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An innovative biomass gasification process and its coupling with microturbine and fuel cell systems

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Abstract

The use of biomass, wood in particular, is one of the oldest forms of producing energy for heating or cooking. Nowadays, new technologies concerning the utilisation of biomass or waste residues are in demand and the trend to use them in decentralised applications for combined heat and power (CHP) production provides an attractive challenge to develop them. At the TU München an innovative allothermal gasification technology, the Biomass Heatpipe Reformer (BioHPR) has been developed. The aim of this project was to integrate the technology of liquid metal heatpipes in the gasification process in order to produce a hydrogen rich product gas from biomass or residues. The gasification product can be further used in microturbine or SOFC systems. The present paper presents the aforementioned gasification technology, its coupling with innovative CHP systems (with microturbine or fuel cells) and investigates, through the simulation of these systems, the optimum conditions of the integrated systems in order to reach the highest possible efficiencies.

Keywords: Biomass; Allothermal gasification; Heatpipes; Combines heat and power (CHP); Microturbines; Fuel cells

1. Introduction

The most common use of biomass for energy production is direct combustion. Biomass can be combusted in grate firing systems, in fluidised bed combustion chambers, or even in pulverised co-combustion systems. However, the direct combustion of biomass raises certain issues such as high temperature chlorine corrosion, low-melting temperature of biomass ash (especially of straw) and the agglomeration in fluidised bed combustion chambers [1]. Another characteristic of biomass fuels is their low-energy density (energy content per volume) compared with conventional fossil fuels. For example, 5 m^3 of wood or 25 m^3 of straw bales are needed in order to replace 1 m^3 fuel oil (1000 liters). Such variations are important for logistic aspects, like transportation and storage. Simple techno-economic calculations indicate that the direct combustion of biomass is economically viable and environmentally effective only on a local scale. Consequently, the optimal plant size for heat and power production from biomass is very small ranging mainly from a few hundred kilowatts to a few megawatts.

Fig. 1 shows typical power ranges and efficiencies of currently available power systems. Gas engines, micro-turbines and fuel cells are well-suited systems for small-scale power production because of their high efficiency at low-power ranges. These technologies are only compatible with gaseous fuels, therefore the implementation of biomass to a gas engine, microturbine or fuel cell system is only possible with the introduction of a preliminary gasification step.

Gasification technologies are divided into autothermal and allothermal ones. In the autothermal gasification, the partial combustion of biomass provides the required heat for the gasification. In the allothermal gasification process, the necessary heat is usually provided from an external source. The most common way to introduce the required heat into the gasifier is to transfer bed material from a combustion chamber. Some examples of this technology

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Nomenclature

c_p	specific heat capacity, kJ/kgK
$H_{u,B}$	lower heating value of biomass, kJ/kg
$\dot{m}_B$	fuel (Biomass) mass flow, kg/s
$\dot{m}_D$	water steam mass flow, kg/s
$P_{el,net}$	net electrical power, kW
$\dot{Q}_{Tot}$	total heat flow, kW
T	temperature, °C
t	temperature, °C

Greek letters

η	efficiency
λ	air ratio
σ	excess steam ratio

are the Battelle gasification process [2] and the Fast Circulating Fluidised Bed reactor in Güssing [3]. A highly promising allothermal gasifier, the so-called Biomass Heatpipe Reformer (BioHPR) has been developed during a European Union funded project of the 5th Framework Program. BioHPR is capable of producing hydrogen-rich gases, which can be further used in microturbines or high-temperature fuel cell systems.

2. The BioHPR

BioHPR utilises liquid metal heatpipes in order to create high heat fluxes from a combustion chamber to the gasifier, where the endothermic gasification reactions take place. High temperature heatpipes are metal pipes containing an alkali metal (Na, K, etc.). Heat is transferred into the heatpipe at the evaporation zone. This heat is released at the condensation zone from the heatpipe to its environment as shown in Fig. 2.

