Development of flexible fluidised-bed gasification process for co-production of synthesis gas and biochar

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Abstract

In the FlexSNG project a fluidised bed gasification process is developed that can co-produce biochar and good-quality synthesis gas and can also switch between two operation modes: (1) co-producing biochar and synthesis gas that is further converted to biomethane or other synthesis products, and (2) maximizing the fuel conversion to syngas. In 2022, three test runs were conducted at an atmospheric-pressure CFB gasification test rig of VTT to identify optimal gasification and gas clean-up process conditions for both operation modes and various biomass residues and organic waste feedstocks. This studied gasification process consists of a fluidised-bed gasifier, a hot gas filter and a catalytic reformer. The tests were focused on finding optimal process conditions in the gasifier for co-production of biochar and synthesis gas from woody residues and straw. Two different operating principles were examined: ordinary CFB gasifier operated at different temperatures and so-called Bubbling Circulating Fluidised Bed (BCFB), in which the lower part of the gasifier is operated at low temperature and the secondary oxygen is then used to raise the temperature.

These tests showed that gasification temperatures below 700 °C and low fluidising velocities at the bottom part of the gasifier were best suited for maximized biochar co-production, resulting in high carbon content (>70 %) in the biochar product. The low gasification temperature employed in co-production mode evidently results in increased tar loading in the raw synthesis gas - potentially creating further challenges in hot gas filtration and reforming (e.g. soot formation, clogging by tars). These challenges have been overcome by partially decomposing the tars in the upper section of the gasifier by injecting secondary oxygen (mixed with nitrogen) and elevating the gas temperature to 820-850 °C. The first two tests, however, also demonstrated that under all operating conditions part of the biochar is attrited in the fluidized bed into fine dust, which passes the recycling cyclone and can be collected only as filter fines.

The tests also clearly pointed out that operation under normal CFB gasification mode is more straightforward than the BCFB mode where the bed is operated at low temperature and freeboard temperature is raised by using secondary oxygen feed. The initial CFB test already showed that high yields of biochar could also be produced by operating the gasifier under CFB mode but at a reduced temperature of 700-750 °C. In this case, shifting between “charring” and “complete” gasification was smooth and could be rapidly realized in less than an hour. On the contrary, in the BCFB design, a massive amount of inert bed material (sand/dolomite) should be fed into the reactor before moving from staged BCFB mode to high temperature gasification. Consequently, the last pilot test was devoted to optimizing the operation under CFB mode. Furthermore, the gasification performance also was studied with a more challenging raw material, straw, representing high alkali agro biomass. This test run was very successful and demonstrated the good flexibility of the CFB gasifier concerning operating conditions and feedstock quality.

One of the major achievements of these preliminary gasification tests was the reliable operation of the raw gas cleaning process designed based on VTT’s recent innovations. No operational problems were met even at the CFB set points realized at low temperatures. Despite the high tar contents, the raw gas could be filtered and reformed without increasing pressure drops related to soot formation. The work continues in 2023 by carrying out process validation tests at a larger pressurized pilot plant of VTT.

Keywords: biomass, gasification, reforming, biofuels, syngas

Additional material:

