

Performance prediction of a downdraft gasifier using equilibrium model: effect of different biomass

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Abstract:

In this paper, a thermochemical equilibrium model was used to simulate the gasification process of biomass and predict the composition of the producer gas. The predicted results agreed well with those of the experiments available in the literature. The model was then employed in order to optimize the selection procedure of a specific biomass for a certain application. For this purpose, at constant operational conditions, the ultimate compositions of various biomasses were used to investigate the influence on syngas characteristics. These included the calorific value, gasification efficiencies and the volume of producer gas.

Keywords: Biomass gasification; equilibrium modeling; Biomass

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1. Introduction

Nowadays due to expansion of energy consumption and its increasing trend, in contrast to fossil fuel which is the primary energy source for power generation, has decreased continuously. Moreover, the aspects of environment and global warming have been concerned recently past. One alternative for clean and renewable energy is energy from biomass. Used of biomass energy utilization can be classified into two main processes, first is thermo chemical conversion and second is biochemical conversion. One advantage of biomass to primary energy source is it can convert to form of solids, liquids and gaseous phase (Saxena, 2009). Gasification is process that converts carbonaceous solid fuel into combustible gaseous fuel.

In this paper, the modeling global reaction in the downdraft gasifier base on equilibrium models was used for predicts gaseous composition and heating value of biomass feedstock. Some performance indices were apply for compare fuel quality of raw material

2. Material and methods

Properties of 31 type of biomass were chosen to simulate in gasification modeling. Biomass properties are showed in (Prusakit, 2014). The global reaction in the downdraft gasifier was used in this work.

For this work heat loss from process assume equal 10% of HHV of feedstock and equivalence ratio equal 0.3. Calculation method and validate data of this model are showed in Cold gas efficiency is calculated by (Dejtrakulwong and Patumsawad, 2011);

$$\varepsilon = \frac{LHV_{gas\ product} \times Y}{LHV_{Feed}} \times 100$$

where, Y is the product gas yield (Nm³/kg_{dry feedstock}), LHV_{gas product} is the lower heating value (MJ/N m³) of the gas product, and LHV_{feed} is the lower heating value (MJ/kg) of feedstock (He et al., 2009)

3. Result and discussion

Biomass which low oxygen content tends to produce low CO and high CO₂ in gas product as shown in Fig. 1 (a), (b) while high carbon content tend to produce high CO (Fig. 2.). High oxygen content in biomass has the advantage because it can be reduce air input. Nitrogen (incombustible gas) provided by air reduces HHV of gas product (Mansaray et al., 1999; Alauddin et al., 2010). Increase of H in biomass tends to increase of H₂ and CH₄ in gas product. In Fig. 3 increase of oxygen in biomass showed decrease of CH₄ in gas product. However, high oxygen content showed high product of H₂ as present in Fig. 3.

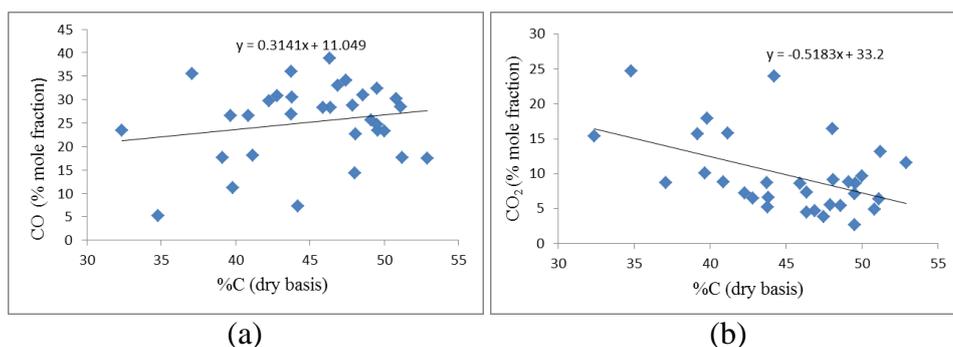


Fig. 1 Relation between carbon content and mole fraction of gas product: (a) CO, (b) CO₂.

