International Journal of Engineering Trends and Technology
ISSN: 2231 – 5381 /doi:10.14445/22315381/IJETT-V69I4P204
Volume 69 Issue 4, 21-26, April 2021

Disposal Municipal RDF Waste around Srinakharinwirot University by Mobile Pyrolysis

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Abstract *- The aim of this project is to study the mobile pyrolysis plant to be used in the preparation of the operation manual for the mobile pyrolysis plant and analyze specific gravity, viscosity, hydrocarbon compounds of pyrolysis oil from municipal waste around Srinakharinwirot University in the form of RDF waste. This is to reduce the problem of municipal waste management and also add value to the municipal waste around Srinakharinwirot University, which had been through the pyrolysis process and become an oil product. From the experiment, it was found that the specific gravity of the sample oil was 0.787 with the viscosity of 3.326 centistokes (cSt) and obtain the amount of oil from the analysis of hydrocarbon compounds at the temperature range of 65-170ºC equals 92 mL, at the temperature range of 170-250ºC equals 108 mL and at the temperature range more than 250ºC in 10 minutes equals 34 mL which is close to the standard property of pyrolysis oil. Finally, the operation manual has been obtained from the study of this mobile pyrolysis plant.*

Keywords — *mobile pyrolysis, pyrolysis oil, RDF waste, waste treatment*

I. INTRODUCTION

Energy is an undeniable factor for humanity's survival and the major driven force of both world and country economy. As for now, Thailand is facing an issue with a fluctuating price of petroleum [1]. This problem has affected the overall picture of Thailand's economy, including its citizens [2]. As the demand for technology and development of economy, Thailand has been producing tons of plastic—later turn into trash [3],[4]. These plastics have adversely affected the environment, prelude to major concerns such as global warming and climate change [5],[6]. Pyrolysis technology has been found as an effective technique to convert plastic solid waste to pyrolysis fuels [7],[8],[9]. Subsequently, researchers have arisen with the idea of transforming trash

This work was fund supported by the Ministry of Energy, Thailand.

Into energy using pyrolysis plant [10],[11]. This process, which is being supported by the government, is practical and effective in terms of reducing trash and producing petroleum products. This also increases the value of municipal waste around Srinakharinwirot University [12]. The research will conduct the demonstration of operating pyrolysis mobile plant, which is located in Srinakharinwirot University, Ongkharak campus, Nakhon Nayok, Thailand.

II. MATERIALS AND METHODS

A. Equipment

1) Air compressors**:** The main purpose of air compressors is to force drive air or gas from one place to another, creating the difference in pressure from 35 psi to nearly 65,000 psi [13]. These deviations cause a decrement in air volume simultaneously and increment in temperature. Air compressors can be classified by their design and procedure into three main types: reciprocating compressors, rotary compressors, and centrifugal compressors.

2) Cooling tower: Cooling tower is where hot water from the condenser or other equipment in the plant comes to decreases its temperature by exposing the heat in water with air. The use of other implementing equipment is necessary to assist in turning hot water into small particles. Subsequently, the principle of sensible heat can be implied to release the high temperature of water [14].

3) Valve: The functions of the valve are to control the direction and flow rate of substance in the tube, whether these substances might be gas, water, or steam. Valve is differentiated into various types: gate valve, globe valve, needle valve, ball valve, butterfly valve, three ways valve, air vent valve, ball float valve, duo check valve, swing check valve, foot valve, knife valve, piston valve, pressure reducing valve, safety valve, solenoid valve, pressure relief valve, steam trap valve.

4) Separator**:** Knock-out drum or knock-out vessel is used to separate liquid that is contaminated in flare gas from the production line.

