Catalytic Pyrolysis by Heat Transfer of Tube Furnace for Produce Bio-Oil

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Abstract

Catalytic pyrolysis by heat transfer model can be solved the control temperature in tube furnace to produce bio-oil by continuous pyrolysis process and this study concern the products yield of bio-oil from mixed biomass consist of Cogongrass, Manilagrass and the leaf of trees, which conducted temperatures in the range of ~ 400-550°C, considering the feed rate of 150, 350, and 550 rpm ($r{\cdot}min^{-1}$)]. Preliminary result of proximate analysis was founded that the high volatile matter, low ash and moisture. The products yield calculation showed that the liquid yield of bio-oil was highest of 55.60 %, and 45.45%., at 350 rpm and 550 rpm., respectively, the solid yield of bio-oil was highest of 27.35 %, at 350 rpm, and the gas yield of bio-oil was highest of 43.60 %, at 150 rpm. Indicated that biomass from mixed biomass had good received yields because of low solid yield and gas yield and high liquid yield. The compounds detected in bio-oil from mixed biomass showed that the functional groups, especially; phenols. For the purpose that; in this research not only concern the feed rate and the heat transfer for contact biomass but also concern the control gas flow and temperature balanced.

Keywords

Catalytic Pyrolysis; Heat Transfer; Continuous Pyrolysis Reactor; Received Oil Yield

Introduction

This research was conducted by using mixed biomass transformed to bio-oil by continuous pyrolysis reactor on standard criteria and analysis the properties of material and products. In present, the fuel is being concerned in every country [1-3]. Now we are looking at the fuel which synthesized from natural matter, especially; residual plant[5-6], by using the pyrolysis method combined with the theory of heat transfer for control the temperature balance in the continuous pyrolysis reactor (tube furnace)(Fig 1). The fuels from natural matter have a good solve and can reduce a waste in widespread areas of central part of Thailand. Continuous pyrolysis reactor is a one excellent of technology for synthesized bio-oil [7-9]. In this case want to produce bio-oil in high potential performance of yield and properties by applied the heat transfer model for control some criteria of reactor to an generate the alternative energy source.

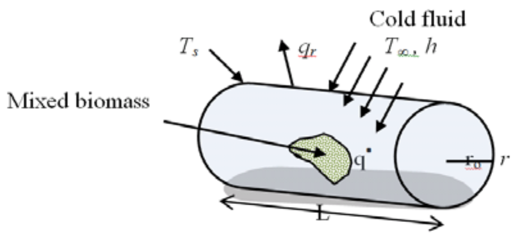

FIG. 1 CONDUCTION IN A CONTINUOUS PYROLYSIS CYLINDER WITH UNIFORM HEAT GENERATION

To determine the temperature distribution in the cylinder reactor, the appropriate from of the heat equation. For constant thermal conductivity k, Equation (1) reduces to

$$\frac{1}{r}.\frac{d}{dr}=\left(r\frac{dT}{dr}\right)+\frac{q^{\bullet}}{k}=0 \qquad (1)$$

Separating variables and assuming uniform generation, this expression maybe integrated to obtain

$$r\cdot\frac{dT}{dr}=\frac{q^{\bullet}}{2k}r^{2}+C_{1} \qquad (2)$$

Repeating the procedure, the general solution for the temperature distribution becomes

$$T(r)=-\frac{q^{\bullet}}{4k}r^{2}+C_{1}\ln r+C_{2} \qquad (3)$$

To obtain the constants of integration C_1 and C_2, we apply the boundary conditions

$$\left.\frac{dT}{dr}\right|_{r=0} = 0 \text{ and } T(r_o) = T_s \tag{4}$$

From the foregoing symmetry condition at r = 0 and Equation (2), it is evident that $C_1 = 0$. Using the surface boundary condition at $r = r_o$ with Equation (3), we then obtain

$$C_2 = T_s + \frac{q^{\bullet}}{4k} r_o^{\,2} \tag{5}$$

The temperature distribution is therefore

$$T(r) = \left[\frac{q^{\bullet} r_o^{\,2}}{4k}\right]\left[1 - \frac{r^2}{r_o^{\,2}}\right] + T_s \tag{6}$$

