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# Plastic to Fuel through Catalytic Pyrolysis

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***Abstract: In this study we focussed on conversion of different types of plastics into fuels using Pyrolysis. In pyrolysis waste plastics were converted into fuels through catalytic depolymerisation using Pyrolysis. The experimental setup semi-batch process. Low density Polyethylene (LDPE), High Density Polyethylene (HDPE) and Polypropylene (PP) Plastics, which were collected from Municipal solid waste are used as feed for Pyrolysis process. We performed pyrolysis on these plastic wastes with catalyst and without catalyst, and compared Results. Waste plastic material pyrolysis was conducted as individual plastics and as mixed feed in a new laboratory scale semi-batch reactor. Plastic wastes were pyrolyzed at temperature range 350-450°C and obtained products were liquid fuel, gas and minor solid residue. Barium Carbonate was used as catalyst, and different amounts of catalyst added to waste plastics to give them as a feedstock for pyrolysis. In this study, the mixture of plastics i.e. polypropylene (PP) and polyethylene terephthalate (PET) is treated using pyrolysis with catalyst in several operating temperature. According to the obtained results, Polypropylene has given best WPO yield from pyrolysis setup used in this work. Yield of 80% is achieved from Polypropylene (PP) by using 10% of Barium carbonate catalyst. In a practical way of implementation, mixture of HDPE and LDPE should be focused. Its result was somewhat satisfied even though the energy recovery was reduced. Clearly, this was the effect of adding low heating value and low yield raw materials (but large contribution in plastic composition), HDPE.***
***Keywords: Waste Plastics, Pyrolysis, Semi-batch process, Barium carbonate, Catalyst, Thermal cracking, Alternative Fuel.***

## I. INTRODUCTION

Plastic fraction inside the municipal solid waste (MSW) is difficult to be decomposed, and its quantity is increasing continuously by the time.

The increasing demand of plastics materials in all sectors is due to its characteristics of relatively low manufacturing cost, durable, lighter and flexible. In general, waste plastic have the composition of 46% high and low density of polyethylene (HDPE and LDPE), 16% polypropylene (PP), 16% polystyrene (PS), 7% polyvinyl chloride (PVC), 5% polyethylene terephthalate (PET), 5% acrylonitrile-butadiene-styrene (ABS), and 5 percent other polymers [4]. Over the world plastic waste has continuously grown in the last decades.

Disposal of waste plastics causes serious environmental problems. Thus, plastic waste recycling has been a focus of many researchers in the past few decades. Pyrolysis appears to be promising technic of conversion of solid wastes plastic (SWP) to more usable materials such as gas fuel and/or fuel oil or to high value feedstock for the chemical industry [1]. Most of the research was conducted to characterize the fuel from Low density Polythene bags, High density polyethylene bottles and Polypropylene bottles are selected as the source of waste plastics. The catalysts used for the study was barium carbonate. The amount of Barium Carbonate used in the pyrolysis reaction was 10-20% of weight of feeding Plastic wastes [2]. The aim of this work is catalytic conversion of high density polyethylene (HDPE) and polypropylene (PP) waste mixture into liquid products that could be used as fuel. The process of pyrolysis was carried out in the presence of mixture $BaCO_3$ catalyst using a semi-batch reactor. The physical properties of obtained liquid products also were determinate. There are numerous factors that influence quality and quantity of the products obtained; size and quality of the raw materials, type of reactor, operating conditions which include temperature, pressure, heating rate, time, type and amount of catalyst. The increase in temperature results in more gaseous products, more oil and reduction in char yield. The oil produced has various industrial applications [3].

## II. MATERIALS

### *A. Feedstock*

The feedstocks used for these experiments were three kinds of municipal plastic wastes, i.e. low density polyethylene (LDPE) bags, high density polyethylene (HDPE) bottles and polypropylene (PP) bottles. The waste plastic materials were shredded and thoroughly washed with tap water. This helps to increase the surface area of material in contact with catalyst during pyrolysis.