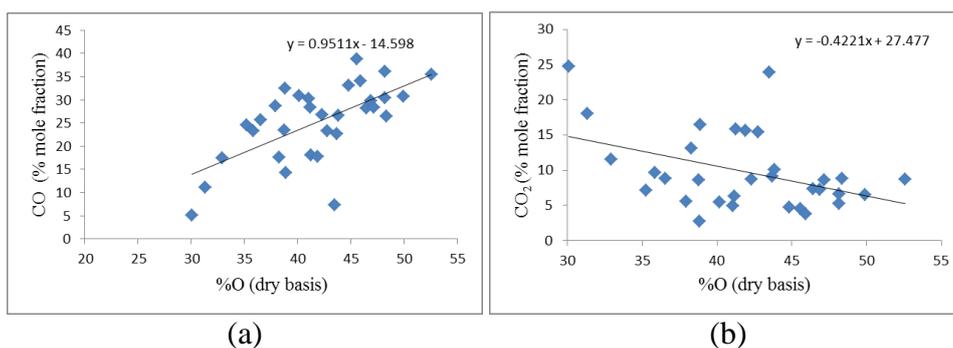


Fig. 2 Relation between oxygen content and mole fraction of gas product: (a) CO, (b) CO₂.

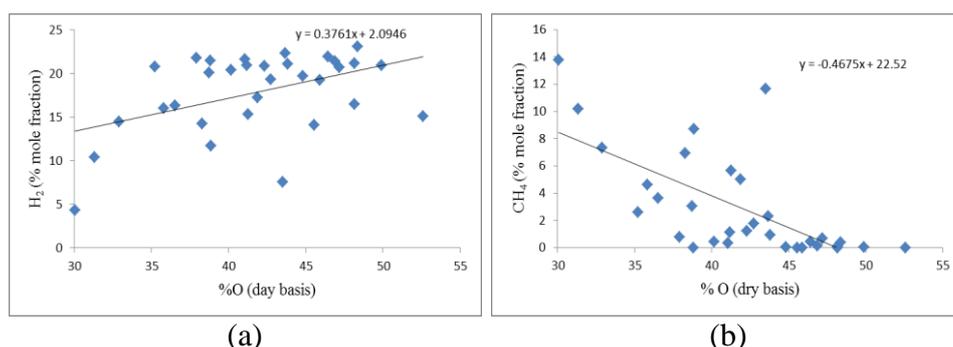


Fig. 3 Relation between oxygen content and mole fraction of gas product: (a) H₂, (b) CH₄.

In Fig. 4 (a), high of carbon and low oxygen tend to low HHV of gas product because nitrogen in air supply while high hydrogen and low oxygen content showed high HHV of gas product because high H₂ and CH₄ are generated. In contrast, high oxygen and high hydrogen content showed low HHV because hydrogen is can be form into water (H₂O) case of reducing of CH₄ and H₂ product while high carbon and oxygen content showed high HHV of gas product because CO in gas product are increased.

Although high oxygen content in biomass showed high HHV of gas product but gas yield are reduce case of low in cold gas efficiency as showed in Fig. 4 (b). As mention above, high carbon content tend to low HHV of gas product and case of low in cold gas efficiency.

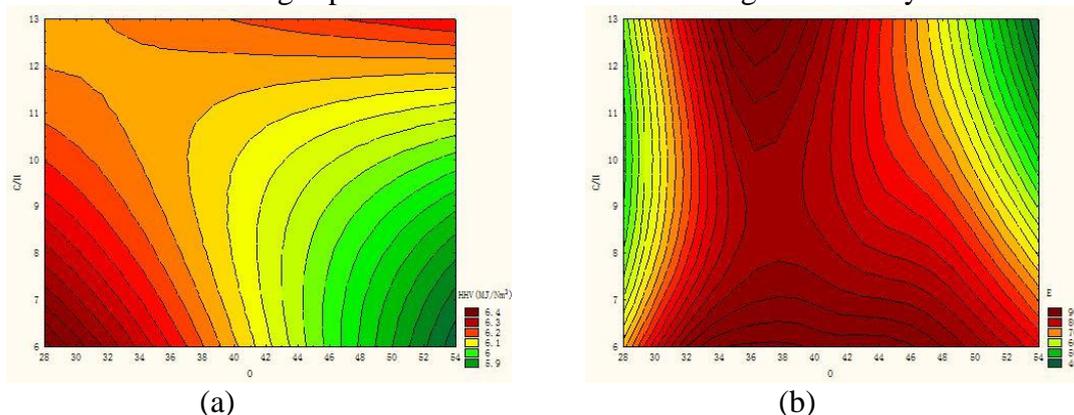


Fig. 4 Relation between C/H ratio, oxygen content and properties gas product: (a) HHV, (b) Cold gas efficiency.

