



## EXPERIMENTAL INVESTIGATION ON NON-BIODEGRADABLE WASTES AS BIO-FUEL – PLASTIC PYROLYSIS OIL

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**Abstract-** Waste plastic disposal and excessive use of fossil fuels have caused environment concerns in the world. Both plastics and petroleum derived fuels are hydrocarbons that contain the elements of carbon and hydrogen. The difference between them is that plastic molecules have longer carbon chains than those in LPG, petrol, and diesel fuels. Therefore, it is possible to convert waste plastic into fuels. The main objectives of this project were to analyze and extract the processes of plastic pyrolysis for maximizing the diesel range products. Pyrolysis of polyethylene (PE), has been investigated both theoretically and experimentally in a lab-scale pyrolysis reactor. The key factors have been investigated and identified. The cracking temperature for PE in the pyrolysis is at 450 °C. High reaction temperature and heating rate can significantly promote the production of light hydrocarbons. Long residence time also favors the yield of the light hydrocarbon products. The effects of other factors like type of reactor, catalyst have also been investigated. The properties and characteristics of plastic pyrolysis oil and diesel has been analysed and compared.

**Keywords:** plastic pyrolysis, cracking temperature.

### I. INTRODUCTION

Pyrolysis is a thermal cracking reaction of the large molecular weight polymer carbon chains under an oxygen free environment and produces small molecular weight molecules. Traditional treatments for post-consumed plastics were landfills or incineration. However, landfill of the post-consumed plastics has potential problems because of limited land resource and high durability of plastics. Incomplete incineration may generate poisonous substances and causes serious health problems. Other methods like gasification and bioconversion are mainly used for organic materials. HDPE, LDPE, PP and PS are all hydrocarbons consisting entirely of carbon and hydrogen, which are similar to hydrocarbon fuels such as liquefied petroleum gas (LPG), petrol and diesel. Plastics are derived from petroleum and have calorific values in a similar range as those of LPG, petrol and diesel.

Mochamad Syamsiro, Harwin Saptoadi, Tinton Norsujianto, Putri Noviasri, Shuo Cheng, Zainal Alimuddin, Kunio Yoshikawa [1] & M. S. Mulgaonkar, C. H. Kuo, A. R. Tarrer [2] The aim of this research was to study fuel oil production from municipal plastic wastes by sequential pyrolysis and catalytic reforming processes. Three kinds of municipal plastic wastes were collected from the final disposal site and the small recycling company in Yogyakarta city, Indonesia. Commercial Y-zeolite and natural zeolite catalysts were used in this study. The results show that the feedstock types strongly affect the product yields and the quality of liquid and solid products. HDPE waste produced the highest liquid fraction.

S. Jaichandar and K. Annamalai [3] & Dr. T. Muraleedharan Nair [4] Growing concern regarding energy resources and the environment has increased interest in the study of alternative sources of energy. To meet increasing energy requirements, there has been growing interest in alternative fuels like biodiesel to provide a suitable diesel oil substitute for internal combustion engines. Biodiesels offer a very promising alternative to diesel oil since they are renewable and have similar properties. Biodiesel is defined as a transesterified renewable fuel derived from vegetable oils or animal fats with properties similar or better than diesel fuel. Extensive research and demonstration projects have shown it can be used pure or in blends with conventional diesel fuel in unmodified diesel engines.

Sunbong Lee, Koji Yoshida & Kunio Yoshikawa [5] & C. Wongkhorsub, N. Chindaprasert [6] Waste plastic can be transformed to oil by the pyrolysis and it may be applicable as a fuel for diesel engines. The pyrolysis oil property varies depending on the raw waste plastic and the pyrolysis condition, which is different from that of

diesel and gasoline. Considering the thermal efficiency, the running stability and the reliability, diesel engines are the most promising energy converter to generate electricity by using the pyrolysis oil.

Soo Hyun Chung, Jong Jin Park, Sang Goo Jeon, Dong Chan Kim [7] & Idusuyi, N, Ajide. O.O., Abu, R. [8] Waste plastics can be converted into fuel oil by pyrolysis using suitable catalysts. Waste plastics attributed to the olefin series are more difficult to pyrolyze than any other thermoplastics for production of fuel oil because of their bonding structures and cracking patterns. Fly ash obtained from the coal combustion was used as catalysts for the pyrolysis of waste plastics including PE and PP of olefin series after the pretreatment by NaOH. There exist a variety of potential feedstocks in Nigeria that could be utilized to produce bio diesel. These feedstocks vary significantly in price depending on supply and demand condition as well as market structural conditions. Feedstock costs would normally be between 50 and 75 percent of the cost of producing biodiesel and thus a reliable source of low priced feedstocks is critical to success.

