OPEN ACCESS
International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-5, June 2019

Performanceof Slow Pyrolysis Open Bach Low-Temperature Reactor for Agriculture Residues

Sugeng Priyanto,Yos Nofendri*,Ahmad Fudholi

Abstract*: Agricultural residues has biomass energy potential as alternative energy. One way to manage agricultural waste is to use pyrolysis. The research method used design manufactures and pyrolysis systems tests to produce biomass from agricultural residues. The pyrolysis system is made of a type of open back reactor which is connected to the cyclone and condenser. Three types of agricultural residues were tested using this pyrolysis system. The design test results show heat propagation outside the vessel is 6 ºC/min, whereas in the reactor vessel is 4.83ºC/min. The results of the tests are gas, oil, and char. The rice husk and corn cobs residues produce gas that will be inserted into the gasoline engine. The volume of both residues is 0.053 m^3 and produces 80 cc of each gas. The acacia wood waste will produce oil and char which have characteristics and are feasible to be used as alternative fuel.

I. INTRODUCTION

Utilization of agricultural waste still requires structuring of governance, so that it can have economies of scale for the community. So far, residues reduction way by burning that only produces pollution for the environment [1]. Processing with pyrolysis systems can make waste as a renewable energy source [2]. In generaly, the results of pyrolysis waste can produce three products, namely: gas, pyrolysis oil and charcoal. It depend on the pyrolysis method, biomass characteristics and reaction parameters [3]. Each pyrolysis product is a fuel that can be converted into a renewable energy source in a variety of different ways [4].

In general, the pyrolysis process uses a reactor made of steel [5]. The slow process of pyrolysis takes place at temperatures above 300°C within 4-7 hours [6]. Also, it is depend on raw material and how to make it. The pyrolysis process is also influenced by time, material moisture content, temperature, and material size [7].

Manuscript published on 30 June 2019.
* Correspondence Author (s)
Sugeng Priyanto, Department Mechanical Engineering, Faculty of Engineering, Universitas Negeri Jakarta. Jl. Raya Rawamangun Muka Raya, Pulogadung Jakarta 13220.
Yos Nofendri, Department Mechanical Engineering, Faculty of Engineering, Universitas 17 Agustus 1945 Jakarta.
Ahmad Fudholi, Solar Energy Research Institute, Universiti Kebangsaan Malaysia, 43600 Bangi Selangor, Malaysia.

Timber production Indonesia in 2015 was 43.7 million m^3. According to its type, the largest production is acacia wood of 22.91 m^3 and meranti wood of 4.47 million m^3 [1]. Wood processing waste is needed to be used as an alternative energy source. The amount of corn cobs waste from agricultural products can be said very much and becomes very potential if it can be used properly. One of the processes of converting lignocellulose materials that are widely studied in the process of converting lignocellulose to ethanol which can be used to substitute gasoline for transportation purposes; corn cobs contain cellulose (45%), hemicellulose (35%) and lignin (15%). Corn cobs are included in the group of biomass materials; the size of corn cobs length varies between 8-12 cm [7]. Rice husk is a hard layer which includes a caryopsis consisting of two halves called lemma and palea which are interlocked[8]. Husk has a bulk density of 1125 kg/m^3, with a calorific value of 3,300 kcal/kg of husk [9]. Unprocessed rice husks have a bulk density of 117 kg/m³, but after undergoing a densification process (compacting), the density of the species reaches 825.4 kg/m³ [10].

II. MATERIAL AND METHOD

2.1. Experiment set-up

A pyrolysis combustion vessels are designed to process capacity of 0.11 m^3 of agricultural waste powder which is combined with a monitoring system of control and gas pressure. The photograph of the pyrolysis combustion vessel system consists of reactors, cyclones, condensers, water cooling, and engines as shown in Figure 1.

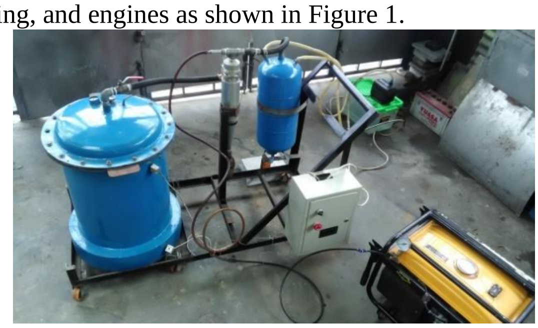

Fig 1. Photograph of pyrolysis combustion vessels

The size of the combustion reactor vessel, uses a small pressure vessel. The reactor body frame has a height of 650 and a diameter of 450 parts coated using fire bricks/SK 34 type refractories of 35, length 90 and width 60 which can withstand heat up to 1400 °C.

