

# EXTRACTION OF THERMOFUELS FROM WASTE PLASTICS

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**Abstract :** Plastic is an indispensable part of our daily life. A plastic material is any of a wide range of synthetic or semi-synthetic organic solids that are moldable. They are usually synthetic, most commonly derived from petrochemicals, but many are partially natural. Its production and consumption has been rising very rapidly due to its wide range of application. There are two types of plastics: thermoplastics and thermosetting polymers. Thermoplastics are the plastics that do not undergo chemical change in their composition when heated and can be molded again and again. Thermosets can melt and take shape once; after they have solidified, they stay solid. In the thermosetting process, a chemical reaction occurs that is irreversible. Due to its non-biodegradable nature it cannot be easily disposed of. So, nowadays new technologies are being used to treat the waste plastic. One of such process is pyrolysis.

This paper describes non catalytic pyrolysis of plastic wastes into useful gasoline range hydrocarbons. Under the pyrolysis and cracking conditions the plastic wastes can be decomposed into three fractions: gas, liquid and solid residue. Here the main consideration is the recovery of liquid products which are composed of higher boiling point hydrocarbons. The waste plastics consisting of high density polyethylene (HDPE) was pyrolyzed in this study. Pyrolysis appears to be a technique that is able to reduce a bulky, high polluting industrial waste while producing energy and/or valuable chemical compounds. The pyrolysis of plastic wastes produces a whole spectrum of hydrocarbons including paraffin, olefins, naphthalene and aromatics. By catalytic cracking more aromatics and naphtha in the range of C6-C8 which are valuable gasoline range hydrocarbons can be produced. This application is further combined with technologies of municipal plastic wastes collection, classification and pre-treatment at front end and product purification and testing at back end to determine the properties of the various products obtained.

**Key words :** plastics , thermo flues, gasoline, char, thermo physical properties ,liquid distillation

## I. INTRODUCTION :

A marvel of polymer chemistry, plastics has become an indispensable part of our daily life. Although plastics are a newer discovery, they have become a part of everyday consumer life and its production and consumption have increased drastically. Plastic have molded the modern world and transformed the quality of life. There is no human activity where plastics do not play a key role from clothing to shelter, from transportation to communication and from entertainment to health care. Plastics have become an 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 plastics are employed in entire gamut of industrial and domestic areas. Plastics are non-biodegradable polymers mostly containing carbon, hydrogen, and few other elements such as chlorine, nitrogen etc. Due to its non-biodegradable nature, the plastic waste contributes significantly to the problem of Municipal Waste Management. The production of plastics is significantly growing. Nowadays the plastic production is more than 200MT worldwide annually. The per capita consumption of plastics from a last few decades is increasing rapidly; it is shown in the table 1.1 the status of per capita According to a nation-wide survey, conducted in the year 2008, approximately 10,000 tones (ten thousand tonnes) of plastic waste were generated every day in our country, and only 60% of it was recycled, balance 40% was not possible to dispose of. So gradually it goes on accumulating, thereby leading to serious disposal problems. [1]. Plastic is derived from petrochemical resources. In fact these plastics are essentially solidified oil. They therefore have inherently high calorific value. The calorific values of some of the plastic materials along with coal are shown in table 1. [7].

Table No 1: Per Capita Consumption of Plastics.

| material      | Btu/<br>pound | Kilojoules /<br>kilo |
|---------------|---------------|----------------------|
| Coal          | 11,500        | 27,000               |
| Polyethylene  | 20,000        | 46,500               |
| Polypropylene | 19,300        | 45,000               |
| Polystyrene   | 17,900        | 41,600               |
| PET           | 9,290         | 21,600               |
| PVC           | 8,170         | 19,000               |

Theoretically this energy can be captured and transformed into other useful forms. It is a well-known fact that energy can neither be created nor destroyed but merely transformed. One of the most common methods of transforming energy from for example, a solid to another form is thermal treatment. Through the various methods of thermal treatment one may obtain heat electricity or chemicals suitable for other applications [7]. Aguado et.al [8] discuss the Recycling of Plastic Wastes.

Waste Plastics are mostly land filled or incinerated; however, these methods are facing great social resistance because of environmental problems such as air pollution and soil contamination, as well as economical resistance due to the increase of space

and disposal costs Ashutosh Dubey et al [3]. In a long term neither the land filling nor the incineration solve the problem of wastes, because the suitable and safe depots are expensive, and the incineration stimulates the growing emission of harmful and greenhouse gases e.g. NO<sub>x</sub>, SO<sub>x</sub>, CO<sub>x</sub> etc. Zadgaonkar, Alka [6]. Accordingly, recycling has become an important issue worldwide. This method can be classified as energy recovery, material recycling and chemical recycling. Among them one of the prevalent alternative methods is the production of converted fuel and chemicals by means of the thermal or catalytic degradation of polymers.

