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Conversion of selected waste Plastic in to Synthetic Fuel (Synthetic Diesel)

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Abstract

Due to spacious applications of plastic e.g. its durability and strength, flexibility and lighter weight, consumption and production of plastic has been arise quickly. There are fortified gains to educe fuel oil form waste plastic. Researchers have formulated many feasible and simple processes to form the truncated chain-hydrocarbons liquid fuel from the plastic waste polymers. But plastics are non biodegradable in nature hence its disposal has become a major problem because it cannot be dispose off directly into the environment. To De-polymerize plastic waste into useful liquid and gaseous fuel product several technologies have been invented. One of the known process is pyrolysis in which Batch reactors are used and temperature ranges between 370 to 550 ^{0}C under atmospheric pressure. The aim of the work is to convert the mixed (selected) plastic waste into crude oil which can be use as hydrocarbons fuel. In the present paper waste plastic pyrolysis oil and its blend with diesel has been introduced as an alternative fuel. Waste plastic oil (W.P.O.) was tested as a fuel in a D.I. diesel engine and it is observed that the engine could operate with 100% waste plastic oil and can be used as fuel in diesel engines [3].

Keywords: Pyrolysis, Alternative fuel, mixed waste plastics, oil/waxes, Waste plastic oil and Diesel engine.

Introduction

Plastic waste is regarded as a potentially cheap source of chemicals and energy. Lots of us have encountered a variety of products that use plastic materials today [6]. Plastics are synthetic organic material and mainly produced by polymerization. Molecular mass of plastic is high and it is possible that to improve the quality and performance and to reduce the cost plastic may contain other substances. Polymers of Plastic are much softened and can be extruded into required shapes. Plastics are synthetic polymers that can be shaped by heat or pressure. There are two main types of plastics, which are Thermoplastic and Thermoses [3].

Many researches involving thermal degradation of waste plastics into liquid fuel have been conducted. Thermal degradations are not only used for polymer but it is also used for aromatics and gas. Furthermore, some researchers have been also conducted using catalytic degradation and pyrolysis resulting in successful outcomes [7]. Approximately 85 to 90% of plastic from our daily life can be recycled or use for the production of synthetic fuel. In order to decrease the volume of non degradable plastic waste material and preserving valuable petroleum resources Pyrolysis is one of the best methods. It is also help full in environmental protection. Because of higher conversion rate of fuel from plastic waste pyrolysis process is in favored.

Pyrolysis System involved, Thermal processing in complete absence of oxygen (at low temperature). It is the process of thermal decomposition of organic matter at high temperature (about 350 to 500^{0}C) in an inert atmosphere or vacuum, producing a mixture of combustible Carbon monoxide, Methane, Hydrogen, Ethane gases, pyroligenous liquid, chemical and Charcoal. Thermal treatment involves conversion of waste in to gaseous, liquid and solid conversion products with concurrent or subsequence release of heat energy. To improve the quality of crude oil from waste plastic pyrolysis so many studies have been carried out by researchers. Objective of this study is to introduce a suitable catalyst into the process to yield the efficiency of product. The experimental setup on laboratory scale for the pyrolysis is mostly flow reactor; which consist of ‘liquid phase contact’ and ‘vapor phase contact’.

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Materials and methods

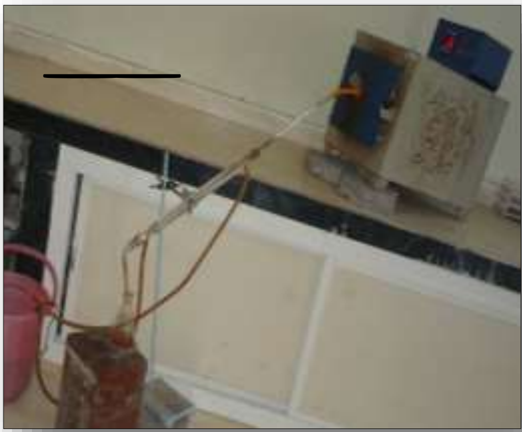
Polymer Materials

Waste plastic material used in present work were Polyethylene (P.E.), Polypropylene (P.P.) and High Density Polyethylene (H.D.P.E.) in the form of plastic disposable glasses, poly shopping bags, packaging poly bags etc. and are obtained from college canteen, during various functions, local market and from waste plastic recyclers.

Plastic cups used as coffee cups or for cold drinks are accumulating as wastes on the earth surface at a rapid rate. Most plastic cups are designed for a single use and then disposed or recycled. They have a coating of 8-18 g/m^2 on one side. Cups for cold drinks have 6-15 g/m^2 on the top side and 8 – 18 g/m^2 on the reverse side. Table 1 above is showing the characteristics of used polymers. Polymers were virgin plastics in the form of pellets [1].

