

Mixed Plastic Wastes to Fuel Oil by Pyrolysis Process for Solid Waste Management

CHAW SU SU HMWE

Department of Chemical Engineering, Mandalay Technological University

Abstract- *In this study, mixed plastic wastes was converted into hydrocarbon oil. Mixed plastic wastes used were high density polyethylene (HDPE) waste and polypropylene (PP) wastes. Zeolite Zh catalyst for pyrolysis of mixed plastic (HDPE and PP) were prepared and characterized by X-ray Diffraction (XRD), Scanning Electron Microscope (SEM). The results show that the typical zeolite Zh can be prepared with molar composition of $2\text{Na}_2\text{O}:\text{Al}_2\text{O}_3:2\text{SiO}_2:35\text{H}_2\text{O}$ by aging at room temperature for 24 hr and crystallized at 100°C for 24hr. The pyrolysis process was carried out with fluidized bed reactor. Physical properties of product crude liquid sample were measured. The results of product fuel oil were significantly appeared as alkane and alkene groups. From this study, yields of liquid and gas were 53.35% and 31.25 % respectively.*

Indexed Terms- *Crude liquid, Mixed plastic waste, Pyrolysis, Zeolite catalyst*

I. INTRODUCTION

Plastics are widely used and provide a fundamental contribution to all main daily activities: agriculture, automobile industry, electricity and electronics, building materials and packaging. Due to population increase, the demand for plastic products has steadily increased over the last 40 years. Since plastics are non-biodegradable, they cannot be easily returned to the natural carbon cycle. Plastic waste is significant portion of the total municipal solid waste (MSW) [1].

The disposal of waste plastics has become a major problem all over the world. Disposal methods for municipal and industrial plastics wastes are landfill, incineration (energy recovery), material recycling (similar recycled product or monomer recovery), and chemical recovery. Energetic, political, environmental and economical point of view, the

suitable treatment of plastic wastes is important for the waste management [1].

Since waste plastics have a high volume to weight ratio, the cost of land filling plastic is increased. So, the other methods should be preferred as an alternative waste management to replace land filling. Incineration of plastic waste produces greenhouse gas and some highly toxic pollutants.

Recycling of plastic is generally considered to be higher in the waste processing hierarchy than conversion. As such, recycling of plastics is favoured over disposal. In recent years, however, the number of new types of containers and different beverages such as bottled water has grown significantly, making it more difficult to recycle. Because of their relative high chemical energy, plastics are attractive candidate materials for conversion technologies that either produce alternative fuels or chemicals, or fuel gases for power conversion to electricity [2].

Pyrolysis is generally defined as the controlled heating of a material in the absence of oxygen. Pyrolysis process is usually conducted at temperatures between 350 and 900°C and results in the formation of a carbonized char (solid residue) and a volatile fraction that may be separated into condensable hydrocarbon oil and a non-condensable high calorific value gas. The present of catalyst lowers the reaction temperature and time. In addition, catalytic degradation yields a much narrower product distribution of carbon atom number with a peak at lighter hydrocarbons and occurs at considerably lower temperatures [3]. Catalytic degradation of plastics is found to have greatest potential to be developed into a commercialized process [4].

To solve the disposal of waste plastics, conversion of mixed plastic wastes by pyrolysis process was studied.

II. MATERIALS AND EXPERIMENTAL STUDIES

A. Materials

Raw materials for this process were high density polyethylene (HDPE) wastes and polypropylene (PP) wastes. These plastics were collected locally as used laundry bottles, shampoo bottles and soft drink bottles. Selected particle size range of the plastic wastes was -4+8 mesh. Bulk densities of HDPE waste and PP waste were 0.298 g/cm³ and 0.198 g/cm³ respectively. Prepared synthetic zeolite Zr catalyst was used as a catalyst in the pyrolysis process.

B. Experimental Study

1) Preparation of raw materials and catalyst

HDPE waste, used laundry bottles and shampoo bottles and PP wastes, used soft drink bottles were washed and dried. After that, these plastic wastes were chopped and mixed for the process.

In order to prepared synthetic zeolite by hydrogel process, hydrogel solution (synthesis gel) was prepared by agitation silica and alumina source solutions. The hydrogel solution with a molar composition of 2Na₂O: Al₂O₃: 2SiO₂: 35H₂O and the pH range of (13-14) were done in aging at various temperatures for a desired period to form the nucleation for crystal growth. Then the resulting hydrogel was transferred into the polyethylene container and put into oven to form hydrothermally crystalline. Crystallization was carried out at 100°C. After completing crystallization, the resultant precipitate was separated by filtration. The crystalline mass was washed until a pH range of 9-10 and dried at 100°C for 24 hours.