5) Distillation column: Plate distillation column - The selection of this particular type of distillation column has to be precise in both dimension and material wise. The process can be boiled down into meeting 3 essential criteria, which yields a proper specification for constructing the column. Plates are put in place in order to make sure that the mass transfer between the liquid phase and gas phase is accurate. The placement of plates is also crucial to the prevention of

liquid overflow inside the system. The proportion between the flow rate of liquid and gas is what constitutes differences between the three existing flow patterns. 1) Crossflow: This is the most common type of flow that offers a good length of the liquid path, thus yielding a good mass transfer coefficient.
2) Reverse flow: A long and drawn-out liquid path that suits the transfer of a smaller proportion but also decreases the size of the system's downcomer by a significant amount. 3) Double pass: Splitting the flow of fluid into 2 ways. This is preferably used when the ratio between liquid and gas is greater than normal. The transfer of fluid between the upper and lower plate is directed over the weir and passes down through a downcomer that has its lower end submerged in the liquid of the lower plate [15]. Regulating components that prevent the returning flow of gas are caps, which contains risers that make way for gas to flow through different types of plate: bubble cap tray, sieve or perforated tray, valve tray.

Packed bed distillation column - Packed bed distillation column is used when the required size of the column is smaller than 2 feet in diameter. The cost of construction for a packed bed column is relatively cheaper but strictly only for the smaller scale. Bigger packed bed columns are prone to a system failure called channeling [16]; a lower flow rate of fluid causes the contact between gas and liquid to diminish, making the whole mass transfer less effective. Various types of packings made of different types of materials of construction are available, and both random and structured packings are commonly used.

6) Condenser: Air-cooled condenser - Air-cooled condensers are made up of multiple layers of small tubes, which are connected to outside fins. These fins will conductively dissipate the heat from the coolant, and any liquid result from the condensation due to the outward flow of the coolant will be stored at the liquid receiver.

Water-cooled condenser - Water cooled condenser has consisted of shells and tubes. Cold vapor from the coolant will enter the condenser via the shell and will be condensed around the outer surface of the tube. The removal of excess gas can be achieved by connecting the purge pipe to the top part of the condenser tube to prevent contamination.

***7) Pump*:** Pumps are a critical component for generating movement and flow of fluid. The pump can be classified by its function into 4 types: centrifugal, rotary, reciprocating, and specialized.

B. Operating Manual

***1) Preparation*:** Air-cooled condenser - Open the reactor lid with an adjustable wrench (12 inches) to clean the inside of the reactor. Using a metal spade to scrape off any excess sediments before the extraction using a cyclone machine.

(a)

(b)

(c)

Fig. 1 Reactor preparation (a) Opening the lid of a pyrolysis reactor (b) Using metal spade to scrape off any remaining sediments and (c) Extracting excess sediments and any remaining solid from previous operating sessions using cyclone machine

Cooling tower preparation - Replace water inside the cooling tower's water reservoir.

Fig. 2 Pumping out old water from the cooling tower

2) Raw material preparation: Preparation of raw material for the pyrolysis reactor.

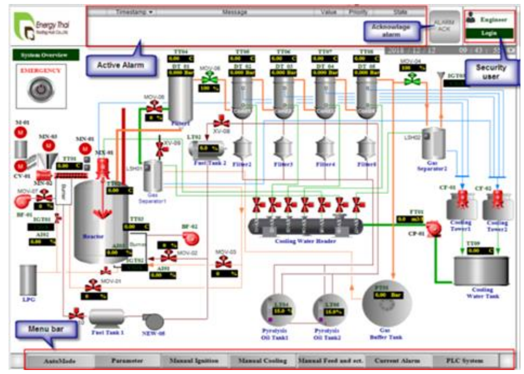
(a)

(b)

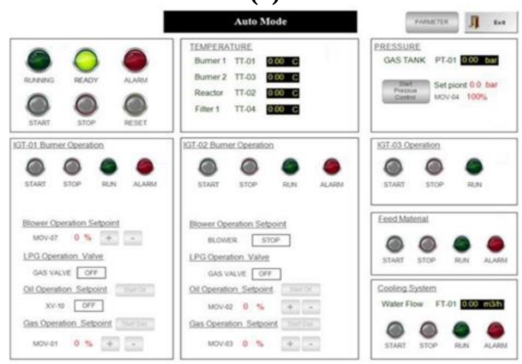
Fig. 3 Raw material preparation (a) Dumping RDF waste into the reactor and (b) RDF waste from the area around the university