Polymer	M_w	M_n	ρ, Kg.m^{-3}
H.D.P.E.	33,800	6950	950
L.D.P.E.	292,000	22,000	919
P.P.	200,000	65,000	903
P.S.	-	135,135	1050

Figure 1 (A and B): Laboratory setup of working model.



Methodology

Pyrolysis or cracking processes break down polymer chains into useful lower molecular weight compounds. This can be achieved by the application of heat at atmospheric pressure in the absence or presence of oxygen, which can be either thermal or catalytically degraded. The material collected was subjected to cutting by using scissors manually. This was done to increase the surface area of the material & helps in keeping good contact between material and bottom surface of vessel during melting process. The material was then directly taken into the melting process. For this purpose a manually design stainless steel vessel was used. The vessel was put on an electrical domestic heater and a temperature of around 150^{0}C was maintained for melting. Total time taken for single batch of reaction was around 25 to 30 minutes.

Molten waste plastic pellets were taken into a round bottom borosilicate flask reactor of volume 0.25 lit (250 ml). This waste plastic material is catalytically degraded to form liquid slurry with the help of a suitable catalyst. Experiment is conducting on various catalyst/feed ratios (1:2, 1:3, 1:5, 1:6, 1:7) at different reaction temperatures. The process occurs in the presence of oxygen at a temperature ranging from 385–420^{0}C. Liquid slurry is converted into gaseous vapor after a specific temperature; then again it condensed into liquid form (with a small capacity laboratory glass condenser) to produced plastic fuel oil. Laboratory scale setup is installed to conduct the experiment with majority of selected plastic types: Polyethylene (P.E.), Polypropylene (P.P.) and High Density Polyethylene (H.D.P.E.). For identifying the optimal condition required for the production of plastic oil, effect of temperature, reaction time and feed catalyst ratio have been studied. Reaction times mentioning here is total time required for complete the experiment at a standard temperature. On laboratory scale it is difficult to collect and analyze the exhaust gases. According to literature the non-condensable gases effluence during process are exists in the range of L.P.G. and the rate of heat supplied was 8 to 10^{0}C/min.

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Results and discussion

The degradation was started at 365^0 C for every process but at this reaction temperature, the reaction time required for complete process was more i.e. about 48 to 50 min. For the catalytic degradation at high reaction temperatures the reaction time taken was less but the liquid product yield was also decreased along with the increased gaseous product yield. From the literature it has been seen that the liquid products produced at high temperatures were unstable in liquid form, they turned into solid form. But the liquid produced between 380 to 410^{0}C was very stable in liquid form.

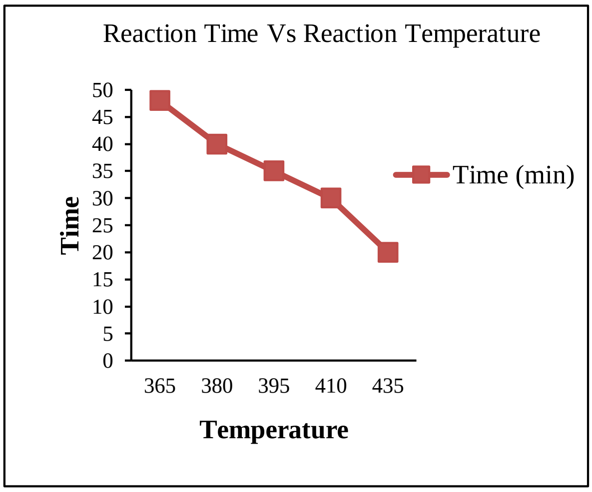

Figure 2: Reaction time Vs Reaction temperature in catalytic degradation

Figure 2 is showing the reaction time required for completion of catalytic degradation (pyrolysis) at various reaction temperatures. At 365^{0}C it takes 48 mins, at 380^{0}C 40 mins, at 395^{0}C 35 mins, at 410^{0}C 30 mins and at 435^{0}C reaction completed in 20 mins.

