

# Pyrolytic Oil Production from Municipal Plastic Waste and its Performance in a Diesel Engine

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Pyrolytic oil production from municipal plastic waste by sequential pyrolysis and catalytic reforming processes have been studied in this paper. Three kinds of municipal plastic wastes were collected from final disposal site and small recycling company in Yogyakarta city, Indonesia. Commercial Y zeolite and natural zeolite catalysts were used in this study. The batch-type pilot scale reactor with the capacity of 1.6-2.6 kg feedstock was used and 100 g of catalyst was loaded in the reforming reactor. The experiments were carried out at the pyrolyzer temperature of 450°C and the reforming temperature of 450°C. A preliminary diesel engine performance test has also been investigated utilizing these oils. The results show that the feedstock type strongly affect the product yields and the quality of liquid and solid products. From HDPE waste, we could produce both the highest liquid fraction and very high heating value solid product. The catalyst presence reduced the liquid fraction and increased the gaseous fraction. Pyrolysis with natural zeolite catalyst produced higher liquid product compared with Y zeolite catalyst.

*Key Words:* pyrolysis, plastic waste, natural zeolite, diesel engine

## 1. Introduction

A significant growth of plastics consumption in modern life has resulted in an increased production of plastic wastes. Thus, plastic wastes have become a major stream in solid waste and caused significant environmental problems worldwide. Disposing of plastic wastes by landfilling is not a suitable option due to slow degradation rates. Therefore, alternative methods such as chemical or feedstock recycling which involves pyrolysis of plastics into fuel have been introduced not only for wastes reduction but also for fuel production.

Pyrolysis involves the degradation of the polymeric materials by heating in the absence of oxygen. These pyrolytic products can be divided into a gas fraction, a liquid fraction and solid residues [2]. However, the thermal degradation of plastics has a major drawback such as a very broad product range and requires high temperature. Catalytic degradation therefore provides a means to address these problems.

The direct catalytic cracking has been used widely due to several advantages, mostly in terms of the energy efficiency, with regards to the use of the reactor, the reaction temperature and the residence time. However, the direct catalytic cracking of plastic wastes suffers from a number of drawbacks which has prevented its commercial success. The first relates to difficulty to recover the catalyst after use, which increases the operational cost. Furthermore, direct contact with plastic wastes will make catalyst deactivate rapidly due to the deposition of carbonaceous matter and the poisoning effect of extraneous elements and impurities such as chlorine, sulfur and nitrogen containing species that maybe present in the plastic wastes [1]. Therefore, separation of catalytic reforming reaction from pyrolysis stage can be applied to overcome these problems. This method has been firstly tested by Bagri and Williams [2] for polyethylene and polystyrene using zeolite-Y and ZSM-5 catalysts. The use of other catalysts such as silica alumina and Al-MCM-41 have also been investigated by others [3]. In this paper, we describe the pyrolysis and catalytic reforming of municipal plastic waste in Indonesia over commercial and

natural zeolite catalysts in a pilot scale batch system.

## 2. Materials and Methods

### 2.1 Materials

The feedstocks used for these experiments were three kinds of municipal plastic wastes, i.e. polyethylene bag with (2) and without (1) crushing and washing, and HDPE waste after crushing and washing. They were obtained from final disposal site and a small plastic recycling company in Yogyakarta city, Indonesia. The catalysts used for these works were commercial Y zeolite and natural zeolite. The Y zeolite was obtained from Zeolyst while natural zeolite was collected from Klaten, Indonesia.

### 2.2 Pyrolytic and catalytic reforming experiments

Pyrolysis and catalytic reforming experiments were carried out in a pilot scale two stage reactor using batch system. It consists of the pyrolysis reactor and the catalytic reforming reactor. The snapshot of the experimental apparatus was shown in Fig. 1. The pyrolysis reactor and the reformer were made of stainless steel and covered with an electric heater. The pyrolyzer's inner diameter and height are 200 mm and 400 mm, respectively. The reformer's inner diameter and height are 100 mm and 400 mm, respectively. A shell and tube type condenser was installed at the outlet of the reformer to separate gas and liquid products.

In these experiments, 1.6-2.6 kg of the feedstock was fed into the pyrolysis reactor. The pyrolyzer and the reformer were then heated up to the preset temperatures. The catalyst (100 g) was loaded in the catalytic reforming reactor, where the pyrolysis gas generated in the first reactor was reformed. After having the reforming reaction, the gas was condensed into liquid products in the condenser. Liquid products were then collected and weighed for mass balance calculation.

The experiments were carried out at the pyrolyzer temperature of 450°C and the reforming temperature of 450°C. The gaseous products were burned off to prevent emission from hydrocarbon gases.