## II. EXPERIMENTAL METHOD

As different types of plastics behave differently in pyrolysis process, the major type of plastic, polyethylene (PE). The plastics used in this series of experiments were virgin plastic particles for the fundamental investigations thus the material variability can be eliminated. All of these particles were granular particles with dimensions of approximately 3 mm long and 3 mm wide. This chapter will discuss the pyrolysis of polyethylene.

### Effects of catalysts

Catalytic pyrolysis was studied previously and the published results show that catalyst can change the reaction process and the distribution of pyrolysis products, particularly, for PE that produced high molecular weight products in pyrolysis. As the proportion of wax (heavy molecular weight hydrocarbons) is high in the PE pyrolysis products, catalytic pyrolysis was investigated to convert the wax into diesel range fuels rather than use high reflux rate distillation that consumes a large amount of energy. According to previous studies, pore size and the ratio of Si/Al are the two key factors determining the effect of zeolite catalyst because zeolites are crystalline micro-porous aluminosilicate.

The catalyst of NKC-3A zeolite mainly consists of alkali metals and silica aluminate, which adsorbs molecules with certain range diameters no larger than 3A (0.3 nm). The NKC-3A zeolite catalyst is widely used in petroleum processing for gas cracking, which can adsorb water molecules while excluding hydrocarbon molecules. In the experiment, the effects of the zeolite with different pore sizes on the pyrolysis product were examined.

### Experimental reactor apparatus



**Fig. 1 Reactor Apparatus**

The objective of this project is to maximize the proportion liquid range product from pyrolysis of hydrocarbon plastics. In order to optimize the liquid range product, the effects of factors which influence the pyrolysis process need quantifying. Many of these factors affecting the distribution of the products were identified in previous studies and this has been discussed. However, some of the factors cannot be controlled in the process under the reaction conditions. Those adjustable factors will be controlled to optimize the process and to achieve the study objective. In this part of the study, a series of experiments were designed to identify and quantify the effect of the

factors on the process and the distribution of the products. According to the results and the findings from each experiment, the apparatus and reaction conditions were modified to maximize the proportion of liquid product.

#### **Temperature profile of plastic pyrolysis - Materials and methods**

In this work, the goal for this experiment was to understand the process of the plastic pyrolysis by monitoring and analyzing the temperature profile. In the system, electronic furnace was applied to heat the reactor as an external heating resource. There are two heating sources in the furnace. The front one was used for heating the reactor in this experiment, which has a maximum power output of 881 W. The output power was dialed at Load 100 to provide its maximum power. The reactor was made of stainless steel pipe with an inner diameter of 28 mm and thickness of 2 mm. The system also consists of nitrogen purging bottle and a water-cooling condenser, both of which are connected to the reactor. Connected to the condenser are a liquid collector and a gas collector. The temperature on the outer wall of the reactor was measured by using thermocouples 1 (Thermal-well 1) and the Centre space temperature in the reactor was measured using thermocouple 2 (Thermal-well 2).

The experiments used materials supplied by a plastic recycling company which was a mixer of PE (weight) in the form of post-consumer plastic chips. During the experiment, 10.00 grams of the supplied materials sample chips were placed in the Centre section of a combustion boat inside the reactor that was for maintaining consistency of the sample location in the reactor. The combustion boat was half of a pipe that was separated into three sections. The Centre section was at the heating zone of the furnace, which had the highest temperature in the process.

### **III. RESULT AND DISCUSSION**

#### **Extraction, temperature and time**

The 10g plastic mixture was completely pyrolyzed and after the experiment almost nothing was left in the central section of the combustion boat. The products collected included non-condensable gases in the gas collector, dark brown liquid in the liquid collector, yellow or brown wax and char in the reactor. Then the non-condensable gas was pumped into a balloon with an aluminium inner layer.

The wall temperature, T1, and the space temperature, T2, were simultaneously measured during the experiments and the results are shown in Figure 6-1 for the experiment with plastics in the reactor. From Figure 6-1, it was found that large temperature gradient existed between the reactor outer wall and the space inside the reactor. Towards the end of the experiment, both temperatures (T1 and T2) approached constant values of 1030 °C and 500°C, respectively. This was also found in the temperature profile from other researches. There was an increase on the T2 curve from the 16<sup>th</sup> minute to the 20<sup>th</sup> minute. However, this is not observed on the T1 curve. This means the temperature of the gas in the reactor had a sudden change during this period. Due to the small quantity of the mass of gas, the effect of this temperature change on the wall of the reactor was too minor to be detected by T1.

