The Use of Preheated Low-Enriched Air in Downdraft Gasifiers: Energy and Exergy Analysis

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Abstract: In comparison with air, the use of oxygen as a gasifying agent is less exergetically efficient. For small-scale cogeneration plants, smaller than 1MW of thermal power, the use of oxygen is expensive and inefficient. The improvement in the technology of membrane separation of gases gives rise to the possible inclusion of oxygen-enriched air as a gasifying medium. The article aims at presenting a numerical study analyzing the gasification of treated wood in downdraft gasifiers with preheated low-enriched air (from 21 vol% to 30 vol%). The analyzed system consists of three subsystems: (i) for air enrichment by polymeric membrane, (ii) for preheating of enriched air by heat exchange with the product gas, and (iii) a downdraft gasifier. The increase of oxygen level in enriched air increases the temperature at the carbon boundary point (optimal gasification point), the amounts of combustible gases in the product gas, energy and exergy efficiencies and decreases the amount of air (oxygen) required for complete gasification as well as the amount of N2 in the product gas. The preheating of enriched air by heat exchange with the product gas is more beneficial for the gasification with lower levels of enrichment.

Keywords: Biomass gasification, Exergy analysis, Medium preheating, Oxygen enrichment, Treated wood.

1. Introduction

The global campaign for a larger use of renewable energy justified by the need for sustainable development causes the increase of biomass use as a fuel and development of new, energy efficient technologies for its transformation. Turkenburg [1] recognizes three main energy conversion routs for biomass: thermochemical and biochemical conversions, and extraction. Among thermochemical conversions there are: combustion, gasification, pyrolysis, liquefaction, and hydro thermal upgrading [2].

Gasification is the conversion of biomass or any carbonaceous fuel to a gaseous product with a useable heating value [3] and can be used for production of heat and/or electricity, and other biofuels: synthetic natural gas, biodiesel, methanol, hydrogen. The generation of electricity and useful heat from the same power plant is called “cogeneration” or “combined heat and power” (CHP).

In the Republic of Serbia, like in many countries, there are incentives for using renewable energy for electricity generation. The feed-in tariffs for the electricity produced from wood and agriculture biomass recognize three categories depending on the installed capacity [4]: (i) for plants with the capacity up to 1 MWel the electricity price is 13.26 c€/kWh, (ii) for plants with capacity between 1 and 10 MWel, the price is calculated as 13.82-0.56P (where P is capacity of the plant in MWel and the price is in c€/kWh), and (iii) for plants with the capacity larger than 10 MWel the price is 8.22 c€/kWh. In the domestic market small and medium-sized companies are dominant in the sawmill industry and their production volumes and thus their needs for heat are such that they do not require the CHP installations bigger than 1 MWel [5]. In this power range of currently available power systems the most efficient are those that use: gas engines, micro turbines