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Preliminary study on single stage micro gas turbine integrated with South Sumatera Indonesia low rank coal gasification

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ABSTRACT

The decrease of the world's petroleum resources encourages the use of an alternative energy such as coal gasification. The low rank coal is the most potential resources in South Sumatra, Indonesia. The utilization of low rank coal from South Sumatra (MT-46) using gasification to drive the single stage micro gas turbine is more preferable. The objective of this study was to investigate the effect of air-fuel ratio (fixed fuel mass flow) on turbine rotation, turbine inlet temperature and turbine power. The gasification was conducted using an atmospheric downdraft gasifier with equivalent ratio of 0.25. The results showed an increasing of air-fuel ratio (1.6 to 3) of gas burner tended to increase the turbine rotation from 22000 rpm to 25000 rpm and turbine power from 0.75 to 1.03 kW. On the other hand, the increase of air-fuel ratio tended to decrease the turbine inlet temperature from 577 ^{0}C to 402 ^{0}C.

Key word : *Gasification, Low rank coal, Downdraft, Gasifier, Direct mikro gas turbine.*

Introduction

Indonesia is one of the world's coal producing countries with 3% of world reserves (28 Bilions tons). Indonesia low rank coal reserves are 5% of word reserves that dominated in South Sumatera (Winarno and Drebenstedt, 2014). Low rank coal utilization requires a converting system that has a high efficiency of conversion. Gasification is one of the coal converting system into thermal energy (gas producer) with high of efficiency (Kirkels and Verbong, 2011) and low pollutant produced (Yun and Chung, 2007).

The thermal energy generated from the coal gasification process can be utilized for various applications. Direct fired micro gas turbine (DMFGT) is one of method to utilize thermal energy to mechanical energy. The downdraft gasifier have many advantages to integrate with direct micro gas turbine especially to produce heat or power (Matteo *et al.*, 2008).

Research conducted to micro gas turbine driven by full (100%) of producer gas has been done by several researchers. Sridhar *et al.* (2007) conducted research on high pressure (4 to 4.3 barg) open top downdraft gasifiers to drive single stage micro gas turbine with power generated between 7.89 to 11.43 kWe on air fuel- ratio range (A/F) of 5.60 to 6.90. Al- Attab and Zainal (2018) has investigated on direct micro gas turbine using 100% of producer gas produced by pressurized downdraft gasifier, LPG was used. to support at start up process at maximum pressure operation of 1.2 barg, the results showed when the operation on single stage turbine the power produced by turbine just to compress air and producer gas mixed only. Al-Attab

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and Zainal (2014) has investigated on direct micro gas turbine using 100% of producer gas produced by pressurized downdraft gasifier at pressure maximum 1 barg and air-fuel ratio in range 3 to 5, the startup process was supported by LPG, the results showed when the operation single stage the power produced by turbine just to compress air only. Another reporting by Al-Attab and Zainal (2014) is a investigation on direct micro gas turbine using producer gas produced by atmosfheric downdraft gasification, the results showed producer gas from atmospheric downdraft gasification must be coupled with LPG (dual fuel operation) to drive a micro gas turbine.

In this research the single stage micro gas turbine using a single fuel producer gas from atmosfheric gasification of South Sumatera Indonesia low rank coal was investigated.

Methodology

The gasification system was used in this research is an imbert downdraft gasifier with diameter of 26.8 cm, height of 90 cm and diameter of throat of 12 cm. that was equipped by gas cleaning system (cyclone, spray tower and filter) (Vidian *et al.*, 2017). The fuel was used in this research is low rank coal from South Sumatera Indonesia. The proximate and ultimate of low rank coal shows in Table 1.

The mass flow of air gasification was measured using orifice flat meter. The equivalent ratio of gasification process was calculated using equation (1).

Table 1. Low Rank Coal Analysis (Vidian *et al.*, 2017)

Parameter	Unit	Average Value
Total Moisture	Mass Fraction (%, Ar)	27.79
Proximate		
Moisture Inherent	Mass Fraction (%, Adb)	13.59
Ash	Mass Fraction (%, Ar)	5.13
Volatile	Mass Fraction (%, Ar)	33,72
Fixed Carbon	Mass Fraction (%, Ar)	33.37
Ultimate Analysis (dry basis)		Value
Carbon	Mass Fraction (%,Adb)	57.35
Hydrogen	Mass Fraction (%,Adb)	4.31
Oxygen	Mass Fraction (%,Adb)	17.37
Nitrogen	Mass Fraction (%,Adb)	0.77
Heating Value	Unit	Value
Gross CV	kcal/kg, (Ar)	4759
Gross CV	kcal/kg, (Adb)	5695

