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PREDICTION OF PRODUCER GAS COMPOSITION FROM COAL GASIFICATION USING CYCLE TEMPO

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ABSTRACT

Coal gasification in Indonesia is currently being promoted to meet the needs of electrical energy. Early prediction of the gas composition resulting from the gasification process is needed in development of gasification system. In this study, a simulation of the gasification process of low-rank coal was carried out using cycle tempo. The simulation aims to predict the gas composition of low-rank coal gasification by varying the air-fuel ratio. The variations of the air-fuel ratio were in between of 1.25 to 1.5. The simulation results present the maximum fraction of combustible gas of CO, H_2, and CH_4 was 21.25 %; 19.31 %, and 3.15 % respectively. The difference between simulation and experimental results has a similar trend with the literature.

KEYWORDS: *Gasification, Coal, Simulation, equilibrium, Combustible Gas*

Article History

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INTRODUCTION

Coal is a fossil energy source that still dominates as an energy source, especially for power plants [1]. Indonesia is one of the largest coal-producing countries in Asia [2]. The use of coal for power generation in Indonesia is still dominated by the direct combustion system, as it is known that the direct combustion system has environmental problems [3]. One of the alternatives to solve this problem is to change the direct combustion system into a gasification process. An initial prediction of producer gas composition is needed in the process of changing. We can estimate the number of inputs and outputs from the gasification process through simulation.

Several simulation models have been developed in predicting the producer gas composition. Thermodynamic model is very simple and interesting method. The thermodynamic model is based on equilibrium [4-6]. Currently, there is much software that has been developed based on thermodynamics to estimate the producer gas composition resulting from gasification such as Cycle Tempo, Aspen Plus [7-9], AspenHysis [10], and Engineering Equation Solver [EES] [11-12]. The mathematical equations are already available in the software, we just need to adjust the block diagram of the process. Cycle tempo is software that uses the principle of a single-stage or two-stage equilibrium.

Several gasification simulations have been done by researchers utilizing cycle tempo software. Nandwana et al [13] simulated coal fuel and cow manure gasification using a single-stage equilibrium. The simulation results show the composition of the combustible gases ofCO18.18 %; 14.06 %, H_2 12.39 %; 10.32 %, CH_4 0.62 %; 0.13 %, respectively. Ozgoli [14] simulated a gasification process using sugar cane bagasse fuel with a two-stage equilibrium model. The simulation results show the composition of CO 15.21 %, $H_2$10, 31 % and CH_4 5.41 %. El-Sattar et al [15] carried out a gasification simulation using a two-stage equilibrium model with corn stover pieces (CSP) as fuel, the simulation results show the mole fraction of the combustible gas of CO 12.65 %, H_2 17.09 % and CH_4 1.15 %. Vera et al [16] carried out a gasification simulation using a single-stage equilibrium model with olive tree leaves and prunings as fuel. The simulation results show the combustible gas mole fraction of CO 20 ± 3 %, H_2 18 ± 3 %and CH_4 3 %.

El-Sattar et al [17] carried out a gasification simulation using a two-stage equilibrium model with rice straw as fuel, the simulation results show the combustible gas composition of CO 15.59 %, H_2 14.17 % and CH_4 1.02 %. Altafini et al [18] performed a gasification simulation using a two-stage equilibrium model fuelled by Pinus Eliottii sawdust, the simulation results show the composition of CO 21.82 %, H_2 14.38 % and CH_4 1.72 %. Fortunato et al [19-20] simulated a gasification process using two-stage equilibrium with sawdust as fuel, the simulation results show the composition of CO 19.45 %, H_2 14.95 %, and CH_4 2.60 %. Depoorter et al [21] performed a simulation using a tree stage equilibrium with corn cob as fuel, the mole fraction of combustible gaswas CO 21.24 %, H_2 17.05 % and CH_4 2.31 %. Vera et al [22] simulated a gasification using a single-stage equilibrium model with olive pits as fuel. The simulation results show the composition of CO 21.61 %, H_2 19.86 % and CH_4 1.5 %. El-Sattar et al [23] simulated using a two-stage equilibrium model with sawdust as fuel. The simulation results show the combustible gas composition of CO 22.35 %, H_2 20.53 % and CH_4 1.24 %. Ferreira et al [24] performed a simulation using single-stage equilibrium with MSW as fuel. Pappinisseri et al [25] simulated a gasification process taking a one-stage equilibrium model with coconut, rubberwood, and bamboo as fuel. The simulation results show the combustible gas composition of CO 10.16 %; 7.26 %; 6.51 %, $H_2$9.59 %; 8.04 %; 5.79 % and CH_4 0.13 %; 0.05 %; 0.02 %, respectively.

