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RESEARCH ARTICLE

HYDROCARBON FUEL PRODUCTION FROM PLASTIC WASTE

*Daida Sharath, Berhe Tekle Tajura and Solomon

Department of Chemical Engineering Wolkite University, Ethiopia

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ABSTRACT

Pyrolysis of waste plastic is a prospective way of conversion of waste plastic into hydrocarbon fuel. The present research is focused on the conversion of waste plastic into hydrocarbon fuel by two processes namely vacuum and catalytic cracking (activated granulated charcoal, activated granulated charcoal with calcium oxide and calcium oxide). Waste plastic materials polyethylene, polypropylene and polystyrene were collected from local convenience store packing materials. Waste plastic material pyrolysis was conducted as individual plastics and as mixed feed in laboratory scale of flask. Hydrocarbon molecules from the basic materials are split under the impact of catalyst inside the flask in 100–267 °C. The reduction of process takes place from 500–600 °C to 267 °C in the presence of catalyst. The analyses of pyrolysis products suggested that it can be used as a viable alternative to motor fuel. The comparison of the GC-FID (TPH) report of the obtained oil with that of the commercial petrol clearly proves that the prepared oil is composed of petrol components.

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INTRODUCTION

Due to the erratic change of energy prices and unfavorable forecast of world economy, considerable efforts have been devoted to substitute raw fossil fuels with various other sources for the production of energy. The various factors, such as ever increasing diesel consumption, large outflow of foreign exchange, and concern for environment, contribute to the search for a suitable environmental friendly alternative to fossil fuel. It is clearly envisaged that the increasing GDP and the limits of greenhouse gases can only be compensated by the application of waste recycling process (e.g. plastic, paper, metals, etc. The plastics have become one of the most important and indispensable materials in our contemporary world .These plastics are not presently biodegradable and are extremely troublesome components for land filling and that end up in incineration facilities release toxic gases such as carbon monoxide (CO), which causes health hazards; sulfur dioxides (SO2), which contribute to acid rain; nitrogen oxides (NOx), which contribute to ozone depilation and acid rain; and carbon dioxide (CO2), a greenhouse gas that contributes to global warming (Miskolc *et al*., 2009; Mani *et al*., 2011). To avoid the impact of plastic waste, mechanical and thermal recycle of plastic waste method used but, the attractive method to recycle plastic waste is thermal or catalytic method which produces hydrocarbon fuels. Hydrocarbon fuels are the same as fossil fuels and which means they made up of hydrogen and carbon compound. The simplest of these is methane, natural gas. Oil is a hydrocarbon fuel because it is made up of various different compounds rather like methane, but it is liquid rather than gas. These hydrocarbon fuels can be produced from plastic wastes by pyrolysis process because of can be cost effective compared to other processes. Pyrolysis is the thermal decomposition of plastic wastes in to hydrocarbon fuel in the presence or absence of catalyst. The pyrolysis thermally degrades the plastic component to produce an oil and gas product. This oil may be used as a liquid fuel or returned for refining (Sannita *et al*., 2012; Torres *et al*., 2000). The pyrolysis has a wide temperature range and it can be performed with or without a catalyst. The aim of the present research is to investigate the waste plastic pyrolysis in the presence and absence of the catalysts such as activated granulated charcoal or calcium oxide to produce very low-emissive liquid hydrocarbon oil. The amount of waste plastic residue has to be reduced, with an increase in the efficiency of the fuel oils, thus providing an alternate energy resource to the environment. This would bring about a major reduction in the pollution caused due to landfills of plastic wastes and air pollution through the incineration of plastics.

Corresponding author: **Daida Sharath,**
Department of Chemical Engineering Wolkite University, Ethiopia.

MATERIALS AND METHODS

Materials

The waste plastics were collected from the various places across the neighborhood. Namely, high-density polyethylene

(HDPE) was collected in the form of garbage containers, (PS) in the form of disposable cutlery, and polypropylene (PP) as used waste plastic containers. The melt flow index (MFI) and the temperature of individual and mixed raw materials are listed in the experimental table below. The waste plastic materials were crashed and thoroughly washed with tap water. This helps to increase the surface area of material in contact with catalyst during pyrolysis.

Figure 1. Plastic wastes

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 granulated charcoal and calcium oxide. Granulated charcoal was produced from wood that is obtained from chemistry department and the laboratory chemical calcium oxide also obtained from chemistry department. Those catalysts are used to speed up the reaction by decreasing reaction temperature.