The air-fuel ratio (A/F) stoichiometric of gasification process was calculated using equation (2).

$$ER = \frac{\left(\mathit{Air}/\mathit{Fuel}\right)_{Actual}}{\left(\mathit{Air}/\mathit{Fuel}\right)_{Stoichiometric}} \quad .. (1)$$

Where:

$$\left(\mathrm{Air}/\mathrm{Fuel}\right)_{\mathrm{Stoichiometric}} = \frac{1}{0{,}232}\left[\frac{8}{3}\mathrm{C} + 8\mathrm{H}_2 + \mathrm{S} - \mathrm{O}_2\right]\left(\frac{\mathrm{kg\ of\ air}}{\mathrm{kg\ of\ fuel}}\right) .. (2)$$

Micro gas turbines were used in this research is a combining of turbocharger and coastair burner. The turbocharger is type RHF5 consists of a radial turbine and a centrifuge compressor as shown in Figure 1, the maximum temperature of the gas that can pass through the turbine is 750 ^{0}C. The coast air burner was used as shown Figure 2, air and producer gas is not mix before combustion process exists.

The mass flow rate of air and producer gas were measured using orifice plate meter. The turbine inlet and outlet temperature was measured using type K thermocouple. The turbine rotation was measured using a tachometer. The air-fuel ratio was used as parametric of operation of gas burner was calculated using equation 3. The power of turbine was calculated using equation 4.

The star-up of coastair gas burner used single fuel of producer gas, at star-up process, the mass flow of producer gas was adjusted 11.54 kg/h then the producer gas was ignited at the front of coastair burner. After the flame appeared, the mass flow rate of air and producer were adjusted of 18.26 kg/h and 11.54 kg/h respectively then closed the front of burner.

The exeperimental set-up was used as shown in Figure 3.

$$A/_F \ Gas\ burner = \frac{Mass\ flow\ rate\ of\ air}{Mass\ flow\ rate\ of\ producer\ gas} \quad .. (3)$$

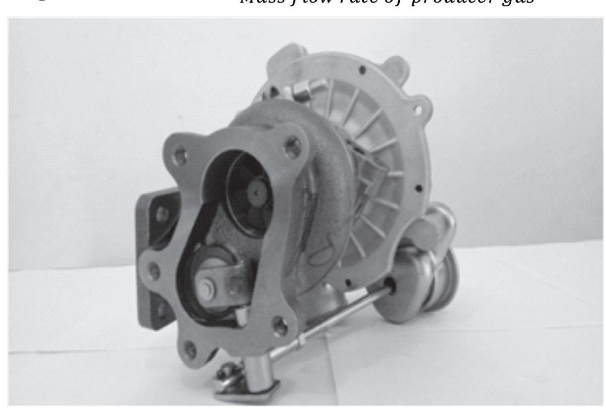

Fig. 1. Turbocharger

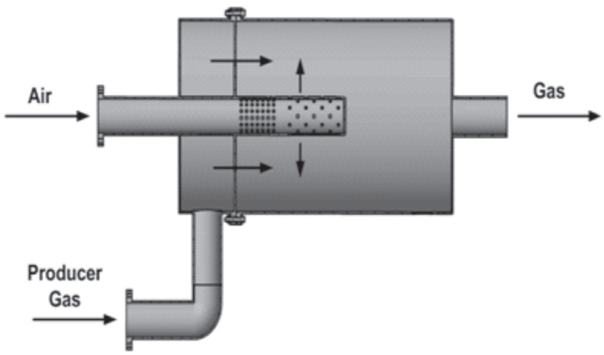

Fig. 2. Coastair burner

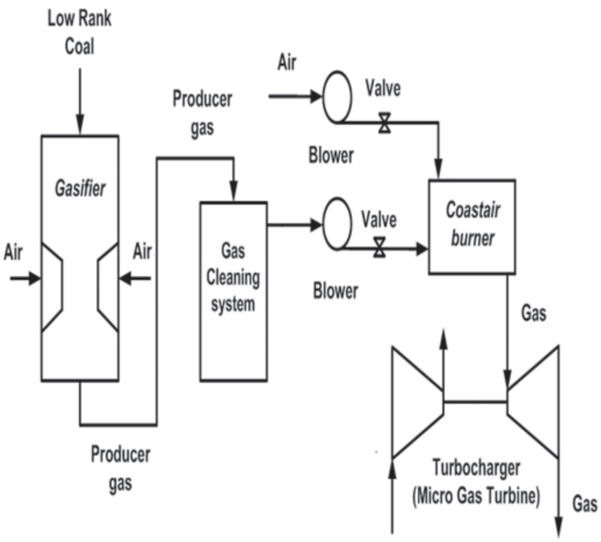

Fig. 3. The experimental set-up

$$Turbin\ Power = \dot{m}\ (\Delta h) \quad ..\ (4)$$

Results and Discussion

Gasification Process

The gasification process was done at an equivalent ratio about 0.25 with the producer gas compositions as shown on Figure 4. The low rank coal consumption rate was about 4.3 kg/h. The combustible gaseous were dominated by CO of 28% followed by H_2 of 9.26% and CH_4 of 0.77%.