### *B. Catalyst*

The catalyst influences not only the structure of the products, but also their yield. Hence the results of pyrolysis in the absence of catalyst were compared with results obtained by pyrolysis which was carried out in the presence of the catalyst Barium Carbonate. Although Barium Carbonate is relatively insoluble in water, it is toxic to humans because it is soluble in the gastrointestinal tract. The insoluble compounds of barium (notably sulfate) are inefficient sources of $Ba^{2+}$ ion and are therefore generally nontoxic to humans.

## III. EXPERIMENTAL SETUP

A wide range of reactors have been used on a laboratory scale for the plastic pyrolysis process. The reactor set-up in this research is a semi-batch reactor. A common variant between the batch and semi-batch operations is the vacuum, which causes the reduction of temperature of the reaction to take place inside the borosil round bottom flask. The two types of feed patterns were used, namely individual types of plastics and mixed types of plastics.

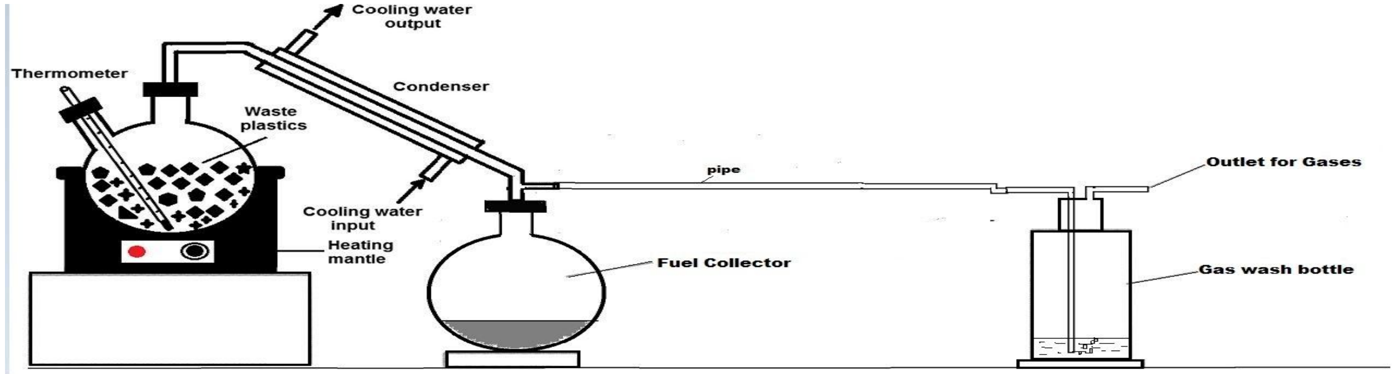


Fig. 1 Semi-batch reactor setup for Pyrolysis

The pre-processed waste plastic materials were transferred into an empty round bottom borosil glass flask of capacity 500 ml. The empty weight of round bottom flask was found to be 194.04 g. After the raw materials were loaded into the round bottomed flask, the main opening was connected to a 300 ml borosil condenser and the other neck we used to keep a thermometer. The condenser was connected to a receiving adapter with the help of borosil adaptor with one outlet for gases which can't get condensed. The outlet of Adaptor then connected to 250 ml borosil gas wash bottle with the help of a pipe. The round bottom flask is fixed with heating mantle. We start the heating mantle with 40°C and raise it gradually for the temperature to reach more than 350°C. The temperature can be observed in the thermometer. The process temperature is maintained 350°c to 430°C. The process temperature remains within the range 350°C to 450°C. The oil was collected in the oil collector. The whole process of pyrolysis took place under 1 h 40 min to complete.

## IV. RESULTS AND ANALYSIS

### *A. Results*

The results obtained from the pyrolysis process with catalyst and without catalyst were compared as shown in the table 1 given below.