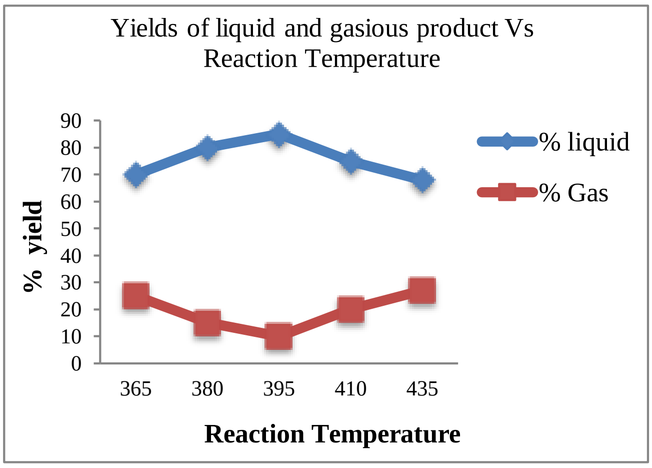

Figure 3: Yields of liquid and gaseous products Vs Reaction Temperature

Figure 3 is showing the products distribution of liquid and gases produced from the catalytic degradation (pyrolysis) of P.P. and P.E. in percentage at various reaction temperatures during experimental setup. Maximum yield of liquid product occurred at 395^{0}C for feed catalyst ratio of 1:3 with the specific gravity of 0.731, which exists in the range of gasoline products.

Feed (gm)	Cat. (gm)	Feed/ cat. Ratio	Reac. Temp (^{0}C)	Reac. Time (min)	Synthetic fuel (ml)	% Yield
50	10	5	395	48	37.5	75
48	16	3	395	30	40.5	85
50	25	2	395	24	40.0	80
50	8.4	6	395	60	35.0	70
50	7.2	7	395	62	33.5	68

Table1: Product Distribution at various feed catalyst ratio

The feed/catalyst ratio, reaction time required for conversion, reaction temperature needed and the Percentage yield of synthetic diesel are given in the table1. Figure clearly showed that the trial with 1:3 feed/catalyst ratio was optimum with 85% liquid product yield having reaction time of 30 min & the reaction temperature of 395^{0}C when compared with the other ratios.

Synthetic fuel sample was tested in Atomic absorption spectrometer for checking the availability of metallic compound in the fuel product. Results of samples are showing in the table.

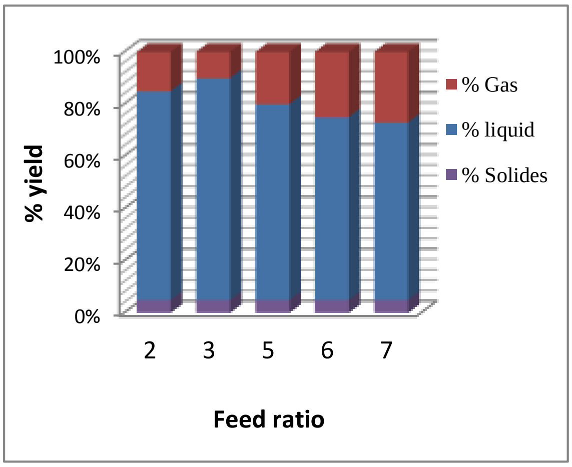

Figure 4: Product Distribution at various feed catalyst ratio

Metals	Amount in mg/kg
Zinc (Zn)	Nil
Lead (Pb)	Nil
Cadmium (Cd)	0.4
Chromium (Cr)	Nil
Nickel (Ni)	Nil
Iron (Fe)	6.8
Copper (Cu)	0.4

Table 2: Metals Concentration in synthetic fuel.

Formulae:

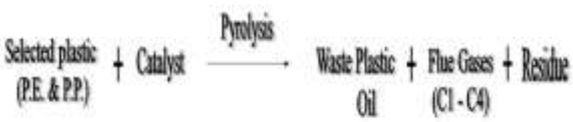

Table 5: Comparison between regular gasoline, waste plastic oil & synthetic diesel extracted during laboratory study

Characteristics	Regular Gasoline	W.P.O.	Synthetic fuel
Color, Visual	Orange	Yellow	Pale Yellow
Specific Gravity at 28^0C	0.742	0.725	0.731
Gross Calorific Value (cal/gm)	11210	11262	11253
Net Calorific Value (cal/gm)	10460	10498	10487
API Gravity	56.46	60.65	44.06
Flash Point (Abel) ^{0}C	23.0	22.0	22.0
Fire point ^{0}C	27.0	25.0	26.0
Pour Point ^{0}C	< -20^0C	< -20^0C	< -20^0C
Kinematic Viscosity	2.25	2.0	2.10
Sulphur content (present by mass max)	0.1	<0.002	NIL

Conclusion

The present experiment studied extensively the cracking nature of P.P., P.E. and H.D.P.E. under catalytic methods (pyrolysis) with the application of a suitable catalyst.