Evaluation Equation (6) at the centerline and dividing the result into Equation (6), we obtain the temperature distribution in nondimensional form

$$\left[\frac{T(r) - T_s}{T_o - T_s}\right] = 1 - \left[\frac{r}{r_o}\right]^2 \tag{7}$$

Where T_o is the centerline temperature. The heat rate at any radius in the pyrolysis cylinder may, of course, be evaluated by using Equation (6) with Fourier's law [10,11]. To relate the surface temperature, T_s, to the temperature, T_∞, of the cold fluid, either a surface energy balance or an overall energy balance may be used. Choosing the second approach, we obtain

$$q^o(\pi r_o^{\,2} L = h(2\pi r_o L)(T_s - T_\infty)$$

Or

$$T_s = T_\infty + \left[\frac{q^{\bullet} r}{2h}\right] \tag{8}$$

The foregoing approach may also be used to obtain the temperature distribution in cylindrical and in solid spheres for a variety of boundary conditions [11].

Experimental

Feedstock and Experimental Set-up

Preparation of mixed biomass, crust and bring to oven at 100 °C for ~ 2 hr until it is completed dry or less than 5 percent moisture. The samples were separated through a sieve to the approximate 450-1,000 microns.

The samples were fed to continuous reactor (Fig. 2), for pyrolysis process at ~ 400-550 °C and control the N_2 flow rate around 0, 50, 100, 150, 200, 400 ml/hr and feed samples averaging of 150, 350, and 550 rpm (r·min⁻¹). The bio-oil product were analyzed by Ultimate analyzer, Proximate analyzer, calculate the received oil yields and analyze the chemical compound by Gas Chromatography with Mass Spectrometer.

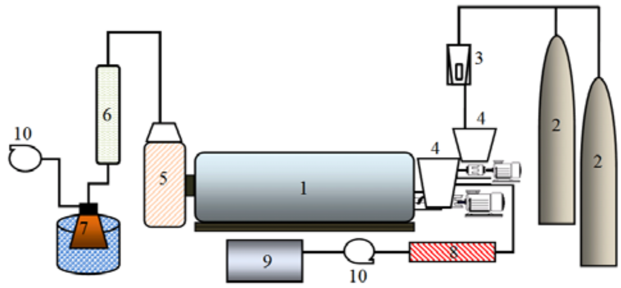

FIG. 2 SCHEMATIC DIAGRAM OF EXPERIMENT SETUP: 1. PYROLYSIS REACTOR (TUBE FURNACE) 2. NITROGEN TANK 3. ROTAMETER 4. HOPPER 1,2 5. SEPARATOR 6. CONDENSER 7. FLASK IN ICE BUCKET 8. ELECTRICAL COIL HEATER WITH TEMPERATURE CONTROLLER 9. ENCLOSED DEIONIZER WATER TANK 10. VACUUM PUMP

Proximate Analysis

Proximate analysis is the most used analysis for characterizing biomass in connection with their utilization, this experiment was analysis by ASTM D 3173-3175. The process are determined the distribution of products obtained when the sample is heated under specified conditions. Proximate analysis separates the products into 4 groups: (1) moisture, (2) volatile matter, (3) fixed carbon, the nonvolatile fraction of char, and (4) ash.

Ultimate Analysis

In the experiment was analysis form of element components of bio-oil concerned with determination of only Carbon (C), Hydrogen (H) and Nitrogen (N) in a sample, these analyzed by Ultimate analyser [12-13].

Received Oil Yield

$$\%\ \text{Liquid yield} = 100 \times \left[\frac{W_{Liq}}{W_{ini}}\right]$$

$$\%\ \text{Solid yield} = 100 \times \left[\frac{W_R}{W_{ini}}\right]$$

% Gas yield $= 100$ - % Liquid yield - % Solid yield

W_{ini}	=	Initial weight
W_R	=	Residual solid weight
W_{Liq}	=	Liquid product weight

Chemical analysis

Gas Chromatography with Mass Spectrometer, GC-MS was used to analyse the light components in bio-oil and investigating the molecular compositions qualitatively [14-15]. The analyses detective and identify organic compounds both aliphatic hydrocarbon and aromatic hydrocarbon.

