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Analysis of the Rice Husk Pyrolysis Products from a Fluidized Bed Reactor

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Abstract

Rice husks are pyrolyzed in a fluidized bed pyrolyzer using glass beads as the fluidizing media. The effects of the rice husk feeding rate and the fluidizing nitrogen gas flow rates on the mass fraction of the produced syngas, bio-oil and char are studied. The highest bio-oil mass fraction in the product is around 30% when the rice husk feeding rate and the fluidizing nitrogen gas flow rate are 10 g/min and 40 L/min, respectively. The chars collected at different parts of the system are analyzed by TGA. The results indicate that although the chars have different content of volatiles, they are relatively clean. GC/MS analysing results indicate that the major compounds in the bio-oil are aromatic compounds, including toluene, phenol, furfural, methylphenol, ethylphenol, benzenediol, and etc.

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Keywords: pyrolysis; rice husk; bio-oil; fluidized bed pyrolyzer

1. Introduction

The demands of using biomass as renewable energy are growing due to the public concerns on the global warming from fossil fuel combustion [1-2]. Biomass is the one of the most abundant renewable energies [3]. Biomass pyrolysis is a thermochemical process which produces solid chars, liquid bio-oils and syngases as the final

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products. Syngases usually contain CO, CO_2, H_2 and CH_4, have relatively high HHV values, and can be co-combusted with natural gases in a combustor [3]. The upgraded bio-oil can be used as the fuels for diesel engines [4]. The solid chars can be co-gasified with coals in power plants [3].

As a high potential alternative energy resource, fast pyrolysis of biomass has been extensively studied since 1970s [5-6]. Different kinds of biomasses have been used to undergo the fast pyrolysis reactions, including sawdust, switchgrass, Eucalyptus loxophleba, grape residue, pine sawdust, rice straw, white oak, cherry seeds, corn cob, straw oreganum stalks and etc. [7]. The mass fraction of the gaseous product, liquid product and the solid product produced from the biomass pyrolysis is influenced by the biomass composition and the operating conditions of the pyrolysis process. In this work, rice husks are pyrolyzed in a fluidised bed pyrolyzer using glass beads as the fluidizing media. The produced the solid char and liquid bio-oil are collected and analyzed.

2. Experimental

A schematic drawing of the experimental installation is shown in Fig. 1. Rice husks from Changhua county in Taiwan stored in the feeding storage 1 are delivered to the fluidized bed pyrolyzer 5 through the screw feeder 2. The internal diameter and the length of the cylindrical fluidized bed pyrolyzer are 50 mm and 350 mm, respectively. The pyrolyzer is filled with 200 g glass beads (0.42 mm – 0.84 mm) as the bed materials. The pyrolysis of the rice husks produces chars, oils and syngases. Chars are collected inside the reactor 4 and in the cyclone 7. Liquid oils are collected in the 20 °C water trap 9 and in the 0 °C ice trap 10. Syngases are introduced to the vent.

In a typical experiment, rice husks are dried in a 50 °C oven for at least 12 hr before the experiment. Nitrogen from gas cylinder is introduced to the pyrolyzer with a carrier gas flow rate of 30 L/min or 40 L/min. Nitrogen with a flow rate 10 L/min is introduced to the upper half of the feeding storage to prevent the entrance of the gaseous products into the feeding storage. The temperature of the reactor is set as 600 °C. After the system reaches the steady state for 30 min, rice husks in the feeding storage are fed to the system through the screw feeder with a feeding rate of 10 g/min or 20 g/min. The total feeding time and reaction time is 30 min. After the feeding, nitrogen gas is still introduced to the system for 30 min to ensure no accumulation of the volatiles in the system. The total mass of the solid chars is determined by those collected in 4 and 7. The mass of the liquid oil is determined by those collected in 9 and 10. The amount of the gaseous products is determined by mass balancing between the rice husk feeding, the solid product and the liquid product.

