The Studies on Procedure Optimization for Production of Petrochemicals from Waste Thermoplastics

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Abstract

In the aim of study, we investigated the optimization of oil production from three wastes plastic types were polyethylene, polystyrene and polypropylene by pyrolysis process. Generally, there are 3 main factors affecting on pyrolysis process; temperature, heating rate and flow rate of N_2 (g) (minutes), respectively. The experiment results that the controlling of pyrolysis process was adjusted temperature with 3 waste plastic types at 400, 500, 600 and 700 °C, heating rate at 10 °C/min and flow rate of N_2 at 0.5 l/min at 1, 3 and 5 minutes were found that temperature at 700 °C and flow rate of N_2 (g) at 1, 3 and 5 min were increased the highest % yield and different significant for all waste plastic types. The methods of quality analysis of crude oil from different plastic types such as flash point, cloud point, viscosity and specific gravity. The results obtained after the analysis of variance (ANOVA) showed that there were not significant differences ($P>0.05$) in the viscosity and specific gravity value. However, there were significant differences ($P<0.05$) in the flash point and cloud point of the oil samples from different polymer respectively.

Keywords: Waste plastic, Crude oil from plastic, Pyrolysis

1. Introduction

In recent years the consumption of plastics has increased drastically; as a consequence the responsible disposal of plastic wastes has created serious social and environmental arguments [1]. Although a significant amount of the thermoplastics are utilized in products with a long life span, the majority are used in short term applications such as packaging. Thus, the quantity of thermoplastics found in waste is increasing correspondingly. Research into alternative methods of recycling thermoplastic waste is being carried out. Pyrolysis is an alternative process to incineration and material recycling. This method allows the recovery of the monomer and the production of other petrochemical products. The corresponding temperatures defining the pyrolysis states are with the following temperature ranges to 600–800°C and greater than 800°C [2]. The products obtained from pyrolysis of thermoplastics were gas production temperature increases while oil and wax production temperature decreases.

The aim of this work was to extend the optimization of petrochemicals production of different thermoplastic wastes that should be a most suitable for pyrolysis procedure. The main scope was to define the factor affecting on pyrolysis process; temperature, heating rate and flow rate of N_2 (g) (minutes), respectively and determination of crude oil quality was analyzed to standard methods.

2. Material and Methods

2.1 Plastic samples

The experiments were carried out with three different recycled polymers, polyethylene (PE), polystrylene (PS) and polypropylene (PP), all obtained as single material collections and a successive process of mechanical shredding, washing and pelleting. A small particle size was chosen to reduce the effect of heat transfer.

2.2 Fluidised bed reactor

The pyrolysis was carried out using a fuidised bed reactor. A schematic diagram of the reactor can be seen in Fig. 1. In total three polymers each of 50 g in weight were infused in the glass boiler reactor. An expander section at the top of the reactor enabled the velocity of the carrier gas and pyrolysis vapors. Nitrogen was used as the fluidising gas which was set at 0.5 L/min from the cylinder at room temperature. The reactor was also externally heated using an electric ring furnace. The temperature in the reactor was varied between 400 and 700°C, thermocouples were used to give a temperature profile of the entire height of the reactor. After the pyrolysis vapors gas had passed to remove expander section at the top of the reactor. The remaining lighter components were condensed using glass condensers in inlet-outlet water traps. A vessel containing glass wool was put in-line after the condensers to crude oil

2.3 Condition of pyrolysis reactor

The experiment of condition pyrolysis reactor was showed in Table 1.

Table 1. Condition of pyrolysis reactor

Plastics types	Heating rate (°C/min)	Flow rate of N_2 (L/min)	Flow time (min)	Temperature reactor (°C)
PE	10	0.5	1,3 and 5	400, 500, 600 and 700
PS				
PP				

2.4 Analysis of crude oil quality

Crude oil quality was analyzed to American Society Testing and Materials (ASTM) such as flash point, cloud point, viscosity and specific gravity.

2.5 Statistical analysis

Analysis of variance (ANOVA) was used to test the data obtained while Turkey's test method was used to compare the means.

