

Possibility study of gasifier with axial circulating flue gas for reducing Tar

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Abstract. This present research article aims to study the possibility of gasification by axial core flue gas circulating kiln and find the efficiency of syngas production. An axial core flue gas circulating tube was installed in the center of the updraft gasifier in purposing of tar reducing. In the present study, the eucalyptus wood chip 4, 8, and 10 kg with the moisture content 16% were examined. Several type-K thermocouples were employed to measure the temperatures at preheat, combustion, reduction, pyrolysis, drying, and gas outlet zone. The results showed that the temperatures in the combustion and the reduction zone of the kiln with the axial core flue gas recirculating were lower than the kiln without the core owing to installing the core would reduce the combustion zone area in biomass burning. Obviously, the temperature in the pyrolysis and drying zone were nearly the same as both with and without the core. In consideration of syngas components, it was found that CO production from the gasifier with the core was higher than the gasifier without the core about 25%. Other gases, however, were almost same. The syngas production efficiency obtained from the gasifier with the core decreased with increasing the mass of biomass. It showed that the highest efficiency was 30% at 4 kg supplying biomass. In comparison, the efficiencies of both the kilns with and without the core were not different. For liquid product, the amount of liquid decreased about 47.23% comparing with the gasifier without the core.

1. Introduction

Gasification is an attractive technology for convert fuel from biomass through incomplete combustion at high temperatures to syngas. This technology is environmentally friendly that is to reduce carbon dioxide (CO₂) from the burning of biomass fuels. The processes of gasification include drying, pyrolysis, oxidation and reduction. The first stage of gasification is drying. Usually the moisture content of biomass in this zone is removed by the radiation heat from oxidation zone. The temperature in this zone remains less than 120 °C. Then pyrolysis process starts to destroy structure of biomass at temperature about 200 – 400°C. Char, water vapour, methanol, acetic acid are the main products of pyrolysis zone. The moisture vaporised in the drying zone and others in the pyrolysis zone travels down towards oxidation zone. Temperature in this zone rises to about 900 – 1200°C. The main product of oxidation process is carbon dioxide (CO₂) [1]. The product of oxidation zone then passes through the reduction zone. The temperature in this zone is about 600 – 900°C. Gasifier is the reactor for producing syngas. Syngas normally consist of carbon monoxide (CO), carbon dioxide (CO₂), hydrogen (H₂), methane (CH₄) and tar. There are four types of gasifiers classified according to application: updraft or counter current



gasifier, downdraft or co-current gasifier, crossdraft gasifier and fluidized bed gasifier. Other types of gasifiers are currently under development. In all types of gasifiers, the carbon dioxide (CO_2) and water vapour (H_2O) are converted (reduced) as much as possible to carbon monoxide, hydrogen and methane, which are the main combustible components of syngas. The updraft gasifier achieves the highest efficiency but the disadvantage is the excessive amount of tar in syngas. Tar is the seriously problem to operation of internal combustion engine. This problem is reduced in the downdraft gasifier. Crossdraft gasifier has certain advantages over updraft and downdraft gasifiers but the disadvantages are high exit gas temperature and poor CO_2 reduction. The information from previous study about “Tar” levels from gasifiers shows that general agreement about the relative of tar production, with updraft gasifiers being the dirtiest, downdraft the cleanest and fluidized bed intermediate [2, 3]. There are many attempts to develop of gasifier that expects of tar formation and tar conversion or removal during gasification. However it is not easy to find new technic or design that can fulfill all requirements. Installing an axial core flue gas circulating tube in the center line of the kiln (reactor) to change the direction of syngas to reduce “Tar” is the idea of this research.

2. Materials and methods

2.1 Characteristics of fuel

As shown in figure 1, Eucalyptus wood chip is biomass that can be processed into energy and it has plentiful in Thailand. Chemical formula for eucalyptus is $\text{C}_{4.1}\text{H}_{5.7}\text{O}_{2.8}$ Eucalyptus wood chip was used as fuel for producing syngas by updraft gasifier with axial core flue gas circulating kiln. The consumption of biomass was varied at 4, 8, and 10 kg with the size was 5-10 mm thick and the moisture content 16%.

2.2 Experimental Setup and Measuring Devices Used

Figure 2 shows the schematic of the updraft gasifier with axial core flue gas circulating kiln consisted of an axial core flue gas circulating tube installed in the center line of the kiln (reactor). The kiln's capacity was 0.41 m^3 . For combustion zone, the throat size diameter was 40 cm and diameter of the syngas outlet tube was 6 cm. The temperature of the syngas was cooled down by the condenser. Several type-K thermocouples were employed to measure the temperatures at preheat, combustion, reduction, pyrolysis, drying, and gas outlet zone.



