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Investigation of Biomass Pyrolysis on Non-catalytic Process for Bio-oil Production

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Abstract. In this study, we have focused on surveying the ability to produce liquid fuels (bio-oil) from biomass by pyrolysis method without catalyst. The influence of process parameters on the yield of liquid biomass fuels has been carried out. The results showed that the experimental conditions through a thermal pyrolysis with fixed bed and non-catalyst, recovery of bio-oil are depended on their parameters, such as: pyrolysis temperature, size of the biomass materials and partial pressure of nitrogen gas in environmental pyrolysis reaction. Effects of temperature impact significantly on the pyrolysis process. The maximum bio-oil production (liquid product) was achieved at 550^{o}C, the yield of gas product increases with increase in the reaction temperature, while residue product is inverted. On studying effluence of other parameters, the maximum bio-oil production was achieved at conditions: 0.354 mm to 0.5 mm of biomass size, 0.5ml/min of nitrogen gas flow rate and 7.5^{o}C/min of the heating rate. This result will be the basis for orientation of researching on the ability to produce bio-oil from biomass by pyrolysis method in next time.

Keywords: Biomass, Bio-oil, Non-catalytic process, Pyrolysis.

1. Introduction

Depending on fossil fuel resources (coal and oil, natural gas) has caused instability of the world's economy particularly the economies in developing countries and the greenhouse effect. Besides, according to experts, the fossil fuels reserves will be exhausted in the future. Consequently, research on resources of clean and renewable energy has been the goal for decades. One of them, the biomass (sources of bioenergy) is considered as the potential source because it is abundant [1,2,9]; especially, it is also considered as a renewable energy source [2,9]. In the world, about 20% energy is currently produced from biomass. In some countries, the ratio of energy from biomass is about 40% – 50%. However, biomass is now mainly used as a material for burning, but this method is low for effective production of energy and can be environmental degradation reason by CO emissions. So, the current research is focused on improving the efficiency of energy production from this material by methods such as catalytic or non-catalytic pyrolysis to convert biomass into liquid fuel (bio-oil).

In Viet Nam, the activities of agriculture produce annually a large amount of biomass such as bagasse, straw, cob, husk, and rubber seed... Following of biomass experts, Vietnam is one of the first countries for biomass production in the world. Currently, the biomass is not yet being used effectively for the production of energy, the mainly biomass is used for burning and rejecting, so it is one of the causes of environmental degradation as well as the indiscriminate clear clogged canals destroyed eco-environment, particularly in Mekong delta - Vietnam. Therefore, research pyrolysis process to produce bio-oil fuels from biomass which is an urgent issue for the current situation. The study of biomass pyrolysis technology to increase efficiency

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of biomass energy, it not only solves the fuel problem now and future, but also solves polluted environment in agricultural activity for building an agriculture sustainable development in Vietnam.

2. Materials and Experimental

The raw materials for this study were rice husks which are readily and in large quantities available in Vietnam. Firstly, we studied the size of this biomass. Next, the humidity of biomass was determined by weight method. In our study, the best humidity of biomass is about 11.92%. The pilot system has been designed, fabricated and installed at Refinery and Petrochemicals Technology Research Center (RPTC) - Ho Chi Minh University of Technology - Vietnam, *Fig. 1*. The reactor is a fixed bed model. Material for reactor is “304-steel”, with thickness of 3mm. The reactor parameters are 440mm and 65mm, long and diameter respectively. The reactor is installed inside of electric heating furnace. The temperature reaction is regulated by control system.