Results and Discussion

Preliminary, proximate analysis of mixed biomass used in the three species (Cogongrass, Manilagrass and the leaf of trees) was founded that the fixed carbon of mixed biomass was 17.28 wt.%, which will have a major effect on the quality of bio-oil as well. The other three proximate analysis as following; The moisture, ash and volatiles of mixed biomass were 2.51, 17.00 and 63.21 wt.%, respectively (Table. 1). The results showed that the stability for the range of material compound in mixed biomass can be synthesized bio-oil in high efficiency, because consist of the high volatile matter and low ash and moisture.

TABLE 1 PROXIMATE ANALYSIS AND ULTIMATE ANALYSIS OF MIXED BIOMASS

Proximate analysis (wt.%)	mixed biomass	Ultimate analysis (wt.%)	mixed biomass
Moisture	2.51	C	38.23
Ash	17.00	H	5.27
Volatiles	63.21	N	1.00
Fixed carbon	17.28	O	55.16

The ultimate analysis of mixed biomass was found that the element contents as following; carbon, hydrogen, nitrogen and oxygen were 38.23, 5.27, 1.00 and 55.16 %, respectively (Table. 1)., according to the result of safflower seed [12,13] showed the carbon, hydrogen, nitrogen, and oxygen of 49.5, 6.9, 3.0, and 40.6, respectively.

The result of products yield (3-phase; gas, liquid and solid) of bio-oil by during pyrolysis, which takes place at temperatures in the range of ~ 400-550°C, to compare the received oil yield from mixed biomass at a feed rate of feed rate of 150, 350 and 550 rpm; revolutions per minute ($r \cdot min^{-1}$)]. Preliminary calculate of the product oil yield of mixed biomass, the result showed that the gas yield of bio-oil obtained mixed biomass were 43.6, 19.05 and 29.25 %, at 150, 350 and 550 rpm., respectively., (Fig. 3).

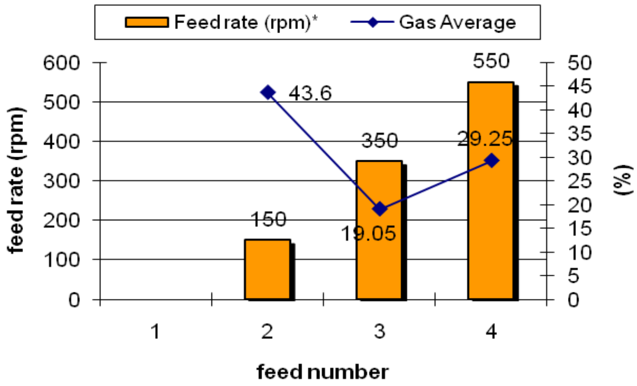

FIG. 3 GAS YIELD OF BIO-OIL OBTAINED FROM MIXED BIOMASS

Liquid yield of bio-oil obtained from mixed biomass was highest of 55.6 %, at 350 rpm. And the another of liquid yield obtained from mixed biomass were 29.55 and 45.45 %, at 150 and 550 rpm., respectively (Fig. 4). Indicated that the liquid yield of bio-oil obtained from mixed biomass was high volume (> 50 %) by the heat control in continuous pyrolysis reactor and can be improving to high efficiency of bio-oil production on next step.