TABLE I
Experimental Results Of The Process With And Without Catalyst

| Type of Plastic materials | Weight of plastic used in grams | Weight of catalyst ($BaCO_3$) used in grams | Yield to liquid product (%) | Temperature maintained °C) | Time taken for Pyrolysis (minutes) |
|---|---|---|---|---|---|
| Low Density Polyethylene | 30.055 | 3.043 | 52 | 350-450°C | 100 |
| | 31.5 | No catalyst | 50 | 350-450°C | 100 |
| High Density Polyethylene | 31.25 | 3.226 | 43 | 350-450°C | 100 |
| | 30.866 | No catalyst | 39 | 350-450°C | 100 |
| Mixed LDPE(50%) and HDPE(50%) | 40.698 | 8.032 | 54 | 350-450°C | 100 |
| | 40.742 | No catalyst | 48 | 350-450°C | 100 |
| polypropylene | 30.681 | 4.564 | 78 | 350-450°C | 90 |
| | 31.140 | No catalyst | 75 | 350-450°C | 90 |

### *B. Analysis*

#### *1) Physical properties*

The physical properties of both pyrolysis oil commercial diesel fuel were analysed and compared. In the table 2 given below the physical properties of both pyrolysis oil and diesel fuel are listed.

TABLE II
PHYSICAL PROPERTIES OF PYROLYSIS OIL AND DIESEL FUEL

| Sl. No. | parameter | Unit | Pyrolysis Oil | Diesel Fuel |
|---|---|---|---|---|
| 1 | Density | Kg/m$^2$ | 760 | 850 |
| 2 | Calorific Value | k-J/Kg | 42380.658 | 45187.5 |
| 3 | Kinematic viscosity (40 °C) | mm$^2$/s | 2.23 | 3.05 |
| 4 | Fire point | °C | 54 | 56 |
| 5 | Flash point | °C | 58 | 50 |
| 6 | Sulfur content | % | 0.045 | 0.05-0.25 |
| 7 | Carbon residue | % | 0.05 | 0.20 |

#### *2) FTIR Analysis*

Functional group analysis of commercial fuels (both petrol and diesel) and Waste Plastic Oil samples was carried out using Fourier Transform Infra-red Spectrometry. A spectrometer was used which had data processing and spectral library search facilities. A small amount of the liquid fraction derived from the polymer pyrolysis was mounted n a handmade potassium bromide disc which had been previously scanned as a background. The infra-red spectrum of the sample was then taken. The resulting spectra were normalized to the CH peak around 3000 cm$^{-1}$. Direct comparisons of peak intensity could then be taken. The graph of wavenumber vs. absorbance gives information about the functional group of diesel fuel oil.

