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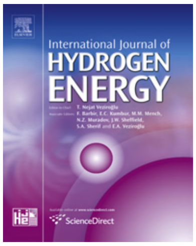

Effect of agglomeration/defluidization on hydrogen generation during fluidized bed air gasification of modified biomass

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ABSTRACT

This study presents the effect of particle agglomeration on syngas emission during the biomass air gasification process. Various operating conditions such as operating temperature, equivalence ratio (ER), and amount of bed materials are employed. The concentrations of H_2 and CO increase along with the operating time as agglomeration begins, while CO_2 decreases at the same time. However, there is no significant change in the emission concentration of CH_4 during the defluidization process. The lower heating value increases while the system reaches the agglomeration/defluidization under various operating parameters. When the system reaches the agglomeration/defluidization process, the LHV value sharply increases. The results are obtained when the system reaches agglomeration/defluidization. The temperature increases while bed agglomeration occurs. A higher temperature increases the production of H_2 and CO, contributing to the LHV calculation.

1. Introduction

Biomass gasification is a renewable and CO_2-neutral energy resource, and fluidized bed is recognized as an important technique for gasification of biomass. Gasification involves a series of endothermic reactions supported by the heat produced from the combustion reaction. It yields combustible gases such as hydrogen, carbon monoxide, and methane through a series of reactions. The following are the four major gasification reactions [1–3] and their chemical reactions at different temperatures, as shown in Fig. 1 [4]:

1 Water–gas reaction

$$C + H_2O \rightarrow H_2 + CO \quad \Delta H = +13{,}138 \ \text{kJ/kg mol carbon} \tag{1}$$

2 Boudouard reaction

$$C + CO_2 \rightarrow 2CO \quad \Delta H = +17{,}258 \ \text{kJ/kg mol carbon} \tag{2}$$

3 Water–gas shift conversion

$$CO + H_2O \rightarrow CO_2 + H_2 \quad \Delta H = -4198 \ \text{kJ/mol} \tag{3}$$

4 Methanation

$$C + 2H_2 \rightarrow CH_4 \quad \Delta H = -7490 \ \text{kJ/mol carbon} \tag{4}$$

Accordingly, the operating temperature can affect product distribution during gasification according to the chemical

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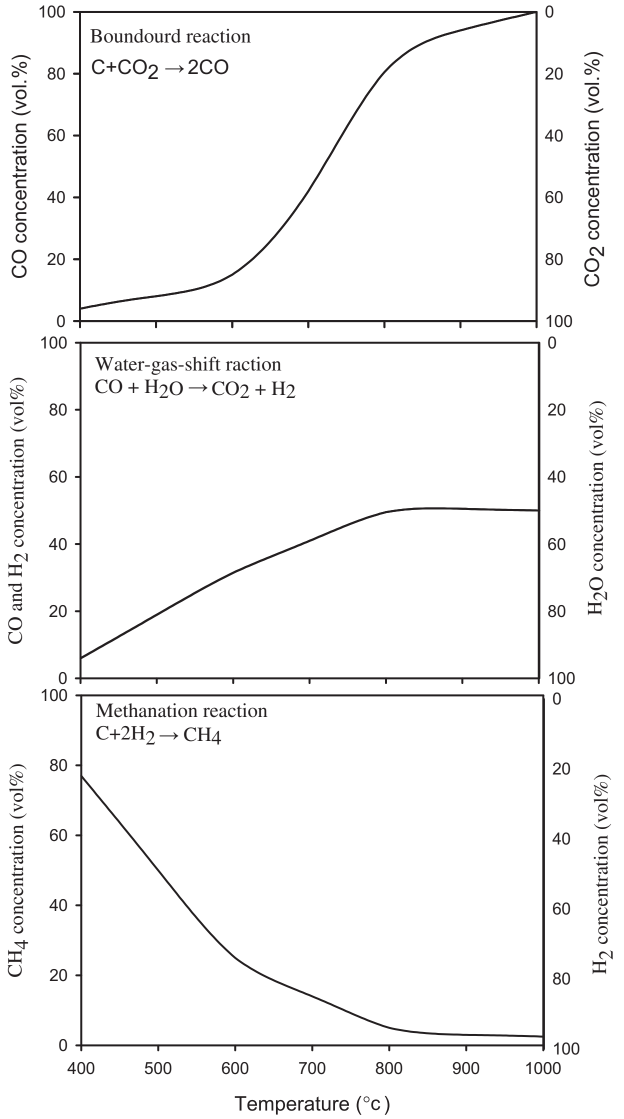

