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Degradation of Plastic Waste to Liquid Fuels

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Abstract**-- The aim of this research is to extract liquid fuels from waste plastic by sequential pyrolysis reforming processes. The kinds of plastic wastes were collected mainly Low Density Polyethylene (LDPE) and High Density Polyethylene (HDPE).. The waste polyethylene samples were subjected to thermos-catalytic degradation using kaolin as catalyst in a batch locally fabricated reactor at a temperature range of 350 to 500^{0}C and atmospheric pressure. The catalyst increased the yield of the product and decreased the reaction time. The pyrolysis products was tested in a diesel engine with diesel blends and found satisfactorily. The properties of the fuel obtained from Waste plastic fuel obtained by pyrolysis method are comparable with the properties of petroleum fuel. Thus it can be suggested that the waste plastic fuel can be used in engine as alternative fuel.**

Index Terms**—Diesel, Kaoline, Pyrolysis, Waste plastc**

I. Introduction

ENVIRONMENTAL pollution due to plastic wastes is a global phenomenon today. Recycling waste plastic into reusable plastic products is a conventional strategy followed to address this issue for years. However this technique has not given impressive results as cleaning and segregation of waste plastic was found difficult by indispensable in this technique. It is estimated that approximately 10 thousand tons to plastic waste per day is generated in our country. Plastic wastes include different type's viz. Low Density Poly Ethylene (LDPE), How Density Poly Ethylene (HDPE), Polypropylene (PP), Polystyrene (PS), Poly Vinyl Chloride (PVC) etc. As the plastic waste segregation is difficult it was essential to have novel technologies for plastic waste disposal. Pyrolysis is one of the technique used for waste disposal and also to produce products like industrial diesel, gaseous fuel, carbon block etc. The distillate fuel can be used for diesel electric generators. Diesel burners/stoves, boilers, hot air generators, diesel pumps etc. The distillation can be further fractionated into fuels as gasoline, diesel and kerosene.

Literature survey portrays many studies on degradation of plastic fuels from plastic waste. Many researchers have taken keen efforts with plastic waste to produce petro fuel. Panda et.al. (2014) conducted experiment on low-density polyethylene samples subjected to thermos-catalytic degradation using kaoline as catalyst in a batch reactor at temperature range of 400 to 500^{0}c and atmospheric pressure. They concluded that the fuel properties of the oil obtained by different standard methods are similar to petrochemical fuels [1]. Sriningsih et.al. (2013) conducted experiment and produced fuel from LPDE plastic waste over natural zeolite supported Ni, Ni-MO, Co-Mo metals. By using this, they concluded that the conversion of plastic waste into fuel is expected to reduce the environmental pollution, support the use of soil, and increase the energy storage [2]. Syamsiroet. al. (2013) produced fuel from municipal plastic waste in sequential pyrolysis and catalytic reforming reactors. They observed that the catalyst presences reduced the liquid fraction and increased the gaseous fraction. They also concluded that plastic wastes produced higher heating value solid products than those of biomass and low rank coal [3]. Sharma et.al. (2014) summarized, liquid hydrocarbons with appropriate boiling range produced from pyrolysis of waste plastic appear suitable as blend components for conventional petroleum diesel fuel [4]. Hazartet. al. (2014) utilized polymer wastes as transport fuel resources [5]. Premkumaret. al. (2014) converted hospital low density polyethylene waste into hydrocarbons using fly ash as catalyst. They observed that the flame temperature of the flame produced by the burning gas was highest when cat/pol ratio was 0.2 [6]. Sudhirkumar .J (2013) run the S.I engine with plastic petrol derived from waste plastic. The tests were conducted at constant speed. He concluded that the difference in the measured performance from the base line operation of the engine, i.e, when working with gasoline fuel and the plastic petrol used as a substitute to gasoline in the existing SI engines without any modifications [7].

The aim of the experimental was to study fuel oil production from plastic wastes by sequential pyrolysis reforming processes by using kaolin clay. The major composition of kaolin clay is SiO2 43.12%, Al2O3 46.07% and LOI at 1,000^{0}C 9.9%. Other compositions are MgO, CaO, ZnO, K_2O, TiO_2.