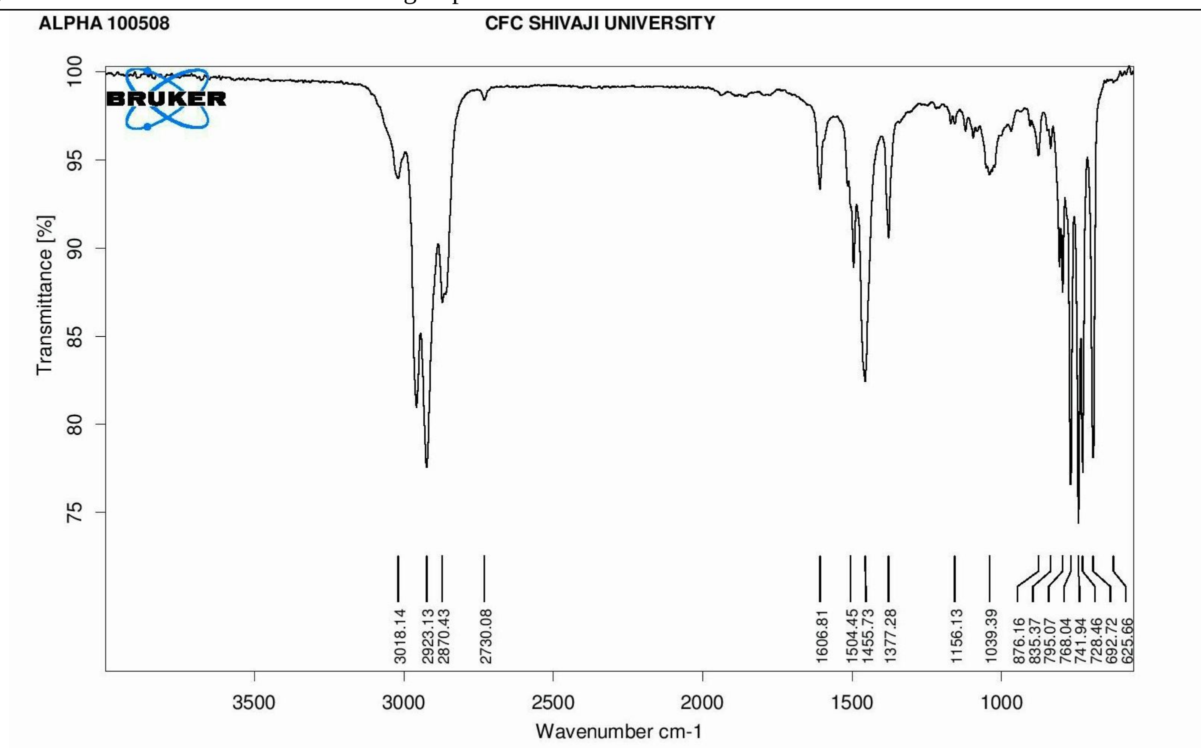


Fig. 2 Graph of wavenumber cm$^{-1}$ vs. Transmittance [%] of commercial Petrol fuel