In addition, in the refractory stone wall the combustion vessel reactor is made grooves for the position of a spiral element spaced 100 by 5 lines heating element in a spiral-shaped design and equipped with a thermocouple to measure the temperature of the heating element which is conducted into the inner tube.

The inner tube or reservoir used has a height of 580 and a diameter of 350 wall thickness one so that the test material does not come into direct contact with the electric heater which can damage the electric heater, the tube is adjusted to the size of the reactor vessel after fireproof bricks and cement are installed.

The shape of the reactor vessel lid was chosen using the torispherical head model equipped with a thermocouple to measure the temperature of the inner tube on the reactor vessel to obtain heating rate data and a pressure gauge used to measure the pressure in the reactor vessel.

2.2. Experiment procedure

The combustion vessel pyrolysis process for processing agricultural waste products such as rice husks, corn cobs, and acacia wood powder. The process of burning acacia wood powder, the gases from combustion from the inner tube flow through the check valve towards the cyclone, dirt and dust particles that are of the heavier type contained in the gas to be set aside in the container. Also, the reduced gas from dust and dirt particles is flowed through the check valve to flow into the gas inlet pipe and condenser to convert the gas phase to liquid.

The first raw material used is rice husk agricultural waste material and the second is corn cobs waste, gas results from the pyrolysis process of corn cobs waste and rice husk are used as a substitute for gasoline fuel [11]. The gas replaces gasoline to operate the gasoline engine on a 3000-watt electric generator. The third raw material is acacia wood powder. The gas from pyrolysis is converted from the vapor/gas phase to the liquid phase using a condenser. Bio-oil from acacia wood will be tested to obtain chemical constituents. The process of testing the bio-oil liquid from acacia wood was tested using GC-MS to show the content chemically such as the levels of Aliphatic Hydrocarbon, Aromatic Hydrocarbons, Oxygenated[12].

III. RESULTS AND DISCUSSION

Figure 2 shows the rate of time in minutes for changes in the combustion temperature of rice husks in the inner tube. Adding the temperature outside the inner tube is hotter in the 5-minute range; this is due to radiation from the heating element directly about the outer thermocouple. Also, in 20 minutes the temperature of the inner tube chamber for burning rice husks is hotter due to the rate of heat distribution and the object of burning rice husks in the tube space in the wider result of temperature measurement using thermocouple installed in the tube chamber in hotter. Therefore, the rate of addition of time to increase the temperature in the tube chamber is in line according to the 3500C set point limit. Also, the process of pyrolysis gas formation of rice husk was initially found when the temperature reached 2200°C [13]. Decomposition of gases resulting from pyrolysis of rice husks using cyclone for the separation of elements that have heavier density types in the form of thick tar and ash liquid. The volume of the burning object of rice husk is 0.053 m3 in the tube chamber to produce 80 ccs of gas to operate the gasoline engine for 10 minutes.

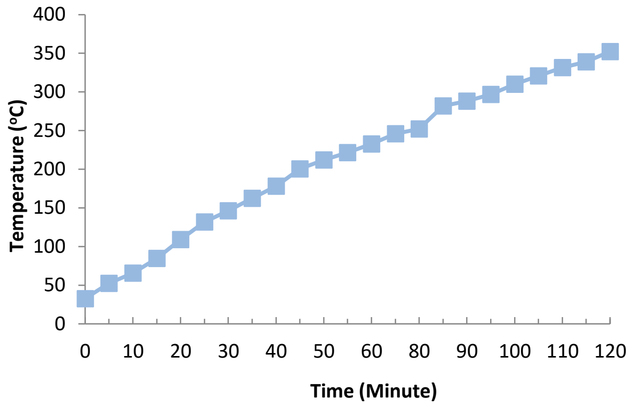

Fig 2. Pyrolysis temperature rate made from rice husk

Figure 3 shows the rate of adding time in minutes to changes in the addition of combustion temperature of corn cobs to the reactor. The impression of changes in temperature addition to the length of combustion in the tube chamber is longer than the burning process of rice husk. This, firstly the slow addition of combustion temperature is influenced by the size of the grain volume, chopping and partly the hardness of the corn cobs [14]. The two effects of changes in the addition of combustion temperature to corn cobs of grain are more likely to emit liquids mixed with gas so that it requires a longer heating time to become a gas. Therefore, the object of combustion of corn cobs in the inner chamber for achieving even distribution of the combustion temperature and the rate of addition of a stable combustion temperature according to the 3500°C setting/set point requires 45 minutes. The process of pyrolysis gas formation of corn cobs is obtained when the temperature reaches 2400°C and the separation of the density of species contained in the gas using cyclon in the form of dilute liquid more glucose, followed by tar and ash. The material for corn tangkol chopped in the volume of 0.053 m^3 in the tube in combustion produces a volume of 80 cc gas to operate the gasoline engine for 10 minutes.

