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Low cost Pyrolysis experiment on plastic material (HDPE & LDPE)

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Abstract

In the present time decomposition of plastic waste is a major problem around the globe. The plastics once used are dumped in landfills or are accumulated in the municipal waste. This results in pollution in the environment as plastics do not decompose by natural means. Hence, considering this issue, the proposed work is focused on treatment of plastic and using them as a fuel for vehicles and machines. An experimental setup is created for the process of pyrolysis to produce useful oil by burning plastic material. The oil produced in the pyrolysis process can be used as alternate fuel in place of diesel or petrol. HDPE and LDPE plastics are used in the experiment and objective was made to minimize the cost of the complete experiment. The result shows that pyrolysis oil obtained from the experiment is cheaper compared to the conventional fuel available such as diesel etc.

Keywords:*Plastics, pyrolysis, diesel, petrol, low cost, HDPE &LDPE*

I. INTRODUCTION

The Pollution from plastics is the collection of materials of plastic (such as plastic bottles and other objects) in the environment of the earth which severely impacts the wildlife, habibat from wild life, as well as humans. Plastics which are types of pollutant are classified in several types, such as micro, debris meso or macro depending on the size of the particulate. Plastic materials are cheaply available and are quite durable, hence the outcome levels of producing plastic by man is higher. Although, the structure of chemical composition of plastic makes it hard to degrade process by natural means and as a result they have very slow process of degradation. Altogether, these two factors have resulted in high concentration of plastic pollution in environment.

Fig. 1. Pollution due to plastic

A. *Plastic Recycling*

The issue of plastic waste increased because utilization of plastics made applications are increased in industries, commercial aspects and household items. Residential and industries generate huge amount of plastics as waste. These wastes affect the ecosystem severely when incinerated or burnt openly along the road side or dumping areas. Plastics are majorly found in open parks, gardens and private properties.

Around 50% of the plastic wastes are generated from the household usage which are majorly in the form of plastic packaging material. Once plastic is disposed, it gets contaminated and while recycling such items it generates a serious issue of contaminated plastics which impacts and recovers more severe properties that could harm the ecosystem.

II. LITERATURE REVIEW

(Miandad *et al.*, 2019) experimentally performed various test in order to utilize the process of pyrolysis to convert several plastic waste and biomass waste into energy or any other useful product. Bio-refineries which are based upon pyrolysis have immense capability to do that for better economic and safe environmental solutions. Various types of plastic were taken such as PE, PET, PP and PS, as single or mixed in different proportions and in the presence of a catalyst Natural Zeolite (NZ), pyrolysis was carried out. NZ was also modified with the help of thermal activation (TA-NZ) at 550^{o} C and acid activation (AA-NZ) with HNO_3. The liquid oil produced by the catalytic pyrolysis of PP (40% and 54%) and PE (40% and 42%) was less than the oil produced by PS (70% and 60%) with the help of TA-NZ and AA-NZ catalysts, correspondingly. After this, analysis of oil was performed by gas chromatography-mass spectrometry (CG-MS) which explained the composition of aromatics, aliphatic and other hydrocarbon compounds in oil. AA-NZ showed better activity than the TA-NZ as showed different effects on percentage of weight of catalytic pyrolysis products and liquid oil chemical composition.

(Thahir *et al.*, 2019) optimized the product obtained from pyrolysis by using fixed bed type reactor in a sealed pack condition (-3 mm H_2O), from as much as 500 g of polypropylene plastic waste to make the least use of oxygen entering into the reactor. Vapour coming out of pyrolysis goes through 4 tray distillation cap plate column for fractionation. For this purpose, heat is being utilized from reactor itself. This process showed different result on different temperature conditions. At condition of 500-650^{o}C, optimum yield of liquid oil at 580^{o}C was 88 wt%, consisting of kerosene in tray 1st, gasoline in 2nd and 3rd tray and 4th tray had no condensate. Different set of results were obtained at conditions of 600^{o}C and 650^{o}C. Specifications of fuel obtained from plastic waste has similar properties like octane-cetane number, ash content, viscosity, etc. when compared to fossil fuels.

