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Appropriate Feedstock in Wood Gasification for Rural Electrification

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Abstract

This research paper describes results of experimental tests of Biomass gasification system. The biomass gasification system was developed as a part of the triple hybrid generation system, which consists of wind power 40 kW, solar panels 20 kW and biomass 20 kW in Ashikaga Institute of Technology (AIT). This research will enable rural areas to elaborate autonomous systems of electrification due to the availability of abundant biomass resources.

The downdraft type gasifier, which is being used, was designed and assembled by AIT. One feature of this biomass gasification system is that the produced gas operates a rotary engine for power generation. In the experiment, temperatures are monitored both at the oxidation and reduction layers in the furnace. In addition, contents of produced gas such as Carbon monoxide (CO) and Hydrogen (H_2) gas are monitored. Experimental test was carried out in two different operational conditions. These conditions include closed top operation and open top operation. In closed-top operation, the top lid of the gasifier is closed during operation and opened except when feeding biomass resources. In open top operation, the top lid is opened throughout operation. Finally, it was observed that in closed top operation, the temperature gradient was more constant with greater output of CO and H_2. In the open top operation, there was a drop in temperature with smaller output of CO and H_2 being produced compared to closed operation.

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Keywords: Biomass; downward draft gasification; drying layer; pyrolysis layer; reduction layer; oxidation layer.

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1. Introduction

From the second half of the 20th century, energy demand tends to be notably increasing due to world population increase and improvement of life style. The renewables-led transformation of the power sector has given focus to a new debate over power market design and electricity security, while traditional energy security concerns have not gone away [1]. Especially in developing countries, an increase of primary energy consumption per capita is expected in the next years and decades [2]. In order to improve this situation, development of renewable energy technologies such as wind power, solar power, hydraulic power and biomass power has become important to replace fossil fuels.

For the last two decades, gasification technology has been under intensive development and is being used for generating electricity and heat. If gasification is coupled with the production of a higher value liquid fuel, the combination could be a viable alternative energy technology [2]. Regarding the gasification of biomass, it has come to attract attention again, the reason being that wood materials does not synthesize nitrogen oxides that pollute the environment. These systems are suitable for autonomous electrification of rural areas due to the availability of raw material. In addition to that, biomass plants help in the development of rural areas through job creation. These are some of the reasons why research in biomass gasification is gaining more interest nowadays.

2. Theory

2.1 Principle of gasification

When burning wood or charcoal, combustible gases such as carbon monoxide and hydrogen are produced. Solid biomass gasification is the burning of solid fuels like wood or charcoal with controlled air flow so the output gas still has combustion potential. The produced gases are then piped, in this case, to the engine, after passing a process of filtration to remove ash content and tar. The produced gases pass through a bed of fuel at high temperatures to undergo a chemical reduction process.

Thermal conversion processes for biomass involve some or all of the following processes [3]:

Pyrolysis:	Biomass + Heat → Charcoal, oil and gas
Gasification:	Biomass + Limited oxygen → Fuel gas
Combustion:	Biomass + Stoichiometric oxygen → Hot combustion products

2.2 Downdraft gasifier

Biomass gasifier generation system for power supply system has been installed in AIT. The engine has little failure due to tar adhesion because it uses rotary engine instead of piston where the failure is more likely to occur. The engine oil container volume was doubled in order to trap tar. To enhance heat insulation in the gasification furnace, an insulating cover is attached around the combustion furnace. This makes easier to maintain higher the temperature inside of the gasifier during operation.

The main chemical reaction formulas of the gasification furnace are shown below [4]:

$$C + O_2 \Rightarrow CO_2 \quad (1)$$

$$H_2 + \frac{1}{2}O_2 \Rightarrow H_2O \quad (2)$$

$$C + H_2O \Rightarrow CO + H_2 \quad (3)$$

$$C + 2H_2O \Rightarrow CO_2 + 2H_2 \quad (4)$$

$$CO + 3H_2 \Rightarrow CH_4 + H_2O \quad (5)$$

Most of the oxygen used in the gasifier, either as pure oxygen or air, is consumed in reactions (1) through (2) to provide the heat necessary to dry the solid fuel, break up chemical bonds, and raise the reactor temperature to drive