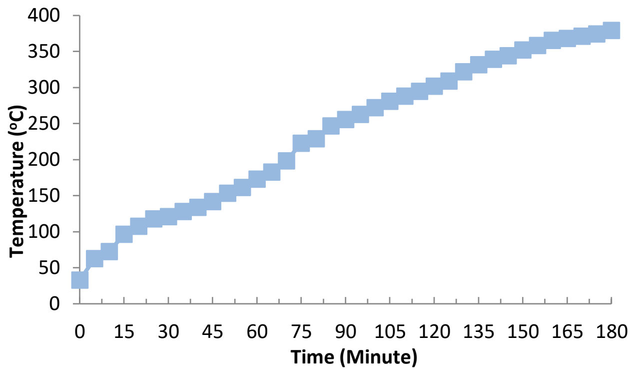

Fig 3. Pyrolysis temperature rate made from corn cobs

Figure 4 shows the rate of addition of time to increase the combustion temperature of acacia wood fibers in the inner tube chamber.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication (BEIESP)

Indicates the rate of addition of temperature is very slow and a long period in the tube chamber in the process of burning acacia wood fibers.

This, influenced by several conditions and the nature of the first acacia wood fibers of hardness, the density of debris over rice husks and the count of corn cobs affect the time and rate of change in addition to the burning temperature of acacia wood fibers in the inner tube chamber. Therefore, to obtain the rate of addition of combustion temperature evenly in the inner tube chamber, it takes 120 minutes. This affects the combustion process of acacia wood fiber to get the gas output from combustion. The initial gas output is obtained when thetemperature reaches 2300C, the volume of the burning object of acacia wood fiber is 0.053 m^3, the combustion process takes 480 minutes at setting/set point 4000°C. A check valve regulates the gas produced from the combustion process in the tube chamber in the reactor flowed to the cyclone to clean the gas from the combustion ash and other elements of heavier density. Then the gas is supplied to the condenser system circuit to convert the gas phase to liquid; the liquid volume obtained is 0.76 liters during the process.

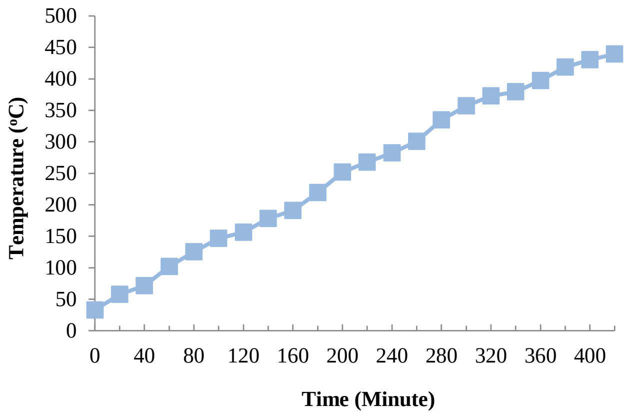

Fig 4. Pyrolysis temperature rate made from acacia wood

The characterization of acacia wood fiber bio-oil in the laboratory using GC-MS (Gas Chromatography-Mass Spectrometry) to display the separation and identification of the levels and chemical content present in bio-oil. Characteristics of the effect of temperature on the physical and chemical properties of acacia wood fiber bio-oil as in Table 1. It shows the results of the process at various temperatures of 2500°C, 3000°C and 3500°C the values of density, viscosity, and pH were found.