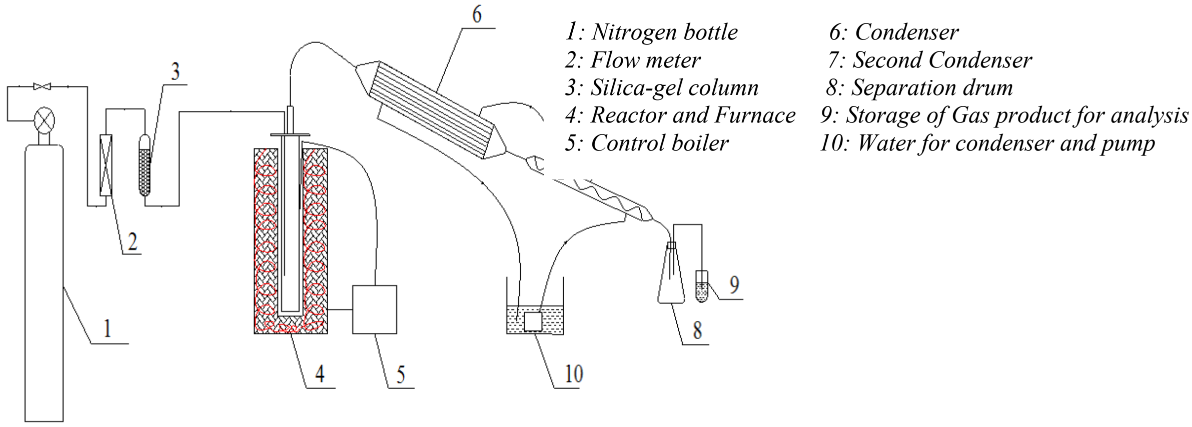

Fig. 1: Schema of experimental.

The experimental studies have been performed by *Fig. 2*. After sizing and humidity determination, biomass has put in reactor (4) with quantity of 30g for each experiment. To avoid the oxidative reaction, before reaction, oxygen inside the reactor has been purged by Nitrogen flow (1). The products from reactor have been condensed by condenser system (6) and (7). The range of reaction temperature is from 450^{o}C to 700^{o}C.

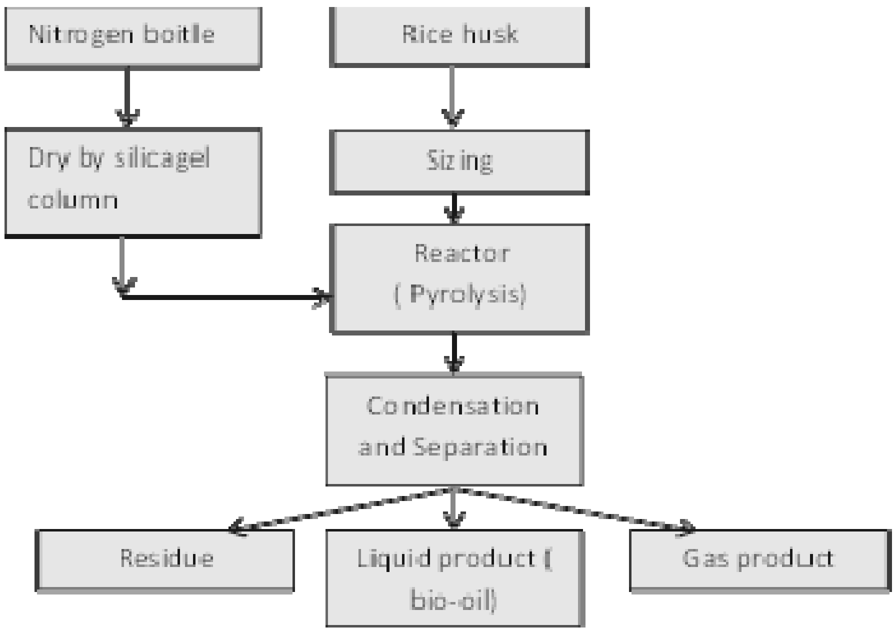

Fig. 2: Experimental process.

Effect of Nitrogen partial pressure has been studied under different nitrogen flow rates (100ml/min, 200ml/min, 500ml/min, 1000ml/min, and 1500ml/min). Effect of heating rate has been investigated on range of from 2.5°C/min to 15°C/min. Effect of biomass size has been carried out with the average diameters of biomass that are d < 0.25mm, 0.25mm < d < 0.354mm, 0.354mm < d < 0.5mm, 0.5mm < d < 1.0mm, and 1.0mm < d < 2.0mm.

3. Results and Discussions

3.1. Effect of Pyrolysis Reaction Temperature

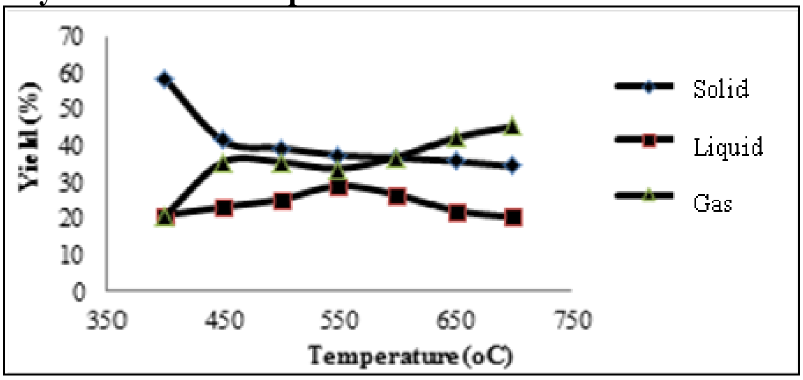

Fig. 3: Effect of reaction temperature on yield of pyrolysis products.

