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A REVIEW ON PYROLYSIS PROCESS TO CONVERT WASTE PLASTICS TO FUEL

Piyar Mahammad Dewan, Saddam Hussain
Gurukul Vidyapeeth Institute of Engineering and Technology, Banur, Punjab
Department of Petrochem & Petroleum Refinery Engineering

A B S T R A C T - Plastic waste is regarded as potentially economy source of chemicals and energy. Lots of us have come across a variety of products that use plastic materials today. As a result of the increasing level of private consumption of these plastic materials huge amounts of wastes are discharged to the environment. Catalytic cracking is a process that converts waste plastics into valuable liquid hydrocarbon products that can be utilized as an energy source for numerous purposes such as diesel engines, generators, vehicles, etc. The gaseous by- product obtained in the process can be used for domestic use by refilling it in the cylinders and also to run gas turbines. Thus cracking process can be considered as another non-conventional energy source. Crude oil is the ultimate source of plastics and most of the chemicals. Out of total 100 million tons plastics produced every year all over the world, 25 million tons is dumped. By throwing away such heavy amount of waste plastics, wasting lots of energy in the form of crude oil that is used to make plastics. The wasted energy can be recovered back using Pyrolysis process. This process save our conventional energy source i.e. crude oil. In this scenario our paper aims to solve the twin problem of environment pollution due to plastic and need for an alternative fuel source.

I. INTRODUCTION

The productions of plastics increasing day by day as the plastics are used in many field. The demand of plastics increases with the increase of world population. It produces the pollutant to the environment. Plastic has become an important part of our daily life. The demand of energy has been increasing day by day. The consumption of liquid fuel is very high and limited resources of fuel production has created bottleneck leading to an energy crisis. So, to minimize the plastic waste and the energy fulfil, an alternative has been developed known as pyrolysis. Plastic waste management is a big issue in the world. According to Central Pollution Control Board (CPCB), India generates 5.6 million tons of plastics every year. Approximately 60% of waste plastic is recycled [1].

The plastics waste constitutes two major category of plastics; (i) Thermoplastics and (ii) Thermoset plastics. According to Central Pollution Control Board (CPCB) thermoplastics constitutes 80% and thermoset constitutes approximately 20% of total post-consumer plastics waste generated in India. The demand of plastic is increasing with the growth of population. The production of plastic has reached about 299 million tons in 2013 and has increased by 4% over 2012 [2]. Plastic recycling method is most useful in order to reduce the plastic disposal to the landfill. Recycling method is difficult and it can be costly [3].

Normally, pigmented or dyed plastics have lower market value. Clearly transparent plastics are often desirable by the manufacturers since they can be dyed to transform into new products, thus have greater flexibility. Pyrolysis is a thermochemical decomposition of organic material at elevated temperatures in the absence of oxygen. It degrades long chain polymer molecules into smaller, less complex molecules through heat and pressure. This process produces mainly oil, gas and charcoal which are valuable for industries and refineries. This project is selected with an objective of using this non degradable waste plastic as a source to extract fuel as well as to reduce plastic disposal to the landfill, recycling method is considered as another alternative to manage plastic waste. This after analysis can be used as an alternative source of energy [4-5]. The produced oil can be used as a fuel such as furnaces, boilers, turbines and diesel engine without any upgradation. Pyrolysis doesn't produce contaminants thus it is considered as green technology [6-7].

There are so many research paper published regarding the pyrolysis process for liquid fuel production. The main parameters include temperature, type of reactors, residence time, pressure, different catalysts usage and type of fluidizing gas with its flow rate. Additionally, some relevant discussion regarding the optimization of liquid oil yield was also presented in this paper.

II. REVIEW OF PYROLYSIS:

Pyrolysis of Plastics

Different types of plastics having different compositions are normally reported in terms of their proximate analysis. Proximate analysis is a technique to measure the chemical properties of the plastic compound based on four particular

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elements which are moisture content, fixed carbon, volatile matter and ash content [8]. Volatile matter and ash content are the major factors that influence the liquid oil yield in pyrolysis process. Based on Table 1, it was observed that the volatile matter for all plastics is very high while the ash content is considered low. These characteristics show that plastics have high potential to produce large amount of liquid oil through pyrolysis process.

Process parameter plays an important role on the product yield. It can optimize the production of final end products such as liquid oil, gaseous and char. Those important parameters are temperature, type of reactors, pressure, residence time, catalysts, type of fluidizing gas and its rate. Desired product can be produced by the controlling of relevant parameter.