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II. Material and methods

By going through the above literature we want to go by the pyrolysis method by using kaolin as a catalyst to produce fuel from plastic. Pyrolysis is a thermo chemical decomposition of organic material at elevated temperature without the participation of oxygen. It involves the simultaneous change of chemical composition and physical state [8][9]. The process involve of heating plastic waste without the participation of oxygen environment. The plastic will melt, but will not burn. After it has melted, it will start to boil and evaporate. The vapours are then passed through a cooling pipe and when cooled the vapour will condense to a liquid and some of the vapours with shorter hydrocarbon lengths will remain as a gas.

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The exit of the cooling pipe is then going through a bubbler containing water to capture the last liquid forms of fuel and leave only gas that is then burned. If the cooling of the cooling tube is sufficient, there will be no fuel in the bubbler, but if not, the water will capture all the remaining fuel that will float above the water and can be poured off the water. On the bottom of the cooling tube a reservoir that collects all the liquid fuel. The block diagram of the process of oil from waste plastic is shown in Fig. 1.

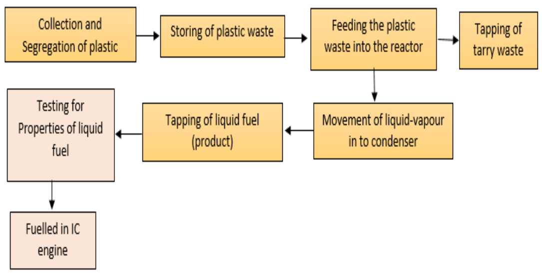

Fig. 1. Block diagram showing the process of oil from waste plastic

The main equipment used for this process are reactor, condenser and the receiver. All the equipment are designed and fabricated.

***Reactor*:** This is an insulated stainless steel cylindrical where the chemical reaction takes place. The reactor is heated by heating coils to achieve a maximum temperature of 500^{0}C. Provision is made for various mounting and accessories viz., thermometer, pressure gauge, thermocouple etc. The reactor is designed and fabricated locally. The detail of the reactor is given in Table I.

TABLE I
Details of the Reactor

Item	Size
Inner diameter	17.8 cm
Outer diameter	22 cm
Length	48 cm
Thickness of the top cover	3mm
Volume	10.8 ltr
Material	MS

Condenser: The gaseous output from the reactor is passed through a double walled condenser with inlets and outlets for cooling water. The gaseous hydrocarbons at a temperature of around 350^{0}C are condensed to around 30-35^{0}C.

Receiver: The condensed hydrocarbon in the liquid form is collected in the receiver. The provisions made for collecting the uncondensed gases in to the gas collector.

The experimental set up is shown in Fig. 1.

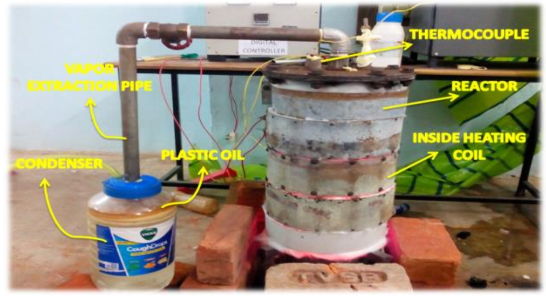

Fig.2. Experimental set up of the pyrolyisis method

A. Experimental Details

The waste plastics for the process consisted mainly of HDPE, LDPE, PP and PET products in the form of used plastic disposable waste and packaging bags used for the packaging of electronics devices from surrounding. The material that was collected was subjected to cutting by using scissors manually into small pieces to increase the surface area of contact during melting process.

The material was then directly taken for the melting process. For this purpose a cylindrical stainless steel vessel of 25.2 cm diameter and 27 cm height was used. The weight of the vessel was 1.4 kg. The vessel was put on an electric domestic heater and a temp of around 150^{0}C was maintained for melting. Total time taken for single batch of reaction was around 15 minutes. Continuous stirring was done during the process to avoid sticking of the plastic materials to the bottom of the vessel and for better distribution of heat. The gases coming out of the process are directed into the water bath. Here the gases are completely absorbed. During the stirring of the process, the lid of the vessel was opened intermittently. Some of the gasses escaped to the atmosphere. The molten plastic in liquid form was cooled to room temperature to obtain the solid form. Then the material was broken in to small sizes and then ground to powder. The powered samples were subjected to pyrolysis process.

