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# Effect of gas composition produced by gasification, on the performance and durability of molten carbonate fuel cell (MCFC)

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ABSTRACT

Utilization of biomass using gasification technology combined with Molten Carbonate Fuel Cell (MCFC), is an option to solve fossil fuels and environmental pollution problem. Various types of biomass give different composition of the gas produced by gasification process and indirectly affect the performance and durability of MCFC.

This research is focused on determination of gas composition produced by gasification process (CO, $CO_2$, $H_2$ and $N_2$) that gives optimum performance and durability of MCFC either in dry or wet condition. Using mixture design method, the gas composition supplied to MCFC anode is varied in the range of 14%–25% for CO, 9%–17% for $H_2$, 10%–20% for $CO_2$, and 51%–58% for $N_2$. The effect of feed gas composition on the performance and durability of MCFC is characterized by using potentiodynamic method and accelerated load cycle method respectively. SEM and XRD is used in this study to evaluate gas composition effect on MCFC anode morphology.

Based on experiments that are carried out, the optimum result is obtained by using syn-gas from coconut shell gasification with composition of 25% CO, 12% $H_2$, 10% $CO_2$ and 53% $N_2$ in wet condition. Electrical power of 0.13 W is generated within 228 days of durability or it is decreased by 135 mV/1000 h or 16% (v/v)/1000 h.



## 1. Introduction

The increase of electrical energy demand and greenhouse gases are the main factors that drive the urge to utilize alternative source of energy which is both environmentally friendly and capable to increase national electricity production. Indonesia is abundant in some sources of biomass that are potential to be utilized as alternative source of energy as shown in Table 1.

Gasification is a mature technology for industrial scale application to convert biomass into syngas. The composition of syngas produced from gasification depends on its biomass source. Table 2 below shows some studies on syngas production from gasification of biomass that is abundantly available in Indonesia.

Based on the studies listed in Table 2, the composition of biomass-based syngas generally lies in particular compositional range as shown in Table 3.

Gasification process is commonly followed by syngas combustion for power generation. However, combustion causes environmental problem as it produces side flue gas containing greenhouse gases. Another technology option to couple gasification process in power generation is by using fuel cell. Fuel cells are electrochemical devices that is capable in converting chemical energy derived from biomass gasification into electrical energy directly and continuously with water and heat as byproduct (Larminie and Dicks, 2003).

One of fuel cell that is suitable for converting syngas directly is molten carbonate fuel cell (MCFC). MCFC operates at temperature of 650 °C and able to directly convert CO and $H_2$ into electrical energy continuously (Bagotsky, 2006). Molten carbonate with $LiAlO_2$ matrix acts as electrolyte in MCFC, while Ni act as anode and NiO act as cathode. The following is the general reaction mechanism that takes place in MCFC (Bodén, 2007).

$$Anode \quad 2H_2 \rightarrow 4H^+ + 4e^- \tag{1}$$

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**Table 1**
Potential biomass in Indonesia (EBTKE, 2012).

| Biomass | Production (ton/year) | Energy (GJ/year) |
|---|---|---|
| Rubber | 31,0 million | 496,0 million |
| Logging waste | 1,2 million | 11,0 million |
| Residual from wood sawmill industry | 1,1 million | 10,6 million |
| Palm empty fruit bunch | 3,5 million | 15,4 million |
| Palm fiber | 3,7 million | 35,3 million |
| Palm fruit shell | 1,3 million | 17,2 million |
| Sugarcane bagasse | 6,5 million | 78,0 million |
| Rice husk | 14,3 million | 179,0 million |
| Coconut shell | 1,1 million | 18,7 million |
| Coconut coir | 2,0 million | 24,0 million |

**Table 2**
Results of biomass gasification (% v/v).

| Biomass source | CO | $H_2$ | $CO_2$ | $N_2$ | Author |
|---|---|---|---|---|---|
| Rubber wood | 18 | 16 | 10 | 54 | (Susanto, 1986) |
| Wood waste | 17 | 16 | 10 | 55 | (Rajvanshi, 1986) |
| Palm empty | 15 | 12 | 20 | 51 | (Lahijani et al., 2013) |
| fruit bunches | 14 | 9 | 14 | 56 | (Moni and Sulaiman, 2013) |
| Palm fruit shells | 20 | 11 | 10 | 58 | (Susanto, 1986) |
| Sugarcane bagasse | 15 | 15 | 12 | 56 | (Rajvanshi, 1986) |
| Rice husks | 16 | 10 | 10 | 57 | (Rajvanshi, 1986) |
| | 20 | 11 | 11 | 55 | (Susanto, 1986) |
| Coconut shell | 19 | 10 | 11 | 54 | (Rajvanshi, 1986) |
| | 25 | 12 | 10 | 51 | (Susanto, 1986) |
| Coconut coir | 16 | 17 | 10 | 55 | (Rajvanshi, 1986) |

