Comparision of Characteristics and Qualities of Pyrolytic Oil and Distilled Pyrolytic Oil from Municipal Plastic Wastes Case Study: Warinchamrap Municipality

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Abstract— *The objective of this research is to study and compare characteristics and qualities of pyrolytic oil (PO), infiltrated pyrolytic oil (IPO), and distilled pyrolytic oil (DPO) from municipal plastic wastes (MPWs) with the standard engine oil for 4-stroke engines and diesel engines. Each of pyrolytic oil was obtained from the pyrolysis plant operating by Muang Sa-ad Co., Thailand. Municipal plastic wastes were supplied from the closed landfill which located at Warinchamrap Municipality site at Ubon Ratchathani Province. According to testing items, all types of pyrolytic oil products have almost characteristics and qualities similar to engine oil for 4-stroke engines and diesel engines. Consequently these pyrolytic oils could be valuable diesel-range as both of engine oil for 4-stroke and diesel engines. However, they are still not suitable for diesel-engine usage in terms of flash point, Kinematic Viscosity, pour point and cetane number of the hydrocarbons. Furthermore these parameters need to be investigated and controlled for the pyrolytic oil.*

Keywords—**Pyrolytic Oil, Pyrolysis, Municipal Plastic Wastes, Engine Oil.**

1. INTRODUCTION

In recent, problem of solid waste management is seriously and increases environmental pollution. Population growth and city development are subject to a increasing rate of municipal solid waste production. Nowadays the production and consumption of plastics are more than ever increasing because life style has to urgent and needs comfortable; as a consequence, the responsible disposal of plastic wastes has created serious social and environmental arguments [1]. For the recycling of plastic wastes, the pyrolysis technology is becoming a promising alternative, in order to recover fuel oil and hydrocarbon feedstock [2-4]. In 2009, All countries of Thailand has quantity of solid waste generated 15.11 million ton. (41,410 ton per day) The recycle wastes are about 30 % of total solid wastes and have portion of plastic wastes (PWs) about 16.8 %. From the total 2.5 million tons of PW, most of these PWs still are disposed to landfill and only are recycled from the landfill approximately 3% by scavenger [5]. Due to disposal method in Thailand, landfills and open dumps show high portion, but the portion of recycling method is low. Plastic waste is a big issue in Thailand, because the amount of recycled plastic is still low due to the high investment and operating cost. It is reported that the PW accounts for about 14 percents of all generated solid waste amounts in year 2000. Yet, the recovery rate of PWs is only 23 percents. Hence, the amounts of PWs that end up in disposal sites are enormous [6].

Warinchamrap municipality is one-third of municipalities that received financial support of the reforming PW to oil project from EPPO in 2009-2010. The others are Khonkhan and Pitsanulok municipality. The commercial pyrolysis plant (Muang Sa-ad Co., Thailand) was located at Warinchamrap site using a commercial rotary kiln reactor. Municipal plastic wastes (MPWs) were supplied and separated from the closed landfill by a front end system. Pyrolysis technology of reforming MPWs to useful oil at Warinchamrap site has two parts, the first part is separation of MPWs from the closed landfill and the second part is the catalytic pyrolysis for reforming MPWs to pyrolytic oil. Under pyrolysis condition, the MPWs can be decomposed into three fractions: gas, liquid, and solid residue. The liquid fraction is mixed plastic oil (MPO) or pyrolytic oil products. This liquid product is usually composed of higher boiling point hydrocarbon as fuel oil. The yield of fuel oil is around 55-60% with this technology [7].

The objective of this research is to study and compare characteristics and qualities of pyrolytic oil (PO), infiltrated pyrolytic oil (IPO), and distilled pyrolytic oil (DPO) producing from municipal plastic wastes (MPWs). The characteristics and qualities of PO, IPO, and DPO were compared with the standard engine oil for 4-stroke engines and diesel engines according to the Notification of Department of Energy Business; Prescribing the

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Characteristic and Quality of Diesel Oil (No.5) B.E. 2554 (2011) (NDEB) [10]. The characteristics of liquid products are similar to crude oil which has lower quality than the commercial oil. It was not good to use as alternative fuel oils [11, 12]. Thus, it must be improved characteristic and quality before using in vehicle as a valuable diesel-range and gasoline-range hydrocarbons. So that, the distillation of raw pyrolytic oil or crude oil for valuable diesel-range and gasoline-range hydrocarbon is operated and developed for a standard and safety engine concern. Further investigations are required to enhance the generation of value added products (fuel) with low investments without affecting the environment [13-15].

