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A Review: Energy Recovery from Plastic Wastes Through Pyrolysis

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ABSTRACT
The pyrolysis process is an advanced conversion technology that has the ability to produce a clean, high-calorific value fuel 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 economical advantages. Under pressure and heat, the long chain polymers of hydrogen, oxygen, and carbon decompose into short-chain petroleum hydrocarbons with a ceiling length of around 18 carbons. Hydrocarbon molecules from the basic materials are split under the impact of the catalytic (carbon material) convertor inside the reactor at higher temperatures. Present paper states that different types of plastic waste collected from Municipal Solid Waste can be used as feedstock for Pyrolysis process to extract fuel. These Plastic wastes are such as LDPE, HDPE, PP and PET plastic wastes. The extracted fuel can be used as alternative of Commercial Diesel Fuel.

KEY WORDS: *Plastic Wastes, Pyrolysis, Thermal Reactor, Alternative Fuel*

I. INTRODUCTION

Plastic fraction inside the municipal solid waste (MSW) is difficult to be decomposed, and its quantity is increasing continuously by the time. The increasing demand of plastics materials in all sectors is due to its characteristics of relatively low manufacturing cost, durable, lighter and flexible. In general, waste plastic have the composition of 46% high and low density of polyethylene (HDPE and LDPE), 16% polypropylene (PP), 16% polystyrene (PS), 7% polyvinyl chloride (PVC), 5% polyethylene terephthalate (PET), 5% acrylonitrile-butadiene-styrene (ABS), and 5 percent other polymers [4]. Over the world plastic waste has continuously grown in the last decades. Disposal of waste plastics causes serious environmental problems. Thus, plastic waste recycling has been a focus of many researchers in the past few decades. All the reasoning and arguments for and against plastics finally land up on the fact that plastics are non-biodegradable in nature. The disposal and decomposition of plastics has been an issue which has caused a number of research works to be carried out in this regard. Currently the disposal methods employed are land filling, mechanical recycling, biological recycling, thermal recycling, and chemical recycling. Of these methods, chemical recycling is a research field which is gaining much interest recently, as it turns out to be that the products formed in this method are highly advantageous [2]. Pyrolysis appears to be promising technic of conversion of solid wastes plastic (SWP) to more usable materials such as gas fuel and/or fuel oil or to high value feedstock for the chemical industry [1]. Chemical recycling via pyrolysis process involves thermochemical decomposition of organic and synthetic materials at elevated temperatures in the absence of oxygen to produce fuels. The process is usually conducted at temperatures between 500-800°C. These pyrolytic products can be divided into liquid fraction, gaseous fraction and solid residues [5]. In terms of heating rate, there are two main types of pyrolysis i.e. fast pyrolysis and slow pyrolysis. Slow pyrolysis requires slower heating rate, and lower temperatures than the fast pyrolysis. In general, the slow pyrolysis is designed to the get more of solid products or char even the other product phases is still exist [1]. There are numerous factors that influence quality and quantity of the products obtained; size and quality of the raw materials, type of reactor, operating conditions which include temperature, pressure, heating rate, time, type and amount of catalyst. The increase in temperature results in more gaseous products, more oil and reduction in char yield. The oil produced has various industrial applications [3]. The most frequently used catalysts are zeolites and mesoporous materials because of their porous structure and acid properties [4].

II. LITERATURE REVIEW

Ferdianta Sembiring et al. (2018) [1] used the mixture of plastics i.e. polypropylene (PP) and polyethylene terephthalate (PET) for pyrolysis with catalyst in several operating temperature. According to their study, PET is problematic to be treated using pyrolysis due to wax-like by-product in liquid which may cause pipe clogging. The catalyst is the mixture of natural zeolite and bentonite which is able to handle PP and PET mixture feed to produce high grade liquid fuels in terms of calorific value and other fuel properties.

