Pyrolysis of Polyethylene and Polypropylene Packaging Wastes

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Abstract—This study aims to investigate the suitable process to pyrolysis waste plastics to product gas and oil. Pyrolysis of low density polyethylene (LDPE), high density polyethylene (HDPE), polypropylene (PP) and mixture of PP:PE (ratio 50:50) packaging wastes was studied to find the effective pyrolysis conditions. The packaging wastes were pyrolyzed under nitrogen at 300-350°C for 2 h. The pyrolysis reactor was design to prevent the radical combination. Oil products from pyrolysis of LDPE, HDPE, PP and PP:PE mixture (ratio 50:50) packaging wastes are 57.84, 78.13, 55.19 and 73.11 %wt/wt respectively. Analysis of pyrolyzed products compared with standard diesel fuel indicated that modification of product oil prior to utilization as fuel is necessary.

Keywords—Packaging waste, pyrolysis process, hydrocarbon compounds, fuel oil

1. INTRODUCTION

Environmental problems from plastics wastes have been increased rapidly in agreement with GPD of world population. General treatments of waste plastics involve incineration, landfill and recycle. Incineration and landfill are easy and effective but subsequence pollution and limitation of land to be buried make them less important in recent years. Waste plastics recycle covers a very small amount of wastes compared to their disposal. The numbers of recycle process also affect quality of polymers. Most of plastics wastes in Thailand are packaging materials, comprised of polyethylene (PE), polypropylene (PP), polystyrene (PS) and polyvinyl chloride (PVC). They are non biodegradable plastics. Numbers of research for recycle of those wastes have been studied in recent years.

Recycle of plastics involves many technical difficulties due to different rheological properties of plastics materials. Resins having high melt flow index are suitable for injection molding techniques while those having low melt flow index are more suitable for extrusion blow molding. Moreover, interaction of incompatible polymers results to low mechanical properties of the blends.

Plastics are generally high calorific value products ranging approximately from 18,000 to 38,000 kcal/kg [1]. The utilization of waste plastics for their energy or for related chemical production may be an alternative option. There are two main processes exploring these options; incineration and pyrolysis. Incineration is a destructive process in which hydrocarbon are converted to their combustion products whereas pyrolysis may convert them to other hydrocarbon, wh9ich may be utilized as fuel.

Pyrolysis are classified into low, medium and high temperature based on the range of the temperature used to decompose the plastic structure [2]. Temperature ranges less than or equal to 600°C, 600-800°C and greater than 800°C are used to define the pyrolysis states [3]. The products obtained from pyrolysis of plastics depend on the type of plastics, feeding arrangement, residence time, temperatures employed, reactor type and condensation arrangement.

In this study low temperature pyrolysis of PE and PP were carried out in a newly designed glass reactor to produce gas, oil and wax residues.

2. METHODOLOGY

2.1 Materials

Low density polyethylene (LDPE), high density polyethylene (HDPE), polypropylene (PP) and mixture of PP:PE mixture (ratio 50:50) packaging wastes were shredded into 5-mm size and subjected to pyrolysis.


Fig 1


Fig 2


Fig 3

Fig. 1 Low density polyethylene (PE)
Fig. 2 High density polyethylene (HDPE)
Fig. 3 Polypropylene (PP)

2.2 Method

The experimental reactor was designed for the decomposed materials to leave the reactor before radical combination reaction and condense in the condenser (Fig. 4). The reaction temperature was measure at the upper part of the liquid mixture in the reactor. Products from pyrolysis comprised of gas, liquid and residue solid. The liquid products and residues were analyzed compared with standard for diesel.

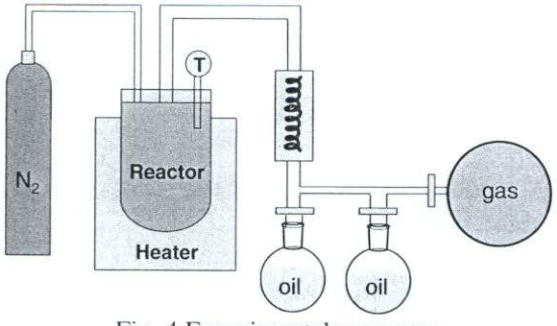


Fig. 4 Experimental apparatus

3. RESULTS AND DISCUSSION

Pyrolysis of LDPE, HDPE, PP and PE:PP mixture (ratio 50:50) packaging waste were carried out at 300-350°C under nitrogen atmosphere for 2 h. The pyrolysis results are shown in Table 1, 2 and Fig. 5. Oil products from pyrolysis of PE, HDPE, PP and PE:PP mixture (ratio 50:50) packaging wastes are 57.84, 78.13, 55.19 and 73.11 %wt/wt respectively. With the designed process, more than 50 percent of clear oil solution was obtained whereas gas and solid residue were found in small amount.

