. Before starting the unit make sure all the connections are alright. Start the burner and note the time of the pyrolysis process, the flame speed from the burner should be constant so that we can get maximum yield from the waste materials. With help of sensor we can check the temperature at different intervals. The valve which is mounted after the pressure gauge on the outlet of reactor is closed initially after 30 minutes from the starting time. Then after some time if the pressure gauge shows some variations, it means gases have started coming out of the reactor and the valve is opened after some pressure created inside the reactor. As valve is opened the gases start coming out of reactor, through the arrangement passes into the condensing unit. After 35 minutes when the temperature is measured it is about 350-400^oC and the mixture of plastic and polythene inside the reactor gets melted and vapours start coming out from the exhaust, which contains the fuel particles. When these vapors are passed into the condenser they get condensed and convert into fuel which is dark red in colour. This liquid fuel is further filtered to get cleaner liquid fuel. The whole process of Pyrolysis takes around 30 to 45 minutes for processing a feedstock of 1Kg. by weight. Since the heating rate is uniform, the outcome is also uniform and after about thirty minutes the output is regular, the reason is that all the waste polythene inside the reactor gets converted into fuel with small amount of residue left behind. So, by burning 6oo grams of waste plastic, the yield obtained is about 70 percent that is 400ml pyrolytic oil, and there are some losses in the sense like-some ml fuel is left inside the condensing unit and some amount get spit out from the collecting chamber, so overall 70-74 percent yield.

V. DETERMINATION OF PYROLYTIC OIL PROPERTIES

After production of fuel it is very important to determine and analyze the various fuel properties. Various fuel properties are analyzed in the laboratory using different equipment. The properties are illustrated below:

A. Determination of Calorific value

Calorific value can be defined as the energy released per kg of the fuel. The property defines the energy content of the fuel [18]. In this study, the calorific value is measured with the help of a bomb calorimeter and the Calorific value of pyrolytic oil was found to be 40769.017 KJ/Kg.

B. Determination of Viscosity

Viscosity is a measure of fluid friction or resistance of oil to flow, which tends to oppose any dynamic change in the fluid motion [1]. There is a decrease in the viscosity of oil when the temperature of oil is increased and thereby the substance flow readily. Fluids with lower viscosity are easier to pump and can atomize into fine droplets [8]. The kinematic viscosity of pyrolytic Oil is found to be 0.0037 stokes at 60^{0}C.

C. Determination of density

Density of a substance is defined as the mass per unit volume [1]. It is expressed in kilograms per cubic meter. The greater the fuel density, the greater the mass of fuel that can be stored in each tank and the greater the mass of fuel than can be pumped for a given pump [7]. The Density of the derived fuel is 790 Kg/m^3

D. Comparison of properties of pyrolytic oil with Diesel

Table 2 shows the comparison between the waste plastic pyrolytic oil and diesel. The comparison shows that the calorific value of Pyrolytic oil and diesel are similar and the oil can be used to run the compression ignition engine. The Kinematic viscosity of diesel is much less than that of the pyrolytic oil that means that the pyrolytic oil has high flowing capacity as compared to diesel. The densities of both the oils are almost the same that means pyrolytic oil has the similar properties as that of diesel. Thus, from this comparison, it can be concluded that the pyrolytic oil can be used to run the diesel engine.

Table 2. Comparison of Properties between Waste Plastic pyrolytic oil with Diesel

Properties	*Diesel*	*Waste plastic pyrolytic oil*
Calorific Value(KJ/Kg)	44800	40769.017
Kinematic Viscosity (Centistokes)	1-4.11	3.7
Density at 30^0C (in g/cm^3)	0.79	0.79
Flash point (in ^{0}C)	70	100

VI. CONCLUSION

This paper describes the importance of plastic pyrolysis and its usefulness for sustainable development. The paper also described the design and fabrication of pyrolysis setup for the extraction of oil from waste plastic. Further this paper also indicates the properties of the oil derived from pyrolysis like calorific value, density, Kinematic viscosity etc which was found comparable to diesel. This means that the pyrolytic oil derived from waste plastic can be used in the Compression ignition engines which uses diesel as fuel or it can be used in blended form with diesel to run the engine.

Conflict of Interest: The authors declare that they have no conflict of interest.

Ethical Statement: The authors declare that they have followed ethical responsibilities.

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