Using the Elemental Balance Method for Calculating Thermal Efficiency for Biomass Gasification

Description

On the basis of the assumptions and equations in the stoichiometric ratio method, Melgar developed a model to calculate the thermal efficiency for biomass gasification as shown in Figure 1.

$$\eta = \frac{[a(\Delta H°_{fCO2} - \Delta H°_{fCO}) + c \cdot \Delta H°_{fH2O} + d(\Delta H°_{fCO2} + 2\Delta H°_{fH2O})]}{\Delta H°_{fCO2} + \frac{m}{2} \cdot \Delta H°_{fH2O}}$$

Figure 1: Equation to Calculate Thermal Efficiency for Biomass Gasification

Where $\Delta H°_{fCO2}$ is the standard enthalpy for CO_2 formation, $\Delta H°_{fCO}$ is the standard enthalpy for CO formation, and $\Delta H°_{fH2O}$ is the standard enthalpy for H_2O formation. In addition, in the coefficient for CO, c is the coefficient for H_2, d is the coefficient for CH_4, and m is the number of hydrogen atom in biomass chemical formula. Based on this equation, the thermal efficiency calculation procedures can be described as follows:

1. The same as in the stoichiometric ratio method, the coefficient a, c and d can be calculated on the basis of gas composition results from the GC.
2. According to the CRC Handbook of Chemistry and Physics (Haynes, 2011), $\Delta H°_{fCO2}$ = -393.5 kJ/mol, $\Delta H°_{fCO}$ = -110.5 kJ/mol, $\Delta H°_{fH2O}$ = -285.8 kJ/mol. Moreover, m is the number of hydrogen atoms in the dry biomass CH_mO_p.
3. Plug the results of a, c, d, m and other known factors into the equation (20), the thermal efficiency can be calculated.

This method is based on the same optimized pressure in the gasifier, but in reality, the pressure used for different types of biomass was different. Therefore, using woodchip gasification as the baseline, the calculation of actual thermal efficiency requires the correction of pressure ratio as well. Therefore, the corrected thermal efficiency η’ can be calculated:

$$\eta_{biomass'} = \eta_{biomass} \times \frac{P_{biomass}}{P_{woodchips}}$$

Figure 2: Corrected Thermal Efficiency

In Figure 2, where $\eta_{biomass}$ is the calculated thermal efficiency, $\eta_{biomass}'$ is the corrected efficiency, $P_{biomass}$ is the pressure used for gasifying this type of biomass, $P_{woodchips}$ is the pressure used for woodchip gasification.