The effect of pyrolysis reaction temperature to product yield and product quantity has been studied [1,4,6]. These effect will affect the primary as well as secondary reactions of pyrolysis process [6,7]. The optimal reaction temperature for pyrolysis process depends on material type. In this study, we have examined optimal temperature for rice husk on the conditions: Size: >2mm, heating rate: 5°C/min, nitrogen flow: 01lit/min. The results showed that *(Fig. 3)* when reaction temperature of pyrolysis increases (from 400°C to 700°C), residue products of pyrolysis decrease (from 58.25% to 34.33%) while inversely, the yield of gas products increases (from 20.88% to 45.30%). These results correspond to previous studies about pyrolysis process [2,4,5,6]. It can be explained that when increasing reaction temperature, it will lead to increase cracking reaction, so components such as: hemicellulose, cellulose and lignin in biomass have been cracked to gas products. Besides, when reaction temperature is very high, the intermediate products have been cracked continuously in the gas phase. The lowest yield of liquid products is 20.87% at 400°C, the highest yield is 29.02% at 550°C, and then this yield has decreased when reaction temperature is over 550°C. This result can be explained that at 550°C, the energy is corresponded to energy for cracking the chemical bondings of biomass and in such conditions, the products is mainly in the liquid state. If reaction temperature of pyrolysis process continues increasing, it will lead to continue cracking liquid products to gas products and this case may be gasification process.

3.2. Effect of Nitrogen Partial Pressure (Inert Gas) to Yield of Liquid Products

According to previous studies [2,6,8], the partial pressure of inert gas affects to yield of liquid products on pyrolysis process. The inert gas that reduces partial pressure of hydrocarbon inside the reactor will reduce polymerization reaction of unsaturated components. It leads to reduce residue products. In this study, we have examined the partial pressure of nitrogen under different flow rates of 100ml/min; 200ml/min, 500ml/min, 1000ml/min and 1500ml/min. The pyrolysis temperature has been chosen at optimal temperature of 550°C, heating rate of 5°C, and size of biomass is > 2mm. The results showed that with the difference of partial pressure of nitrogen, the yield of residue (solid) has been almost unchanged, while the yield of gas product and liquid product have been changed significantly. At 0.5ml/min of nitrogen, the yield of liquid is maximum and yield of gas product is minimum. These results correspond to balance of reaction material. When nitrogen partial pressure continues increasing, it maybe leads to increase the pressure local in environmental reactor and the cracking will be locally increased. Besides, the yield of liquid decreases that mean the yield of gas product increase respectively. This result shows that the effects of nitrogen partial pressure have not affected to total yield of pyrolysis process but they have affected to yield of gas and liquid products of reaction.

3.3. Effect of Biomass Size to Yield Products (Fig. 5)

The size of raw material has affected to yield of pyrolysis process [5,6,8]. Investigratons of biomass size have been carried out in the conditions: nitrogen flow of 0.5ml/min, pyrolysis temperature of 550°C and rate heating of 5°C/min. Research biomass have an average diameter of < 0.25mm; 0.25 to 0.354mm; 0.354 to 0.5mm; 0.5 to 1mm; 1 – 2 mm; and d > 2mm. The results showed that when the size of biomass increased, the yield of residue product increased slowly while the yield of gas product decreased especialy when the size changes from 0.25 to more.

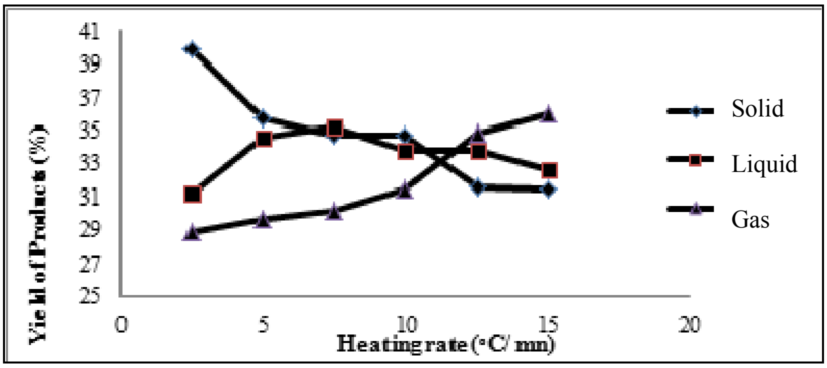

Fig. 4: Effect of inert gas (nitrogen) partial pressure to yield of pyrolysis products.

