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Hydrogen generation in a downdraft moving bed gasifier coupled to a molten carbonate fuel cell

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ABSTRACT

This paper describes the steady-state simulation of a moving bed downdraft gasifier which allows the conversion of agricultural biomass into a hydrogen-rich gas mixture so that it has an adequate composition for being used as a feedstock in a molten carbonate fuel cell (MCFC). In order to emphasize the applicability of the results, fuel specifications for a 250 kW MCFC (HM-300, MTU, Friedrichshafen, Germany) was used as a reference. The final design makes possible to produce 350 Nm^3/h of a biogas in a vessel of 0.8 m diameter × 2.5 m height capable of treating 50 kg/h of dry biomass using 45 Nm^3/h of air at 800 K and 1 bar.

Keywords: Gasification; Fuel cells; Modelling; Biomass; Biogas

1. Introduction

Fossil energetic resources are limited in time and space and therefore are condemned to depletion. Besides, its usage causes a large environmental impact in the biosphere since they pollute air, water and soil. These facts, together with the continuous increase in energy consumption and new international regulations regarding environmental emissions have favoured an increasing interest in emerging technologies for cleaner and more efficient energy generation.

Within this context, fuel cells come into sight as one of these promising technologies. Fuel cells are systems for power generation which generates electricity in the form of direct current by means of the combination between hydrogen and oxygen in an electrochemical reaction. Nowadays, fuel cells are getting a growing attention due to their potential use in portable and stationary applications due to its low environmental impact and their superior yield (Larminie, 2002).

Traditionally, fuels used for hydrogen production in MCFCs have been natural gas and, more recently, methanol. Natural gas is a mixture of low molecular weight hydrocarbons being methane the major component (80–95%, w/v). Methane is a molecule with a high hydrogen-to-carbon ratio (H/C) occurring in large deposits and with a wide distribution network available. Methanol is also a molecule with a high H/C ratio but needs to be synthesized at 50–150 bar from a mixture of CO and H_2, which, in turn is produced from natural gas. Neither natural gas nor methanol, are renewable resources. Therefore, it seems interesting to explore unconventional feedstocks which can satisfy the rewarding characteristics of those fuels while being considered as non-fossil. This fact would emphasize the cleanliness of fuel cells as a competitive technology (Leva and Zaninelli, 2009; Strik et al., 2008; Rodriguez-Castellanos et al., 2007; Kowalski and Zenouzi, 2008).

In the past years many authors have developed models for molten carbonate fuel cells. These models are predominantly described by differential mass balances, most of them 2D and 3D plug flow descriptions, applied on both single cells and stacks and in steady and unsteady state conditions (Yoshiba et al., 1998; Bosio et al., 1999; Koh et al., 2000; Kim et al., 2002; Mangold and Sheng, 2003). An interesting review of these models is reported in Koh et al. (2001). However, only one paper (Donolo et al., 2006) describes the coupling of these models to a gasifier an the implications from a energetic point of view. Zhang et al. (2010) provide also an interesting overview of the recent advances in thermo-chemical conversion of biomass including novel applications to fuel cells.

Based in a previous study (Parreno, 2004), biomass of agricultural origin was selected as a most promising feedstock for this purpose. Fuel cells and reformers require a premium

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