The effect of Air-Fuel Ratio on Rotating of Turbine

Figure 5 shows the effect of air fuel ratio to the turbine rotation. Increasing of air-fuel ratio (from 1.6 to 3) tended to increase the rotation of the turbine

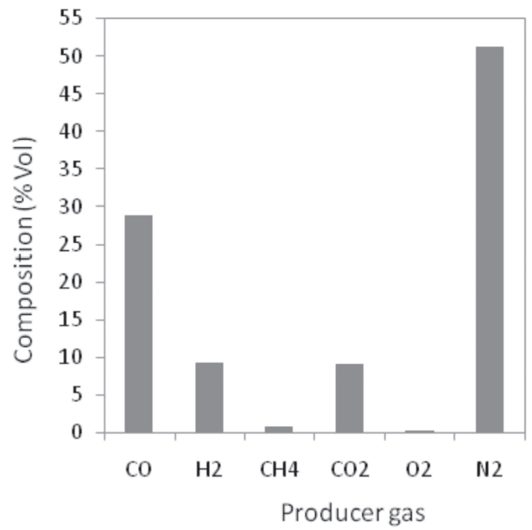

Fig. 4. Producer Gas Composition

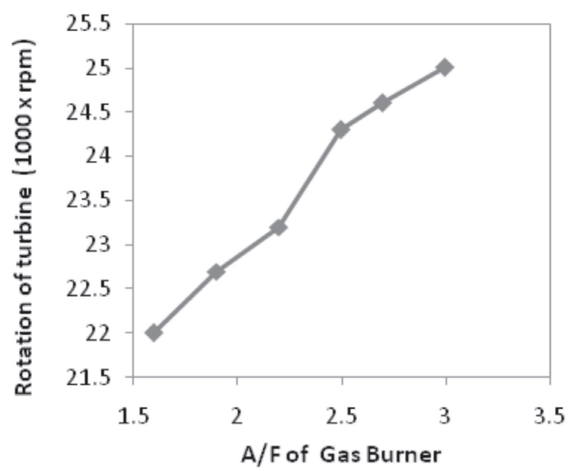

Fig. 5. Rotating turbine with different A/F of Gas Burner

(from 22000 to 25000 rpm). Due to increase of air-fuel ratio would increase the burned fuel and the mass flow of flue gases to drive of turbine (Saddig *et al.*, 2013). The maximum pressure operation was 0.1 barg.

The effect of Air-Fuel Ratio on Turbine Inlet Temperature

Figure 6 shows an increase in air-fuel ratio (fixed of fuel mass flow) tended to decrease the turbine inlet temperature (the temperature out of the gas burner), this was because the excess air on combustion process (fixed of fuel mass flow) followed by the increase in concentration of N_2, which further absorbed heat from combustion (Saddig *et al.*, 2015).

The maximum temperature of inlet turbine occurred at A/F of 1.6. Based on combustion principle maximum temperature could be reached at A/F stoichiometric (A/F stoiciometric of 1.04).

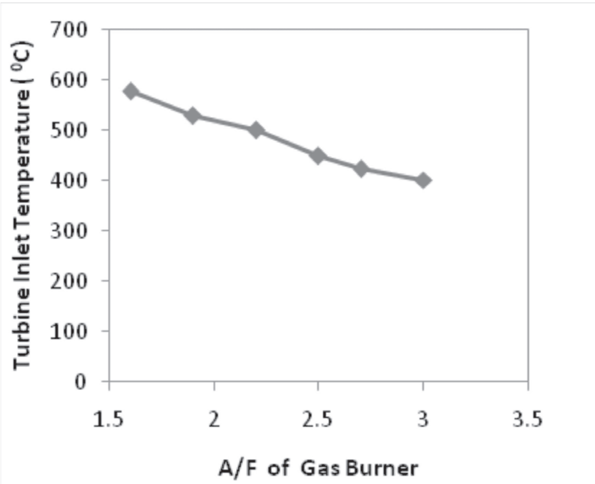

Fig. 6. Turbine inlet temperature with different A/F of Gas Burner

The effect of Air- Fuel Ratio on Turbine Power

Figure 7 shows the effect of air and fuel ratio on turbine power, the increase of air-fuel ratio tended to increase the power generated by the turbine shaft. Due to increase of air-fuel ratio would increase the rotation of the turbine shaft as shown in Figure 2. The power generated in range of 0.76 to 1.03 kW on air fuel ratio of 1.6 to 3. According to the result has been reported by Al-Attab and Zainal, (2010)