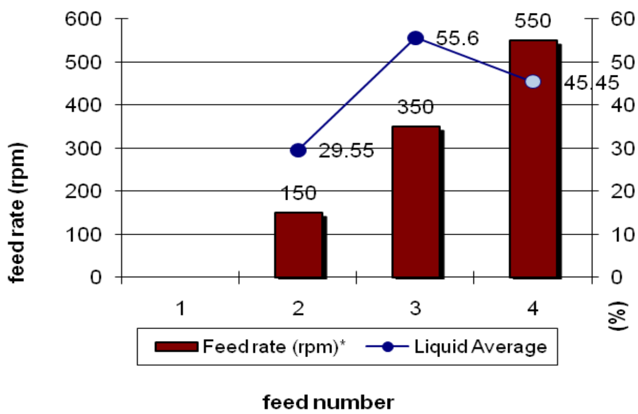

FIG. 4 LIQUID YIELD OF BIO-OIL OBTAINED FROM MIXED BIOMASS

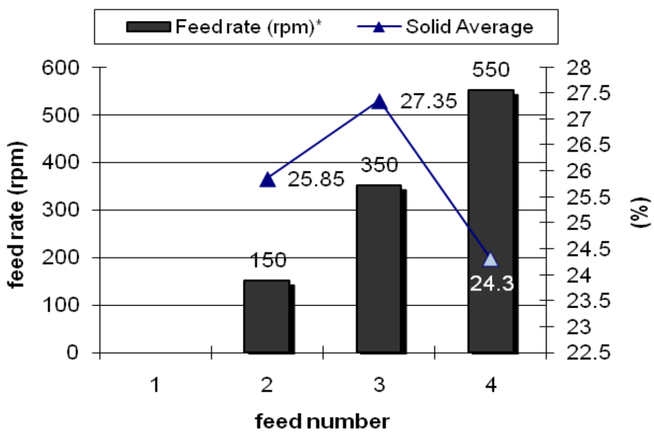

FIG. 5 SOLID YIELD OF BIO-OIL OBTAINED FROM MIXED BIOMASS

Solid yield of bio-oil obtained from mixed biomass was highest of 27.35 %, , at 350 rpm. And the another of solid yield obtained from mixed biomass were 25.85and 24.3 %, at 150 and 550 rpm., respectively (Fig. 5).

TABLE 2 COMPOUNDS DETECTED IN BIO-OIL FROM MIXED BIOMASS

Compound	%	formula	MW	Detection
1,2-Benzenediol	0.5			×
1,2-Cyclopentanedione, 3-methyl-	0.82	$C_6H_8O_2$	112.12	×
2-Cyclopenten-1-one, 2,3-dimethyl-	1.08			×
Phenol	19.78	C_6H_6O	94.11	×
Phenol, 2,3-dimethyl-	2.23	$C_8H_{10}O$	122.16	×
Phenol, 2,4-dimethyl-	1.41			×
Phenol, 2,5-dimethyl-	0.42	$C_8H_{10}O$	122.16	×
Phenol, 2,6-dimethoxy-	12.47			×
Phenol, 2,6-dimethyl-	*	$C_8H_{10}O$	122.16	
Phenol, 2-ethyl-	0.85	$C_8H_{10}O$	122.16	×
Phenol, 2-methoxy-	3.81			×
Phenol,2-methoxy-4-(1-propenyl)-, (E)-	*	$C_{10}H_{12}O_2$	164.19	
Phenol, 2-methoxy-4-methyl-	0.72	$C_{10}H_{12}O_2$	164.19	×
Phenol, 2-methoxy-4-propyl-		$C_{10}H_{12}O_2$	164.19	×
Phenol, 2-methyl-	2.87	C_7H_8O	108.13	×
Phenol, 3,4-dimethyl-	0.62			×
Phenol, 3-methyl-	3.86	C_7H_8O	108.13	×
Phenol, 4-ethyl-	1.54	$C_8H_{10}O$	122.16	×
Phenol, 4-ethyl-2-methoxy-	2.23	$C_9H_{12}O_2$	152.18	×

*can not determined

The compounds detected in bio-oil from mixed biomass showed that the hydrocarbon compounds compose of hydroxyl and carboxyl groups, especially; phenols (Phenol, 2,3-dimethyl-, Phenol, 2,6-dimethoxy-4-(2-propenyl)-, Phenol, 2-ethyl-4-methyl-, Phenol, 2-methoxy-, Phenol, 3-methyl-, Phenol, 4-ethyl-2-methoxy-), alcohols, and ketones (Table. 2) as same the result of pyrolysis two energy crops [15] and the other result of pyrolysis biomass [3-5-16,17,18,19,20].

Conclusions

The continuous pyrolysis reactor for produce bio-oil from mixed biomass showed the proximate analysis of mixed biomass presented a high volatiles content and showed a moderate level of fixed carbon. The amount of the elemental composition of mixed biomass, can found the concentration of carbon was relatively high volume. The products oil yield showed that liquid yield of bio-oil obtained from mixed biomass was a good result was 55.6 %, at 350 rpm. Also the result of solid yield bio-oil obtained from mixed biomass as same a high volume at 350 rpm. The compounds detected in bio-oil from mixed biomass can found the phenols, alcohols, and ketones, especially; phenols group. Thus, in this research, the process of continuous pyrolysis depended on the mechanism of heat transfer with cylinder shape. If control the N_2 flow, control temperature system balance, accordingto as good as the heat transfer model, the yields and qualities of bio-oil should to be high efficiency and the another concern that to the overall performance system of the continuous pyrolysis reactor.

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