Figure 1. Eucalyptus wood chip

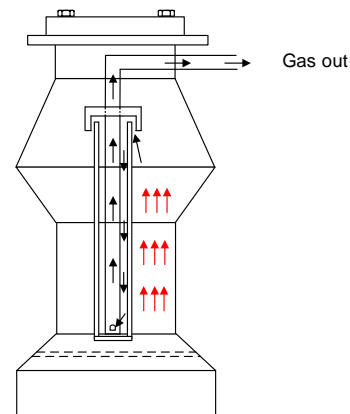


Figure 2. Schematic of updraft gasifier with axial core flue gas circulating kiln

Production of syngas from eucalyptus wood chips by updraft gasifier with axial core flue gas circulating kiln for reducing “Tar” is the target of this research. The experimental apparatus diagram was shown in figure 3. The experimental apparatus was made of the steel with 140 cm high and 60 cm base diameter. The kiln was insulated by thermal insulator outside the combustion zone. An air was used to be a working fluid blew by the blower through the flow meter into the combustion chamber at bottom

of the gasifier. The air temperature in front of the gasifier was 30-32 °C and volume flow rate 0.0033 m³/s. Type K-thermocouples were used to measure the temperatures of the flowing air at inlet of the gasifier (T1), inlet of the combustion zone (T2), inlet of the reduction zone (T3), inlet of the pyrolysis zone (T4), inlet of the drying zone (T5) and inlet of the gas outlet zone (T6). Moreover, the ambient temperature was also measured during the experiment.

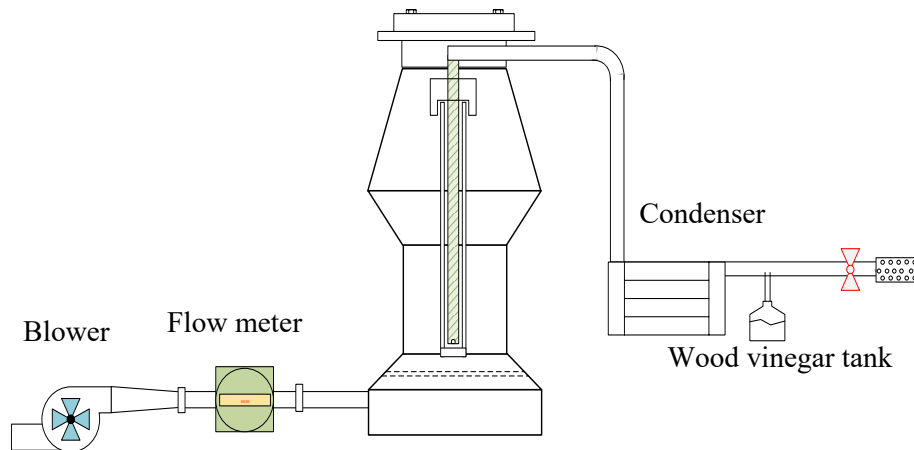


Figure 3. The schematic diagram of the experimental apparatus

3. Data processing

In the present study, Eucalyptus wood chip was used as a biomass to produced syngas by the process of gasification. Eucalyptus was chopped into pieces the length of 3-5 cm and 5-10 mm thick with the moisture content 16%. Moisture content indicates the amount of water contained in the material compared to the mass of material. Moisture content can be determined by using the equation as follow:

$$M_w = \frac{w-d}{w} \times 100 \quad (1)$$

where, M_w is the moisture content (%), w is the mass of material (kg), d is the mass of dry material (kg)

In the present experiment, the mass balance principle is used for calculating the Air to Fuel ratio (A/F ratio). The first variable is the amount of air used for incomplete combustion, which is between 20-30%. This research is calculated at a maximum percentage of 30%. Then air consumption 30% for gasification process and chemical formula for eucalyptus $C_{4.1}H_{5.7}O_{2.8}$ are used to analyse. Using the relationship is as follow.[4]



The syngas production efficiency (η_s) of the updraft gasifier with axial core flue gas circulating kiln can be evaluated by the ratio of mass of syngas production (m_g) and the consumption of biomass(m_f) which was expressed in equation (3).

$$\eta_s = \frac{m_g}{m_f} \times 100 \quad (3)$$

where, η_s is syngas production efficiency (%), m_g is mass of syngas production (kg), m_f is the consumption of biomass (kg)

