Optimization study of fluidized-bed sugar-cane bagasse gasification varying air-ratio, bed diameter, and operational pressure

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The development of power generation systems based on Biomass, such as BIG/GT, demands exhaustive optimization of the main reactor, i.e., the gasifier. Mathematical models and simulations, based on fundamental differential mass and energy balances, are the most efficient tools for such tasks. In the present case, CSFB (Comprehensive Simulator for Fluidized Bed) was employed. Its first successful version operated in 1987 [1, 2]. Since them, several improvements were incorporated [3 to 6, 8]. It has been proved to be a reliable instrument for simulations of sugar-cane bagasse [4] and is capable of providing important information about the internal and overall behavior of gasifiers.

The present work is part of a more comprehensive optimization study on power generation based on sugar-cane bagasse [4 to 8]. In this particular case, the following parameters have been left as constants:

?? The characteristics of the feeding bagasse, including its moisture and particle size distribution.
?? Bed depth and freeboard height.
?? Mass flux of bagasse feeding, or the ratio between feeding ratio and transversal area of the gasifier. The values in kg s^{-1} m^{-2} were given by $5.0x10^{?7} A\ P$, where "A" is the cross sectional area (m^2) of the combustor or gasifier and "P" the absolute operational pressure (Pa). This approximate correlation fits most of existing efficient operations [4, 5, 6, 8, 9].
?? Temperature of the injected air and feeding bagasse.
?? No steam injection. Preliminary simulations have shown that the moisture contents of the bagasse are enough to provide the needed water as gasification agent [4 to 6, 8].
?? Inert characteristics (composition, densities, and particle size distribution).

The parameters adopted as variables are:

1. "Oxygen or air ratio". This parameter is given by the ratio between the mass flow of injected oxygen and the mass flow of oxygen necessary for the stoichiometric combustion of the biomass. The values were left to vary between 0.18 to 0.27
2. Bed and freeboard diameter, which were left to vary between 0.40 and 0.70 m.
3. Gasifier internal pressure. Values of 1 and 20 bar have been tested.

For the first time in this series of studies, the effect of sealing gas (CO_2) injection was taken into account. It has also been assumed that the ratio between the mass flow of injected CO_2 and feeding rate of bagasse was constant. "Cold" and "Hot" gasification efficiencies were chosen as objective functions, and the definitions used here are:

?? "Cold" efficiency as

$$?_c \ ? \ \frac{F_G (1 ? w_{H2O} \ ? w_{TAR})_G H_{Gc}}{F_B H_B} \tag{1}$$

?? "Hot" efficiency as:

$$?_h \ ? \ \frac{F_G H_{G_h}}{F_B H_B} \tag{2}$$

where "F_G" represents the mass flow of produced gas and "F_B" the inlet mass flow of bagasse (kg/s); "H_G" represents the enthalpy of the produced gas and "H_B" the High Heat Value of the inlet bagasse (J/kg); "w" represents the mass fraction of the indicated component in the exit gas.

In addition, considerations regarding exergetic efficiency were also presented. All efficiencies are plotted in graphs to facilitate the visualization of their values against the studied variables. It was possible to verify that air factor is the most influential variable, followed by the pressure level. As the bed and freeboard diameters were selected to maintain the same flux (mass flow of feeding divided by the equipment transversal area), almost no influence of this parameter on the efficiencies was verified. Discussions on the possibilities of certain operations are included.

Future studies will explore other combinations of variables.

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