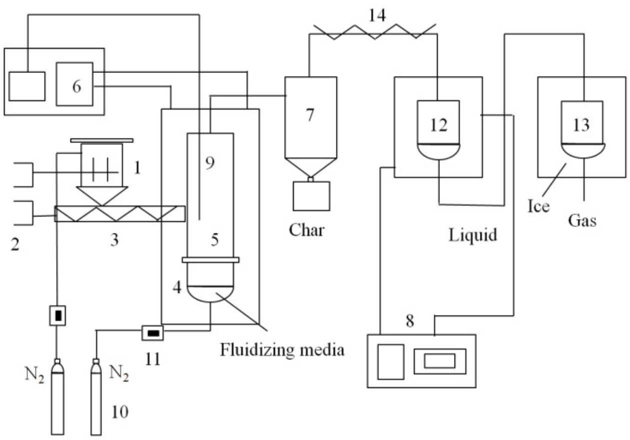

Fig. 1 Schematic drawing of the fast pyrolysis process: (1) feeding storage; (2) screw feeder; (3) oven; (4) fluidized bed pyrolyzer; (5) thermocouple; (6) temperature controller; (7) cyclone; (8) heating wire; (9) 20°C cold trap; (10) 0°C ice trap; (12) gas cylinder; (13) mass flow rate controller.

The rice husks and the collected chars are analyzed by thermogravimetric analysis (TGA) using pure nitrogen as the carrier gas (Q50, TA instruments). The oil samples are extracted with butanone (1:1 by volume) and are qualitatively analyzed by Gas Chromatography-Mass Spectrophotometer (GC/MS) using a VF-5ms column (220-MS, Agilent Varian). In GC/MS analysis, the injector temperature is 150 °C; the split ratio is 50:1; the volume of injected sample is 1μL; temperature is hold at 35 °C for 1 min, follows by heating up to 50 °C by a heating rate of 5 °C/min and up to 240 °C by a heating rate of 10 °C/min and is hold at 240 °C for 23 min; pure nitrogen flow rate is 1 ml/min.

3. Results and discussion

The mass fractions of the products obtained from rice husk pyrolysis operated at different biomass feeding rates and nitrogen gas flow rates are shown in Table 1. The oil mass fraction slightly decreases with the increasing of rice husk feeding rate. It is due to the fact that the fed rice husks cannot be instantaneously pyrolyzed in the reactor. The rapid pyrolysis is usually occurred within 2 seconds [8]. When the carrier gas flow rate increases, oil mass fraction increases significantly. High carrier gas flow rate enhance the contacts between the biomass and the fluidizing glass beads from strengthened bubbling flow regimes. The improved heat transferring enrich the oil mass fraction in the product.

Table 1. The composition of the three-phase products from the rice husk pyrolysis

Feeding rate (g/min)	Carrier gas flow rate (L/min)	Char (%)	Bio-oil (%)	Gas (%)
10	30	30.65	20.42	48.93
10	40	38.52	29.44	32.04
20	30	33.63	19.83	46.54
20	40	31.63	27.14	41.23

Typical rice husk TGA analysis (not shown here) indicates that the decomposition of the rice husks occurs at around 320 °C and the volatiles (including liquid and gaseous products) are approximately 60% by mass. The maximum solid mass fraction is thus around 40%. In Table 1, the mass fractions of the chars are between 30% and 39%, indicating a relative "clean" char without volatiles. The TGA analyses of the chars collected at different operation conditions are shown in Fig. 2. In Fig. 2, the chars still contain volatiles. The most "clean" chars are those collected from the pyrolyzer operated at 10 g/min rice husk feeding rate and a carrier gas flow rate of 40 L/min.

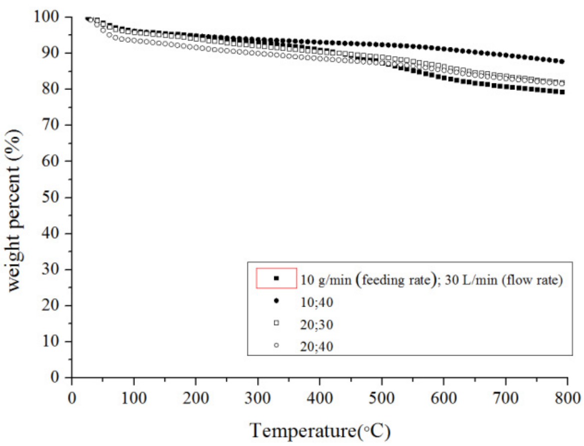

Fig 2. TGA analysis of the chars collected from pyrolysis operated at different feeding rates of rice husks and gas flow rates.