Christine Cleetus et al. (2013) [2] In their Research Article: Synthesis of Petroleum-Based Fuel from Waste Plastics and Performance analysis in a CI Engine, different oil samples are produced using different catalysts under different reaction conditions from waste plastics. The synthesized oil samples are subjected to a parametric study based on the oil yield, selectivity of the oil, fuel properties, and reaction temperature. Depending on the results from their study, an optimization of the catalyst and reaction conditions was done. Gas chromatography-mass spectrometry of the selected optimized sample was done to find out its chemical composition. Finally, performance analysis of the selected oil sample was carried out on a compression ignition (CI) engine. Polythene bags are selected as the source of waste plastics. The catalysts used for the study include silica, alumina, Y zeolite, barium carbonate, zeolite, and their combinations. The pyrolysis reaction was carried at polymer to catalyst ratio of 10:1. The reaction temperature ranges between 400°C and 550°C. The inert atmosphere for the pyrolysis was provided by using nitrogen as a carrier gas.

K. Vamsi Krishna Reddy et al. (2017) [3] From their research paper "Pyrolysis of Waste Plastic and SEM Analysis of its Burnt Residue", they used experimental setup containing three units namely Reactor unit, condensing unit, and piping unit to convert plastics into fuel through Pyrolysis. From this experiment, it is clear that there won't be any high amount of wastage, as all the plastic will be converted into either semi-solid/ liquid/gaseous fuel. The liquid fuel obtained have comparable properties to that of fossil fuels. The solid residue can be converted into briquette which can be used as an alternative to coal, thus solving the problem of plastic disposal and Fossil Fuel Wastage.

K. Miteva et al. (2016) [4] converted waste polyolefin mixture to liquid fuel using mixture of Al_2O_3 and SiO_2 as a catalyst. According to the obtained results in their work, the retention time and the percent of SiO_2 in the catalyst mixture have predominant effect on the amount of liquid product. Decreasing the quantity of SiO_2 in the catalyst mixture increased the yield of liquid product.

Mochamad Syamsiro et al. (2014) [5] studied fuel oil production from municipal plastic wastes by sequential pyrolysis and catalytic reforming processes. According to their study, the feedstock types strongly affect the product yields and the quality of liquid and solid products. HDPE waste produced the highest liquid fraction. The catalyst presences reduced the liquid fraction and increased the gaseous fraction. Pyrolysis with natural zeolite catalyst produced higher liquid product compared with Y zeolite catalyst.

Gaelle Gourmelon (2014) [7] raised the issue of increase in plastic production but no any increase in plastic recycling. According to him North America, Asia, Europe and former Soviet Union are the four biggest players in plastic production, 22% to 43% of waste plastics are landfilled for disposal, approximately10-20 million tons of plastic ends up in ocean each year. As the economy and population grow, global demand for plastic is expected to continue to grow especially in developing countries. Governments must regulate the plastic supply chain to encourage recycling, and consortia must coordinate and monitor the supply chain and provide guidelines for plastic waste processing, especially in developing countries.

Faisal Abita et al. (2016) [8] reviewed the pyrolysis process for each type of plastics and the main process parameters that influenced the final end product such as oil, gaseous and char. The key parameters that were reviewed in this paper included temperatures, types of reactors, residence time, pressure, catalysts, type of fluidising gas and its flow rate. Several viewpoints to optimize the liquid oil production for each plastic were also discussed in this paper. Various types of reactors are reviewed in detail with their parameters as above mentioned are reviewed for each type of reactor.

Mohanraj C et al. (2017) [9] reviewed various conversion techniques to convert waste plastics into oil. Author says most of the plastic wastes are generated from packing industries that contains polyethylene and polypropylene, practiced frequently by researchers include catalytic processing, thermal degradation, and co-processing.

Dr. M.Eswaramoorthi et al. (2016) [10] reviewed Plastic Waste Management by Pyrolysis process with Indian perspective , they concluded that recovery of plastic waste to fuel oil has a great potential as the fuel oil produced has good calorific value. Among all the processes, the pyrolysis process has been reported to be the most efficient method for converting plastic wastes into fuel oil.

Dr. S.Vinothkumar et al. (2016) [11] discussed about crude oil preparation from the plastic bags. The main of this paper is to convert the waste plastics into the resources. They stated that it will use the pyrolysis process which will process the hydrocarbon fuels. Also the fuel produced from the bio fuel will be considered as the bio fuel in the precious chemical engineering process.

