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Use of Catalyst in Pyrolysis of Polypropylene Waste into Liquid Fuel

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Abstract

Pyrolysis of polypropylene (PP) waste was carried out by developing lab scale borosilicate glass reactor of one litre capacity. Reactions were carried out by using about 200 grams of PP waste. The nitrogen gas was purged in required quantity in the reactor to create pyrolytic condition. The maximum temperature in a reactor was kept about 450^{0}C. Reactions were carried out with and without using natural zeolite (NZ) as a catalyst. It was found that, time required for completion of the pyrolysis process was 90 minutes without catalyst and 65 minutes with natural zeolite. Results showed that in absence of catalyst, process gives about 80.82% of liquid fuel and in presence of 10 % natural zeolite, about 86.40 % yield is obtained. It is observed that by using natural zeolite, oil percent can be enhanced and one can obtain high calorific value fuel than that of oil without catalyst. GC-MS results of oil samples showed presence of petroleum fractions (C_5-C_{20}) with some high molecular weight fractions from C_{20}-C_{30}.

Keywords: Catalyst, pyrolysis, polypropylene, natural zeolite, calorific value, GC-MS.

Introduction

Plastics are made up of long chain molecules called polymers[1]. They are light weight polymers of carbon along with hydrogen, nitrogen, sulphur and other organic and inorganic elements. The main drawbacks for utility of plastics are they are manufactured from fossil fuel which is a non-renewable source and their non - biodegradable nature[2-3].

Plastic waste pollution is increasing day by day in developed and developing countries because of their non-biodegradable nature. In India, plastic waste generated per day is about ten thousand tons that of total municipal solid waste[4]. Due to improper segregation and recycling system for these plastic wastes, load on landfill sites increases which ultimately cause environmental pollution and affects marine biodiversity[5].

Thermoplastic waste mainly consists of polyethylene terephthalate, high density polyethylene, polyvinyl chloride, low density polyethylene, polypropylene and polystyrene. For food packaging, generally polyethylene and polypropylene materials are used. As polypropylene is more resistant to heat, harder, denser and more transparent than polyethylene, it is used for microwavable packaging and sauce or salad dressing bottles[6]. These types of thermoplastic waste can be recycled by using different methods like mechanical recycling, chemical recycling, incineration, pyrolysis etc.

Pyrolysis is one of the recycling options for plastic waste which involves heating of organic material at elevated temperature in absence of oxygen[7]. It is one of the best methods to reduce load of plastic waste on available landfills. It converts plastic waste into different petroleum fractions which can be used in many industries as an alternative fuel for running boilers, generators, and turbines. By using suitable catalyst, process yield can be enhanced and reaction time can be minimized which ultimately achieves efficiency in the process.

Production of hydrogen and carbon nanotubes is possible by catalytic pyrolysis of waste polypropylene[8]. Pyrolysis of polypropylene waste material gives petroleum fuel grade liquid product without using catalyst[9-10]. Catalytic cracking of polypropylene (PP) waste by using zeolite beta (BEA) catalyst enhances percent of oil as compared to that of without catalyst[11]. Use of synthesized catalysts from fly ash also gives good results in pyrolysis process of plastic waste[12]. Kaolin catalyst found effective for thermo degradation of polypropylene waste for conversion into fuel[13]. Some authors studied pyrolysis process for converting mixture of waste tyre and polypropylene into petroleum fuel by using ZnO as a catalyst[14]. Present research work focuses on use of natural zeolite catalyst in pyrolysis of polypropylene waste into liquid fuel.

Material and Methods

In present research study, experiments were performed without catalyst and by using 10 percent of natural zeolite. Polypropylene waste was collected from canteens, mess, ice-cream parlors etc. Washing, shredding and drying was done manually. Waste quantity of about 200 gram was used as a feedstock for reaction. Natural zeolite was selected as a catalyst due to its cost effectiveness, easy availability and chemical properties. It was heated upto 200^{0}C in an oven for an hour to remove impurities.

The whole pyrolysis reactor set up has following parts: i. Nitrogen gas cylinder ii. heating mantle iii. Borosilicate glass reactor with recovery bend iv. Thermocouple with temperature indicator v. Condenser and vi. Collection flask.

Before starting reaction, 200 grams shredded plastic waste was fed into a reactor and nitrogen gas was purged into it for 5 seconds with pressure of 5kgf/cm^2 to make pyrolytic condition. Reactions were carried out at maximum temperature of 450^{0}C. Vapours generated after depolymerisation of material were passed through condenser and oil obtained was collected in a flask. Uncondensed gases produced during the experiment were passed in cold water bath.