Plastics pyrolysis, on the other hand, may provide an alternative means for disposal of plastic wastes with recovery of valuable liquid hydrocarbons. In pyrolysis or thermal cracking, the polymeric materials are heated to high temperatures, so their macromolecular structures are broken down into smaller molecules and a wide spectrum of hydrocarbons are formed. These pyrolytic products can be divided into a gas fraction, a liquid fraction consisting of paraffin's, olefins, naphtha and aromatics (PONA), and solid residues. In catalytic cracking, more aromatics and naphtha are selectively formed in the presence of commercial fluid cracking catalysts (FCC) or reforming catalysts, so that the productivity and economics of pyrolysis processes are improved. [5] Cracking was realized both in the batch and continuous systems. It was also examined that the results obtained by batch cracking are useable to the continuous reactor planning. The goal of these experiments was the developing of a waste free so-called green technology [6].

The main objective of this study was to investigate the result of pyrolysis on the plastic material and to collect the liquid product obtained and to conduct basic tests such as flash point, fire point etc. One more objective is quantitative analysis of gaseous, liquid and solid products from thermal and catalytic degradation of HDPE and the comparison of the physical properties of the liquid products and to suggest the best reactor design along with the economical factors effecting the commercialization of this technique.

## 2.0 LITERATURE:

Wiwin Sriningsih et al [1] discussed about the pyrolysis of plastics under the presence of zeolite catalysts. They used Ni/Z, Ni-Mo/Z and Co/Z to determine the optimum characteristics for hydro cracking of LDPE plastics. They carried out experiments using these catalysts and produced liquid distillate in the range of diesel and gasoline. Acid treatment of the catalysts was carried out in acidic medium in order to activate the **Throat et.al[2]** discussed about basic process of the plastic pyrolysis in an industrial field and gave an idea on what the basic processes of the procedure on an industrial scale. This gives an insight into the pre-treatments that must be carried out with the raw material so that even mixed plastic wastes such as PVC can also be used as an input to the system. **Ashutosh Dubey et.al[3]** describes about the sources of waste plastics in day to day life and gives a theoretical insight into the basic process of pyrolysis in order to segregate the waste and process it to produce useful products. They give a brief introduction of the structure of the plastic industry and the various methods to segregate the wastes. They stress out that recycling plastics is the need of the hour so that the environments can be saved from the pollution caused by the landfills and the non-biodegradable nature of the plastics which lead to a variety of problems. Basically a rough figure of solid waste management procedure is described in the paper. **Nikolett Borsodi et.al [4]** describes about the study of pyrolysis of contaminated waste plastics. The pyrolysis of clear and contaminated waste plastics was carried out in a tubular reactor, applying 500°C temperature. Y-zeolite catalyst was applied to reduce the contaminant level in the products and the effect of pre-treatment of raw materials was also studied. It was established that the catalyst could increase the yields of volatile products but its effect was significant only in case of clear, non-contaminated raw materials. In the absence of catalyst the pre-treating of raw materials had only moderate effect on the quantity and quality of the products. The determined properties of the low contaminated products were advantageous with respect to their energetic utilization. However it was also cleared that the pyrolysis of high contaminated raw materials could not result in acceptable hydrocarbon fractions for refinery plants. **Jindaporn et.al [5]** discussed the HDPE plastic wastes were fast pyrolyzed at temperature of 400-450°C and char (solid residues) obtained were collected and analysed. Proximate and ultimate analyses showed that pyrolysis char had a large amount of volatile matter (51.40%) and fixed carbon (46.03%), small amount of moisture (2.41%) and little amount of ash (0.16%). Contents of carbon, hydrogen and nitrogen were found to be 42.65, 3.06, 0.43%, and 1.80%, respectively. Calorific value and density of the char were also determined and reported as 4,500 Cal/g and 1.59 g/cm<sup>3</sup>, respectively. Char derived from the fast pyrolysis of HDPE plastic wastes was crushed into powder and extruded to produce briquettes. One kilogram of the char based briquette was used as a fuel for the combustion process (boiling water). Atmospheric-pressure thermal activation at 900°C for 3 hours was performed to promote surface area and specific pore volume of the char.