2. EXPERIMENT

2.1 Raw Materials

The compositions of MPWs which were separated from the MSWs in the closed landfill by the front end system including polypropylene (PP), polyethylene (PE) and polystyrene (PS). These types of PWs are the main components of the plastics fraction. The properties of MPWs have 20% of dirty contaminated contents and 10% of moisture contents.

2.2 Pyrolysis of Municipal plastic waste

The commercial pyrolysis plant (Muang Sa-ad Co., Thailand) is operated using a rotary kiln reactor with silica-alumina as a catalyst. [14]. In addition, the commercial filler, mainly consisting of kaolinites (china clay), was mixed with the catalyst [16]. In each batch, the catalyst and commercial filler was filled up about 3% of the input of MPWs (by wt%). The amount of the catalyst and filler were about 30% and 70% of the mixure (by wt%). In addition the calcium hydroxide ($Ca(OH)_2$) was filled up in the reaction about 1% of the input of MPWs (by wt%) for buffer and HCl absorber. The MPWs were fed and burned in the reactor. Briefly, these MPWs are burned up to 350-450 °C by LPG burner in atmospheric pressure. And then they are maintained with long lapse time or the retention time at 380-450°C about 6-8 hours. In a typical run, the reactor is heated without oxygen. The gaseous products are condensed to liquid oil in a condenser tank at 25-30°C. When the liquid fractions cool down, they reform to the pyrolytic oil (PO) [7].

2.3 The sample of pyrolytic oil

The infiltrated pyrolytic oil (IPO) was obtained from PO which was coagulated with commercial clay about 1% of total pyrolytic oil (by wt%) in coagulation tank that operates using coalescence and centrifugal force. Finally, the IPO is clear with a gold-yellow color. After that, the IPO was filtered using a commercial fuel filter size 0.5 micron.

The distilled pyrolytic oil (DPO) was obtained from PO which was distilled based on the boiling point of 150-300 °C and was filtered using a commercial fuel filter size 0.5 micron.

2.4 Determination of physical/chemical characteristics and qualities of pyrolytic oil

The pyrolytic oil samples were tested by the quality control division of PTT Public Company Limited, Thailand. These pyrolytic oil samples were classified into 3 types as follows: the pyrolytic oil (PO), the infiltrated pyrolytic oil (IPO), and the distilled pyrolytic oil (DPO).

- Physical property as appearance was determined by visual.
- API Gravity@ 60°F and Specific Gravity @ 15.6/ 15.6°C were determined according to ASTM D 4052-09.
- Kinematic Viscosity@40°C,(mm^2/s) was determined according to ASTM D 445-06.
- Flash Point,(P.M),(°C) was determined according to ASTM D 93-06.
- Normal Distillation such as Initial BP, 10% vol. Recovered, 50% vol. Recovered, 90% vol. Recovered,(°C) were determined according to ASTM D 86-05.
- Sulphur Content, (%wt) was determined according to ASTM D 2622-05.
- Water and Sediment,(% vol) was determined according to ASTM D 2709-96.

3. RESULTS AND DISCUSSION

3.1 Pyrolysis of MPWs

The results of each pyrolysis batch of MPWs under atmospheric pressure show that thermal and catalytic cracking can be carried out with the yield of 55-60% (by wt%) fuel oil (about 10% of carbon black residue) in the reactor temperature range of 350-450°C [17]. Temperature of gas that flows from the reactor into gas tank was 220-400°C, and then the PO was obtained using a condenser in the temperature range of 25-30°C. The temperature profile can be observed in Fig.1.

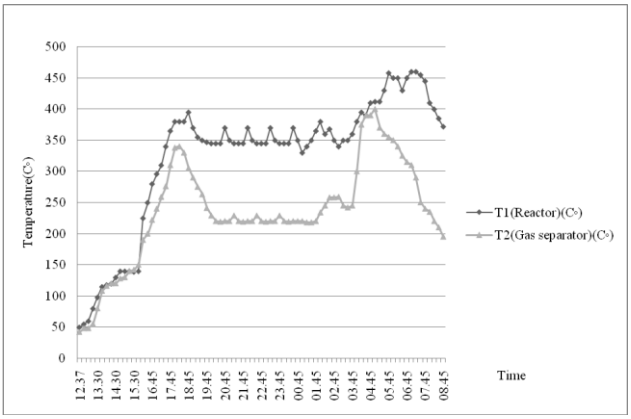

Fig.1. Temperature Profile of the commercial rotary kiln reactor for PO Product.