Figure 2. Charcoal catalysts

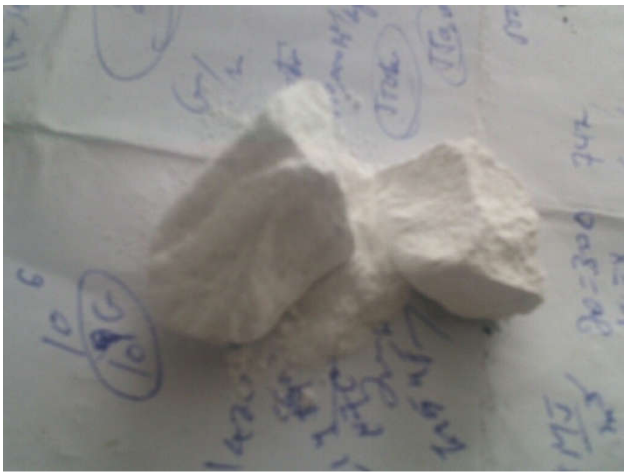

Figure 3. Calcium oxide catalysts

Equipment selection

The main equipment for plastic pyrolysis are single shaft plastic shredder, mechanical sieve, plastic extruder and heater, flask, liquid oil storage tank and material handling Equipments like bucket elevator belt conveyor screw conveyor.

Methodology

Pre- processing of plastic waste

- Size reduction is the process of reducing the size of plastic using shredder equipment up to 2mm.
- Separation is the process of separating unwanted materials like metals.
- Washing is the process of cleaning separated plastic to omit contamination and increase quality of product.
- Drying is the process of removing moisture content from plastics to decrease reaction temperature.

Experimental setup

The Wide ranges of flask have been used on a laboratory scale for the plastic pyrolysis process. The two types of feed patterns were used, namely individual types of plastics and mixed types of plastics. The composition of the individual and mixed plastic wastes is given in Tables 1, 3, 5, and 7. The pre-processed waste plastic materials were transferred into an empty round bottom borosil glass flask of capacity 1000 mL The empty weight of round bottom flask was found to be 343.12 g. After the raw materials were loaded into the round bottomed flask, the opening was connected to a condenser and the condenser was connected to a receiving adapter. The round bottom flask is fixed with heating mantle. The oil is collected at the bottom end. During the whole process, the temperature was maintained around 100 to 267 °C and a vacuum pressure of about 300 mm Hg maintained. A vacuum pump was used to create vacuum inside the round bottom flask. The temperature was raised according to the gradient. The experimental setup is shown in Fig 4. The condensed oil was collected in the oil collector. The melting points of the various feed types with and without the catalysts are summarized in the Table 1, 3, 5, and 7. The collected oil was refluxed and further distilled. After distillation process, three types of fractions were obtained from the present research. The whole process of pyrolysis took place under 50 min to complete.

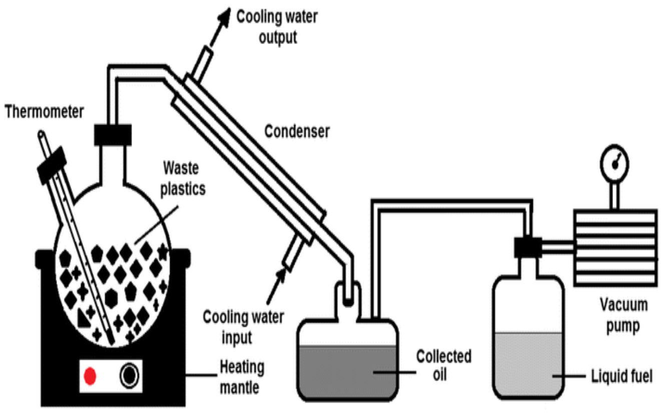

Figure 4. Experimental setup

Pyrolysis process

The pyrolysis process is an advanced conversion technology that has the ability to produce a clean, high-calorific value fuel

Table 1. Experimental setup for individual plastics without catalysts and melting point

Materials	Weight(gm)	Catalyst	Melting Point(^{0}C)	Time(mins)	Pressure(mmHg)
Polystyrene (PS)	10	Null	127	20	-320
Polyethylene (PE)	12	Null	120	15	-250
Polypropylene (PP)	22	Null	132	30	-300

Table 2. Experimental setup for individual plastics with catalysts and their melting point

Materials	Weight (gm)	catalyst (gm)	Melting point (^{o}C)	Time (min)	Pressure (mmHg)
Polystyrene (PS)	10	Charcoal + Calcium oxide=4	110	15	-270
Polyethylene (PE)	12	Charcoal=5	100	10	-200
Polypropylene (PP)	22	Calcium oxide=10	115	20	-255

Table 3. Experimental setup for mixed plastics without catalyst and their melting point

Materials	Weight (gm)	catalyst	Melting point(^{0}C)	Time (min)	Pressure (mmHg)
PS,PE, and PP	50	Null	206	30	-280