Fig. 1 – Illustration of thermodynamic equilibrium of different gaseous products concentration (Pressure = 1.0–atm) (Basu, 2006) [1].

reactions involved. Previous research has noted the chemical equilibrium trends of the carbon–oxygen–hydrogen system, which indicates that when the temperature increases, the product concentrations of H_2 and CO increase but those of CO_2 and CH_4 decrease [4].

The equivalence ratio (ER) is commonly used in connection with the gasifier air supply. It is defined as the ratio between the actual air fuel and the stoichiometric air fuel. The quality of gas obtained from a gasifier strongly depends on the ER value, which must be significantly below 1.0 to ensure a condition far from complete combustion. An excessively low ER value (<0.2) results in several problems including incomplete gasification, excessive char formation, and low heating value of the gas product. In contrast, a too high ER value (>0.4) results in the excessive formation of products of complete combustion, such as CO_2 and H_2O, at the expense of desirable products such as CO and H_2.

However, biomass gasification has a greater tendency toward bed material agglomeration. Previous research have investigated the mechanisms of bed material agglomeration and other control methods [5–13]. Olofsson et al. (2002) [14] found that a high content of alkali and alkaline earth metals exists in biomass materials. They also reported two possible mechanisms of particle agglomeration included (1) homogeneous agglomeration which is considered a slight agglomeration on the particle surface, and than it results a uniform particle size distribution of agglomerates. Moreover, (2) heterogeneous agglomeration is recognized a fast increasing or variation of particle size of agglomerates lead to defluidization, and K, Na, Si, and Ca are assumed to be the sources of particle agglomeration. Fryda et al. (2008) [15] studied three different biomasses, namely, giant reed, sweet sorghum bagasse, and olive, for the fluidized bed agglomeration process. The results presented that the agglomerations of the giant reed and sweet sorghum bagasse are due to their K-rich content. Other study has estimated the agglomeration behavior during gasification processes, indicating that the initial agglomeration temperature in gasification is lower than that in a combustion atmosphere [8].

A material balance of the reaction in biomass fluidized bed gasification is widely studied in previous studies [16–18]. He et al. [19] indicated the municipal solid waste as a biomass source in the gasification process, and the results showed that the average yields of gas, char and tar phases are 0.21 Nm^3/kg, 25.86 wt%, and 38.54 wt%, respectively. Moreover, Gil et al. [20] provided the effect of different type of gasifying agent on biomass gasification, the yield of the gas and tar are 1.25–2.45 Nm^3/kg, and 3.7–61.9 g/kg while air is taken as gasifying agent during the gasification process. The decomposition of tar or char plays an important role on the generation and formation of hydrogen in the gasification process. Nevertheless, to crack the tar component into the useful gases to increase the heat value is widely studied. Many studies reported several ways to control the tar formation in the fluidized bed gasification process included catalytic cracking, thermal cracking, self-modification, mechanism controlling, and plasma controlling [21–25]. However, recently researches only focused on the agglomeration behavior during the biomass gasification process [26,27]. Particle agglomeration in fluidized bed operation is also a complex process during the biomass combustion and gasification, the effect of agglomeration on the tar decomposition is not clear. Therefore, the aim of this study is to evaluate the effect of particle agglomeration on behavior of the generation and proportion of gaseous products.

According to the evaluation of previous researches on the effect of the operating condition on fluidized bed gasification for gaseous product distribution, most biomass fuels contain alkali metals that could cause particle agglomeration during fluidized bed operation. The agglomeration behavior influences not only the fluidization itself but also product distribution. Bed agglomeration causes serious problems, and it may result in an unscheduled system shut down. Therefore, this study focuses on the effect of particle agglomeration on product distribution such as H_2, CO, CO_2, and CH_4. Various operating conditions, which include the operating temperature, ER, and amount of bed materials, are considered.