The PO was taken into the reactor again and heated up in the temperature range 300-400°C of reactor. Then, the PO was distilled based on the boiling point of 150-350°C in diesel range [8-9]. The DPO was obtained from this distillation condition. The temperature profile can be observed in Fig.2.

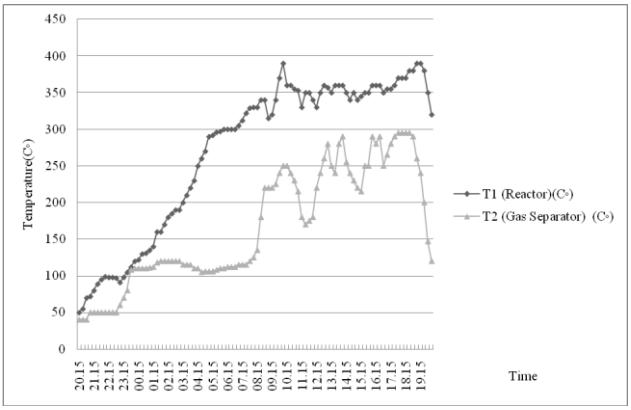

Fig.2. Temperature Profile of the commercial rotary kiln reactor for DPO Product.

The characteristics and qualities of pyrolytic oil products were summarized as shown in Table 1.

Table1. Characteristics and Qualities of Pyrolytic Oil (PO), Infiltrated Pyrolytic Oil (IPO), and Distilled Pyrolytic Oil (DPO)

Test items	Test methods	Standard Indicators (1)	Standard Indicators (2)	Results		
				DPO	IPO	PO
1.Appearance	Visual	Clear	Clear	C&B	Hazy	C&B
2.APIGravity@60°F	ASTM D 4052-09	31.2-34.8	31.2-34.8	55.05	45.36	52.62
3.Specific Gravity@15.6/15.6 °C	ASTM D 4052-09	0.81-0.87	<0.92	0.7585	0.8000	0.7685
4.Kinematic Viscosity@40°C, mm^2/s	ASTM D 445-06	1.8-4.1	<8.0	0.607	1.398	1.267
5.Flash Point,(P.M), °C	ASTM D 93-06	>52	>52	<25.0	<25.0	<25.0
6.Distillation :Initial BP, °C :10% vol. Recovered, °C :50% vol. Recovered, °C :90% vol. Recovered, °C	ASTM D 86-05	 <357	Not notice -	85.6 110.0 125.1 156.9	67.6 114.9 183.8 384.2	45.1 102.1 217.4 330.4
7.Sulphur Content, %wt	ASTM D 2622-05	<0.035	<1.5	0.0038	0.0216	0.0021
8.Water and Sediment, % vol	ASTM D 2709-96	<0.05	<0.3	0.005[(a)]	0.005[(a)]	0.005[(a)]

Remark: BP is Boiling point.
(1) is Engine oil for 4-stroke engines
(2) is Engine oil for diesel engines
C&B is Clear and Bright

To supervise of the provision of Clause 5 of Notification of Department of Energy Business; Prescribing the Characteristic and Quality of Engine Oil B.E. 2554 (No.5) (2011) [10] in characteristic and quality of engine oil that is appropriate and in accordance with the international standards shall be produced follow this notification. For Muang Sa-ad Co., the pyrolysis plant tries to develop and produce the pyrolytic oil to be similar commercial diesel oil.