Table 4. Experimental setup for mixed plastics with catalysts and their melting point

Materials	Weight (gm)	Catalyst (gm)	Melting point (^{0}C)	Time (min)	Pressure (mmHg)
PS, PE, and PP	50	Charcoal +calcium oxide=15	150	24	-315
PS,PE, and PP	50	Charcoal=10	100	15	-320

from a wide variety of biomass and waste streams. It is the thermo-chemical decomposition of organic material at elevated temperatures in the absence of oxygen. The pyrolysis provides various operational, environmental and economic advantages. Hydrocarbon molecules from the basic materials are split under the impact of the catalytic (carbon material) convertor inside the flask at 100–267 °C. The higher yield of liquid fuel assumed to be 95.25 %.

Distillation

The distillation is a method of separating mixtures based on differences in their volatilities. The collected oil from pyrolysis process was found to contain various percentages of gases and various densities of oil. The presence of the catalyst has enhanced the medium to reflux and then distilled to obtain three fractions viz. gas, light oil, and heavy oil.

Analysis of products

The liquid products were analyzed by gas chromatograph (TRACE GC) with a flame ionization detector. It was provided with a 50 m × 0.32 mm Rtx (Cross bond 100 % Dimethyl-polysiloxane) column. To further narrow down the qualitative analysis, a GC-FID total petroleum hydrocarbons (TPH) was also used. Each fraction was also subjected to a separate analysis viz. flash point, fire point and density. The results observed for the prepared oil were compared with the GC-FID report of commercial petrol. The effect of temperature depends on the increase in the time taken for the pyrolysis process (see Fig. 5).

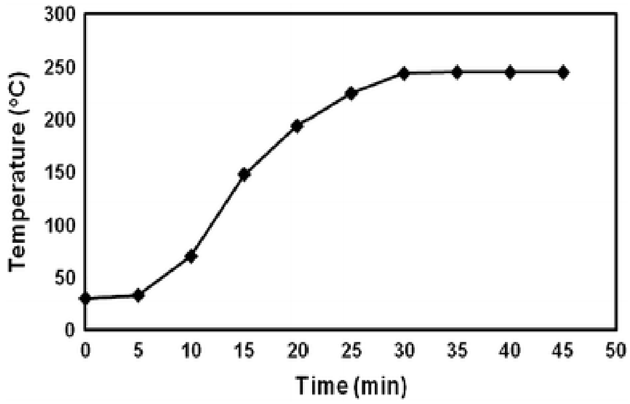

Figure 5. Effect of contact time

RESULTS AND DISCUSSION

Physical properties of oil

Specific gravity and density

A 10 mL specific gravity bottle was used to determine the specific gravity of the samples. 10 mL of the sample was pipette out into a pre-weighed bottle up to its brim. This gives the weight of the sample which when divided by 10 gives the specific gravity and hence the density of the sample can be found out. It can be found to be having a specific gravity of 0.811 and a density of 811.7 kg/m3.

Flash point

The flash point of a volatile material is the lowest temperature at which it can vaporize to form an ignitable mixture in air.

The flash point is used to determine the

- Volatility of liquid fuels,
- Amount of low boiling fraction present in the liquid fuel, and
- Explosion hazards.

The flash point of the sample can be determined using Pensky Martens closed cup flash point test. About 30 mL of the sample was heated and stirred for every 1 °C rise in temperature. An ignition source is directed into the cup at regular intervals with intermittent stirring until a flash that spreads throughout the inside of the cup is seen. The corresponding temperature is known as the flash point and was found to be 65 °C.

Flame characteristics

The flame characteristics of the light fraction oil were studied and this was compared with kerosene and petrol. It was observed that there were no carbon settlements on the tiles. This suggests that the oil from pyrolysis process has similar characteristics of petrol. Henceforth, the chemical properties of the light fraction oil were checked by the GC-FID TPH analysis.

Regeneration of spent catalyst

The spent catalyst was first dissolved in some amount of water and heated to around 80 °C. The residue material was separated using Whatman no. 40 filter paper.