3) Operating procedure for pyrolysis plant: 1. Pumping in LPG to ignite burner head of the reactor by using Programmable Logic Control (PLC) software

2. Open Programmable Logic Control (PLC) software for the pyrolysis plant



(a)



(b)

Fig. 4 PLC software (a) PLC panel and (b) Auto Mode panel

3. Startup the system by using Auto Mode - (a) Open Auto Mode window then check for the bright green light indicator labeled “Ready” (b) Press “Start” button on the Auto Mode window (c) Initiation procedure of Burner 02 with the following steps:

(1) Start blower BF-02 and set the timer

(2) Open LPG valve then ignite for 3 seconds

(3) After a successful ignition, wait until an internal temperature reach 100ºC

(4) After the reactor temperature has reached 100ºC, open valve MOV-2 (51-53%) as set the delay for turning off LPG

(5) Switching to an internal gas system can be done by pressing the “Start Gas” button (configurable at valve MOV-03 control panel)

Fig. 5 Auto Mode with bright green light indicator labeled “Ready” on

4. Initiate filling system - (a) If the temperature of TT-02 exceeds the preset temperature, open MOV-06 at 100%, then close MOV-5 and XV-09 (b) If the temperature of TT-02 is lower than the preset temperature, open MOV-05 and XV-09, then close MOV-06 at 0%.

5. Initiate cooling system - (a) If the temperature of TT-02 exceeds the preset temperature, open XV-01 to XV-05. Press Start CP-01(Water Pump), CF-01(Fan), and CF-02(Fan) (b) If the temperature of TT-02 is lower than the preset temperature, close XV-01 to XV-05. Press Stop CP-01(Water Pump), CF-01(Fan), and CF-02(Fan).

6. Start mixing reactor tank - (a) If the temperature of TT-02 exceeds the preset temperature, press Start MX-01 (b) If the temperature of TT-02 is lower than the preset temperature, press Stop MX-01.

7. Gas separator 1 - If the water level inside is lower than LSH01 for more than 30 minutes, the system will automatically open XV-06 to fill the water up to levelLSH01. XV-06 will close automatically after the water level has reached LSH01.

8. Gas separator 2 - If the water level inside is lower than LSH01 for more than 30 minutes, the system will automatically open XV-07 to fill the water up to level LSH01. XV-07 will close automatically after the water level has reached LSH01.

Fig. 6 Gas Separator 1 and 2

4) Sample collecting**:** After the process of pyrolysis is over, start collecting sample petrol from the collecting tank. Fill up the 4.5 liters container by opening the access valve at the collecting tank.

5) Shutting down the mobile pyrolysis plant: Press the "Stop" button on the Auto Mode panel to stop the operation of the mobile pyrolysis plant, then switch off the plant.

C. Analysis

1) Viscosity analysis**:** To analyze the viscosity of the sample, use Brookfield viscometer at 40ºC. Place the sample (1-2 mL) into the sample cup, then put it back into the viscometer. Adjust the cone until it meets the sample and set it to 20 RPM. The result will be displayed in the centipoise unit (cP). To convert the result into centistokes (cSt), solve equation (1).

$$\mu_{cSt} = \frac{\mu_{cP}}{\rho \times 1000} \tag{1}$$

where

μ_{cP} = Viscosity (cP)

μ_{cSt} = Viscosity (cSt)

P = Density of the sample (g/cm^3)

2) Specific gravity analysis**:** Specific gravity of the sample can be measured by using a hydrometer. Pour the 15.6ºC sample into a beaker, then slowly insert hydrometer into the sample until it floats. Read the result by observing the scale at the lowest point under the surface tension curve of the liquid.