This result can be explained by effective thermal, that mean the thermal conduction is depended on the size of biomass putting inside of reactor. When the size of biomass is small, the capacity of thermal transfer is better than in the case of bigger biomass size. The uneven change of yield pyrolysis products on different biomass size may be caused by operation of compression during experiments. The results showed that the highest yield of liquid products havs been got at biomass size of 0.354 – 0.5mm.

3.4. Effect of Rate Heating to Yield of Products

On pyrolysis process, the rate heating is one of the important parameters. For this study, the experimental conditions are temperature of 550°C, nitrogen flow of 500ml/min and size of biomass 0.354 – 0.5mm. The heating rates for study are 2.5°C/min; 5°C/min; 7.5°C/min; 10°C/min; 12.5°C/min; 15°C/min. The result described in *Fig. 6*, when the heating rate increased, yield of residue and gas products decreased. Maximize yield of liquid products is 35.21% when heating rate is 7.5°C/min.

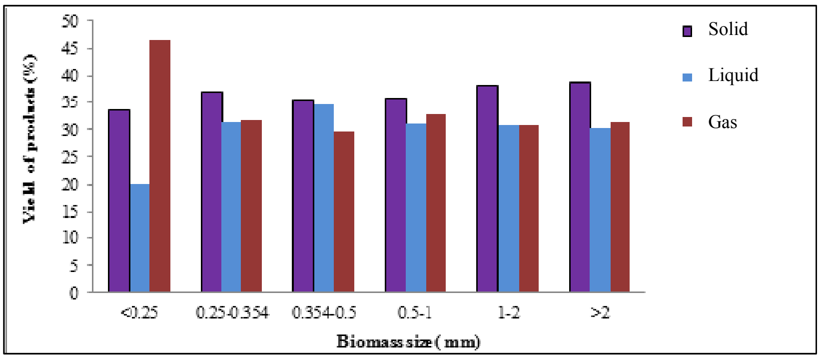

Fig. 5: Effect of biomass size to yield of pyrolysis products.

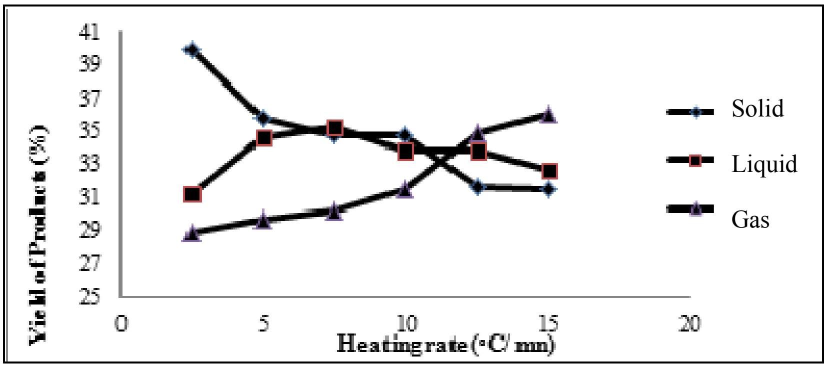

Fig. 6: Effect of heating rate to yield of products of pyrolysis process.

These results can be explained that at low heating rate, the primary reaction occurs slowly that leads to small liquid products and also rags products. At the high heating rate, the volatile products separated from the solid phase quickly because the contact time is often very high in fixed bed reactor and it leads to continue cracking intermediate products. So the yield of liquid products decreased and gas products increased.

4. Conclusion

Investigation on capacity of bio-oil production from biomass has been carried out in non-catalyst condition. The effect of parameters of process, such as: temperature reaction, inert gas partial pressure, heating rate and biomass size to yield of bio-oil products has been studied. The optimum conditions of biomass pyrolysis process for liquid fuels production have been determined. In our study, when experimental conditions are temperature reaction of 550^{o}C, nitrogen flow of 500ml/min, biomass size of 0.354 – 0.5mm and heating rate of 7.5^{o}C/min, the yield of bio-oil products is highest. Our study confirms that fuel oil can be produced from biomass. Results of research is a basis for further research and production technology for bio-oil from biomass resources, which is abundant in Vietnam, helps solving energy in the future and environmental pollution problems in agricultural production at VietNam.

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