2) Experimental apparatus for pyrolysis process

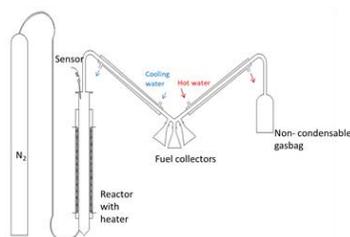


Fig.1 Schematic Diagram of Catalytic Fluidized Bed Reactor

The reactor was encased by the heating unit with a temperature controller. The nozzle has been welded with the reactor to connect the nitrogen inlet pipe. In this process, nitrogen was used as a fluidizing and carrier gas.

3) Pyrolysis Process of Mixed Plastic (HDPE and PP) Wastes

The pyrolysis processes were carried out with zeolite Zr catalyst in this fluidized bed reactor at the temperature range of 300-400°C. High density polyethylene (HDPE) and polypropylene (PP) were mixed at the ratio of 1:1. Two hundred grams of waste plastic particles were mixed with 40g of catalyst and placed in the reactor. Nitrogen as a fluidizing and carrier gas was flowed into the reactor with a constant rate 600cm³/min. The reactor was heated slowly at the rate of 5°C/min until the temperature range, liquid fuel started to drop. Final heating temperature range was 400°C-410°C. The heating was increased from liquid fuel first drop temperature to final setting temperature by using the heating rate of 2°C/min. Hot water container was heated by electric hot plate. Vapours leaving the reactor passed into the first condenser (hot water condenser) were condensed as wax and small amount of crude liquid fuel. Remained vapours were passed through the second condenser (cold water condenser) and condensates were collected as crude liquid fuel. These products were collected at the joint of the ends of the first and second condensers. The non condensable gas was collected in the gas collector. After reaction, char residue were remained in the reactor.

III. RESULTS AND DISCUSSION

A. Determination of prepared zeolite for pyrolysis process

The XRD pattern of prepared zeolite catalyst was shown in Fig. 2. The broad peaks at 2 θ values 16.5° and 28.5° gives the highest peak intensity of zeolite Zr. Fig. 3 shows the SEM micrograph of prepared zeolite Zr. From this figure, the morphology of zeolite Zr was found tubic shape. And Fig.4 shows the FTIR result of prepared zeolite Zr. The mid infrared (IR) region of the spectrum was 3479 cm⁻¹, OH stretching, 400-1300 cm⁻¹, aluminosilicate lattice

since this region contained the fundamental vibrations of framework structure.

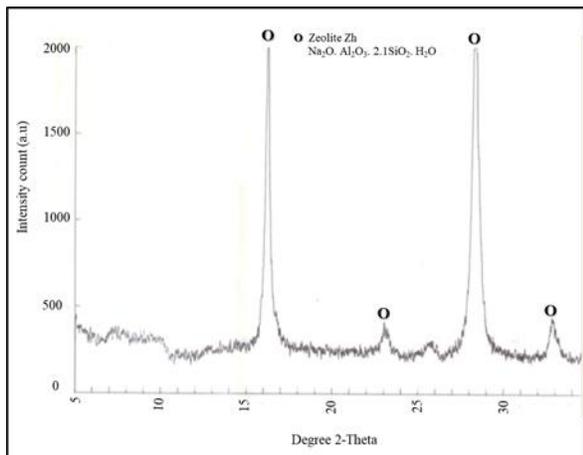


Fig.2. XRD Pattern of Prepared Zeolite Zh



Fig.3. SEM Monograph of Prepared Zeolite Zh

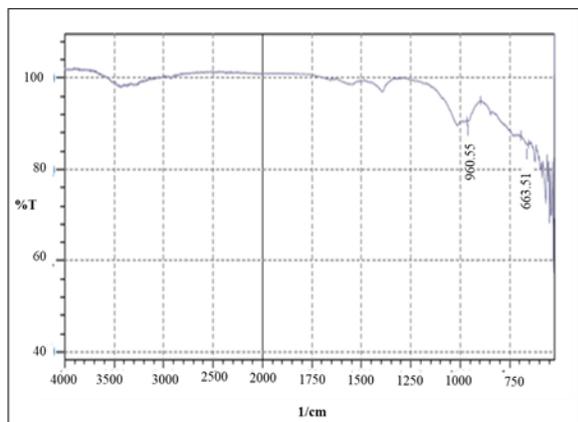


Fig.4. FTIR Spectrum of Prepared Zeolite Zh

B. Physical Properties of Product Crude Liquid Fuel
The cracking behaviour of waste HDPE and PP was investigated in the fluidized bed reactor in present of zeolite Zh catalyst at temperature range of 300°C to 400°C. Plastic to catalyst ratio used in this process

was 10:1. The physical and chemical properties of the product crude liquid fuel were shown in Table 1. The yields (%) of products are described in Table 2. Distillation curve for product crude liquid fuel was shown in Fig. 5. The FTIR spectrum of the product was shown in Fig. 6.