Table 1. Variation in the temperature of the pyrolysis process against the physical properties of acacia wood fiber bio-oil

Parameter	Temperature (°C)		
Density	250	300	350
	16.42	16.41	16.42
	16.42	16.41	16.42
	16.42	16.41	16.42
Viskositas	5.10	4.58	6.20
	4.80	4.55	6.52
	5.17	4.45	6.30
pH	4.20	3.43	4.35

Table 2. shows the characteristics of acacia wood fiber bio-oil such as Viscosity, density and pH can be seen from the three temperature variations used 2500°C, 3000°C and 3500°C at the most optimum temperature 3000°C, because physical characteristics approach the process of pyrolysis of acacia wood fiber bio oil stated by Isahak et al. [15], which is used as a reference. Also, at a temperature of 3500°C the most viscosity value of bio-oil is obtained, this is influenced by changes in chemical structure at that temperature. The average value of density is 0.9 - 1.0 gram/mL and the least value is obtained at 3000°C, the comparative result is the density value of 0.940 gram/mL. Therefore, the density value is influenced by the chemical compounds possessed by the bio-oil from the pyrolysis of acacia wood fibers. The condition of acacia wood fiber pH bio-oil can be seen that the pH value is at least 3.43 at temperatures of 3000°C and 3.45 at 3500°C. This, referring to the comparison conducted by Isahak et al. [15] stated that the pH value of 3.43 was obtained at a temperature of 3000°C. Also, the state of acidity can be influenced by the acid content found during the pyrolysis process which breaks down cellulose, lignin, and other acidic substances. Analysis based on examination of the results of the slow temperature pyrolysis process using the most optimum acacia wood fiber material at a temperature of 3000°C.

Table 2. Variation in the temperature of the pyrolysis process against the physical properties of acacia wood fiber bio-oil

Pyrolysis oil sample	**Temperature (°C)**			**Isahak et al. [15]**
	250	300	350	
Temperature viscosity40 (cSt)	5.14	4.62	6.49	31
Density (gram/mL)	1.00	0.99	1.01	0,99
pH	4.20	3.53	4.35	3,82
Volume (mL)	20	50	8	-

Table 3. Shows the main elements of pyrolysis bio-oil, namely phenol, acidic compounds, aromatics, and several other compounds. The content of aromatic compounds, benzene, comes from the degradation of hemicellulose. Also, the degradation of lignin compounds was identified by the presence of phenol and guaiacol compounds. Based on the components shown in Table 3, the pyrolysis oil has the components needed to become bio-oil from pyrolysis. Phenol compounds can increase the combustion ability of liquid products. Also, alcohol compounds have flammable properties so they can also increase combustion that forms carbon dioxide. This liquid product or bio-oil from the result of pyrolysis of acacia wood fiber is then subjected to a combustion test to determine the combustion ability. Test results found that this liquid product can burn. This indicates that pyrolysis bio-oil can be used as an alternative fuel.

Table 3. Variation in the temperature of the pyrolysis process against the physical properties of acacia wood fiber bio-oil

No.	Element	Point boiling	Area peak
1	Phenol	188	3.723

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication (BEIESP)

2	Methoxy toluene	169	4.087
3	Phenol, 2-methyl-	174	4.390
4	p-cresol	202	4.644
5	2,3-Xylenol	206	4.801
6	Phenol, 2,3-dimethyl	218	5.304
7	Phenol, 3,4-dimethyl-	218	5.502
8	Creosol	221	5.774
9	Guaiacol, 4-ethyl-	205	6.576
10	Phenol, 2,6 dimethoxy-	169	7.222
11	Phenol, 2-methoxy-4propyl-	281	7.360
12	3 Furan carbocar boxylic acid-5-ethyl-2,4 dimethyl-, methyl ester	231	8.699
13	Tetracosanoic acid, methyl ester	273	16.550
14	Hexacosanoic acid, methyl ester	271	18.488

IV. CONCLUSION

The use of gas from rice husk pyrolysis and corn cobs is applied to operate the gasoline engine generator to replace gasoline liquid fuel. The test of the operation of the gasoline engine generator uses the gas from the pyrolysis of rice husk and corn cobs separately for 10 minutes, the volume of gas is 80 cc. The process of forming the pyrolisis rice husk gas was initially obtained when the temperature reached 2200°C, then flowed through the check valve to the cyclone for decomposition of gases to dust, liquid, and tar. The results obtained from the decomposition of the gases resulting from pyrolysis of rice husks using cyclone for heavier types of gravity were in the form of thick tar and ash liquid. The process of forming the pyrolysis gas corn cobs counts was obtained when the temperature reached 2400°C, then the breakdown of gases using cyclon obtained the separation of levels of density which contained in the gas in the form of more liquid dilute glucose, tar, and ash.

