



PYROLYSIS OF HIGH DENSITY POLYETHYLENE INTO FUEL OIL IN A BATCH REACTOR

A. Balathiraviam¹, S. Isaiah¹, K. Iyanthirakumar¹, S. Jenio Mervin¹

¹Undergraduate Student, Department of Mechanical Engineering, Francis Xavier Engineering college
 Tirunelveli, Tamilnadu, India.

Abstract: An experimental work was carried out to convert HDPE into oil. A fixed bed batch reactor has been used with a circumferential heating element. The heating coil used has the capacity to heat the feed to up to 500°C. The completely sealed batch reactor was fed with the shredded HDPE and heated in the absence of oxygen. With the temperature rising, the lighter hydrocarbons get pyrolysed with lighter gases of low energy density evolved. With increasing temperature and increasing residence time, thermal decomposition of heavier hydrocarbon gas started to evolve. The output gas from the reactor is fed to a gas burner. The presence and evolution of fuel gases was checked by introducing an ignition source.

I. Introduction

Less than 10% of plastic waste is recycled. Plastic is non-biodegradable material it remains into the soil for many years. The gradual increase in plastic waste has created more impact in social and environmental arguments. The growth in the usage of plastics is a major contributor of environmental degradation today. And plastic product have become an integral part of our daily life as a result of which the polymer is produced at a massive scale world wide. On an average, production of plastic globally crosses 150 Million tonnes per year. Its broad range of application is in packaging films, wrapping materials, shopping and garbage bags, fluid containers, clothing etc.. It is a fact that plastic waste never degrades, and remains on landscape for several years. Mostly, plastic waste is recyclable but recycled products are more harmful to the environment as this contains additives and colors.



II. Literature Review

There are several energy recovery process that have been implemented to recover useful product from plastic such as incineration, chemical recycling etc.,. The drawback in above method incineration (burning) the process is carried out in open flame (combustion) through which some of heat generated is used in boiling processes. However the byproducts of this process are harmful air pollutants such as nitrous oxides, dioxins and other chemicals. Due to the harmful by products produced by this process they are non-ideal due to the environmental concerns. As a way to ease this problem, the pyrolysis of waste plastics for recovery of liquid fuel has been paid more and more attention.

The pyrolysis process represented an ideal method because, it was found that under high temperature the carbon chains can be broken up and various monomers, active molecular groups and some small molecules will be formed[1]. As a result, liquid products with relatively high H/C ratio can be obtained. Plastic pyrolysis has been found to produce an average liquid yield of 50wt% [2]. Thermal cracking, or pyrolysis, involves the degradation of the polymeric materials by heating in the absence of oxygen. The process is usually conducted at temperatures between 500 and 800°C and results in the formation of a carbonized char and a volatile fraction that may be separated into condensable hydrocarbon oil and a non-condensable high calorific value gas [3].

The pyrolysis reaction process includes four stages known as the initiation stage, propagation stage ,hydrogen chain transfer, and termination stage .There are two possible groups of product species resulting from the pyrolysis process: “molecules including alkane ,alkene, and dialkene etc., and free radicals which also contain unpaired electrons either at the end or in the middle of the free radicals [3].The initiation stage is where the molecules break down to form free radicals .

The propagation stage is an intermediate reaction stage in which the free radicals from the initiation stage are further cracked [3]. The proportion of each fraction and its precise composition depend primarily on the nature of the plastic waste and on process conditions [4].



Several factors affect pyrolysis of materials. As earlier indicated, pyrolysis is the use of heat to break down materials without the presence of oxygen. The following factors influence pyrolysis of plastic :chemical composition of feedstock , cracking temperature and heating rate ,type of reactor , residence time ,use of catalyst, pressure.

The yields of gaseous products increase with increasing pyrolysis temperature. The yields of liquid products increases with increasing pyrolysis temperature upto 675K and then slightly decrease from 675 to 850K from the pyrolysis of municipal solid waste [5].The major changes occurs with increasing the temperature. Different types of plastic respond differently to the same temperature in terms of decomposition. The reaction temperature varies for different grade of plastic the maximum degradation of PET occurred at 427.7°C.The thermal degradation of HDPE to have started at 378°C to 404°C and almost completed at 517°C to 539°C using thermogravimetric analysis using different heating rate in which they found that higher heating rate increases the rate of the reaction .The maximum degradation rate of HDPE occurred at 467°C.