In order to examine and explain the sudden increase on the T2 curve at the pyrolysis period of 16 to 20 minutes from the start, the temperature profiles from the separate experiment without plastics can be used as the baseline. In the latter experiment (without plastics), other conditions remained the same as those in the previous experiment so that the baseline curve can be plotted to compare with the temperature curve with 10g plastic mixture in the reactor. (Figure 6-2) The two temperature profiles are the same from the beginning to the 16<sup>th</sup> minute. The temperature curve with 10g plastic rapidly increased from the 16<sup>th</sup> and reached the peak at the 18<sup>th</sup> minute. The temperature then dropped to the baseline curve at the 20<sup>th</sup> minute. The 10g plastic reaction temperature curve is slightly lower than the baseline curve after the 20<sup>th</sup> minute.

At the 16minute of plastic pyrolysis experiment, the temperature of the reactor wall reached 480°C. Considering the high heat conduction rate of the 2 mm thick stainless steel pipe, the temperature of the plastics in the reactor was very likely to be below but close to the reactor wall temperature of 480 °C. The specific cracking temperature of the plastic tested can be identified.

From Figure 6-2, it is also observed that the space temperatures in the two experiments were almost the same from the starting to the 16<sup>th</sup> minute which means the energy required for increasing the plastic temperature was not significant enough to make difference on the space temperature. That is due to the small quantity of mass and relatively low heat capacity of the plastics. At the 16<sup>th</sup> minute, plastics were cracked and vaporized into the reactor space. The temperature of the hydrocarbon vapour was close to 480 °C which is higher than the baseline space temperature of 110 °C. According to other literatures and previous discussion, plastics start with random cracking during which a series of hydrocarbon products such as non-condensable gases (C1 to C4) will be produced. As the volume of the pipe reactor is 250 ml, the volume expansion could be detected instantly with negligible time delay. Therefore, the gases could flow out of the reactor instantly once being generated. This can be confirmed by the volume increase of the non-condensable gases and in this way the on-condensable gas volume measurement can be regarded as the most sensitive parameter for indicating the random cracking at the beginning of the plastic pyrolysis.

The condensable vapour formed liquid products during the cooling process in the condenser.