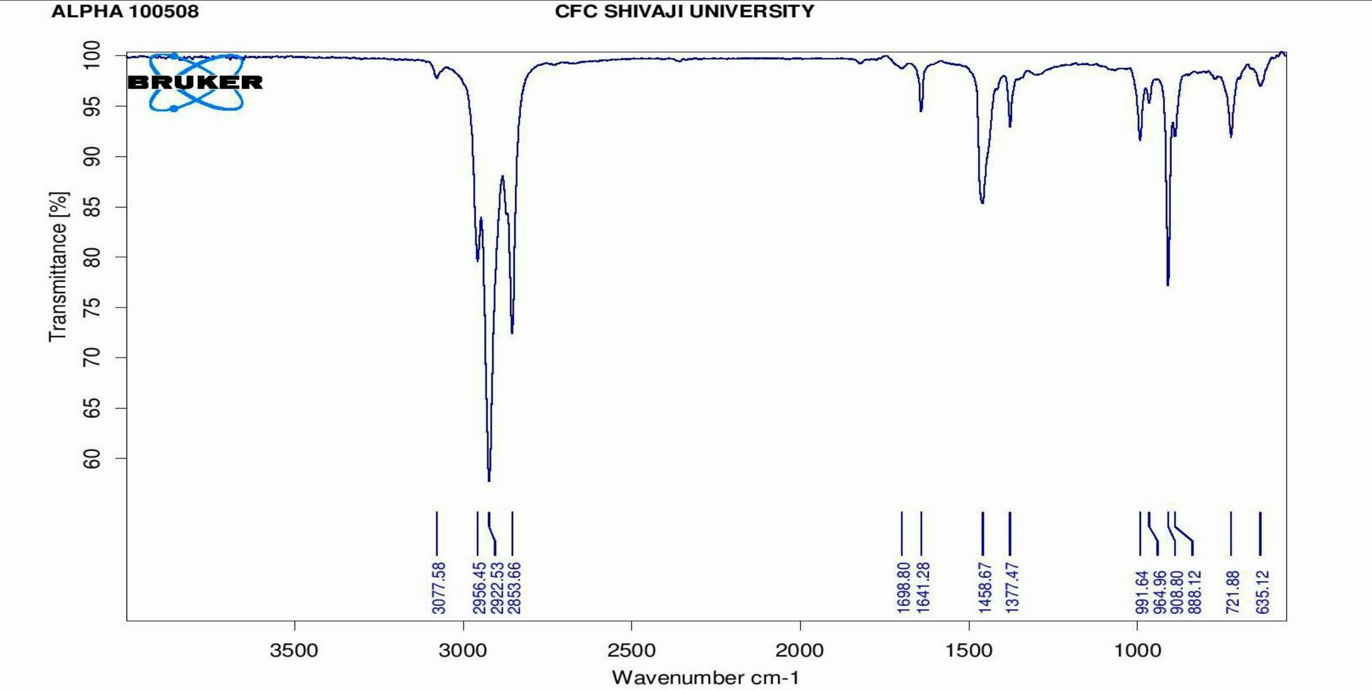


Fig. 3 Graph of wavenumber $cm^{-1}$ vs. Transmittance [%] of LDPE fuel

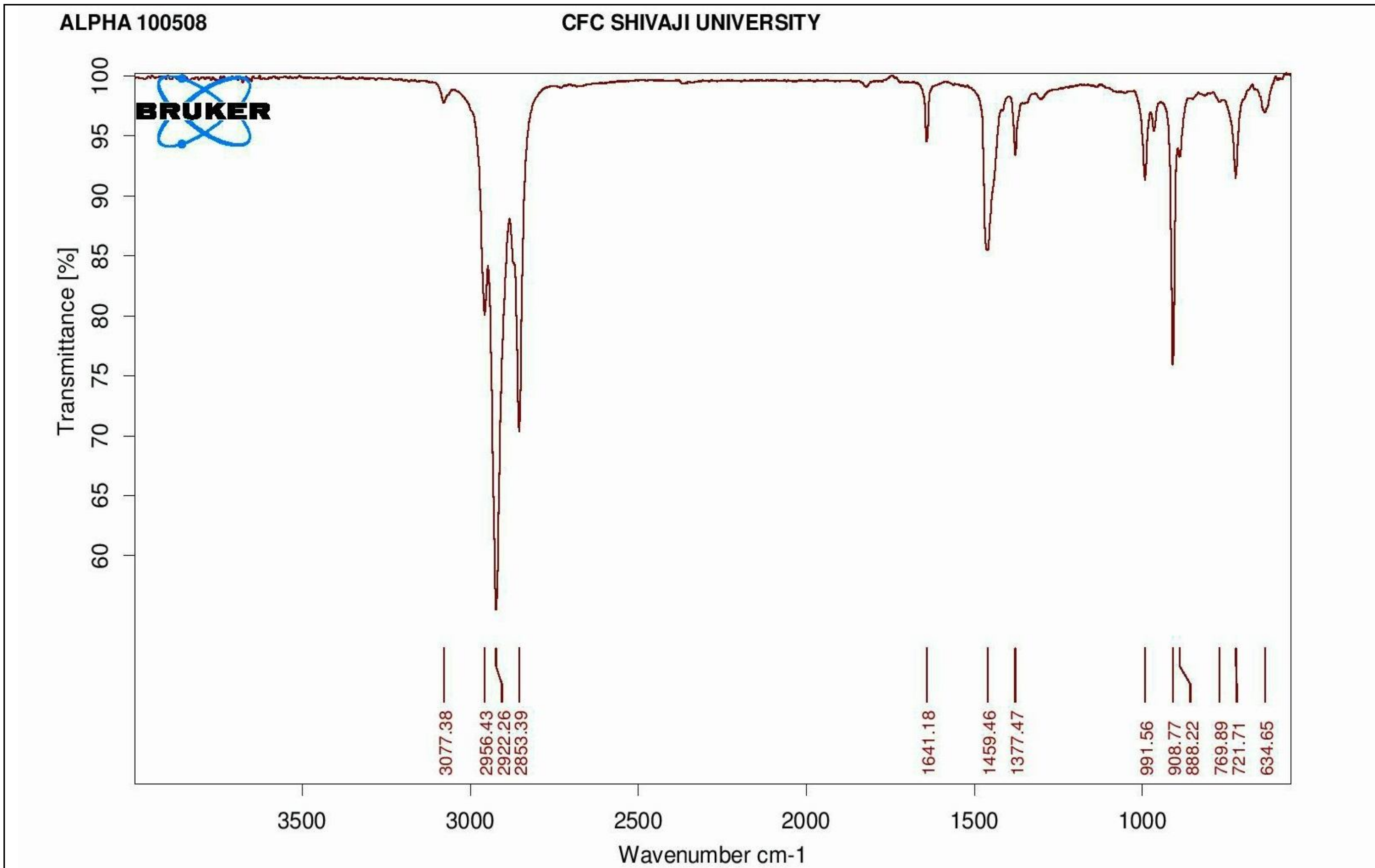


Fig. 4 Graph of wavenumber $cm^{-1}$ vs. Transmittance [%] of Mixed LDPE and HDPE plastic fuel using catalyst

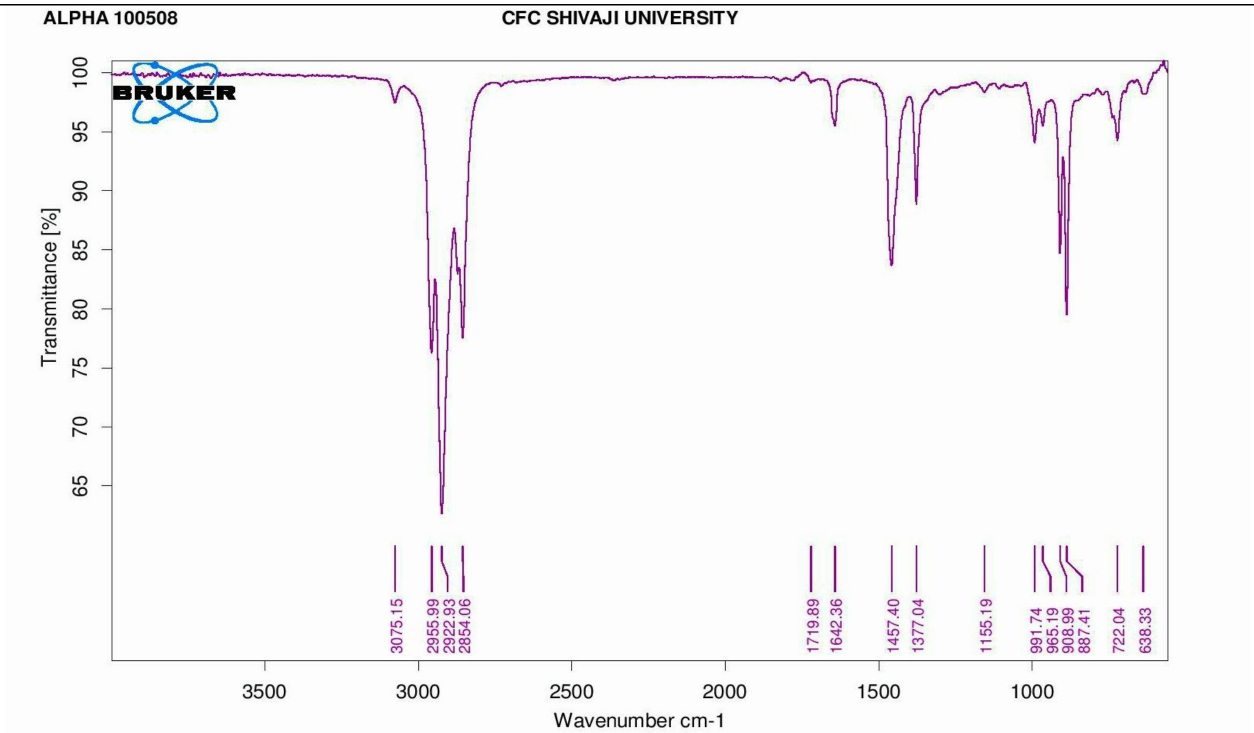


Fig. 5 Graph of wavenumber $cm^{-1}$ vs. Transmittance [%] of Mixed LDPE and HDPE plastic fuel without catalyst