Catalytic cracking has some distinct advantages over thermal cracking, such as, lowering the cracking temperature, increasing the reaction rate and increasing the production of iso-alkanes and aromatics which are desirable for diesel fuel. Suitable cracking catalysts have the ability to both substantially reduce the pyrolysis temperature and control the pyrolysis products [7]. In order to optimize plastic pyrolysis reactions and modify the distribution of pyrolysis products, catalysts are widely used in research and industrial pyrolysis processes [8]. The PE pyrolysis products are mainly straight hydrocarbons from C1 up to C80, which contain much more heavier molecular weight components.

Operating pressure has significantly effect on both the pyrolysis process and the products. The boiling points of the pyrolysis products are increased under higher pressure, therefore, under pressurised environment heavy hydrocarbons are further pyrolyzed instead of vaporized at given operation temperature. It was also found that high pressure increases the yield of non-condensable gases and decreases the yield of liquid products.

III. Experimental work

From the survey we have done through literature review we derived certain details of the operating and experimental parameters such as feed stock, mass flow rate, volume flow rate, temperature and pressure etc., that are fixed to conduct experimental pyrolysis for our experimental setup the reactor core of volume 0.047m^3 . The feed stock is assigned to be 3kg for fixed bed reactor the temperature required to decompose High Density Polyethylene is around 500°C in the presence of nitrogen.

Initially the heating coil is mounted around circumferentially; the thermocouple probe is placed between the heat coil and the outer surface of the reactor coil. The temperature controller and the contactor are in circuit connection with heating coil. The upper lid is opened by ring spanner. The crushed High Density Polyethylene which weighs about 3kg is fed into the reactor core. After that the upper lid is closed air tight then the nitrogen gas of mass flow rate and pressure continuously. Then the heating coil is switched on till it reaches 500°C . At this temperature the High Density Polyethylene is thermally decomposed into gaseous hydrocarbon then it is carried out by the purged nitrogen gas to the condenser. In the annular condenser the phase change occurs the gaseous hydrocarbon is converted into liquid hydrocarbon. The liquid hydrocarbon is collected in the collecting tank. The heating coil is kept on until the required temperature is attained. When the temperature controller reads the temperature of about 45°C at that time the lower lid is opened then the slag is removed.