The BioHPR consists of three main parts as shown in Fig. 3. The first part is a bubbling fluidised bed gasifier, the ‘‘Reformer’’. Biomass is fed into the Reformer from the upper part through a specially designed lock hopper system. The gasification can take place either in atmospheric pressure or under pressures of up to 5 bar [4]. The product gas from the Reformer is first driven to the sand filter, which is the second part of the BioHPR. This integrated sand filter separates dust and coke particles from the product gas. After its way through a cyclone and a ceramic or metallic filter, the product gas can be analysed and used in a gas turbine or a fuel cell. The third part of the BioHPR is the fluidised bed combustion chamber. The dust and coke particles, which are filtered in the integrated filter,

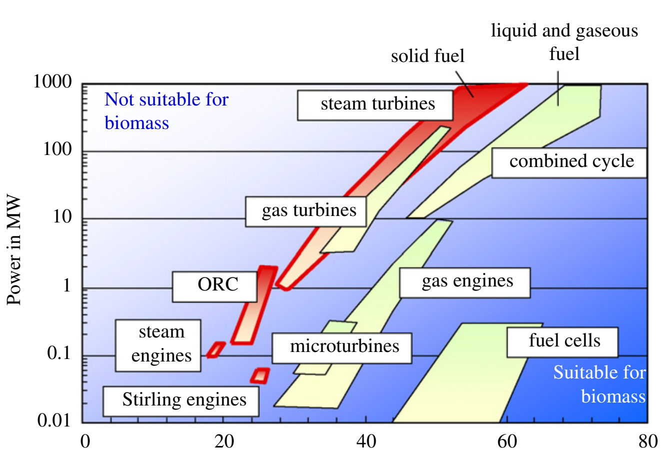

Fig. 1. Efficiency and power range of known plant types [10].

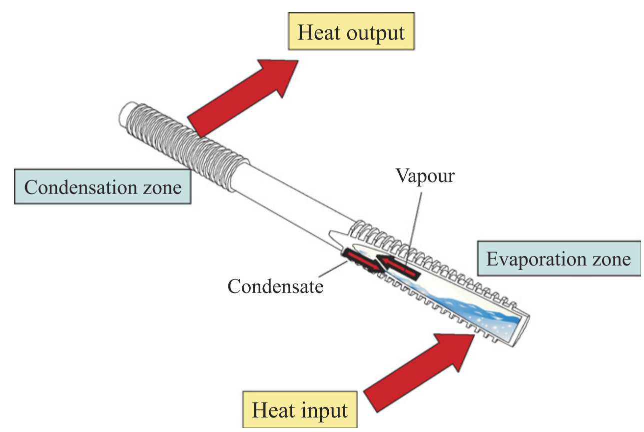

Fig. 2. Functionality of a heatpipe.

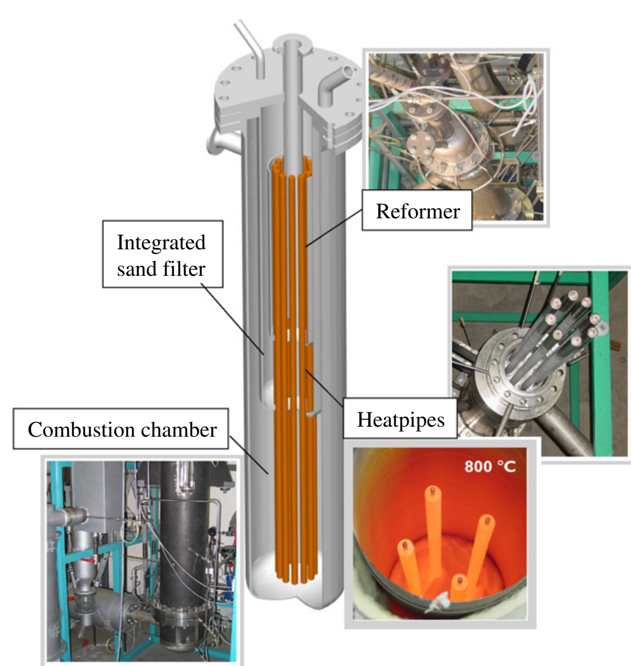

Fig. 3. The BioHPR.