(Nursyamsi, Indrawan and Ramadhan, 2019)LDPE plastic pellets has low density than sand particles, thus makes blocks lighter than sand blocks. Another reason is that, since LDPE exhibits similar properties than that of sand, therefore using it will cause no significant change in strength of block and will also be eco-friendly as these plastics are not decomposable but can be recycled and reused in this manner. First LDPE plastics are converted into LDPE plastic pellets and then it is given the shape of cylinder having diameter 15 cm and height of 30 cm and used as a sample of trial mixes in this study. Then it is mixed with concrete bricks having cuboidal (brick) size of 40 cm x 20 cm x 10 cm, cubical size of 5 cm x 5 cm x 5 cm and briquette. Several test were carried out such as

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visual, content weight, absorption, compressive strength and drag strength tests for the duration of 7 days and 28 days for the trial mixes samples and brick, cube and briquette samples respectively. The reference for concrete bricks was taken from SNI 03-0349-1989 for the similar composition for walls. In this study, ratio of 1:6:0.24 comprising of cement, sand and water was applied, which was obtained from various kinds of experiments on different certain compositions. Also through the same process, replacement percentage of plastic pellets was determined from sand, i.e. 20%. For both types of bricks, i.e. normal brick and with 20% plastic pellet, visual appearance, content weight and absorption was considered to a quality I product but on the other hand, in terms of compressive strength, sample of LDPE plastic pellet brick was in quality III whereas normal brick stood in quality I.

(Sharuddin *et al.*, 2018) discussed about the alternative method to recycle or reuse the indecomposable plastic instead of putting all the plastic as a landfill or using it to convert energy which magnified the water pollution by extensive use of it. As the presence of plastic can never be neglected from almost any part of this world, this shows that how plastics have been extensively used without having any thought of its side effects of using and producing it. This world has also increased the demand of fossil fuels for generating power and fulfilling energy needs. But as the plastic is increasing, being petroleum based material; fossil fuels are also affected by this.

(Anene *et al.*, 2018) carried out the process of experimenting the thermal and catalytic pyrolysis of virgin low density polyethylene (LDPE), high density polyethylene (HDPE), polypropylene (PP) and the blend of LDPE/PP. this experiment was carried out in 200 mL laboratory scale bed reactor at temperature of 460^{o}C in the presence of nitrogen in the atmosphere around it. The ratio in the blend of LDPE/PP was varied to look at the variation on the reaction. Thermal gravimetric analysis was conducted to find out the thermal and catalytic degradation of the polymers at a specified heating rate of 10^{o} C/min. A lesser decomposition temperature was seen in thermal degradation of LDPE/PP mixtures when compared to pure LDPE, thus signifying the interaction both the polymers. When the catalyst (CAT-2) was introduced, degradation temperature was seen falling for the pure polymers. After this, the results obtained from TGA were validated in a bed reactor by using LDPE and PP, correspondingly.

(Khot and Basavarajappa, 2017) discussed about the various ways and explained about the single one, in which problem of plastics can be converted into opportunity for future. As we know, plastics are now the backbone of every household work on a daily basis, and have reached all over the world for its magnificent properties. But also, increasing plastic is filling in landfill waste and creating hazardous problems for the environment. This can be overcome by the process of pyrolysis. In this study, pyrolysis is discussed in detail and the process converts the plastic wastes into oil of high calorific value that can be used in the world as an alternative fuel. These plastics are converted to oil and then further divided in kerosene, gasoline and diesel.

(Chiwara *et al.*, 2017) designed implemented an appropriate system which followed the approach of chemically converting the solid plastic waste (PSW) into useful products. In this study, a technology is proposed not only convert the plastic waste into products but also the real life application and implementation of the same. The outcomes of this research are well to apply in realistic world for further improvement. Also, by this new technique, and useful products, rural areas are envisioned to get development and further get employment because of these industries in the rural areas.

(Bezergianni *et al.*, 2017) attended the issues over increasing energy demands and energy to be sustained for the future generation along with looking at the environmental harmful impacts caused by the collection of plastic waste in the forms of landfill by suggesting the method or technique of waste-to-fuel conversion. A two-step thermochemical process is carried out known as pyrolysis and hydro treatment. South East Asia plant was used for pyrolysis of plastic waste which is known for rendering oil. After pyrolysis, hydro treatment process was conducted to enhance the properties of diesel fraction obtained through pyrolysis at the Centre for Research and Technology Hellas (CERTH) in Greece. The outcome obtained by this process was examined in relevance to diesel fuel characteristics specifications EN590, which put this fuel as a suitable alternative for the commercial fuel diesel with lower emissions of harmful gases and enhanced ignition properties.

(Wong *et al.*, 2016) applied response surface methodology to optimize the oil yield obtained from the data from the process of pyrolysis performed on low density polyethylene (LDPE). Process of pyrolysis was done in the presence of sub critical water and the main focus was on the investigation of the effect of reaction time,

temperature and the mass ratio of water to polymer in case of the oil (liquid) yield. The outcomes observed through the process of pyrolysis in temperature range from 162-338^{o}C was hydrogen, methane, carbon dioxide and carbon monoxide. On the parallel hand, liquid yield showed products like alkanes and alkene having 10-50 carbon atoms. This was obtained on the reaction time 37-143 minutes and the mass ratio from 1.9 to 7.1.