Table: 1 Proximate analysis of plastics

Types of plastics	Plastic type marks	Moisture (wt%)	Fixed carbon	Volatile (wt%)	Ash (wt%)	Ref
Polyethylene terephthalate (PET)	1 PET	0.46-0.61	7.77-13.17	91.75-86.83	0.02-0.00	[9] [10
High-density polyethylene (HDPE)	2 HDPE	0.00-0.00	0.01-0.03	99.81-98.57	0.81-1.40	[11 [10
Polyvinyl chloride (PVC)	3 V	0.80-0.74	6.30-5.19	93.70-94.82	0.00-0.00	[12 [10
Low-density polyethylene (LDPE)	4 LDPE	0.30	0.00	99.70-99.60	0.00-0.40	[13 [14
Polypropylene (PP)	5 PP	0.15-0.18	1.22-0.16	95.08-97.85	3.55-1.99	[15 [10
Polystyrene (PS)	6 PS	0.25-0.30	0.12-0.20	99.63-99.50	0.00-0.00	[16 [13
Polyethylene (PE) Acrylonitrile butadiene styrene (ABS) Polyamide (PA) or Nylons Polybutylene terephthalate (PBT)	7 OTHER	0.10 0.00 0.00 0.16	0.04 1.12 0.69 2.88	98.87 97.88 99.78 97.12	0.99 1.01 0.00 0.00	[15 [17 [17 [10

Temperature is one of the most significant operating parameters in pyrolysis since it controls the cracking reaction of the polymer chain. Molecules are attracted together by Van der Waals force and this prevents the molecules from collapsed. When temperature in the system increases, the vibration of molecules inside the system will be greater and molecules tend to evaporate away from the surface of the object. This happens when the energy induced by Van der Waals force along the polymer chains is greater than the enthalpy of the C–C bond in the chain, resulted in the broken of carbon chain [18]. The thermal degradation behavior of the plastics can be measured using thermogravimetryanalyzer. The analyzer produces two types of graphs which are thermogravimetry analysis (TG) curve and derivative thermogravimetry analysis (DTG) curve. The TG curve measures the weight change of substance as function of temperature and time [19]. The maximum weight loss of the substance happened at temperature of 427.7 ◦C. No significant changes were observed at temperature more than 470 ◦C. Therefore, the authors concluded that the thermal degradation of PET happened at temperature range of 350–520 ◦C [21].

The important parameter is types of reactor. The type of reactors has an important impact in the mixing of the plastics and catalysts, residence time, heat transfer and efficiency of the reaction towards achieving the final desired product. Most plastic pyrolysis in the lab scale were performed in batch, semi-batch or continuous-flow reactors such as fluidized bed, fixed-bed reactor and conical spouted bed reactor (CSBR). The advantages and downsides of each reactor would be discussed in the following subsections.

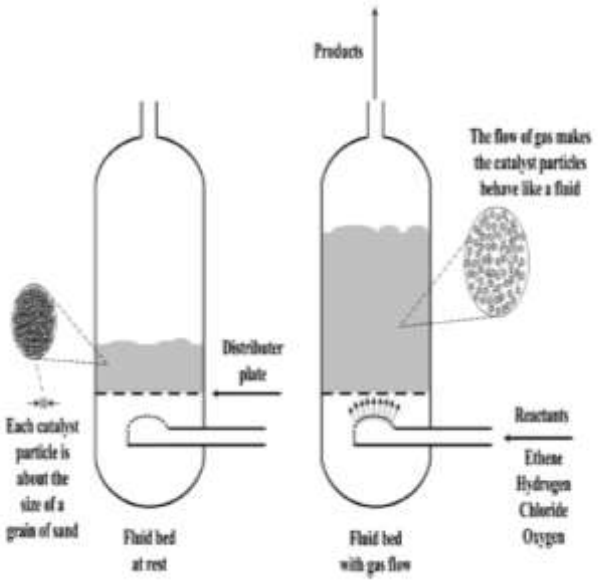


Fig. 1. Diagram of fluidized bed reactor [22].