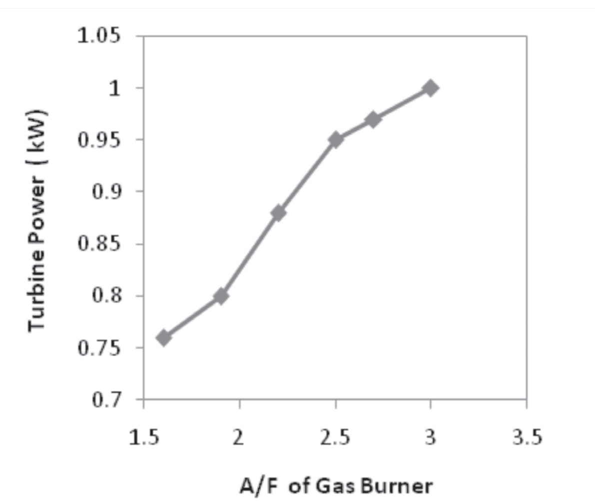

Fig. 7. Turbine power with different A/F of gas burner

for the rotating of turbine below 56000 rpm would produced turbine power below 2 KW.

Conclusion

The results of the study showed that the micro gas turbine could be operate using producer gas from South Sumatera Indonesia low rank coal gasification. Gasification process was done on a imbert downdraft gasifier at equivalent ratio of 0.25. The combustion process of the producer gas in the gas burner takes place on the air-fuel ratio (A/F) of 1.6 to 3. The rotation of turbine could be generated between 22000 rpm to 25000 rpm. Turbine inlet temperature at range of 402 to 577 ^{0}C. Turbine power produced about 0.75 to 1.03 kW.

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References

Al-Attab, K.A. and Zainal, Z.A. 2010. Turbine startup methods for externally fired micro gas turbine (EFMGT) system using biomass fuels. *Applied Energy*. 87 (4) : 1336–1341

Al-Attab, K. and Zainal, Z. A. 2014. Performance of a biomass fueled two-stage micro gas turbine (MGT) system with hot air production heat recovery unit. *Applied Thermal Engineering*. 70 (1) : 61-70.

Al-Attab, K.A. and Zainal, Z.A. 2018. Micro Gas Turbine Running on Naturally Aspirated syngas : Experimental Investigation. *Renewable Energy*. 119 : 210-216.

Kirkels, A.F. and Verbong, G.P.J. 2011. Biomass Gasification: Still Promising? A 30-Year Global Review. *Renewable and Sustuainable Global Review*. 15 : 471-481.

Matteo, P., David, C., Giovanni, R. and Francesco, M. 2008. Evaluation of A Micro Gas Turbine Fed by Blends of Biomass Producer Gas and Natural Gas, *Proceedings of ASME Turbo Expo 2008: Power for Land, Sea and Air, Berlin, Germany*.

Saddig, H. Sulaiman and S.A. Ibrahim, I. 2013. Experimental Investigation of A Twin Shaft Micro Gas Turbine System, *IOP Confrence Series : Earth and Environmental Science*. 16 012011.

Saddig, H., Sulaiman, S.A. and Said, M.A. 2017. Effect Gas

Producer Stage Combustion on The Performance and Emision of Single Shaft Micro Gas Turbine Running in Dual Fuel Mode. *Journal of Energy Institute.* 90(1): 132-144.

Sridhar, H.V. Sridhar, G. Dassapa, S. Paul, P.J. and Mukunda, H.S. 2007. On The Operation of A High Pressure Pressure Biomass Gasifier with Gas Turbine. *The 15th European Biomass Conference & Exhibition, 7-11 May 2007, Berlin, Germany*.

Vidian, F., Basri, H. and Sihotang, D. 2017. Design, Construction and Experiment on Imbert Downdraft Gasifier Using South Sumatera Biomass and Low Rank Coal. *International Journal of Engineering Research and Aplication*. 7 (3) : 39-44.

Winarno, T. and Drebenstedt, C. 2014. Low Rank Coal : Fuiture Energy Source in Indonesia. *Proceeding of the 12th International Symposium Continuous Surface Mining Aachen*.

Yun, Y. and Chung, S.W. 2007. Gasification of an Indonesia Subbitunious Coal in a Pilot- Scale Coal Gasification System. *Korean Journal Chemical Engineering*. 24 (4) : 628-632.