(Taylor *et al.*, 2015) studied about the process of recycling and reusing the plastic waste that is spread all over the world to save environment as well as fulfill energy demands of this world. Different plastic waste was considered such as the blends of LDPE, low density polyethylene and virgin or recycled HDPE, high density polyethylene. Assessment of the reusability of these plastic materials was focused in this study. In this, mechanical assessment was also performed for evaluating the tensile strength and flexibility of sample of these blends of materials. Another study was done, known as thermo gravimetric studies through which activation energy was obtained which responses in the delaying process at 30% and 40% recycled HDPE. This is mainly because at high compositions, properties usually deteriorate. And thus it can be concluded that, since cost of raw material is reduced and properties are also enhanced along with environmental improvement factors, blend of recycled HDPE and LDPE, are feasibly to use in practical world.

III. PYROLYSIS

Pyrolysis is a process of decomposition thermo chemically regarding organic substances at high degree of heat in absence of air. When organic substances are pyrolysed, it generates gaseous as well as products of liquid and are referred to as bio-fuels and leaves behind a residue in solid form which has high content of carbon and char. The chemical reactions under process of pyrolysis are complicated and it takes several stages to accomplish. Maximum processes of pyrolysis are carried out at temperatures between 300-100 degree Celsius. While the temperatures of operation might rise upto extent of 300 degrees having polymers as substance. The higher is the temperature of operation, more is the decomposition thermally, and hence it generates broad range of items having lower weight by molecules having elevated calorific values.

A. *Experimental Setup*

Experiment has been carried out as per the following steps:

1. Initial an air tight steel container was taken in usage. In which 250 gms of plastic has been filled.
2. After filling plastic in the steel container. Copper tube has been connected to the top of steel cane with Teflon tape for condensing the gases.
3. Steel cane has been tightly packed with the help of Teflon tape.
4. The other end of the copper tube is connected with a glass beaker for collecting the fuel.
5. After the whole setup is completed, steel cane is burned at 400-500ºC. Where copper tube is supported with the help of stick.
6. 150 ml of Fuel has been obtained from experiment.
7. Remaining tar left in steel can after experiment.

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Fig. 2. Setup of experiment

B. *Cost Analysis of the Experiment*

After completing the analysis part, the monetary aspect of building the same is analysed. A cost analysis is done on the basis of which, cost structure is made. Below table gives a rough idea of the cost involved in it.

Table 1 Experimental setup cost

Materials and Equipment	Cost (INR)
Steel canister (Mild Steel)	250
Copper tubes	500
Plastic material (HDPE+LDPE) (Kg)	15
Teflon tape (1)	20
Collecting Beaker (1)	35
Total	820 INR

A total of 820 Indian rupees cost is obtained from the setupof pyrolysis experiment.

The price of 250 gm plastic material is Rs 3. The plastic and fuel ratio 1:0.6 is achieved in analysis; its means in 1kg of plastic 600 ml fuel can be produced.

C. *Various fuel price comparison*

The table shows the comparison of various fuels generally used in automobile vehicle is compare.

Table 2 Fuel price comparisons

Fuel	Price at Madhya Pradesh (India)
Diesel (L)	72.87
Petrol (L)	81.81
Auto gas (Kg)	44.48
Plastic oil (L)	25.5