The literature review shows that the composition of the combustible gas produced by the simulation process using cycle tempo varies greatly which is influenced by the input of the ultimate analysis. In addition, the fuel used in the simulation process is generally biomass, while coal is rarely used. The new finding of this research is the utilize of local low rank coal from South Sumatera, Indonesia.

METHODOLOGY

Simulations are carried out using an equilibrium model with the Gibbs energy minimization concept. The simulation was carried out using the two-stage equilibrium method. The gasification process is transformed into a block diagram of the cycle tempo as shown in Figure 1. The input of the simulation is the ultimate analysis of low-rank coal MT 46 from South Sumatera, Indonesia [26] as shown in Table 1.The mass flow rate of fuel is 0.005 kg/s. The ratio of air to fuel is in the range of 1.25 to 1.5.

Table 1: The Ultimate Analysis of Low Rank Coal [26]

Carbon	57,35 %
Hydrogen	4,31 %
Oxygen	17,37 %
Nitrogen	0,77 %
Low Heating Value	22.200,67 kJ/kg

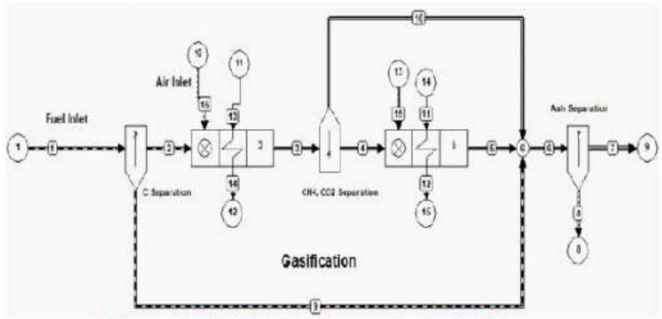

Figure 1: Gasification Process in Cycle Tempo.

RESULTS AND DISCUSSIONS

Producer Gas Composition

Figure 2 presents the influence of the ratio of air to fuel on the fraction of producer gas (CO, H_2, CH_4, CO_2, N_2). The fraction of combustible gas (CO, H_2, CH_4) tends to decrease while the fraction of non-combustible gas (CO_2, N_2) tends to increase. The fraction of CO, H_2, and CH_4 is in between of 20.35 % to 21.25 %; 17.54 % to 19.31 %, and 2.58 to 3.15 % respectively, meanwhile, the fraction of CO_2 and N_2 is in between of 10.50 % to 10.80 % and 44.83 % to 47.78 % respectively. The simulation results present a low decrease in the fraction of combustible gas of CO and CH_4 in the air-fuel ratio between 1.25 to 1.5, this result have the same trend to the results of the simulation conducted by El-Sattar et el [15]. The decrease of H_2 have the same trend with the results Vera et al [22].

The comparison of the simulation and experimental [27] results are shown in Figure 3. The percentage difference is still comparable. According to the report of Fortunato et al [19], the differences between simulation and experimental RDF gasification for the combustible gas fraction of CO, H_2, and CH_4 were about 21.5 %; 50,7 % and 68.7 %. In this simulation, the differences between simulation and experimental of CO, H_2, and CH_4 were about 26 %; 52 % and 92 %. The same trend differences caused by the ultimate analysis are quite the same. The high differences in this simulation were caused by the still difference in the air-fuel ratio on simulation and experimental each of 1.5 and 1.