The reaction temperature for cracking of P.P. and P.E. were 365^0C to 400^0C and the percentage yield of 85% was achieved for synthetic fuel with the application of selected catalyst. Time taken for the complete reaction was about 30 to 35 minutes.

Reaction temperature for Cracking of H.D.P.E. was very high around 460^0C when compare with other plastics. Also 70 to 75% yield of liquid products was achieved with the application of catalyst at this reaction temperature. But the time taken for the completion of the reaction was very high about one hour.

The experiments were conducted on semi batch reactor without any application of stirring. Applied temperature for catalytic degradation of selected plastic (P.E. & P.P.) and reaction time were different for every trial.
At the application of maximum reaction temperature for catalytic degradation minimum time taken for the completion of the reaction was observed. It was investigated that if the reaction temperature increases, the time for the completion of reaction decreases. The percentage yield and the composition of the liquid product (synthetic diesel) varied with feed to catalyst ratio and reaction temperature.

The liquid products were analysed for their selected physical & chemical properties. The specific gravities of sample were existed in the range of regular gasoline and waste plastic oil. Pour Point, Flash Point and Fire Point were also tested & found satisfactory as per general requirements of regular gasoline. It was observed that the percentage yield of gases were more in case of thermal degradation when compared with catalytic method (pyrolysis) and it was increased with the rose in reaction temperature. The solid residue remained was about 3 to 5% for P.P. and P.E. and it was looking like pure carbon.

Experiments were conducted on various temperatures and the reaction time to complete the catalytic degradation of P.E. & P.P. It was investigated that reaction periods (20 min. – 50 min.) varied with different reaction temperatures (365^0C – 435^0C) & optimum reaction temperature was 395^0C at optimum reaction period of 35 min. The respective percentage yields were between 68 % - 84 % and maximum was 84 % for optimum reaction temperature 395^0C and optimum reaction period 35 min.

Hence selected catalyst was found suitable for the greater percentage yield of synthetic diesel at optimum reaction period and reaction temperature. Also characteristics of synthetic diesel derived from selected plastic waste (P.P. & P.E.) equated with the properties of waste plastic oil and regular gasoline.

References

[1] Bajus M., and Hajekova E., "Thermal Cracking of the Model Seven Components Mixed Plastics into Oils/Waxes" in Petroleum & Coal 52 (3) 164-172, 2010.
[2] Demirbas A., "Pyrolysis of Municipal Plastic Wastes for Recovery of Gasoline-Range Hydrocarbons" in Journal of Analytical and Applied Pyrolysis, 72, 97-102, 2004.
[3] Nagori K. And Dohare D., "Feasibility Study of Conversion of selected Plastic in to Synthetic Fuel (Synthetic Diesel) – A Review" in Research Journal of Engineering Sciences, Vol. 3(7), 1-7, July 2014.
[4] Kaminsky W., Schlesselmann B., and Simon C.M., "Thermal degradation of mixed plastic waste to aromatics and gas", 70 (3), 189-197, 2000.
[5] Pawar H. R. and Lawankar S. M., "Waste plastic Pyrolysis oil Alternative Fuel for CI Engine – A Review" in Research Journal of Engineering Sciences, 2(2), 26-30, 2013.
[6] Pouya M. et al., "Experimental investigation of performance and emission characteristics of DI diesel engine fuelled with polymer waste dissolved in biodiesel blended diesel fuel" in Energy 46, 596-605, 2012.
[7] Sahu O. and Abatneh Y., "Preliminary Study on the Conversion of Different Waste Plastics into Fuel Oil" in International Journal of Scientific and Technology Research, 2(5), 226-229, 2013.
[8] Sarker M., Rashid M. M., and Molla M., "Conversion of Low Density Polyethylene (LDPE) and Polypropylene (PP) Waste Plastics into Liquid Fuel Using Thermal Cracking

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Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

Process" in British Journal of Environment and Climate Change, 2(1), 1-11, 2012.

[9] Scheirs J. and Kaminsky W., "Feedstock Recycling and Pyrolysis of Waste Plastics: Converting Waste Plastics into Diesel and Other Fuels" in John Wiley and Sons, 785, 2006.

[10] Williams E. A. and Williams P. T., "Analysis of Products Derived from the Fast Pyrolysis of Plastic Waste" in Journal of Analytical and Applied Pyrolysis, 40-41, 347-363, 1997.

[11] Wongkhorsub C. and Chindaprasert N., "A Comparison of the Use of Pyrolysis Oils in Diesel Engine Energy" in Power Engineering, 5, 350-355, 2013.