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Performance analysis of a biomass gasifier

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Abstract

This paper presents an original modelling of the biomass gasification process and more particularly the wood gasification. Gasification is one of the more efficient ways to convert the energy embedded in the biomass. In the long term, the use of this rather new technology will reduce the too high pressure on the natural resources and that especially in the developing countries. The model based on the minimisation of the Gibbs free energy is performed in the ASPEN PLUS process simulator. The processes occurring in the gasification are here uncoupled in pyrolysis, combustion, Boudouard reaction, and gasification.

In the first part of the paper the model is described and the physical meaning of the relevant parameters are given. In the second part, the results of a sensitivity analysis with respect to the oxygen factor, the air temperature, the oxygen content in air, the operating pressure and the injection of steam are presented. From this study, the following conclusions are derived: there exists a critical air temperature above which the preheating is no longer efficient, there is an optimum oxygen factor, the oxygen enrichment of air plays an efficient role under a certain value and the operating pressure has only a slight positive effect on the process efficiency.

Keywords: Biomass; Gasification; Pyrolysis; Modelling; Sensitivity; Analysis

1. Introduction

Amongst the renewable energies, biomass is expected to be one of the most important in the near future. Indeed, biomass is a renewable fuel, which can be burnt or gasified similarly to other fossil fuels, using the same technologies with special adaptations. It can also be used in co-combustion with coal in large power plants [8,10], but its most suitable use is its gasification at small scale. If similar to conventional fossil fuels, it is different in its composition, its LHV, its

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Nomenclature

η_G	gasification efficiency (%)
T_a	air inlet temperature (K; °C)
T_r	reaction temperature (K; °C)
P	operating pressure (bar)
LHV	lower heating value (MJ/kg)
F	oxygen factor (%)
$\dot{M}$	mass flow rate (kg/s)

Subscript

a	air
b	biomass
g	gas
G	gasification
r	reaction
st	steam

corrosivity. Its big difference is its comparatively low impact on the environment; the content in N and S being very low, so are the emissions of NO_x and of SO_2. On top of that, biomass has a zero CO_2 balance on a period of a few years. On the other hand, governments commit themselves to reduce their CO_2 emissions in the international meetings about the global climate change like in Kyoto (1997), Buenos Aires (1998). In this framework the use of biomass in power generation is promoted.

In this paper, we present one possible option, i.e. a small-scale gasifier of biomass and more particularly of wood. Here, an original model of the biomass gasification process is proposed. It is based on a minimisation of the Gibbs free energy [5] at equilibrium [4]. This implies that the residence time is long enough to allow the chemical reactions to reach an equilibrium state, this assumption of equilibrium is not usually reached in real gasifiers. The considered gasifier is a fluidised bed in which the temperature is supposed to remain constant and homogeneous. However, the higher the reaction temperature, the better is this assumption. The proposed model is valid when the system may be considered as adiabatic and produces results in particular the reaction temperature in the gasifier, independent of the geometry. Along the paper, a sensitivity analysis is carried out with respect to any influencing parameter.

2. Modelling of the gasification process

In the proposed model, the gasification process consists in the uncoupling of four basic processes, namely the pyrolysis, the combustion, the Boudouard reaction and the gasification processes. First, an instantaneous pyrolysis of the fuel is supposed to occur as soon as it is injected in the gasifier, then fractions of the products of the pyrolysis are either burnt or gasified or take part to the Boudouard reaction (see the corresponding boxes in Fig. 1). From a thermal balance taking