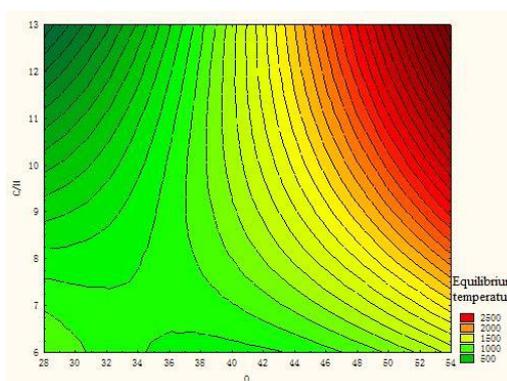


Fig. 5 Relation between C/H ratio, oxygen content and properties gas product: (a) HHV, (b) Cold gas efficiency.

In Fig. 5, Increase of oxygen content and C/H ratio showed increased of equilibrium temperature, while C/H ratio increase and decrease of oxygen content tend to decrease of equilibrium temperature.

3.1 Effect of moisture content

For study effect of moisture content, Air/fuel ratio is fixed at 2 and varies moisture content from 0 – 40 %. In Fig. 6, the increasing of moisture content effects to dropping equilibrium temperature because the moisture content increasing required more heat to vaporize moisture in biomass during gasification process (Dejtrakulwong and Patumsawad, 2011). Consider gas product composition, when moisture increased, N₂ in gas product is decrease because decrease of air supply. CO₂, H₂ and CH₄ are increased, in contrast, CO is decrease when increased of moisture content. In Fig. 7, Gas yield are reduce when moisture content increase. However, cold gas efficiency tends to constant.

3.2 Effect of air fuel ratio

For the study of effect of the air/fuel ratio is varied from 1.5 to 3. In Fig. 8, increased of air supply, combustible gases and HHV of gas product are reduced. In contrast, increased of air supply, gas yield is increased as showed in Fig. 9.

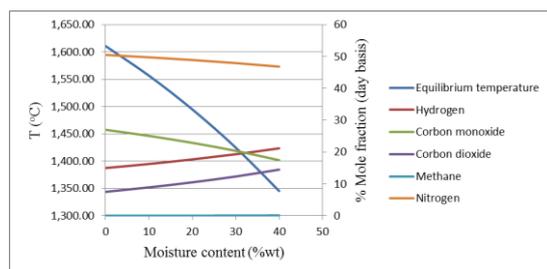


Fig. 6 Equilibrium temperature and gas composition along the moisture content varying.

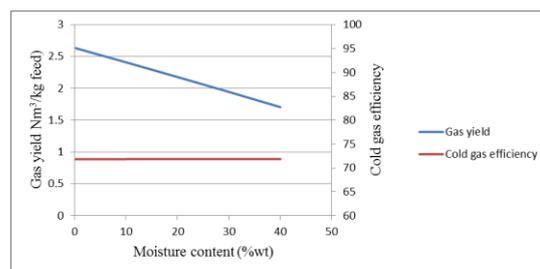


Fig. 7 Gas yield and cold gas efficiency along the moisture content varying.

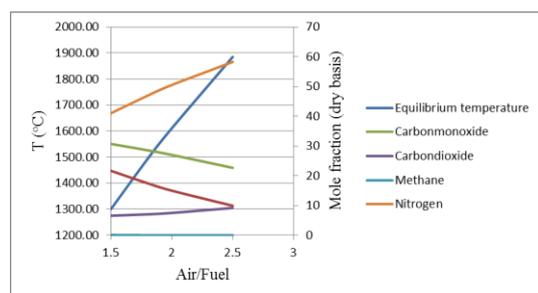


Fig. 8 Equilibrium temperature and gas composition along the Air/Fuel ratio varying.

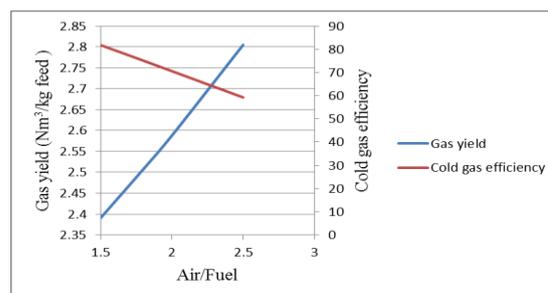


Fig. 9 Gas yield and cold gas efficiency along the Air/Fuel ratio varying.

4. Conclusion

Properties of 31 type of biomass were used to simulate gas product of downdraft gasification base on equilibrium model. The simulation results showed correlation between biomass composition and gas product. These models can be used for the selection of a biomass based on desired conditions. Therefore, the developed model in this study provides a tool for design optimization of a biomass downdraft gasifier.

5. Acknowledgement

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6. References

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