Simulation of a highly efficient dual fluidized bed gasification process

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Abstract

The FICFB gasification concept allows to produce high grade product gas (LHV 10 - 14 MJ/m^3_S) due to the dual fluidized bed configuration. Using a gas engine, a net electric efficiency of 26% can be obtained with a plant configuration making good economic sense for decentralized CHP plants. The solid circulation rate between gasification (bubbling regime) and combustion zone (turbulent regime), necessary for heat supply of gasification reactions, is mainly determined by the volume flow of combustion air. An additional combustion chamber after the combustion zone allows 55% part load operation, referring to the design case, with sufficient solid circulation rate as well as constant excess air, still providing net electric efficiency of 22.5%.

Introduction

Biomass gasification has a significant environmental benefit due to a highly efficient energetic utilization of renewable resources, provides net zero carbon dioxide emissions and therefore contributes positive to the limitation of greenhouse gas effects. There are different ways to supply the endothermic gasification reactions with energy. This can be obtained by partly combustion of the biomass. Disadvantage of this method is the poor product gas quality with a LHV of 4-7 MJ/m^3_S. Gasification with pure oxygen produces higher quality product gas (10 - 18 MJ/m^3_S) with the disadvantage of a necessary, expensive oxygen production. Another method of producing high quality product gas with a LHV of 10 - 14 MJ/m^3_S is the FICFB gasification process [2, 3].

Description of the Process

The FICFB gasification process [2] is a special concept of a twin fluidized bed gasifier. The biomass is fed into the gasification zone which is designed as a bubbling fluidized bed. Steam is used both as fluidization and gasification agent. The bedmaterial, usually quartz, is transported from the gasification zone to the combustion zone carrying ungasified char. The combustion zone operates in fast fluidization regime. Hot bedmaterial leaving this zone is separated by a highly efficient cyclone. To avoid mixing of product gas and flue gas the bedmaterial passes a seal loop before recycling into the gasifier. The hot bedmaterial from the combustion chamber supports the endothermic gasification reactions with energy.

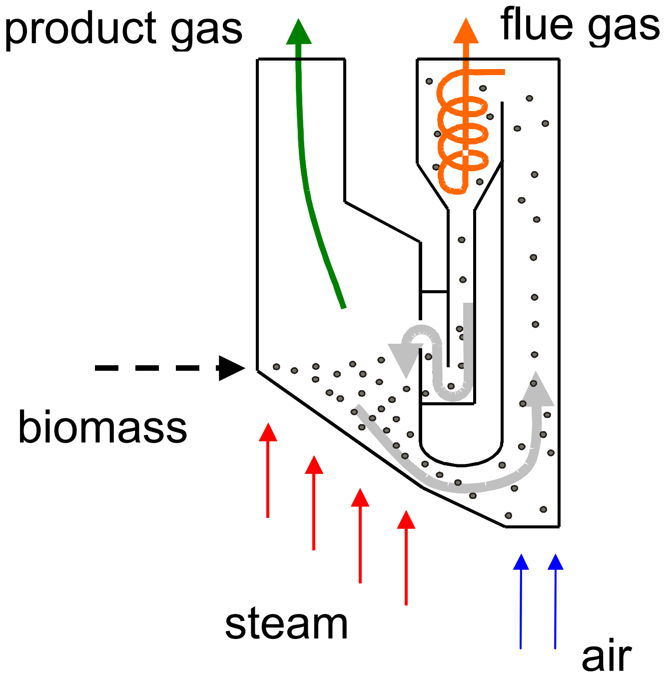

Figure 1: concept of the FICFB gasification process

Modelling of the gasifier

An enhanced equilibrium model of the gasifier was designed and fitted to a pilot plant [2]. The model yields to good results concerning the energetic view of the process and provides also an approach of product gas composition. Calculations are done by implementing the described model into an equation oriented process simulation environment (IPSE Pro™ [4]) to offer flexible handling of the units. The software contains a development tool which allows to implement user-defined models like gasifier, scrubber or gas engines as well as integrating the calculation of the exergy of all streams. Simulation and exergetic analysis of the process shows the advantage of gas engines compared with gas turbines of an electric output below 5 MW, considering todays availability [1].