Figure-1
Polypropylene plastic waste

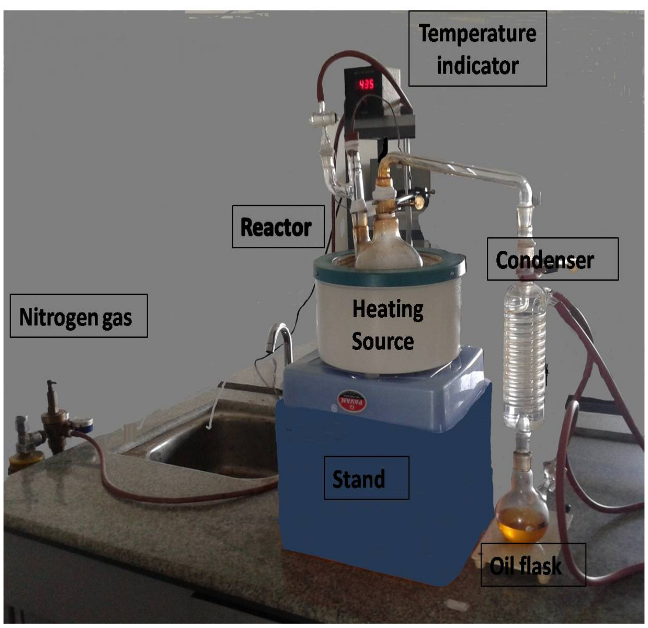

Figure-2
Pyrolysis reactor set up for plastic waste recycling

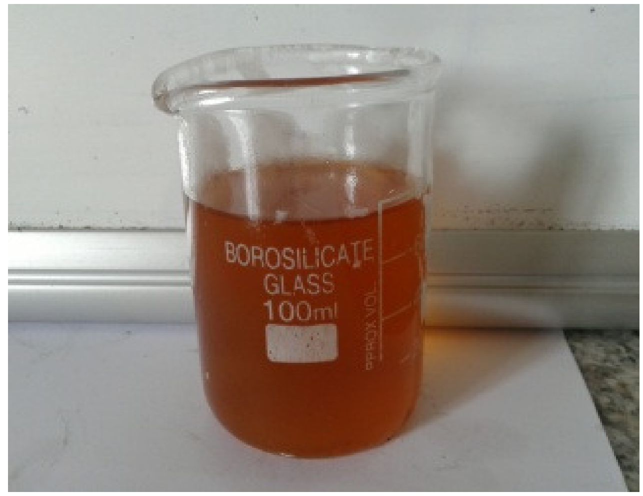

Figure-3
Oil obtained by pyrolysis without catalyst

Figure-4
Oil obtained by pyrolysis with 10 % NZ

Results and Discussion

Polypropylene waste started melting at temperature about 135^{0}C. So melting point was recorded 135^{0}C. Pure polypropylene material has a melting point of about 130^{0}C. Small difference in melting point may be due to presence of additives and other materials in polypropylene waste. The maximum yield was observed at a temperature range of about 400 to 450^{0}C. Process required 25 minutes to start receiving distillate in a collection flask without using catalyst whereas by using NZ process required only 20 minutes. In absence of catalyst about 90 minutes were required to complete the process and with the help of NZ, it has been completed in 65 minutes only.

Percent oil obtained by pyrolysis process with and without catalyst was calculated by using following formula:

$$\text{Percent oil obtained} = \frac{\text{Oil obtained in grams}}{\text{Weight of plastic waste taken}} \times 100$$

Specific gravity of oil samples were determined by using specific gravity bottle. Calorific value of oil samples Digital bomb calorimeter with make model RSB-3 by Rico Scientific was used to determine calorific value of obtained oil samples in the process.

GC make model Agilent-7890, with FID detector was used and MS make model Jeol Accu TOF GCV with mass range 10-2000 amu and mass resolution 6000 was used. Results showed presence of gasoline, kerosene and diesel fractions with some higher molecular weight fractions.

Table-1 displays values of oil and wax percent obtained for PP and reaction time required for the process in absence of catalyst and by using NZ.

In absence of catalyst, oil obtained from the process is about 80% and with the help of 10 % NZ, process gives about 86% oil. With 10 % natural zeolite, time span for completion of process is reduced by 25 minutes with that of in absence of catalyst. By using natural zeolite, yield percent and physical appearance can be enhanced and time required can be minimized which ultimately saves energy required for the process.

Table-1
Percent yield of oil and wax obtained without catalyst and with 10 % NZ

PP Material (200 g)	Oil obtained (%)	Wax obtained (%)	Reaction time (Minutes)
Without catalyst	80.82	18.64	90
With 10 % NZ catalyst	86.41	11.34	65

Table-2
Calorific values of oil with and without catalyst

PP	Calorific value (KJ/Kg)
PP without catalyst	25794
PP with 10 % NZ	27167

Table-2 Displays calorific values of oil samples in absence of NZ and with NZ. Increase in calorific value of oil with NZ catalyst broadens its applications as an energy source.