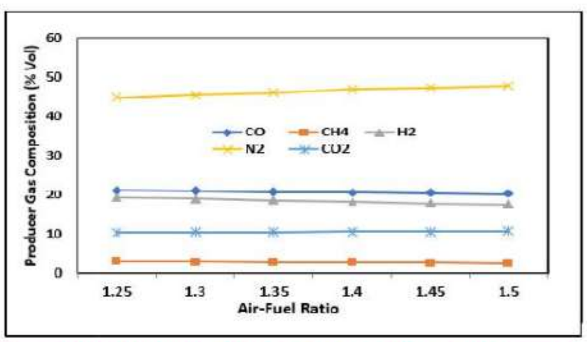

Figure 2: The Influence of Ratio of Air to Fuel on Producer Gas Composition.

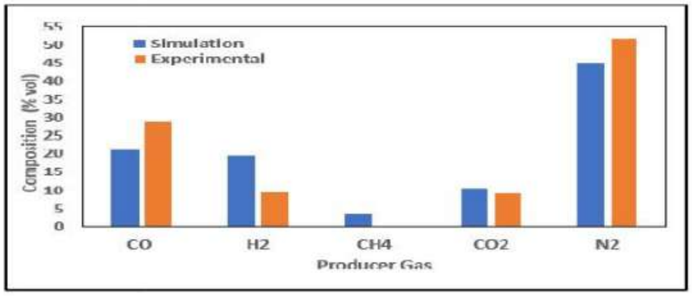

Figure 3: The Comparison of Simulation and Experimental.

The LHV of Producer Gas

Figure 4 shows an increase in the ratio of air to fuel from 1.25 to 1.5 will decrease the LHV of producer gas from 5432.78 to 4849.21 kJ/kg, due to a decrease in the fraction of combustible gases (CO, H_2, CH_4) as shown in Figure 2.

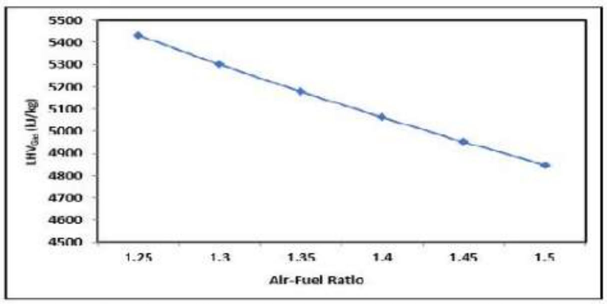

Figure 4: The Influence of Ratio of Air to Fuel on LHV of Producer Gas.

The Efficiency of Gasification

Figure 5. Presents the effect of increasing the ratio of air to fuel on gasification efficiency. An increase in the ratio of air to fuel will decrease the efficiency of the gasification. This decrease occurred due to a decrease in the calorific value of the producer gas, while the calorific value of the fuel used did not change.

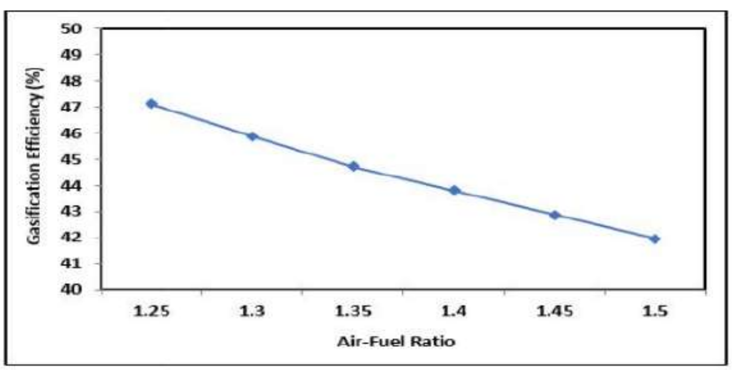

Figure 5: The Influence of Ratio of Air to Fuel on Gasification Efficiency.

CONCLUSIONS

From the simulation carried out, it is obtained that the fraction of combustible gas of CO, H_2, and CH_4 in the ranges of 20.35 % to 21.25 %; 17.54 % to 19.31 %, and 2.58 to 3.15 % respectively at air-fuel ratio 1.25 to 1.5. LHVof producer gas is in the range of 4849.21 to 5432.78 kJ/kg. The result of the simulation has the same trend as the literature. The comparison between simulation and experimental is still comparable based on the literature.

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