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Co-gasification of coal and wood in a dual fluidized bed gasifier

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ABSTRACT

In the last decade the reduction of CO_2 emissions from fossil fuels became a worldwide topic. Co-gasification of coal and wood provides an opportunity to combine the advantages of the well-researched usage of fossil fuels such as coal with CO_2-neutral biomass. Gasification itself is a technology with many advantages. The producer gas can be used in many ways; for electric power generation in a gas engine or gas turbine, for Fischer–Tropsch synthesis of liquid fuels and also for production of gaseous products such as synthetic natural gas (bio SNG). Moreover, the use of the producer gas in fuel cells is under investigation. The mixture of coal and wood leads to the opportunity to choose the gas composition as best befits the desired process. Within this study the focus of investigation was of gasification of coal and wood in various ratios and the resulting changes in producer gas composition. Co-gasification of coal and wood leads to linear producer gas composition changes with linear changing load ratios (coal/wood). Hydrogen concentrations rise with increasing coal ratio, while CO concentrations decrease. Due to the lower sulfur and nitrogen content of wood, levels of the impurities NH_3 and H_2S in the producer gas fall with decreasing coal ratio. It is also shown that the majority of sulfur is released in the gasification zone and, therefore, no further cleaning of the flue gas is necessary. All mixture ratios, from 100 energy% to 0 energy% coal, performed well in the 100 kW dual fluidized bed gasifier. Although the gasifier was originally designed for wood, an addition of coal as fuel in industrial sized plants based on the same technology should pose no problems.

1. Introduction

Today, besides the efficiency of energy use, discussions also exist as to methods of reducing carbon dioxide emissions. Since carbon dioxide emissions from biomass are perceived as neutral [1], it is an energy source which has recently received lot of interest.

There has been large progress made in biomass gasification over the last decade. In Europe there are several industrial plants operating with wood chips, with more currently under construction. These plants are based mainly on fluidized bed technology and steam gasification and used for heat and electricity production.

Biomass has, compared to coal, a lower energy content per kg. Therefore the use of biomass is most economically effective if transportation costs are low. If not enough biomass is available in the areas surrounding the plant, gasification of a mixture of coal and biomass provides an opportunity to build larger plants, which in general work more economically and thus the idea of gasifying mixtures in one plant is advantageous.

Coal as a fuel has a long history. During the 1970/80s oil crises, coal was used as an oil substitute [1,2]. But today, as previously mentioned, not only an oil substitute is required but also a way to minimize carbon dioxide emissions, which many countries agreed to in the Kyoto protocol. Additional environmental benefits such as reduced sulfur and nitrogen emissions when adding biomass to the fuel increase interest in the co-gasification of biomass and coal.

There have been some efforts to include biomass in existing coal plants. Normally, in a large power plant a lot of biomass is required to replace even a small amount of coal and therefore the availability of the former in such large amounts has to be considered. Several reports concerning co-gasification are available [3–6]. However, little literature is available regarding tests using different ratios of biomass and coal [7–9].

This study examines the suitability of coal for use in an existing 100 kW biomass gasifier pilot plant. This gasifier is based on the dual fluidized bed steam gasification process, a technology proven to work efficiently also on a larger scale, as successfully demonstrated in Guessing (Austria [10]). The technology used here is well-suited to co-gasify coal and wood in various ratios, while only small adaptations to existing biomass gasification plants have to be made.

2. Materials and methods

2.1. Schematics and function of the dual fluidized bed steam gasifier

The reactor used in this study is a 100 kW dual fluidized bed gasifier test facility [10–13]. This type of gasifier works on the basis of separating the endothermic gasification process from the exo-

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Nomenclature

MWth	thermal power of the plant	T_C∗	combustion temperature at different heights
LHV	lower heating value	vol.% dry	volume percentage on dry basis
PG1	pressure drop in the fluidized bed of the gasifier	$\dot{m}$	mass flow
T_G∗	gasification temperature at different heights	N m^3	cubic meter at 0 °C and 1.013 bar pressure

thermic combustion process. Since steam is the gasification medium used, the technology produces a nearly nitrogen free, hydrogen rich producer gas. To realize this idea two reactors are combined, with the gasification zone placed in a bubbling fluidized bed reactor and the combustion zone placed in a transporting fluidized bed reactor. Both reactors are connected via two siphons, one connecting the lower part of the gasification zone with the lower part of the combustion zone, the other connecting the lower part of the separator in the combustor with the free board of the gasifier (Fig. 1). To guarantee nitrogen free producer gas, the two siphons are also fluidized with steam.