4. Results and Discussion

4.1. Temperature distribution in the gasifier

The updraft gasifier with axial core flue gas circulating kiln used in the present work have the same element dimensions of width and capacity. Therefore, the density of fuel depends on the amount (mass) of biomass. In the present work, the eucalyptus wood chip 4, 8, and 12 kg with the moisture content 16% were examined. The relationship of biomass time and temperature distribution in combustion zone was shown in figure 4. The results indicated that at a biomass of 8 kg, the temperature in the combustion zone was higher than the other because amount of biomass is not too tight, resulting in a sufficient space for combustion. For a biomass of 4 kg, the heat from the combustion is low, so the temperature in the combustion zone tends to increase slowly. The temperature in this zone is about 400°C. Furthermore, the results showed that the temperatures in the combustion and the reduction zone of the kiln with core were lower than the kiln without core owing to installing the core would reduce the combustion zone area in biomass burning. Obviously, the temperature in the pyrolysis and drying zone were nearly the same as both with and without the core

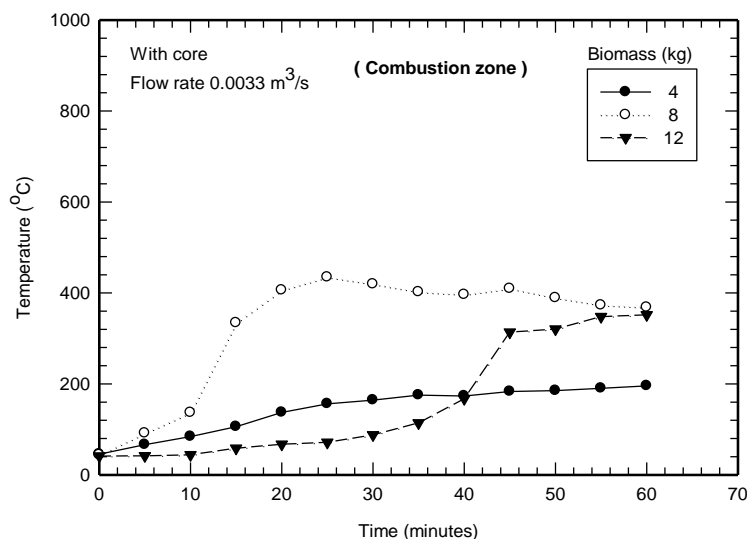


Figure 4. Temperature distribution in the combustion zone for kiln with core.

4.2. Heating value of syngas production.

For the result of heating value of syngas production, figure. 5 shows the effect of type of kiln and heating value of syngas production that the heating value of syngas received from gasifier with axial core flue gas circulating kiln was higher than the case of without the core. This result corresponds to the increased carbon monoxide (CO) content. It was found that the CO content produced by the gasifier with axial core flue gas circulating kiln was increased by 25% compared to the gasifier without the core. In installation of the core, the gas has been heated for a long time to produce more CO. Some of tar may was destroyed become CO. However other gases, carbon dioxide (CO₂), hydrogen (H₂), and methane (CH₄), were almost the same.

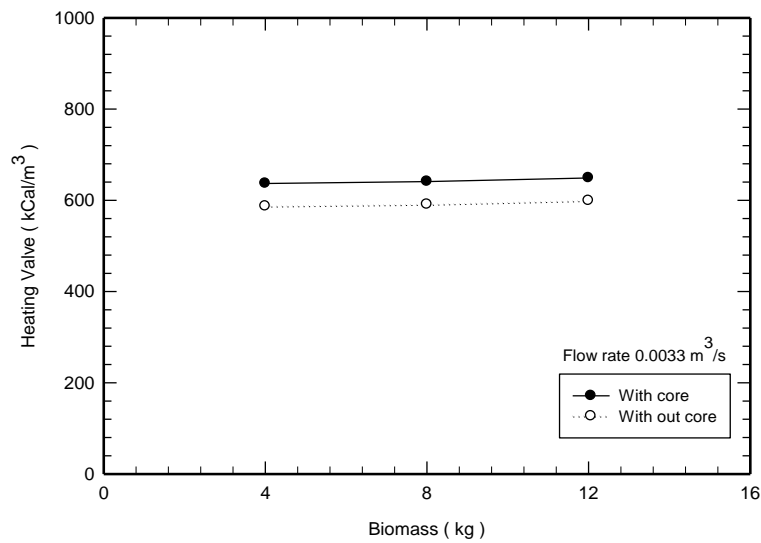


Figure 5. Effect of type of kiln and heating value of syngas production.

4.3. Syngas production efficiency

The syngas production efficiency was calculated by the ratio of mass of syngas production and the consumption of biomass. As shown in figure. 6, the graph shows the effect of type of kiln and syngas production efficiency. It was found that increasing of fuel consumption affects to decrease the syngas production efficiency. Syngas production efficiency obtained from the gasifier with axial core flue gas circulating kiln was higher than the gasifier without core by 10% for fuel consumption 8 and 12 kg. However, the experimental result shows that the highest efficiency was 30% at 4 kg supplying biomass. In comparison, the efficiencies of both kilns with and without the core were not different.