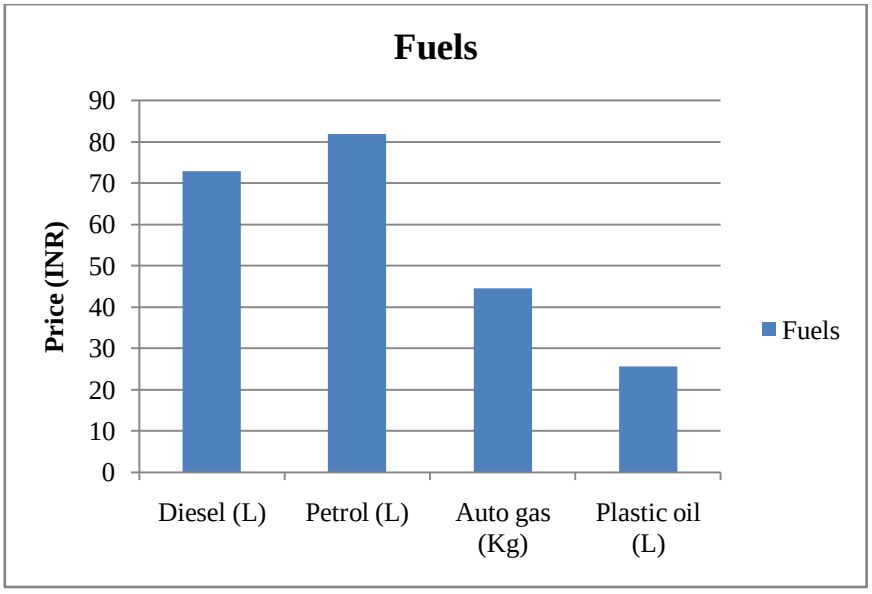

Fig. 3. Price comparision graph

IV. RESULT

The current experiment has been carried out on the process of pyrolysis. This process is used to obtain the fluids from the waste of plastic. Initially a cane of steel was filled with 250gms of plastic and burned at 400 to 500ºC. The oil obtained after the burning of plastic materials is collected by the means of copper tube connected from the steel cane to a glass beaker. The amount of fuel obtained after the pyrolysis in this experiment is 150ml.

A. *Pyrolysis carried out at several temperatures*

The major constituents of plastic material are cellulose, hemi cellulose as well as lignin, each is separated in their behavior of decomposition. Further, decomposition, of every constituent depends on the rate of heating, temperature and the emergence of contaminants because of varying structures of molecules. The procedure of pyrolysis, the three constituents are not decayed as depicted in fig. 3. Semi-cellulose might be easiest method besides pyrolysis and the next might be cellulose, on the other hand lignin would be most hard. Both, lignin as well as semi-cellulose might impact the features of pyrolysis regarding cellulose while they might not impact one another in the process of pyrolysis.

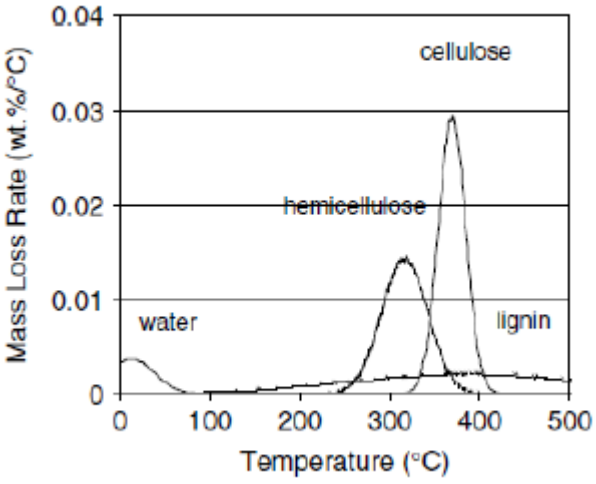

Fig. 4. Decomposition rate of individual biomass components with pyrolysis temperature

From all the Pyrolysis reactions at different temperatures, it has been found that the experiment performed at 400°C in the proposed work provide fuel of much better quality as compared to the other fuels obtained below

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400°C. The residuals obtained at 400°C were minimum because of that the quality of obtained fuel is improved as compared to the residual obtained below the temperature of 400°C were higher because of that the quality of obtained fuel was not so much improved.
The below table shows properties comparison among LDPE and Diesel

Table 3 Properties of LDPE and Diesel

LDPE material	**Values**
Calorific value (KJ/kg)	43695
Density (gm/cm^3)	0.911
Viscosity	2.5
Flash point (^{o}C)	45
Pour point (^{o}C)	24
Diesel	
Calorific value (KJ/kg)	46951
Density (gm/cm^3)	0.875
Viscosity	2.5
Flash point (^{o}C)	63
Pour point (^{o}C)	3

V. CONCLUSION

From the result concluded it has been found that at the temperature of 400°C to 500°C, fuel obtained is of much better quality. It is achieved domestically with low cost of equipment and external large equipment is not required in this experiment. Thus, the experiment proposed has been achieved successfully.

If further experiment is performed at higher temperature than 400°C, it is expected that much better quality fuel might be obtained but for higher temperature experiment, large laboratory equipment and huge amount of space would be required which might eventually increase the overall cost of the experiment as temperatures above 500 degrees can be achieved by use of external furnaces and not domestically. Therefore, this experiment is cost effective at domestic levels with better quality of fuel. The results also discusses that fuel quality obtained below 400 degrees considerably have lower burning properties and they form more residues after the pyrolysis.

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