Materials	Catalyst	Yield to liquid Product (%)	Residue (%)	Temperature maintained (°C) applied (mm Hg	Vacuum pressure	Reaction time (min)
Polystyrene	Null	53	47	140	-450	35
Polyethylene	Null	80	20	130	-300	
polypropylene	Null	67	33	145	-410	40
Polystyrene	Charcoal + calcium oxide	65	35	125	-315	15
Polyethylene	Calcium oxide	85	15	115	-250	25
Polypropylene	Charcoal	75	25	130	-255	20
PS, PE, and PP	Null	74	26	267	-390	50
PS, PE, and PP	Charcoal + calcium oxide	83	17	267	-333	40
PS, PE, and PP	charcoal	95.25	4.75	267	-333	39

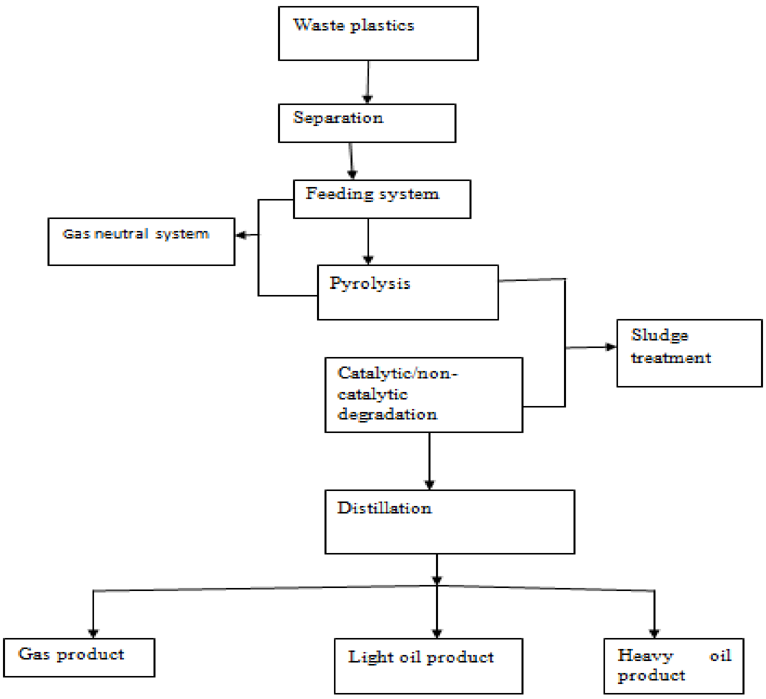

Figure 6. Process flow diagrams

Fire point

It is the temperature at which the fuel will continue to burn for about 5 s after ignition by an open flame source. It is the temperature at which the vapor is produced to sustain a flame. The fire point was determined using the Pensky Martens open cup apparatus. About 30 mL of sample was heated and stirred continuously for every 1 °C rise in temperature. An ignition source was introduced into the cup at regular intervals until a flame sustains for at least 5 s. The fire point of the light fraction oil sample was about 110 °C.

The catalyst was then dried to about 80 °C using a heating oven. The regenerated catalyst was used for another batch operation.

Process Flow diagrams

In order to obtain an oil product in the pyrolysis of waste plastics, the major steps for waste plastics that are derived from the household, industry, etc. are basically shown in Figure 7.

Figure 7. Melting point determination of plastic waste with and without catalyst

We have tried to convert plastic waste in to hydrocarbon fuel and separate residue by pyrolysis process along with various parameters such as, temperature, pressure and time for individual and mixed plastic waste with and without catalytic cracking method. However, we haven't received our liquid product due to the limitation of equipment required in our laboratory. But ,we have observed the effect of catalyst on reaction temperature and time by melting individual and mixed plastic waste with and without catalyst in our laboratory reactor like equipment and we have assumed to obtain the maximum yield around 95.25% with catalytic cracking and results are discussed in the table 11. Pyrolysis is economically and environmentally valuable technology they produce oil or fuel from plastic waste with and without catalytic decomposition in the absence of oxygen. Because of pyrolysis process doesn't consume oxygen, decrease to among of non-biodegradable plastic waste, use cheap raw material, produce low noise and decrease the erratic change of the energy price. By the nature plastic waste contain the component of petroleum pyrolysis produce oil or fuel without any additional chemicals. The production of oil can be done by simple catalytic and non catalytic depolmization of individual and mixed plastic waste and required by laboratory scale distillation followed by condensation.

Pensky marsens closed cup is device used to determine fire and flash point oil. GC-FID analysis indicates that the prepared oil includes hydrocarbons ranging from C_4 to C_{12}, a range that includes commercial gasoline. GC-FID analysis further indicates that the pyrolysed oil has higher percentage of petrol. The residue obtained from the distillation process can be used as lubricants for various types of equipment.

Recommendation

Pyrolysis of plastic waste consumes maximum temperature without catalyst up to 500°C and with catalyst up to 300°C. So, using flask/reactor which has no ability to resist this temperature is impossible. Without converting plastics into gas form storage of melted plastic in liquid form is impossible. Opening of flask at the time of pyrolysis is not possible because of bad odor of plastics can affect human health and environment. Careful selection of reactor/ flask and catalyst is required to have better yield of quantity and quality, extended time.

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