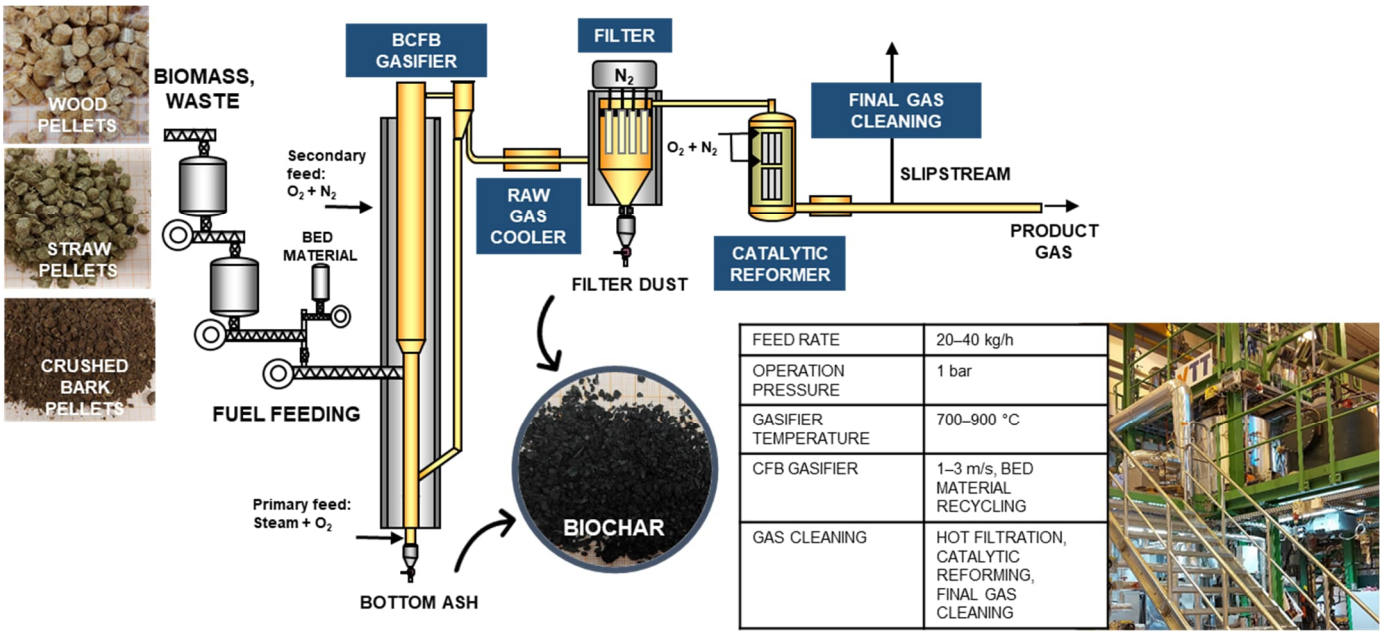

Figure 1. Bubbling Circulating Fluidised-Bed (BCFB) gasifier at VTT's Piloting Centre Bioruukki, Finland.

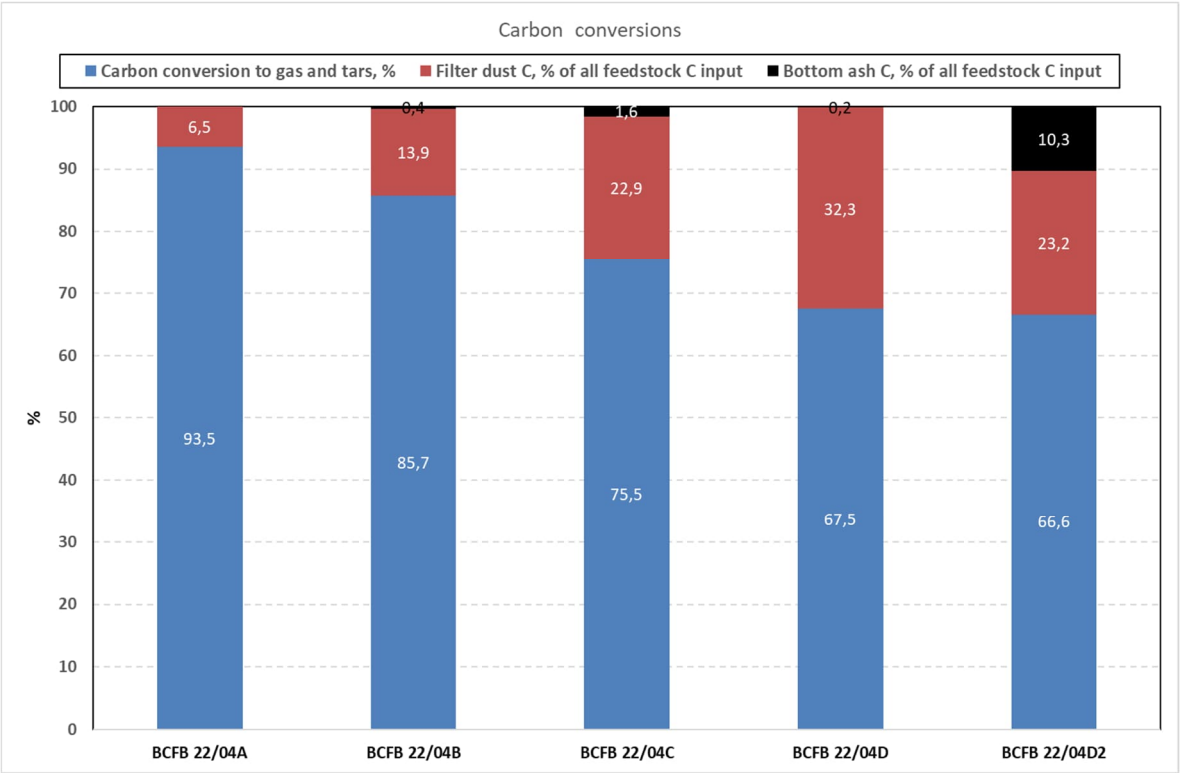

Figure 2. Carbon conversions at the set points of test run BCFB 22/04 at temperature range from 880 °C to 670 °C (at bottom bed). Feedstock: crushed bark pellets.