Table 1 Weight of products from pyrolysis of LDPE, HDPE, PP and PE:PP mixture (ratio 50:50) packaging waste

Sample	Plastics	Sample weight (g)	Products (g)		
			Oil	Gas	Residue
1	LDPE	150.06	86.80	1.09	62.17
2	HDPE	500.43	391.01	2.05	76.61
3	PP	100.00	55.19	1.20	40.61
4	PP:PE	100.00	73.11	0.62	16.50

Table 2 Percent of products from pyrolysis of LDPE, HDPE, PP and PE:PP mixture (ratio 50:50) packaging waste

Sample	Plastics	% of Products (wt/wt)		
		Oil	Gas	Residue
1	LDPE	57.84	0.73	41.43
2	HDPE	78.13	0.41	15.13
3	PP	55.19	1.2	40.61
4	PP:PE	73.11	0.62	16.5

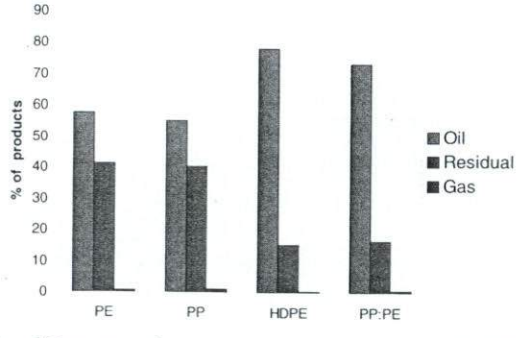
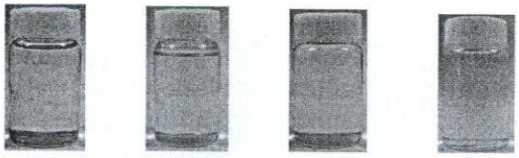


Fig. 5 Percent of products from pyrolysis of LDPE, HDPE, PP and PE:PP mixture (ratio 50:50) packaging waste



(a) (b) (c) (d)

Fig. 6 oil from pyrolysis of (a) PE (b) HDPE (c) PP (d) PP:PE

Liquid products from all samples exhibited clear color liquid as shown in Fig.6. The results showed that purification of oil product is not necessary. However, residues of LDPE consisted samples were dark brown paste (Fig. 7 (a) and (d)).

(a) (b) (c) (d)

Fig. 7 Residue from pyrolysis of (a) LDPE (b) HDPE (c) PP (d) PP:PE

The liquid products from pyrolysis of LDPE, HDPE, PP and PE:PP mixture (ratio 50:50) packaging waste were subjected to physical property analysis and compared with the standard for diesel oil. The results are shown in Table 2.

Table 3 Physical properties evaluation of liquid products

Physical property	Results	
	PE:PP=50:50 packaging waste	Standard for Diesel oil
Flash Point	**<11.5**	> 52
Sulphur Content (% by weight)	**0.0009**	< 0.05
Lead Content (g/L)	**0.0085**	< 0.013
Cetane Index	62	> 47
Specific Gravity (at 15.6 °C)	0.7771	0.81-0.87

The oil products analysis from Table 3 showed the flash point of plastic bags was less than standard for diesel oil (less than 52). The results indicated that the oil produced from pyrolysis should be modified prior to use as fuel since the low flash point oil will have much effect to engine. The specific gravity was lower than the range for diesel oil showed the low molecular weight of hydrocarbon resulted from cracking of plastics. Therefore, the liquid product can be considered for modification for gasoline or diesel applications. The sulphur content, lead content, and calculated Cetane Index are in the range acceptable for diesel fuel.

4. CONCLUSION

Pyrolysis of LDPE, HDPE, PP and PE:PP mixture

(ratio 50:50) packaging waste were pyrolyzed under nitrogen at 300-350°C for 2 h. The pyrolysis reactor was design to prevent the radical combination. Clear solution of oil products were produced with the amount more than 50 percent by weight in all conditions. Analysis of pyrolyzed products compared with standard diesel fuel showed some acceptable results but the flash point was too low indicated that modification of product oil prior to utilization as fuel is necessary.

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