The set up mainly consists of a reactor made of stainless tube sealed at one end and an outlet at the other end. A hand hole is provided to remove the residue after the experiment also to inlet for the raw material. The process used was batch type production. 25 gms. of thermocool powder was loaded for each batch. Catalyst and themocool powder were mixed in a proportion of 1:2 and were taken into a cylindrical reactor of 5.6 cm diameter and 11 cm height. The reactor was perfectly sealed with M-seal to prevent the leakage of vapours from the reactor. The reactor was heated by electric heater. The rate of increase of temperature is 25^{0}C per minute. The vapours coming from the reactor is passes through a glass condenser where condensation of vapours takes place. Proper arrangement was made for the condensation by putting wet jute over the pipelines to support further condensation. The condensed liquids were collected. Vapours results as a result of pyrolysis were condensed over water as plastic crude oil due to density difference. The upper oil was separated and weighed. The reactor hand hole was opened once the temperature falls to 25^{0}C and the remaining residual solid material and weight separately. Fig.3. Sample of crude Plastic fuel obtained and solid black residue.

The non-condensable gases were very less and probably negligible in quantity because most of them were removed during melting process. The reaction time was calculated, when the feed is taken in the reactor and temperature raised from the room temperature till the time when no more oil comes through outlet tube. The physics properties like specific gravity, pour point, flash point etc. are obtained and compared with petroleum fuel.

Fig. 3. Sample of crude Plastic fuel collected and solid black residue

III. Results and Discussions

During the production process, light gases were produced about 10%. The solid residue is black colour were about 15%. The liquid plastic fuel is 75%. Production yield percentage is shown in Table II.

TABLE II
Production yield percentage from pyrolysis setup.

Yield	Percentage
Plastic crude oil	75
Light gases	10
Solid residue	15

From GC-MS analysis the different components obtained in the oil are summarised in Table III.

TABLE III
Components obtained in the oil

Retention time in minute	Name of the component
3.89	3-Decene
3.97	3-Dodecene
5.32	7-methyl -4-undecene
5.36	5-methyl1-4-decene
6.81	2,5-Dimethyl-2-undecene
6.92	CIS-2-Dodecene
7.00	2-Methyl-3-undecene
9.08	TRANS-2.2-Dimethyl1-3-decene
9.13	1-Pentyl-2-propylcyclopentane
9.26	3-Tetradecene
11.87	2-Methyldecan-1-ol
20.69	n-Heneisosane
21.49	n-Heneicosane
21.92	Hexadecene
22.26	n-Hexatriacontane

The fuel properties of the oil were tested and compared with gasoline and diesel is summarized in Table IV.

TABLE IV
Fuel properties of crude plastic oil compared with gasoline and diesel

Properties	Plastic oil	Gasoline	Diesel
Density @ 15^{0}C, Kg/m^{3}	760	720	820 to 860
Kinematic Viscosity at 40^{0}C, mm^{2}/s	1.86	1.076	2.0 to 4.5
Flash point, ^{0}C	-25	38	60 to 80
Fire point, ^{0}C	-20	-	-
Cloud point, ^{0}C	4	-	-15to5
Pour point, ^{0}C	-4	-	-35 to -15
Calorific Value, Mj/kg	43	46.9	43.7
Cetene index	75	40	46

IV. Conclusion

The study shows that fuel oil production from plastic wastes by sequential pyrolysis reforming processes by using kaolin clay. The waste plastic can be completely converted into hydrocarbons using Kaolin as a catalyst. It is observed that in pyrolysis method by using kaolin as catalyst the crude oil obtained is about 75%. The fuel properties of the oil obtained from catalytic decomposition are comparable with the properties of petro fuels. Hence, further investigation can be carried out as an alternative fuel for the engines used for transportation.

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