The qualitative GC/MS analysis of the bio-oil produced at different conditions are shown in Fig. 3. The results show that the major compounds in the bio-oil are aromatic compounds, including toluene, phenol, furfural, methylphenol, ethylphenol, benzenediol, and etc. The changes of the biomass feeding rate and the carrier gas flow rates do not change the major compounds in the bio-oil. Further quantitative analyses are needed to know the effects of the operation conditions on the composition changes of the bio-oil.

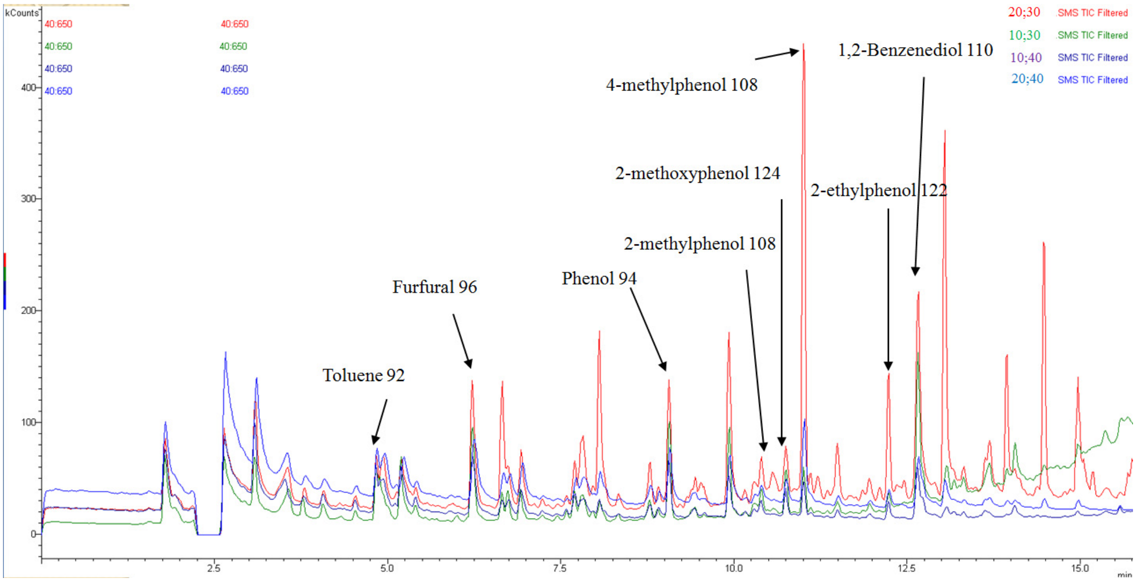

Fig 3. GC/MS analysis of the bio-oil produced at different biomass feeding rates and carrier gas flow rates.

4. Conclusion

Rice husks are pyrolyzed in a fluidized bed pyrolyzer using glass beads as the fluidizing media. The effects of the rice husk feeding rate and the fluidizing nitrogen gas flow rates on the mass fraction of the produced syngas, bio-oil and char are studied. The highest bio-oil mass fraction in the product is around 30%. The mass fractions of the syngas, bio-oil and char from the rice husk pyrolyzer operated at 10 g/min rice husf feeding and 40 L/min nitrogen carrier gas flow rate are 38.52%, 29.44% and 32.04%, respectively. The chars collected at different parts of the system are analyzed by TGA. The results indicate that although the chars have different content of volatiles, they are relatively clean. The most “clean” chars are those collected from the pyrolyzer operated at 10 g/min rice husk feeding rate and a carrier gas flow rate of 40 L/min. GC/MS analysing results indicate that the major compounds in the bio-oil are aromatic compounds, including toluene, phenol, furfural, methylphenol, ethylphenol, benzenediol, and etc.

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