## 3.0 EXPERIMENTAL METHOD:

### 3.1 Polymer Materials Collected

#### 3.1.1 Collection of the waste plastic materials

The waste plastics used by us for the process consisted mainly of HDPE products in the form of used plastic disposable glasses. The glasses were collected from a function hall where they had been used and thrown away. So we obtained the plastic material basically free of cost. As the glasses were used for drinking water the only pre-treatment was to dry the glasses in sun so as to evaporate the water content. Next the glasses were cut into small pieces manually so as accommodate more and more material in the confined space. The picture below shows the material, which we collected.



Fig 1.0 : The waste material collected by us.

### 3.2 Procurement Of The Material

#### 3.2.1 The Pyrolysis Chamber

The basic pyrolysis chamber which we needed was a closed air tight cylindrical vessel of an optimum height which could accommodate the plastics to carry out the reaction. We had many choices of the material of the chamber to be made out of which cast iron and stainless steel seemed to be most appropriate options. However when we compared both the options stainless steel seemed to be more appropriate to our use due to its features such as low cost, weight to strength ratio and availability in the required shape.

So a stainless steel cylinder of about 30cm height and 24.5cm diameter was selected which weighed about 1.8 kg. A cast iron cylinder produced by welding a through pipe would weigh about 15 kg and would cost about three times to the original cost. So choosing steel was beneficial as compared to cast iron. The cylinder was thick enough to withstand any pressure fluctuations which would develop during the process.

#### 3.2.2 The Piping System

The next step after the selection of chamber was to prepare a piping system in order to carry the gases from the chamber to the condensing chamber. Keeping in mind the temperature of gases and the vulnerability of the PVC pipes being prone to reaction we decided to use galvanised iron piping system. So the system was made using 5/8 inch G.I. pipes and two elbows and a coupler. A heavy ball valve was also used in the starting of the system so as to ensure the regulation of flow of gases whenever required.

#### 3.2.3 Condenser

In order to condense the gases a condenser was required and to collect the distillate. Though many laboratory usable glass condensers were available in the market we opted for a bath of water as our condensing medium because the gases fraction was obtained at normal temperatures theoretically and they could be condensed using water easily which would also reduce the cost to a great extent. So a water can of 5 litres capacity filled with water was chosen as the condenser and the end of the pipe for collecting the gases was placed in this water bath slightly above from the bottom.

3.2.4 Heater In order to heat the pyrolysis chamber a heating source was required. From the available sources we chose an electric heater due to its low cost, availability of electricity and transportation facility. The electric heater was a resistance concrete structure to hold it. The spring gets heated when current is passed through it due to its resistance and it in turn heats the pyrolysis chamber. The heater had a rating of 1500 watts. A temperature type of heater which consists of a spring wound around the 300°C

## 4.0 EXPERIMENTATION

The process of heating the plastics in the absence of oxygen so as to break the polymer chains into useful lower molecular weight compounds is called as pyrolysis or cracking. This can be achieved by heating the plastics at atmospheric pressures in absence of air.



Fig 2.0 The Apparatus With The Piping System



Fig 3.0 The Condensing Medium Used

The raw material was cut into small pieces using scissors and the cylinder was filled with the maximum amount of material possible so as to avoid any chance of air trapping inside it. The whole container was sealed using m-seal to avoid any chance of leakages of the gases or any entry of air inside the chamber which would lead to an aerobic combustion forming harmful gases such as CO<sub>2</sub> etc. once this was done the whole setup was heated using the electric heater to a temperature range of about 350-450 degree Celsius





Fig 4.0 Glimpse Of The Heater In Process



Fig 5.0 The Layer of oil Collected Over the water

Once the heating was started we found out that bubbles of the gaseous distillate started appearing at end of the piping system in the water bath. On continuing the heating it was found out that that the gases slowly started condensing in the water bath and started floating above the water due the density differences. The gases continued to be appearing for another 20 minutes. At end of the whole process a thick layer of oil was found to be formed on the top of the water bath. Apart from the liquid distillate some uncondensed gases were obtained as studied theoretically. The gases were in uncompressed state or in a dilute form making it difficult for us to store it as it was not economical for the amount of the raw material we used. Another by-product of the process is black soot left over in the pyrolysis chamber.

#### 4.1 Analysis of Liquid Products:

According to the literature that we went through, the liquid fuel products obtained contains mostly paraffin's, olefins, naphtha and aromatics (PONA). But due to economic reasons we were not able to find their composition. So, we selected to measure the physical properties like fire point, pour point, flash point etc.