In a separator, the upwards-transported bed material is separated from the flue gas stream and led into the gasification zone, where the hot bed material is mixed with the fuel. At the top of the gasification zone the producer gas leaves the gasifier, while at the bottom the bed material together with the residual char is transported to the combustion zone.

In wood gasification, the residual char does not provide enough energy to satisfy the endothermic gasification reactions. For this reason oil is used as additional fuel in the test facility. In industrial sized plants, a small part of the producer gas is recycled back and burned in the combustion zone. As seen in Fig. 1, oil is fed into the reactor together with the primary air (5 N m^3/h). The main part of the char and oil is burned in the extended part of the combustion zone where the secondary air (50 N m^3/h) is introduced.

Initial tests using coal as fuel showed that in the case of coal gasification, no additional fuel is needed [13] for heat supply. At these temperatures (870 °C), coal has a very low reaction rate and therefore a significant amount of coal char is transported to the combustion zone [12]. Oil is also needed to control the gasification temperature, as while the circulation rate is also of course a parameter for control, regulation via the oil feed is more accurate. For that reason the fuel feed was reduced to a number where at least some oil is needed to achieve the required gasification temperature.

Gasifying coal in this reactor required adjustments of the fuel feeding system to be made. Since two fuels had to be fed into the reactor simultaneously, a mixing chamber and an additional hopper were installed. Coal and wood are fed from two separate hoppers and mixed before being fed via a plug screw into the gasifier. For a good reaction and mixture to occur, the fuels are fed directly into the bubbling fluidized bed. In the test facility the gas streams from both zones are measured separately and burned together in a combustion chamber. Fig. 1 shows the gasification reactor and the main assembled parts. A producer gas cooler is essential to cool the gas while stopping all gasification reactions within the gas stream. After travelling through the gas cooler, samples are taken at two points from the producer gas stream for online producer gas measurement as well as for sampling of impurities (tars, ammonia, hydrogen sulfide, etc.).

An electric steam generator provides the steam needed for fluidization of the gasification zone and the two siphons. The provided (saturated) steam has a temperature of 115 °C as it leaves the steam generator. Before the steam enters the gasifier, it is superheated to 300 °C with an electrical trace heating system.

As listed in Table 1, the bed material used in this study is olivine, known from various studies to be catalytically active in terms

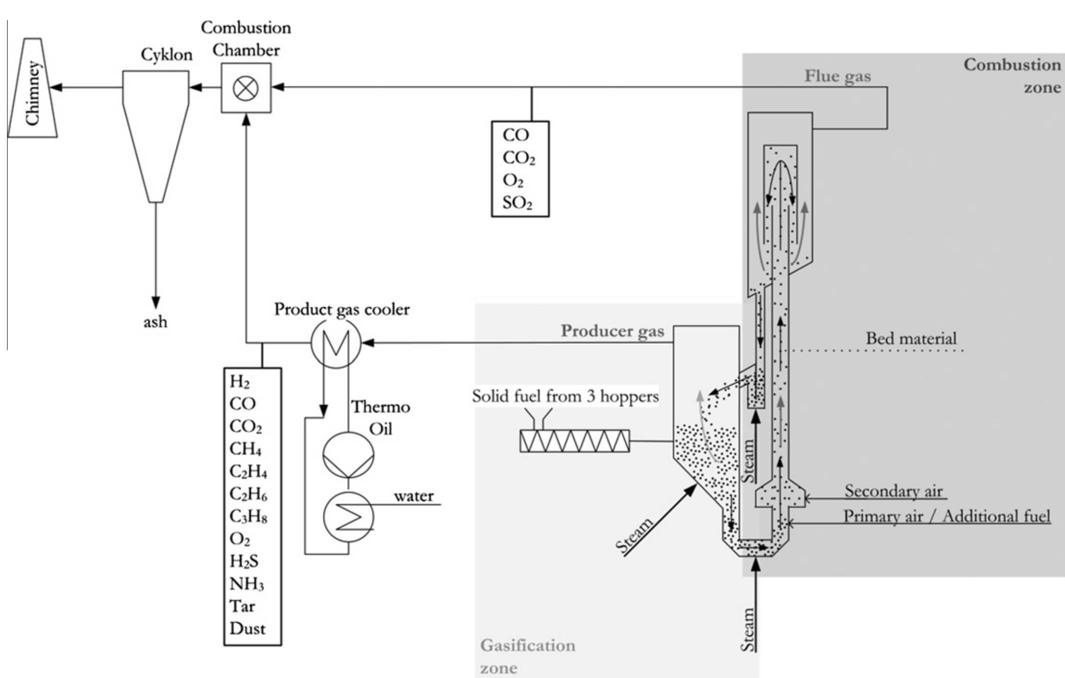

Fig. 1. Scheme of DFB gasifier test facility [12].