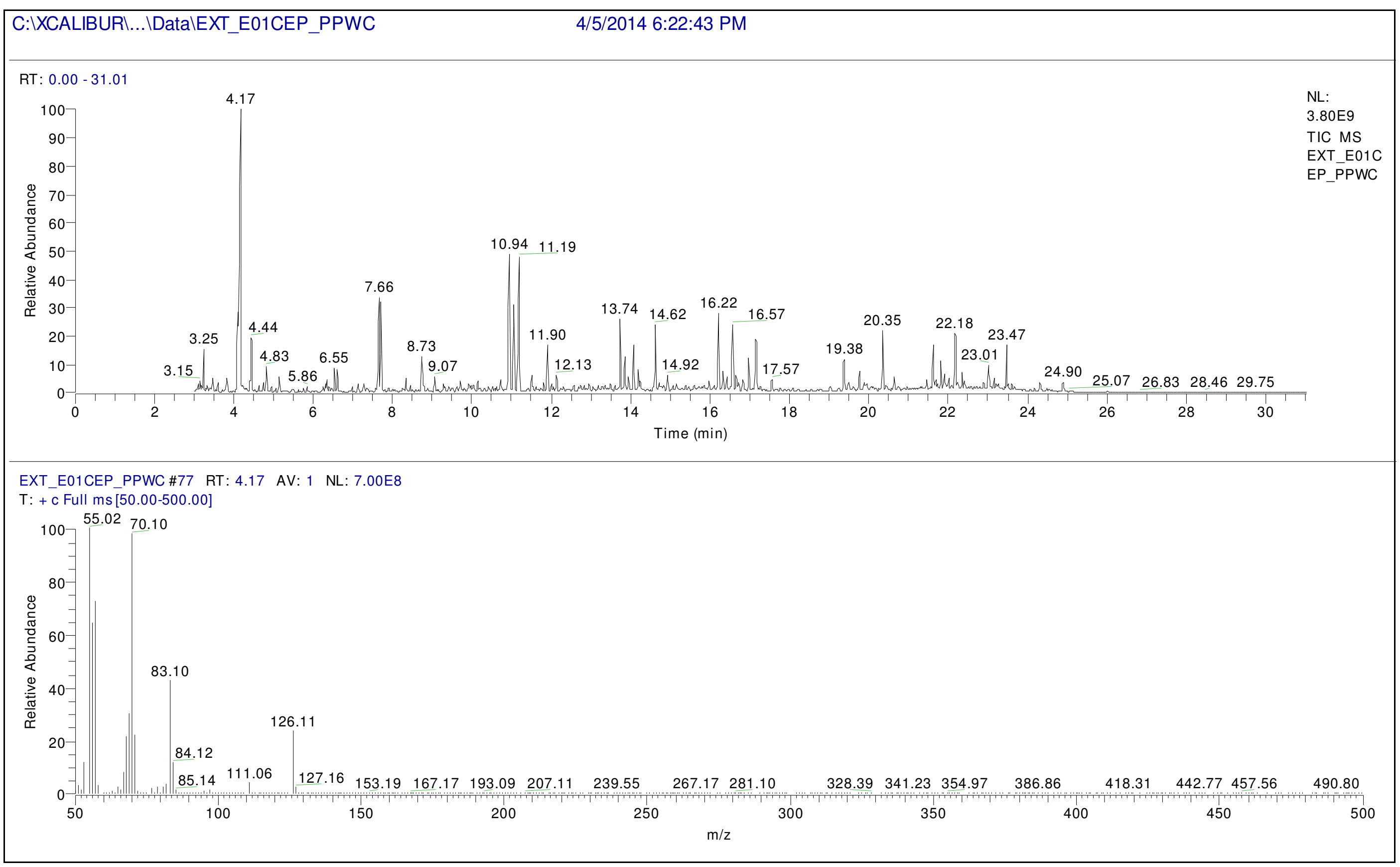

Figure-5
GC-MS of oil sample without catalyst

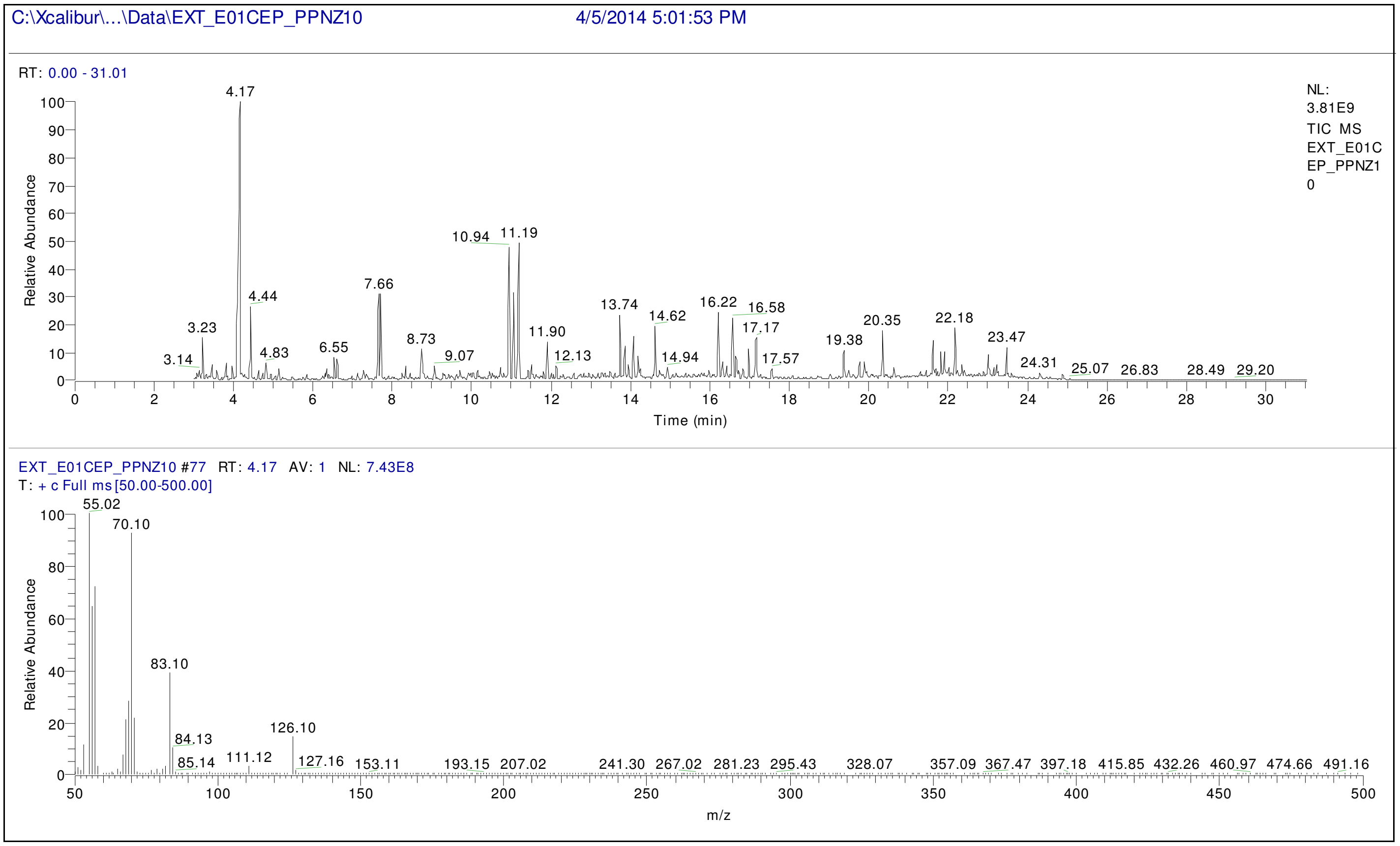

Figure-6
GC-MS plot for oil sample with 10% natural zeolite

GC-MS plot of oil samples obtained without catalyst and by using natural zeolite show presence of petroleum fractions (C_4 to C_{20}) which include alkanes e.g. heptanes, dodecane, alkenes e.g. 2, 4 dimethyl 1-heptene, 3 hexadecene, esters e.g. pentadecyl ester and few high molecular weight fractions (C_{20}-C_{30}) e.g. 9 eicosene, hexadecyl ester etc. which shows their usefulness for fuel in different industrial sectors.

Conclusion

Polypropylene waste can be converted into useful liquid, gas and waxy hydrocarbon fractions by using pyrolysis technique. Optimum temperature range of about 400-450^{0}C maximize percent of oil and lessen the yield of wax. With the help of natural zeolite in the pyrolysis process, one can reduce the reaction time upto 25 minutes for 200 grams of PP waste. The oil obtained by using natural zeolite has higher calorific value which broadens its applications. From obtained results, it is concluded that 10 % natural zeolite enhances oil percent in pyrolysis process and reduces reaction time proves its utility in recycling of PP waste. The oil obtained without catalyst and with natural zeolite has variety of low to high molecular weight hydrocarbon fractions which can be used as an energy source.

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