Part Load Considerations

The CHP plant shown in (fig. 2) was simulated in IPSE Pro™. A net electric efficiency of 26% and a heat-to-power-ratio of 0.45 was determined – using wood with a water content of 10% [1].

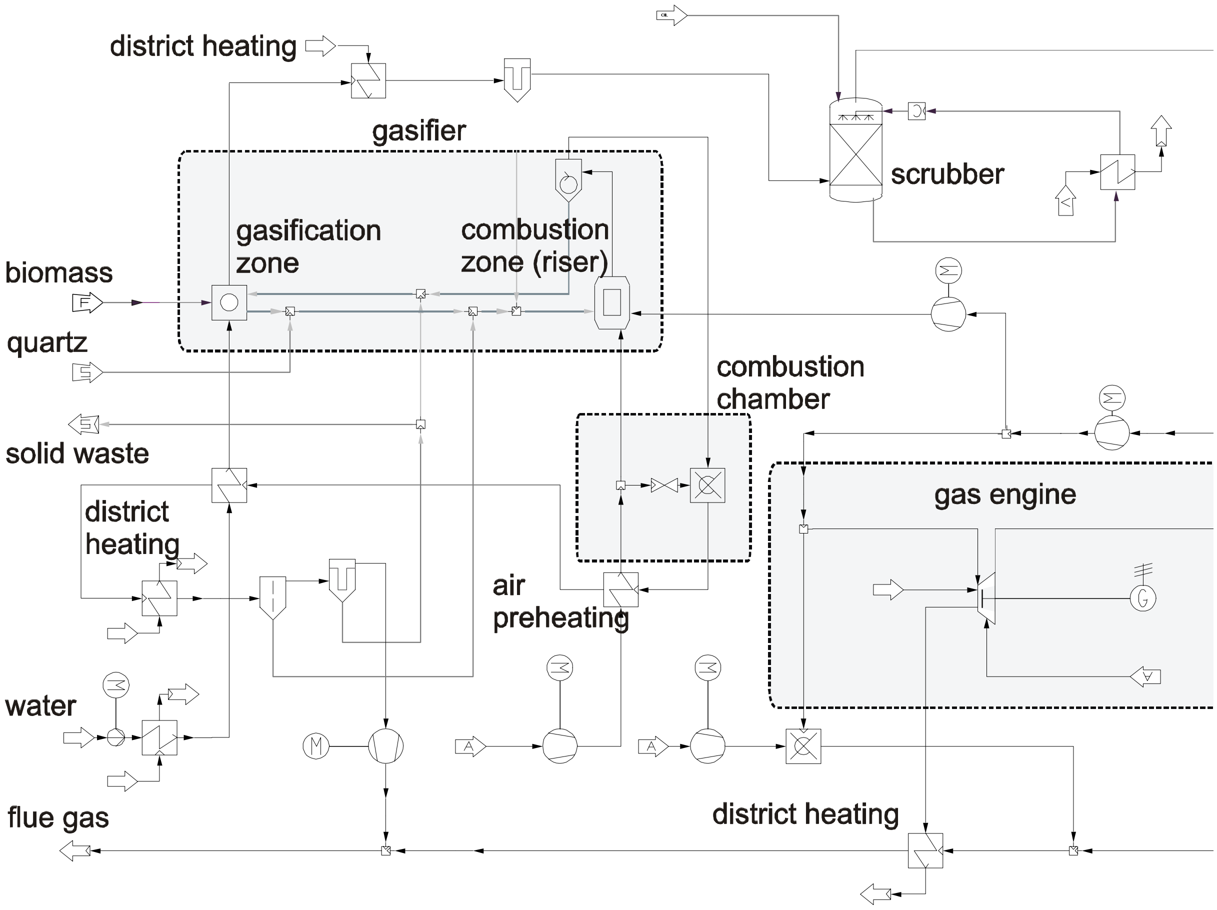

Figure 1: flowsheet of CHP plant

It is important to achieve a flexible operation behavior of the CHP plant. The partial load behavior of the plant is strongly influenced by the fuel composition, the gas engine and the fluidization of the riser. Air fed into the riser is required for fluidization of bedmaterial as well as for combustion of char and recirculated product gas. To obtain highly efficient part load operation the excess air must remain constant, therefor the mass flow of air must be reduced in part load. This would result in a strong decrease of solid circulation at about 80% part load due to insufficient fluidization of the riser. The additional combustion chamber after the riser allows to control excess air independent of the riser fluidization. This leads to a achievable part load of