Table 1 shows that the characteristics and qualities of pyrolytic oil products were relatively compared with the standard engine oil for 4-stroke engines and diesel engines. The API Gravity@ 60°F point of DPO is the highest than IPO and PO. In addition to, DPO has Specific Gravity@15.6 /15.6°C point the lowest than IPO and PO. The Kinematic Viscosity@40°C point distribution of DPO, IPO and PO is 0.607, 1.398, and 1.267 mm^2/s, respectively. Especially, the Kinematic Viscosity@40°C point of IPO and PO is nearly close to the result of Fazal Mabood., et al, in 2010 [18].Typically, the diesel engine oil must have appropriate viscosity because it can be affect the fuel injection system. At the same time it help to lubricate the nozzle of the injector pump. If oil is too thick to spread the spray is not good. But if it too clear is not enough to provide lubrication. The injector pump may be worn until death or the pump leak [8]. The flash point of all samples is lower than the standard indicator. It is different from the result of M.Mani, G.Nararajan in 2009 [19] and Fazal Mabood., et al, in 2010 [18] that has a value of 42-43°C. For distillation at 90% vol. recovered, DPO, IPO and PO have a value of 156.9 °C, 384.2°C, and 330.4°C, respectively. Sulphur content by %wt of all samples is lower than standard indicator, as a value of 0.0038 %wt, 0.0216 %wt, and 0.0021 %wt, respectively. Water and Sediment in all samples was examined by %vol. It has value in specification of standard indicator, as a value of 0.005(a) in every samples. This mean that the 3 types of pyrolytic oil products have almost characteristics and qualities similar to engine oil for 4-stroke engines except for kinematic viscosity@40°C and flash point item. They can also be used as fuel in compression ignition engines [19] and in a Direct Injection (DI) diesel engine [20]. The properties of the oil derived from waste plastic similar to that of diesel [20]. In addition they have almost characteristics and qualities similar to engine oil for diesel engines except for flash point item. Diesel oil which has low flash point may not be volatile enough to start the engine when the engine is cold.

Consequently these pyrolytic oils could be valuable diesel-range as both of engine oil for 4-stroke and diesel engines. The pyrolytic oil has higher calorific value than specification point of diesel (42,000kJ/kg). The calorific value was found that as a value of 41,858 kJ/kg[21]. In addition, the waste plastic oil from the result of M.Mani, G.Nararajan and S.Sampath in 2011 that has a value of 44,340 kJ/kg and compares with diesel (46,500kJ/kg) [20]. However, they are still not suitable for diesel-engine usage in terms of flash point, Kinematic Viscosity, pour point and cetane number of the hydrocarbons[18,22-23]. Because cetane is an important feature in measuring the quality of ignition (Ignition Quality) of diesel fuel at a faster or a time delay in the ignition to have a high cetane. This will allow the engine to restart with a low temperature. And the engine heats up quickly without any interruption due to non-flammable (Misfiring) or white smoke. Reduce gum stains (Varnish) and deposit soot in the engine. Problems with the engine running smoothly [8,19-20,24]. Furthermore these parameters need to be investigated and controlled for the pyrolytic oil.

4. CONCLUSION

The pyrolytic oil was produced from pyrolysis of municipal plastic wastes in the commercial rotary kiln plant. Thermal and catalytic degradation of the pyrolytic oil was studied using silica-alumina and commercial filler. The raw pyrolytic oil is composed of heavy hydrocarbons

as well as diesel-range hydrocarbons. The resulting oil (mixture of liquid hydrocarbons) is continuously distilled in boiling point into heavy hydrocarbons as diesel-range products inside the same reactor. There are 3 types of pyrolytic oil products including PO, IPO and DPO. The physical and chemical properties of the polymer fuels were measured. These products are little different from the properties of commercial oils and standard engine oil of the Clause 5 of Notification. According to testing items, all types of pyrolytic oil products have almost characteristics and qualities similar to engine oil for 4-stroke engines and diesel engines. Consequently these pyrolytic oils could be valuable diesel-range as both of engine oil for 4-stroke and diesel engines. However, they are still not suitable for diesel-engine usage in terms of flash point, Kinematic Viscosity, pour point and cetane number of the hydrocarbons. Furthermore these parameters need to be investigated and controlled for the pyrolytic oil.

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NOMENCLATURE

PO = Pyrolytic Oil
IPO = Infiltrated Pyrolytic Oil
DPO = Distilled Pyrolytic Oil
EPPO = Energy Policy and Planning Office, Ministry of Energy, Royal Thai Government
FCC = Fluid Catalytic Catalyst
H/C ratio = Hydrogen/carbon ratio
PWs = Plastic Wastes
MPWs = Municipal Plastic Wastes
MPO = Mixed Plastic Oil
HCl = Hydrochloric acid
LPG = Liquid Petroleum Gas
PP = Polypropylene
PE = Polyethylene
PS = Polystyrene
DI = Direct Injection
BP is Boiling point
API = American Petroleum Institute
C&B = Clear and Bright

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