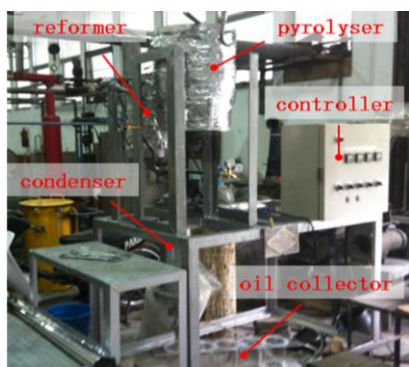


Fig. 1 The photograph of experimental apparatus

### 2.3 Diesel engine test

Engine tests were conducted on a four cylinder, four strokes, and water cooled diesel engine. The experiments were done by mixing 20% of plastic oil and 80% diesel fuel.

Table 1. Technical specifications of the test engine.

Engine parameter	Specification
Type	Nissan Diesel SD22 Series
Bore (mm)	83
Stroke (mm)	100
Compression ratio	22:1
Number of cylinder	4

## 3. Results and Discussions

### 3.1 Effect of feedstocks

The product yields as the effect of the feedstocks can be seen in Fig 2. Commercial Y zeolite was used in these experiments. PE bag 1 obtained from final disposal site still produced water and highest portion of solid residue because of uncrushed and unwashed sample. HDPE waste produced highest liquid fraction. However, the heavy oil fraction was still high which indicated the low quality of the oil.

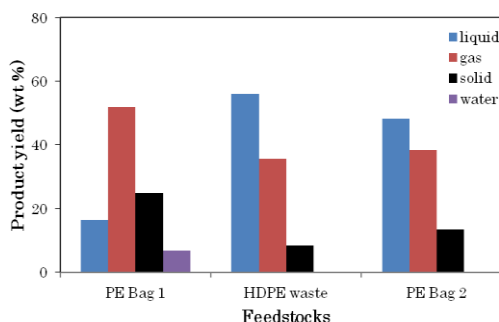


Fig. 2 Effect of feedstocks on the product yields

### 3.2 Effect of catalysts

Fig. 3 shows the product yields obtained from the sequential pyrolysis and catalytic reforming of municipal plastic wastes as the effect of catalysts. It can be seen that the pyrolysis only produced highest liquid fraction. The presence of catalyst reduced the liquid fraction and increased the gaseous fraction. Pyrolysis with natural zeolite catalyst produced higher liquid product compared with Y zeolite catalyst.

### 3.3 Solid residues

The proximate analysis and heating value of the solid residue produced are shown in Table 2. PE bag 1 produced high ash content of solid product due to the impurities which reduce the heating value of the product. However, plastic pyrolysis produced higher heating value solid products than biomass and low rank coal. Therefore, they can be used either for blending with biomass and coal or for single fuel.

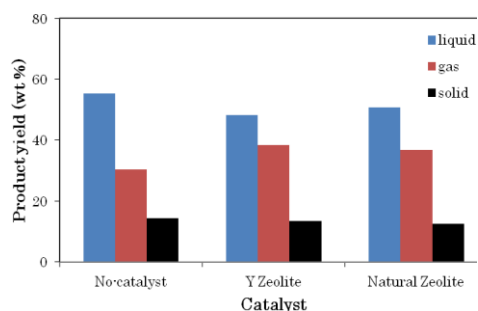


Fig. 3 Effect of catalysts on the product yields

Table 2. Proximate analysis of solid residue.

	Composition (wt%)	
	PE Bag 1	HDPE waste
Moisture	1.12	1.74
Volatile matter	35.29	58.56
Fixed carbon	14.13	8.59
Ash	49.47	31.11
Heating value (MJ/kg)	19.80	26.35

### 3.4 Diesel engine performance

Power variation curves of all test fuels were presented in Fig. 4. It can be seen that power values of all fuels showed increasing trends with respect to increase in engine speed. However, they have no linearity due to the increase in mechanical losses.

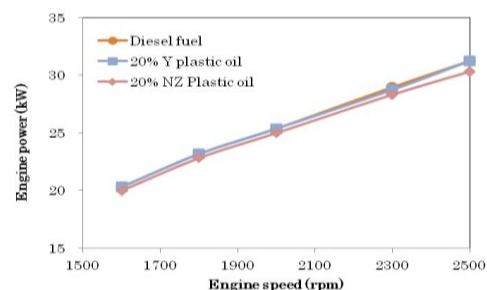


Fig. 4 Variation of engine power with engine speed

## 4. Conclusions

Sequential pyrolysis and catalytic reforming of Indonesian municipal plastic wastes have been done over Y and natural zeolite catalysts. The feedstock type strongly affect the product yields and the quality of liquid and solid products. HDPE waste produced both the highest liquid fraction and very high heating value solid product. 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. Diesel engine tests show that blending diesel fuel with 20% plastic oil gave similar performance with those of single diesel fuel.

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