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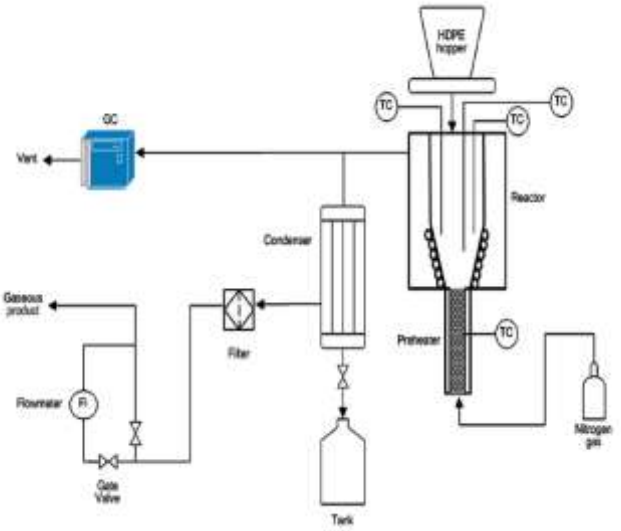


Fig. 2. Diagram of CSBR in HDPE pyrolysis using zeolite catalyst [23].

Catalyst is the parameter which influence the pyrolysis. Catalyst speeds up chemical reaction but remains unchanged towards the end of the process. Catalysts are widely used in industries and researches to optimize product distribution and increase the product selectivity. Hence, catalytic degradation is particularly interesting to obtain product of great commercial interest such as automotive fuel (diesel and gasoline) and C2–C4 olefins, which have a huge demand in petrochemical industry [24]. There are two types of catalyst which are homogeneous and heterogeneous. Homogeneous catalyst used for polyolefin pyrolysis [25-26].Zeolite catalyst are described as crystalline aluminosilicate sieves having open pores and ion exchange capabilities [27-28].

Characteristics of plastic pyrolysis oil:

The experimental calorific value of HDPE, PP and LDPE are all above 40 MJ/kg and were considered high for energy utilization. The calorific value of PS was commonly lower than the polyolefin plastic due to the existence of the aromatic ring in the chemical structure which had lesser combustion energy than the aliphatic hydrocarbon [29-30].

By-products of the plastic pyrolysis:

Char: The char formation was found to be increased with the temperature. The char formation was increased from 2 wt% to 4 wt% in PP pyrolysis and from 0.7 wt% to 2 wt% in PE pyrolysis as the temperature was raised from 668 ◦C to 746 ◦C [15]. Other by-product of pyrolysis is gas. Product images derived from Pyrolysis:



Fig. 3. Plastic Oil



Fig. 4. Product 1 –Below 180 ˚C (extracted - 20%)



Fig.5: Product 2 –Between 210-340 ˚C (extracted - 34%)

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Fig. 6. Product 3 –Residue (Tar 46%) [31]

III. FUTURE PROSPECTIVES:

Plastic waste from landfills; utilizing the embodied energy content of plastics and producing a highly usable commodity that, due to its cleaner burning characteristics. It is in itself more environmentally friendly than conventional distillate. As the confirmation tests of the products obtained are satisfied when compared to diesel and petrol, thus the products obtained through this process can be used as fuel. The characteristic curves will indicate the brake power versus fuel consumption for different ratios of oil and diesel respectively. The present rate of economic growth is unimaginable without saving of fossil fuel energy like crude oil, natural gas or coal. Thermo fuel is a truly sustainable waste solution, producing a highly useful commodity.

The performance curves for fuel consumption Vs Brake power for 40% Oil +60% Petrol as shown below.

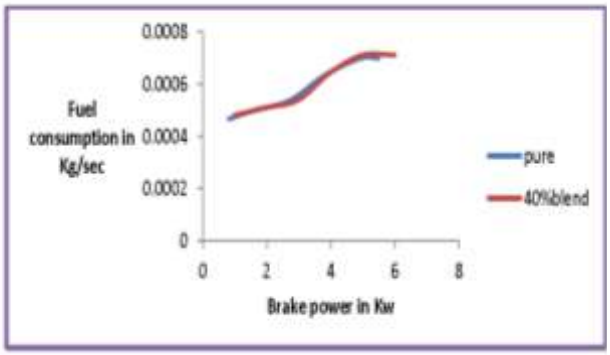


Fig. 7. Fuel Consumption Vs Brake Power

The above stated figures will indicate the thermal efficiency, fuel consumption with brake power. It will indicate the characteristics curves for different ratios of oil and diesel. The characteristics curves will increase with increase of brake power. [31]

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AUTHORS

Piyar Mahammad Dewan

Saddam Hussain

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