3) Hydrocarbon analysis**:** The hydrocarbon content of the sample can be analyzed by using the distillation kit with 300 mL of the sample at three different temperature gaps. (65-170, 170-250, and more than 250ºC).

D. Product Analysis

First of all, the raw materials used in this pyrolysis process are explained. Polyethylene, PE, is one type of polyolefin which was discovered in 1933 by Reginald Gibson and Eric Fawcett [17]. The distinction between 3 types of polyethylene, LDPE, MDPE, and HDPE, is brought out by the variations of specific gravity. Another raw material that can bring a great result in the property of pyrolysis oil is PP, which stands for polypropylene. PP is a synthetic polymer invented by Guilio Natta in 1954 [18]. Other materials such as PS, PET, ABS were also used in this research.

TABLE I PROPERTIES OF PYROLYSIS PRODUCT

Product	Boiling point (°C)	State of matter	Carbon content
Petroleum Gas	< 30	Gas	1-4
Light Naphtha	30-110	Liquid	5-7
Heavy Naphtha	65-170	Liquid	6-12
Kerosene	170-250	Liquid	10-14
Diesel Oil	250-340	Liquid	14-19
Lubricant Oil	> 350	Liquid	19-35
Wax	> 500	Solid	>35
Fuel Oil	> 500	Viscous liquid	>35
Asphalt	> 500	Viscous liquid	>35

TABLE II PRODUCT FROM PYROLYSIS PROCESS AT THE TEMPERATURE OF 800ºC

Raw material	Heat rate (ºC/min)	Product (% by weight)		
		Char	Oil and wax	Gas
PS	5	1.95	95.77	2.28
	10	1.81	95.97	3.40
	15	1.60	92.75	5.65
	20	1.04	92.65	6.31
PE	5	0.18	81.65	18.17
	10	0.10	81.33	18.57
	15	0.01	72.63	27.36
	20	0.00	61.24	38.76
ABS	5	1.12	95.99	2.89
	10	1.43	92.66	5.91
	15	1.47	90.47	8.06
	20	1.57	89.57	8.86
PET	5	9.37	39.02	51.61
	10	8.28	35.40	56.32
	15	5.75	29.71	64.54
	20	5.63	29.16	65.21
PP	5	0.11	83.34	16.55
	10	0.13	82.67	17.20
	15	0.10	82.02	17.88
	20	0.10	68.06	31.84

From Table 2, it is shown that PS and ABS can be transformed into oil and wax, respectively, with exceeding numbers than others, clustered around 90 percent. However, these two materials, simultaneously, can generate quite an amount of char that contains hazard contaminants and is detrimental to the environment [19],[20]. Therefore, PP and PE are normally used as raw materials, albeit the inferior of PS and ABS in oil production. The relatively low amount of char generated in the pyrolysis process of PP and PE compensates for the lower amount of pyrolysis oil.

III. RESULT AND CONCLUSIONS

The aim of the study of the mobile pyrolysis plant is to accumulate all information and to create an operation manual. The experiment covered several fields of study: equipment preparation, processing before pyrolysis oil, oil sample collection, emergency shut down. All these studies lead to enlightenment in the analysis of specific gravity, viscosity, hydrocarbon compounds of pyrolysis oil. The results showed that the specific gravity of pyrolysis oil at 15.6ºC is 0.787; the number is quite close to the standard specific gravity of pyrolysis oil.

In order to properly analyze the viscosity of pyrolysis oil at 40ºC, the test is conducted repeatedly 3 times. The results are 2,557.9 cP, 2,531.5 cP, and 2,755.5 cP. Hydrocarbon compounds at the temperature range of 65-170ºC equals 92 mL, at the temperature range of 170-250ºC equals 108 mL and at the temperature range more than 250ºC in 10 minutes equals 34 mL, which is close to the standard property of pyrolysis oil. This shows the accuracy of the operation manual obtained from the study of the mobile pyrolysis plant.

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