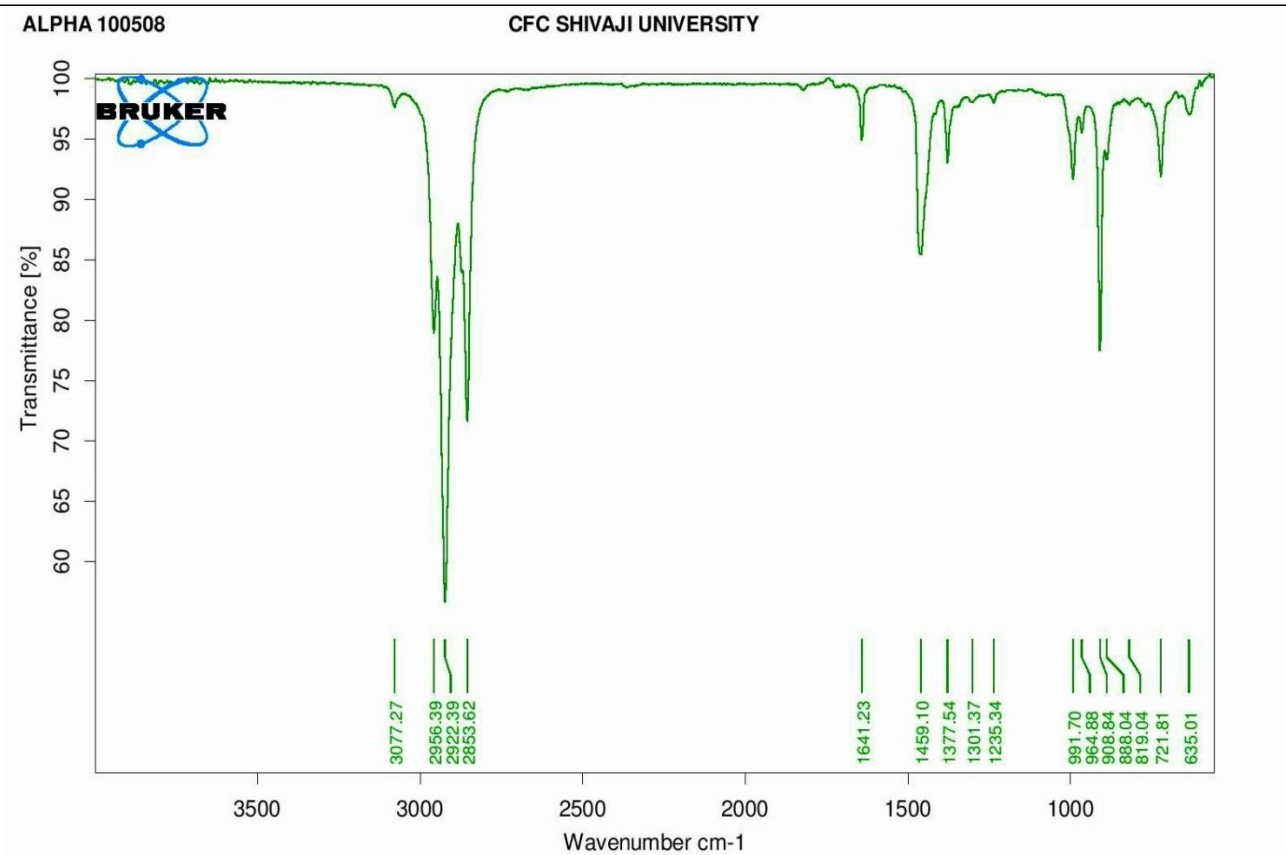


Fig. 6 Graph of Wavenumber $cm^{-1}$ vs. Transmittance [%] for HDPE

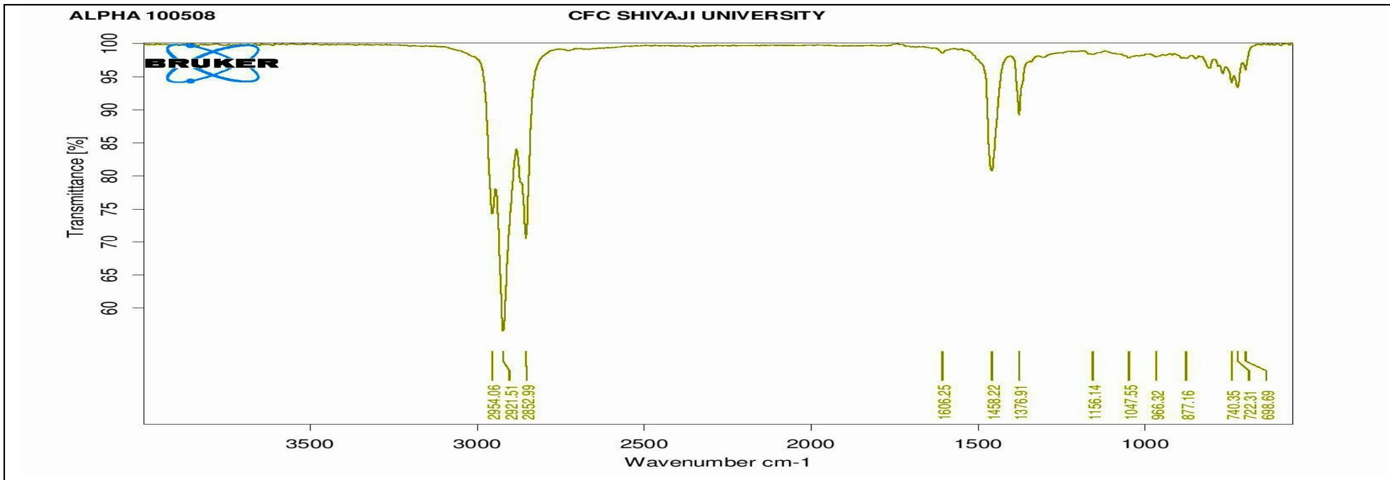

Fig. 7 Graph of wavenumber $cm^{-1}$ vs. Transmittance [%] of commercial Diesel fuel

The area of the spectrum between 3000 $cm^{-1}$ and 2800 $cm^{-1}$ shows the presence of alcohol groups. The peak at 3050 $cm^{-1}$ in fig. 7 is the indication of presence of alkenes group whereas HDPE, LDPE and PP all have sharp peaks in these regions which dominate their spectra. This illustrates the highly aliphatic nature of the oils produced. FTIR for WPO peaks found at approximately 1457 cm and 1377cm reinforce the identification of molecules with group alkane (-CH) present.

## V. CONCLUSIONS

*A.* Waste plastic oil yield from the pyrolysis process varies from 45% to 83%. The yield of oil mainly depends upon waste plastic type and in this work plastic used is LDPE, HDPE, and PP is provided above (i.e. 35% to 80%) parameters of the process.
*B.* Polypropylene has given best WPO yield from pyrolysis setup used in this work. Yield of 83% is achieved from Polypropylene by using 10% of Barium carbonate catalyst.
*C.* Polyethylene Terephthalate is problematic to be treated using pyrolysis because it gave wax like by-product in liquid which causes pipe clogging.
*D.* Polyvinylchloride plastics are also not preferable for pyrolysis process, because it gave black coloured liquid as by-product which did not match with diesel fuel.
*E.* In a practical way of implementation, mixture of HDPE and LDPE should be focused. Its result was somewhat satisfied even though the energy recovery was reduced. Clearly, this was the effect of adding low heating value and low yield raw materials (but large contribution in plastic composition), HDPE.
*F.* From the results of these tests, Pyrolysis using catalyst gave more yield and quality of the products also good compared to Pyrolysis without using catalyst.
*G.* The current research on plastic wastes pyrolysis process is technologically and economically viable for scaling up for industrial scale. There is no scarcity of feedstock as plastic waste generation has already become a habit of the modern society.

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