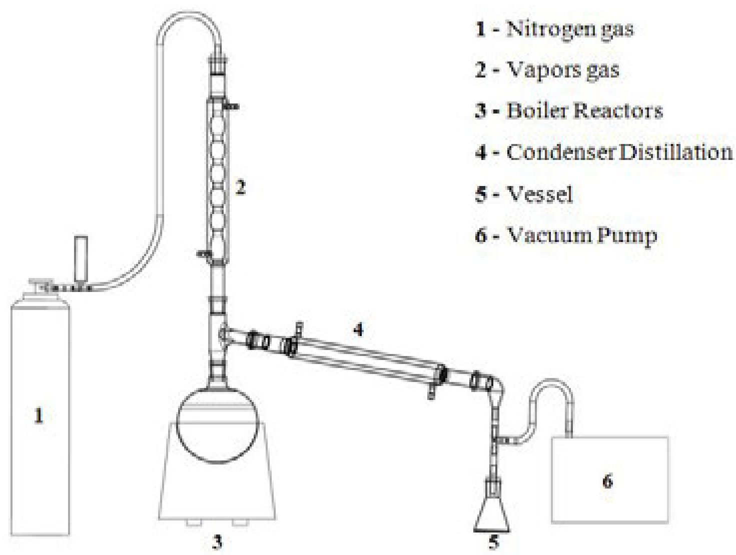


Figure 1. Schematic diagram of Fluidised bed reactor

3. Results and Discussion

3.1 Product yield

The fluidised bed reactor at a temperature range 400-700 ^{O}C, N_2 flow rate at 0.5 L/min at 1, 3 and 5 min. Figure 2 shows the yield pyrolytic products obtained from PP, PE and PS at different temperatures. From Figure 2, while pyrolysis temperature increase from 400 to 700 ^{O}C the yield of oil fraction increase from 60 to 93 %wt for three different polymer at flow rate N_2 0.5 L/min. The highest yield of oil fraction was 93%wt of PS at flow rate N_2 0.5 L/min for 5 min. Temperature is also known to have a very important effect on the selectivities of waste plastic pyrolysis. If in addition we are adding waste plastic then the temperature of cracking must usually be raised in order to bring about sufficient chain scission and obtain products in the liquid from suitable for use as liquid fuels [3].

3.2 Analysis of crude oil quality

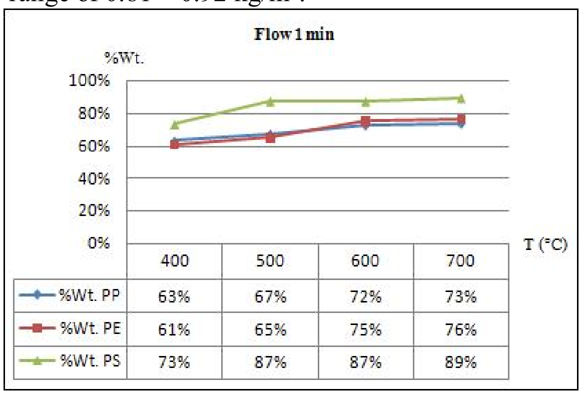
The physicochemical properties of the oil samples from different polymer are presented in Table 2

Table 2. Physicochemical properties of the oil samples

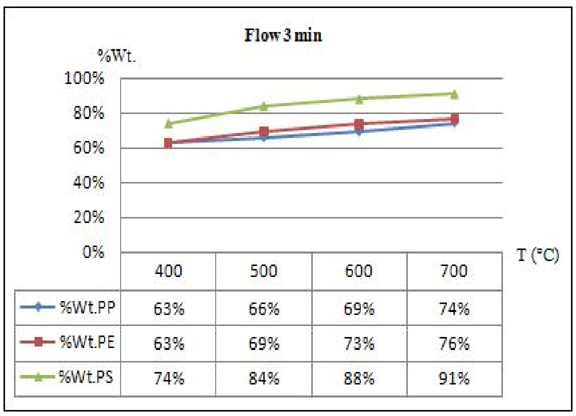
Analysis	PE	PP	PS
Flash point (^{o}C)	40	48^{a}	41^{C}
Cloud point (^{o}C)	5.6^{b}	-5.6^{C}	5.0^{a}
Viscosity (cSt)	2.1^{a}	1.9^{a}	1.8^{a}
Specific gravity (kg/m^3)	0.87^{a}	0.83^{a}	0.92^{a}

Means in the same row with the same superscripts are not significantly different (P>0.05).