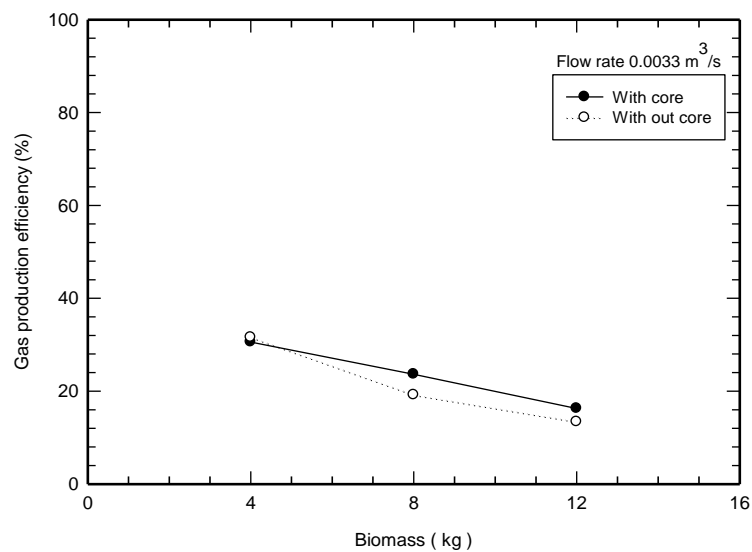


Figure 6. Effect of type of kiln and syngas production efficiency.

4.4. Liquid product

When moisture, gas and smoke condensed at the condenser, it became a liquid product. As shown in figure 7, the experimental result showed the effect of type of kiln to the liquid product quantity. The results show that a liquid product obtained from the gasifier without core was higher than the gasifier with core by 30-40% for all supplying biomass. This result corresponds to the increased of the syngas production efficiency. Due to the installation of the core was increasing time to reduce and changed a liquid product to be syngas. Expecting some of tar may was reduced in this process. Due to the axial flow system, syngas flows back to the combustion zone again before it is sent to the outlet pipe. The liquid product is destroyed become more gas.

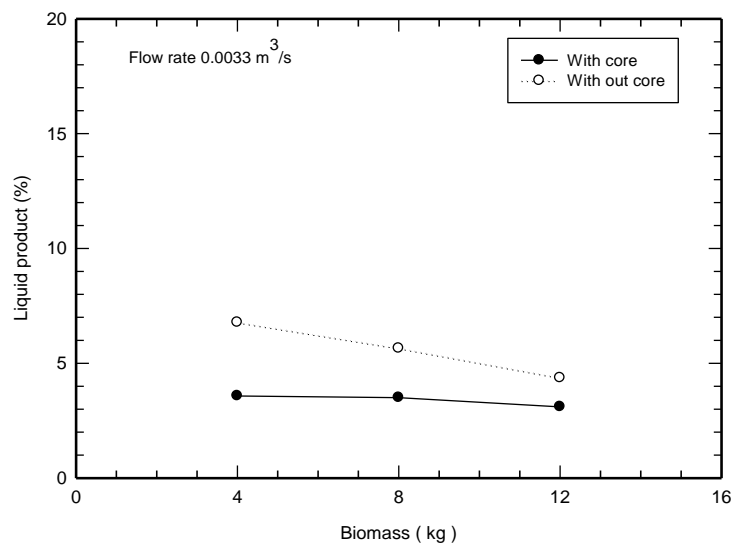


Figure 7. Effect of type of kiln and liquid product.

5. Conclusion

The present study conducted about the possibility for reducing tar in syngas. The updraft gasifier was modified by installing an axial core flue gas circulating tube in the center line of the kiln. From the experimental results and discussion of experimental data, the issue can be summarized as follows:

1. The temperatures in the combustion and the reduction zone of the kiln with core were lower than the kiln without core owing to installing the core would reduce the combustion zone area in biomass burning. For other zones were almost the same.
2. The syngas production efficiency of both the kilns with and without the core was not different. The highest efficiency was 30% at 4 kg supplying biomass.
3. The heating value of syngas received from the kiln with core was higher than the kiln without core that corresponds to the increased of carbon monoxide (CO). Carbon monoxide produced the kiln with core was increased by 25%.
4. The liquid product obtained from the kiln without core was higher than the kiln with core by 30-40% for all supplying biomass. The experimental result points that some of tar may was reduced and changed to be more gas.

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