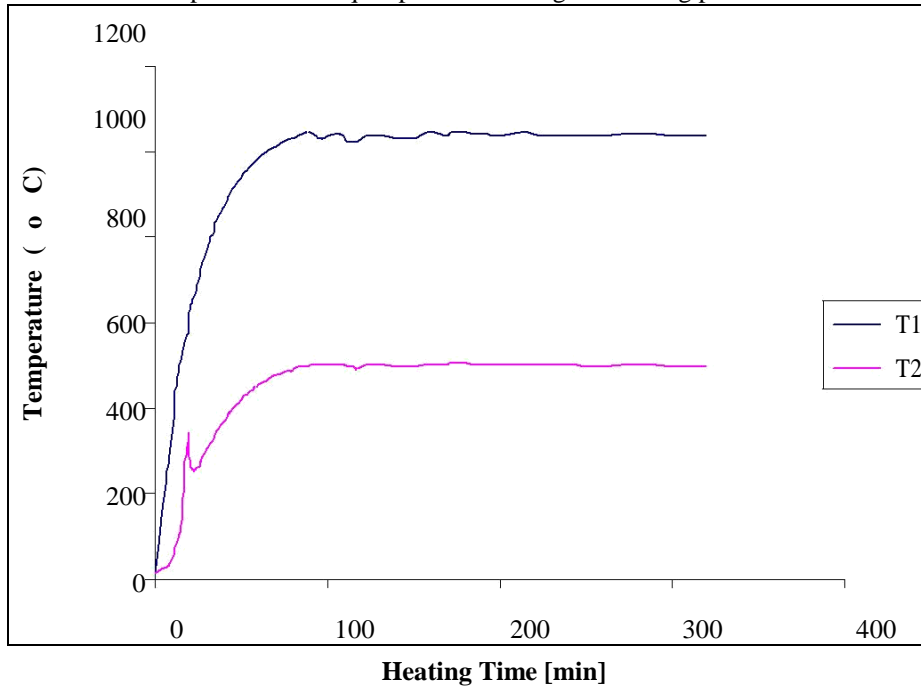


Fig. 2 Temperature Profile of T<sub>1</sub> & T<sub>2</sub>

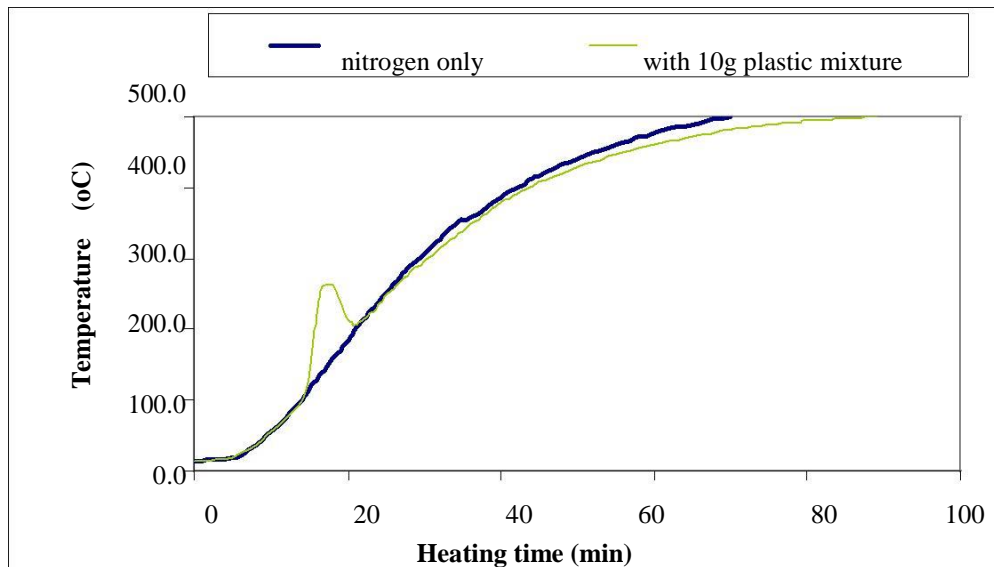


Fig. 3 Comparison of space temperatures between experiment of plastic pyrolysis and experiment without plastics

By further examining the temperature profiles in the plastic pyrolysis (Figure 6-1) and comparison with the baseline temperature (Figure 6-2), it is believed that the sudden increase in the space temperature towards the outer wall temperature occurred when the gases were generated. Hence, during the plastic pyrolysis experiments, a rapid temperature rise in space temperature, T<sub>2</sub>, caused by the hot vapour can be used as another sensitive indicator of vaporization and cracking of plastics. In the plastic pyrolysis experiment, the fast vaporization period lasted about 2 minutes from 16 to 18<sup>th</sup> minutes from the start. It is interesting to see that the space temperature rise followed a single curve indicating the plastics were vaporized during this period; therefore, they have cracking temperatures.

After the short period of fast cracking, it took another two minutes for the space temperature to drop back to the baseline, which means the energy required for the plastic cracking and vaporizing were not detectable and insignificant compared to the heat used for heating up of the system.

In the experiment, because a horizontal reactor was used, some of the heavy molecular hydrocarbons could be condensed near the cooler ends of the reactor which were exposed to the ambient air. With increase in the reactor outer wall temperature, the condensed hydrocarbons may be re-vaporized and re-condensed at the ends of the reactor. This reflux process absorbed and caused loss of a significant amount of heat. In addition to the above heat consumed and lost, the outflow gases would carry away some heat from the reactor.

#### **IV. CONCLUSION**

Post-consumed polyethylene were tested in order to understand the first cracking process on these common waste plastic. It was found that these plastics have similar cracking temperature and the cracking process which lasted about two minutes. All the type of waste polyethylene plastic were cracked when the reactor outer wall temperature was below 480°C. It was found that condensation and vaporization of the pyrolysis vapour near the ends of the reactor required and caused loss of a significant amount of heat. However, the energy required for cracking the plastics was insignificant to be detected. Large temperature gradient between reactor wall and inside space was detected in the experiment. The temperature on the reactor wall is believed to be close to the cracking temperature of the plastic.

During extraction,

Wall temperature = 1030 °C,

Space temperature = 500 °C,

Reaction time = 16 to 20 minutes.

As the plastic pyrolysis is extracted from the reactor in final form of liquid is analyzed to check the properties and characteristics. Then diesel properties is also checked. Then the properties and characteristics is compared to find were the alternate source of energy is formed.

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