about 55% based on thermal power. The electric efficiency only decreases from 25.5% at design case down to 22.2% at minimum part load. This expanded off-design behavior is mainly caused by the operation characteristics of the gas engine and the staged combustion. A higher water content causes a decrease in electric efficiency due to the higher need of energy, which is supported by combustion of recirculated product gas, for evaporating the moisture. This involves higher mass flow of combustion air which reduces the part load range as can be seen in (fig. 2). The decrease of the operation range due to higher ambient temperatures is caused by higher inlet temperatures of the product gas into the gas engine, which reduces the amount of utilizable product gas.

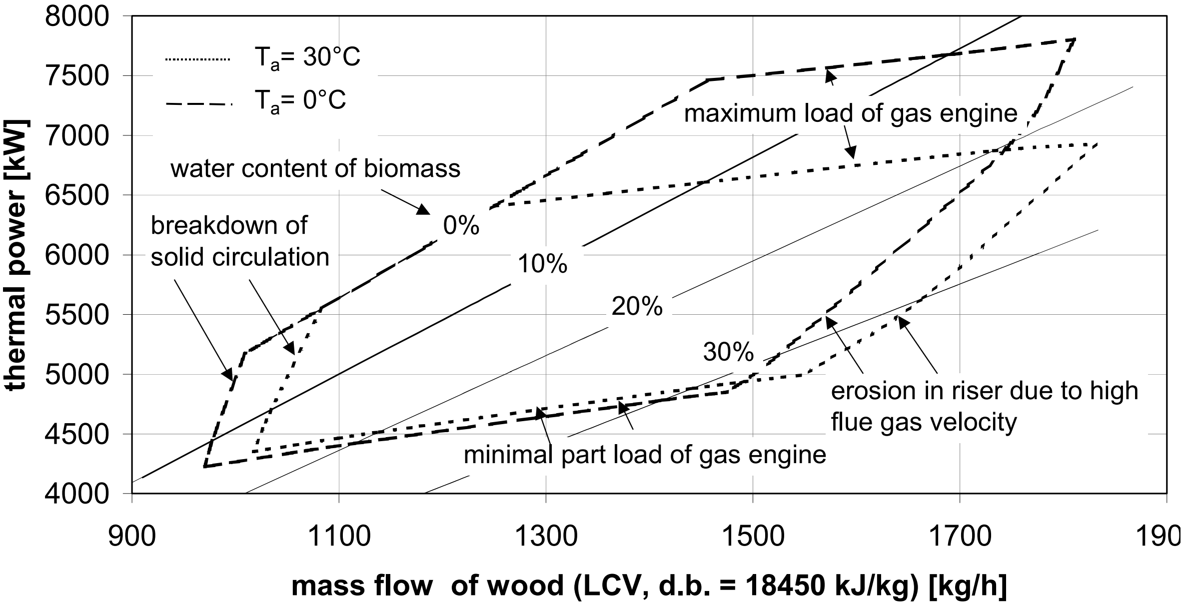

Figure 1: operation field of CHP plant with FICFB gasifier (results of simulation)

The concept of the FICFB process shown in (fig. 1) will be realized now in a demonstration plant in Güssing, Austria.

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