N. Miskolczi et al. (2014) [12] taken most frequently occurring polymers in municipal solid waste such as polyethylene, polypropylene, polyamide, ethylene-propylene copolymer and poly urethane rubber for its thermal degradation into fuel like hydrocarbons. The investigation is done using a horizontal tube reactor. The effects of cracking temperature and residence time on the yields and structure of the products were studied. The gas and liquid products formed were analysed by gas chromatography. The operating parameters affected mostly on the quantity of degradation products, with increasing temperature, the carbon atom distribution of the hydrocarbons obtained became wider and the residence time had a significant effect on the structure of the products.

Sharratt et al. (1997) carried out the catalytic degradation of high-density polyethylene using ZSM-5 zeolite. As the reaction temperature was increased from 290 to 430ºC, the gas yield was increased, whereas the oil yield was decreased and performed the pyrolysis of high density polyethylene over HZSM-5 catalyst using a specially developed laboratory fluidized bed reactor operating isothermally at ambient pressure. The influence of reaction conditions, including temperature, ratios of HDPE to catalyst feed, and flow rates of fluidizing gas, was examined.

Karagoz et al. (2003) studied the conversion of high density polyethylene in vacuum to fuels in the absence and presence of five kinds of metals supported on active carbon catalysts (M-Ac) and acidic catalysts {HZSM-5 and DHC (Distillate Hydro Cracking-8)} catalyst.

Lee et al. (2003), studied the liquid-phase catalytic degradation of waste polyolefinic polymers such as HDPE, LDPE, and PP over spent fluid catalytic cracking (FCC) catalyst was carried out at atmospheric pressure in a stirred semi-batch operation and the difference in the product yields between thermal and catalytic degradation of waste HDPE using spent FCC catalyst in a stirred semi-batch reactor on a laboratory scale.

"Waste Plastic Management" (2004) In this article author has mentioned environmental challenges and issues related to Plastic Waste Management. Rules for manufacturers and usage, various options for plastic waste management are also provided in this article.

III. DISCUSSION

From the study of all above literature, it is understood that Pyrolysis Process is the preferred method for conversion of waste plastics into liquid fuels. The various types of plastics used in the work are High Density Polyethylene, Low Density Polyethylene, Polypropylene, Polyethylene Terephthalate, Polystyrene and Polyvinylchloride. The yield from Pyrolysis process depends upon parameters such as temperature, heating rate, catalyst used etc. whereas pyrolysis process output also depend upon types of waste plastics used. The catalyst used in pyrolysis influences not only the structure of the products, but also their yield.

A wide range of reactors have been used on a laboratory scale for the plastic pyrolysis process. A common variant between the batch and semi-batch operations is the vacuum, which causes the reduction of temperature of the reaction to take place inside the Thermal Reactor. The temperature range for Pyrolysis process in semi-batch reactor is 350°C-450°C. The waste plastic is able to give the liquid products which are with the same values of physical parameters as gasoline or kerosene fuels. the waste plastic is able to give the high yield (77-88%) of liquid product by using semi-batch reactor. The liquid yield was available only at temperatures above 350∘C for all catalysts. With the increase in temperature, the liquid yield decreases after a particular temperature (which was different for different catalyst). Many researchers provided the laboratory test results of waste plastic oil and analytical test reports of waste plastic oil produced from their process. PET is problematic to be treated using pyrolysis due to wax-like by-product in liquid which may cause pipe clogging and Polypropylene gives highest yield compare to other plastic types.

CONCLUSION

Incineration could recover energy from plastic waste by producing high pressure and temperature steam for power generation via steam turbine generator. However, it would need large amount of daily waste as well as a huge capital investment for construction work. This would not be feasible for small city, especially in developing countries where funding is tremendously difficult and public acceptance on incineration is poor. Landfilling is not a suitable option for disposing plastic wastes because of their slow degradation rates. Thus, nowadays, pyrolysis technology gained a lot of attentions since it could convert plastic waste into oil that could be used as crude oil for further upgrading, distillation, or directly utilized with other conventional fossil fuels. This technology is adaptable at a community scale and requires significantly lower amount of budget compared to the incineration.

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