**Table 3**
General composition of biomass-based syngas.

| Type of gas | CO | $H_2$ | $CO_2$ | $N_2$ |
|---|---|---|---|---|
| Composition (% v/v) | 14–25 | 9–17 | 10–20 | 51–58 |

$$\text{Cathode} \quad O_2 + 4H^+ + 4e^- \rightarrow 2H_2O \tag{2}$$

$$\textit{Total reaction} \quad 2H_2 + O_2 \rightarrow 2H_2O \tag{3}$$

MCFC has a high efficiency and produce energy on a large scale (100 kW - 10 MW). Therefore, process coupling between gasification and fuel cell technology is a promising solution to produce clean energy.

Studies on the combination of biomass gasification technology and MCFC are mostly focused only on the effect of one component of the syngas on the performance of MCFC. Meanwhile, the influence of biomass source and biomass-based syngas composition to the performance and durability of MCFC has not been intensively examined. Therefore, the purpose of this research includes:

- Determining the most suitable biomass to produce syngas as MCFC anode fuel;
- Estimating the amount of power generated from gasification using potential biomass source in Indonesia;
- Analyzing the influence of CO, $CO_2$, $H_2$, and $N_2$ composition in syngas and their interaction on the performance of MCFC; and
- Predicting the durability of MCFC for each syngas produced from gasification of the potential biomass in Indonesia.

## 2. Methodology

The overall method of experiment conducted in this research is presented in Fig. 1. The study is started by characterizing MCFC anode using XRD and SEM to determine the initial condition of anodes. The step is followed by designing experiment framework using mixture design method in Minitab 16.1.1 to determine the feed rate at anode. The feed rate at the cathode is set constant at 68 ccm for $CO_2$ and 162 ccm for compressed air. This is done to determine the optimum conditions for each component presents at anode feed gas, to observe the effect of each component on the

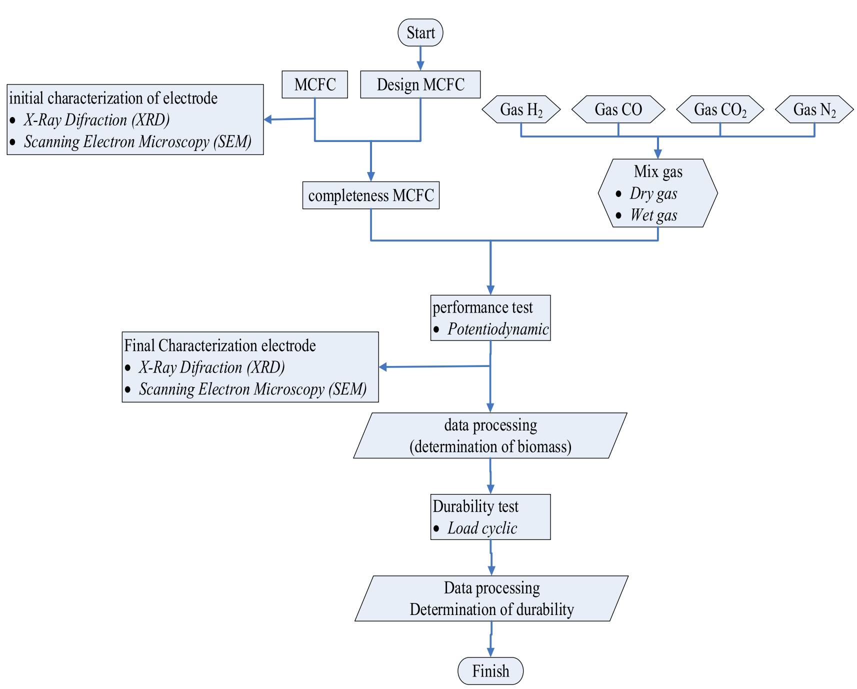


**Fig. 1.** Experiment method flow diagram.