#### 4.2 Flash Point

The flash point of the obtained liquid distillate was obtained using Cleveland's open apparatus. The sample was filled to the brim of the small cup and was heated using the apparatus. The thermometer at the top was used to see the temperature. A match stick was lit at end of rise of each degree of temperature to check the flash point. The temperature at which a momentary flash occurred was noted.

#### 4.2 Fire Point

The same apparatus as used for flash point was used for seeing the fire point of the sample. The temperature at which the sample caught fire was noted down as the fire point.

#### 4.3 Viscosity

The viscosity of the liquid distillate was found out using the redwood viscometer apparatus in our lab. For this purpose the sample was filled in the given space up to the required level and the viscosity was found out.

#### 4.4 Carbon Residue Test

The carbon residue test was carried on the sample in order to find out the amount of carbon the sample would leave when the whole sample was burnt. For this the glass bottle was filled with the sample and heated to 300 degree Celsius so that all of it evaporates leaving the carbon residue which was weighed.

### 5.0 Results And Discussion:

#### 5.1 The Different Products Obtained

##### 5.1.1 The Liquid Distillate

The main product of the experiment was the liquid distillate obtained from the pyrolysis process. For about every 250 g of plastic we used in the process we obtained about 120 ml of the liquid distillate. This can be accounted for about 50% of the plastic mass could be converted into liquid form. The distillate which was collected on the top of water bath was separated and stored in a container for further tests and usage. The temperature at which the product was obtained was in the range of about 350-400 degree Celsius.

##### 5.1.2 The Uncondensed Gases

The main by-product of the process was the uncondensed gases which were released at the top of the water bath. These gases mainly consisted of the low carbon compounds such as butane, propane etc. which cannot be condensed under normal atmospheric pressures. Practically the gases could be confirmed by their odour which resembled that of lpg gas used for domestic purposes. In order to test the same a match stick was lit near the mouth of the collector due to which the gas started burning which proved the theoretical claim of its flammable components. However we were not able to collect the gases as they were in a very dilute state and to collect them extra equipment such as a condenser would be required which would increase the cost of the project. The gaseous output accounted for about 30% of the total output. The product of oil and

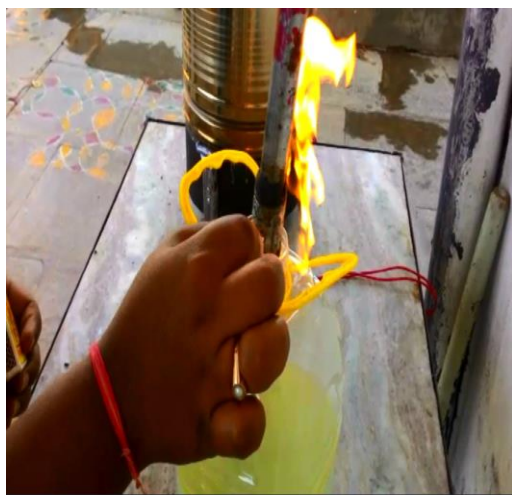


Fig 6.0 The Final Liquid Distillate Obtained



Fig 7.0 The Carbon Char Obtained

## 6. CONCLUSION

The main aim of our project was to convert the waste plastics into an useful product. We were able to convert the plastics into three main products- the liquid distillate, the uncondensed gases and the carbon char. We were able to get a 50% yeild of liquid distillate and the process can be made more viable if we can increase the yeild of the product. By further processing the oil on a commercial scale and creating a cleaner fuel the process can be commercially viable even without the use of a catalyst. The non condensed gases can be collected and used to heat the chamber itself on a commercial scale.

The only problem we encountered was that our system was not 100 % air proof so some of the plastic input was converted to gases such as carbon dioxide etc. The main input of our experiment was high density polyethylene. In order to use other plastics such as PVC (poly vinyl chloride) as input,additional apparatus are required to remove the harmful elements such as chlorine through various chemical process as they may form poisonous gases such as sulphur dioxide and also they corrode the pyrolysis chamber. Care must be taken in the handling of the liquid distillate as it has a very pungent smell and is volatile in nature so its better to keep the distillate in closed containers.

The liquid distillate obtained is flammable and can be put to direct use as fuel in the generators and boilers or can be further procesed to produce a cleaner fuel. Analysing the properties of the oil it has been found to be in the diesel and gasoline range so the bulky waste plastics have been converted to a useful product and it is also viable commercially.

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