As seen in Table 2, There were significant difference (P<0.05) in flash point of oil from waste plastic samples. The waste plastic samples from PP had the highest flash point of 48 ^{o}C of followed by samples from PE (40 ^{o}C) and PS (41^{o}C). The flash point value obtain are 75 ^{o}C. Cloud point obtained for the waste plastic samples were significant difference (P<0.05). The lowest cloud point of PE was -5.6 ^{o}C. The cloud point values obtained are within the range of 0-3 ^{o}C. Thus, the oil from waste plastic samples because of cloud point effected to clog up filter engine which apply to badly flow injection diesel engine. As observed from (Table 2) the values obtained for viscosity matter show not significant difference (P>0.05). However the viscosity values are within the range of 1.8-8.0 cSt. The specific gravity values were not significant difference (P>0.05). The values obtained were closely related to the standard range of 0.81 – 0.92 kg/m^3.



(a)



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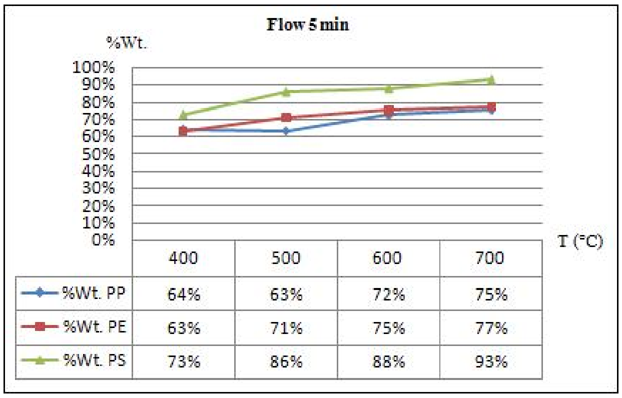

(c)

Figure 2 Relation of yield (%wt) oil and temperature

(a) Flow rate N_2 at 0.5 L/min for 1 min

(b) Flow rate N_2 at 0.5 L/min for 3 mins

(c) Flow rate N_2 at 0.5 L/min for 5 mins

4. Conclusions

The results obtained from the study showed that the optimization of oil production from 3 wastes plastic types by pyrolysis process. The main factor affecting on pyrolysis reactor was a temperature. The optimum condition pyrolysis was flow rate N_2 0.5 L/min for 5 min at temperature reactor 700 ^oC, it was the highest yield (%wt) of PS. The physicochemical properties of the oil samples from different polymer were improved to some value as enhancement of flash point and included to controlling cloud point were limited range standard.

The study performed in research has provided important information showing that prospects for using small-scale simple pyrolysis processes to deal with waste plastics appear good but further investigations are required.

5. Acknowledgement

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6. Reference

[1] A.G. Buekens, H. Huang., *Resources Conservation. Recycling, 1998*, *Vol 23*, pp163–181.

[2] A.L. Bisio, N.C. Merrieam., Technologies for polymer recovery: recycling and potential for energy savings. *Technology and Market Opportunities*, *Munich, Germany*, *1994*, *Chap 3,* pp15–31.

[3] F. Pinto, P. Costa, I. Gulyurtlu, I. Cabrita., Pyrolysis of Plastic Wastes. 1. Effect of Plastic Waste Composition on Product Yield., *Journal of Analytical and Applied Pyrolysis, 1999, Vol 51,* pp39-55.

[4] F.J. Mastral, E. Esperanza, P. Garcı´a, M. Juste., Pyrolysis of High-Density Polyethylene in a Fluidised Bed Reactor. Influence of the Temperature and Residence Time., *Journal of Analytical and Applied Pyrolysis, 2002, Vol63,* pp1-15.

[5] M. S. Mulgaonkar, C. H. Kuo and A. R. Tarrer., Plastic Pyrolysis and Coal Coprocessing with waste Plastics., *Chemical Engineering Auburn University*, *Auburn*

[6] S.L. Low, M.A. Connor and G.H. Covey., Turning Mixed Plastic Wastes into a Useable Liquid Fuel, *6th World Congress of Chemical Engineering*, *2001, Australia*

[7] T.W. Paul, A.W. Elizabeth., Fluidised Bed Pyrolysis of Low Density Polyethylene to Produce Petrochemical Feedstock., *Journal of Analytical and Applied Pyrolysis, 1999*, *vol 51*, pp107-126