TABLE I
THE PHYSICAL PROPERTIES OF PRODUCT
CRUDE LIQUID

Properties	Crude Liquid from Process
Specific gravity (60°/60°F)	0.7904
Kinematic viscosity at 40°C (mm ² /sec)	2.1
Flash Point (°C)	30
Copper Strip corrosion at 100°C, 3hr	No.1(a)
Distillation	
i. Initial Boiling point (°C)	78
ii. 5% vol. recovered at (°C)	104
iii. 50 % vol. recovered at (°C)	220
iv. 90% vol. recovered at (°C)	370

TABLE II
PRODUCT YIELD % OF CRUDE LIQUID

Sample	Catalyst Used	Yield (%) Based on Feed			
		Liquid	Gas	Wax	Char
1.	Zeolite Zh	53.35	31.25	7.97	7.43

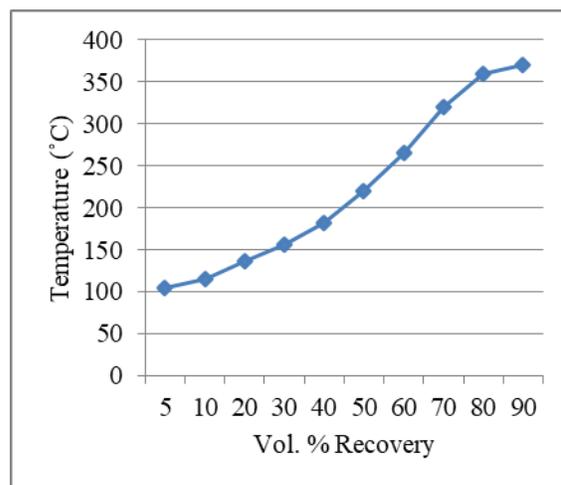


Fig. 5: Distillation Curve for Product Crude Liquid from Pyrolysis Process

According to Table 1 and Fig. 5, it was observed that the product crude liquid contain 50% gasoline. According to Fig. 6, it can be seen that the methylene groups of C-H stretching vibration in normal alkanes and methylene groups of C-H bending vibrations in normal alkanes were found in the product crude liquid. In this study, the calorific value of product crude liquid fuel is 41.46 MJ/Kg and that of by product char is 17.26 MJ/Kg.

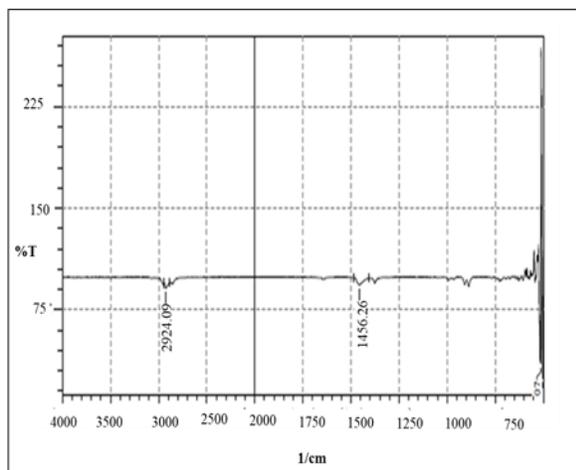


Fig. 6. FTIR Spectrum of Product Crude Liquid from Process

IV. CONCLUSIONS

The conversion of mixed plastics wastes (HDPE and PP) was demonstrated to be useful method for the production of valuable liquid fuel. It was concluded that the prepared zeolite Zh catalyst can be used as a catalyst for plastic pyrolysis process. Product fuel oil was analyzed by FTIR. The results of product fuel oil were significantly appeared as alkane and alkene groups. Product fuel oil was mainly paraffins and composed of more alkane group. Product fuel oil can be used internal combustion engine after distillation. Conversion of mixed plastic wastes into liquid fuel has been recognized as an ideal approach and could significantly reduce the cost of disposal. Therefore, conversion of mixed plastic wastes will reduce dependence on fossil fuels as well as the one of the most critical problem can be solved.

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