Figure.1 Pyrolysis Batch Reactor

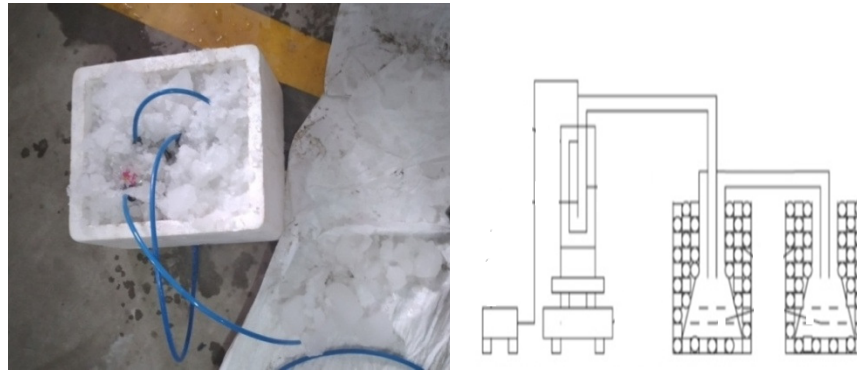


Figure.2 Ice bath condenser arrangement

The feed used in this study was High Density PolyEthylene. However, few runs were made by blending HDPE with LDPE such as plastic paper bags and mat straw. The yield from the blend run was found to be very low and weak. Due to limitation with the heating coil capacity and heating rate, only a small percentage like 10% yield has been obtained. [6] proposed a principle in which another NN yield input control law was created for an under incited quad rotor UAV which uses the regular limitations of the under incited framework to create virtual control contributions to ensure the UAV tracks a craved direction. Utilizing the versatile back venturing method, every one of the six DOF are effectively followed utilizing just four control inputs while within the sight of un demonstrated flow and limited unsettling influences. Elements and speed vectors were thought to be inaccessible, along these lines a NN eyewitness was intended to recoup the limitless states. At that point, a novel NN virtual control structure which permitted the craved translational speeds to be controlled utilizing the pitch and the move of the UAV. At long last, a NN was used in the figuring of the real control inputs for the UAV dynamic framework. Utilizing Lyapunov systems, it was demonstrated that the estimation blunders of each NN, the spectator, Virtual controller, and the position, introduction, and speed following mistakes were all SGUUB while unwinding the partition Principle.



Figure.3 Types of Feed used- HDPE (top) and LDPE (bottom)

IV. Results and discussion

The experiments were conducted in the fixed bed batch reactor. With the limited time, few trials were made with different operating and feed condition and attained only partial outcome. The completely sealed batch reactor was fed with the shredded HDPE and heated in the absence of oxygen. With the temperature rising, the lighter hydrocarbons get pyrolysed with the evolution of lighter gases of low energy density. With increasing temperature and increasing residence time, thermal decomposition of heavier hydrocarbon gas started to evolve. The output gas from the reactor is fed to a gas burner. The presence and evolution of fuel gases was checked by introducing an ignition source.



Figure.4 Fuel gas combusted with an ignition source

In the initial runs, when the reactor was fed with lower amount of feed at around 3 to 4 kg, the evolution of gas was low and the flame obtained was very feeble. In the subsequent runs, the amount of feed was increased and the gas evolution was relatively good and a standing flame was obtained. With a batch feed of 7 kg, standing flame with controllable standoff distance was attained.

V. Conclusion

An experimental work was carried out to convert HDPE into oil. A fixed bed batch reactor has been used with a circumferential heating element. The heating coil used has the capacity to heat the feed to up to 500°C. The completely sealed batch reactor was fed with the shredded HDPE and heated in the absence of oxygen. With the temperature rising, the lighter hydrocarbons get pyrolysed with lighter gases of low energy density evolved. With increasing temperature and increasing residence time, thermal decomposition of heavier hydrocarbon gas started to evolve. The output gas from the reactor is fed to a gas burner. The presence and evolution of fuel gases was checked by introducing an ignition source.

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Reference

- [1]. Yuan xingzhong, “Converting Waste plastics into liquid fuel by pyrolysis”, Department of environmental science and engineering, Hunan University.
- [2]. PSJingli Wu, Tianju Chen, Xitao Luo, Dezhi Han, ZhiqiWang ,Jinhu WuKey “TG/FTIR analysis on co-pyrolysis behavior of PE, PVC and Laboratory of Biofuels,” Qingdao Institute of Bioenergy & Bioprocess Technology, Chinese Academy of Sciences (CAS), Qingdao 266101, China
- [3]. Fengogao, “Pyrolysis of Waste plastics into fuels” ,university of Canterbury (2010).
- [4]. Sachin Kumar and R. K. Singh “Thermolysis of High-Density Polyethylene to Petroleum” Department of Chemical Engineering, National Institute of Technology Rourkela, Orissa 769008, IndiaReceived 7 March 2013
- [5]. AyhanDemirbas “Pyrolysis of municipal plastic wastes for recovery of gasoline-range hydrocarbons” (2004).
- [6]. Christo Ananth, M.A.Fathima, M.Gnana Soundarya, M.L.Jothi Alphonsa Sundari, B.Gayathri, Praghash.K, "Fully Automatic Vehicle for Multipurpose Applications", International Journal Of Advanced Research in Biology, Engineering, Science and Technology (IJARBEST), Volume 1,Special Issue 2 - November 2015, pp.8-12



- [7]. Shah, N., Rockwell, J., & Huffman, G. “Conversion of waste plastic to oil direct liquefaction versus pyrolysis and hydroprocessing.” *Energy and Fuels* 13(4), 832-838. (1999).
- [8]. Aguado, D.P. Serrano, and J.M. Escola, “Catalytic Upgrading of Plastic Wastes, in Feedstock Recycling and Pyrolysis of Waste Plastics”, Spain. (2006)”