The slow temperature pyrolysis process for producing liquid products or bio oil for acacia wood fiber raw materials, the most optimum process temperature conditions at a temperature of 3000°C. The results of the acacia wood bio-oil from the pyrolysis process have chemical characteristics such as the viscosity value of 4.6275 cSt, density 0.9997 gram/mL and pH 3.53. The results of bio-oil or liquid products directly from the pyrolysis process found a deep black color and a distinctive smell of smoke. Apart from that, it has flammable properties so it can be used as an alternative fuel. This, based on the results of characterization using GC-MS tools obtained by the results of chemical compounds derived from the degradation process of thermal cellulose, hemicellulose and lignin which are an alkane, aromatic and phenol compounds.

REFERENCES

1. B. Pranoto, M. Pandin, S. R. Fithri, and S. Nasution, "*Peta potensi limbah biomassa pertanian dan kehutanan sebagai basis data pengembangan energi terbarukan*," Ketenagalistrikan dan Energi Terbarukan, vol. 12, no. 2, pp. 123–130, 2013.
2. C. J. Ellens, "Design, optimization and evaluation of a free-fall biomass fast pyrolysis reactor and its products," M.Sc Thesis 2009.
3. P. Fu, W. Yi, X. Bai, Z. Li, S. Hu, and J. Xiang, "Effect of temperature on gas composition and char structural features of pyrolyzed agricultural residues," Bioresource Technology, vol. 102, no. 17, pp. 8211–8219, 2011.
4. M. I. Jahirul, M. G. Rasul, A. A. Chowdhury, and N. Ashwath, "Biofuels production through biomass pyrolysis-a technological review," Energies, vol. 5(2), pp. 4952–5001, 2012.
5. A. A. Lappas, V. S. Dimitropoulos, E. V Antonakou, S. S. Voutetakis, and I. A. Vasalos, "Design, construction, and operation of a transported fluid bed process development unit for biomass fast pyrolysis: effect of pyrolysis temperature," Ind. Eng. Chem. Res, vol. 47(3) pp. 742–747, 2008.
6. S. Kloss, F.Zehetner, A. Dellantonio, R. Hamid, F. Ottner, V. Liedtke, M. Schwanninger, M. H. Gerzabek, G. Soja, "Characterization of slow pyrolysis biochars: effects of feedstocks and pyrolysis temperature on biochar properties," Journal of Environmental Quality, vol. 41(4), pp. 990-1000, 2012.
7. P. Basu, **Biomass gasification and pyrolysis and torrefaction**, Second Edi. San Diego USA: Academic Press is an imprint of Elsevier, 2013.
8. I. Y. Mohammed, C. H. Lim, F. K. Kazi, Y. Suzana, H. L. Lam, and Y. A. Abakr "Co-pyrolysis of rice husk with underutilized biomass species: a sustainable route for production of precursors for fuels and valuable chemicals," Waste and Biomass Valorization, vol. 8(3), 2016.
9. O. A. Mohameda and I. Ashour, "Production of Bio-oil from Rice Straw," International Journal ofChemical and EnvironmentalEngineeringvol. 7, no. 2, pp. 101-106, 2016.
10. J. Chuxi, X. Yunpeng, Y. U. Hao, G. Shishang, and W. Qing, "Effects of temperature on pyrolysis characteristics of Indonesia oil sands," Journal of Analytical and Applied Pyrolysis, vol. 137, pp. 151-162, 2019.
11. N. Miskolczi, A. Angyal, L. Bartha, and I. Valkai, "Fuels by pyrolysis of waste plastics from agricultural and packaging sectors in a pilot scale reactor," Fuel Processing Technology, vol. 90, no. 7–8, pp. 1032–1040, 2009.
12. O. A. Mohamed, "Production of bio-oil from agriculture waste," Biochemistry & Analytical Biochemistry, vol. 7, no. 1, pp. 1–8, 2018.
13. A. Jayswal, A. K. Sah, P. Pradhananga, R. Sah, H. B. Darlami, "Design, Fabrication and Testing of Waste Plastic Pyrolysis Plant," Proceedings of IOE Graduate Conference, vol. 5, pp. 275-282, 2017.
14. M. A. Aziz, M. A. Rahman, and H. Molla,"Design, fabrication and performance test of a fixed bed batch typepyrolysis plant with scrap tire in Bangladesh," Journal of Radiation Research and Applied Sciences, vol. 11, pp. 311-316, 2018.
15. W. N. R. W. Isahak, M. W. M. Hisham, M. A. Yarmo, and T. Y. Hin," A review on bio-oil production from biomass by using pyrolysis method, Renewable and Sustainable Energy Reviews, vol. 16, pp. 5910-5923, 2012.