Effect of char recirculation in fixed bed gasifiers: experimental and modelling analysis

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Biomass gasification process produces a solid carbonaceous by-product, known as charcoal or simply, char. Small-scale gasification of woody biomass has seen an increased diffusion in the last year, mainly driven by favorable subsidization regimes. This has been particularly true in the South Tyrol region in Italy, where almost 50 small-scale biomass gasification plants for combined heat and power (CHP) production are currently in operation [1]. Nonetheless, disposal of char represents a non-negligible cost in the management of such plants. Almost 1300 tons of char are produced every year in South Tyrol and must be disposed of as a waste, with considerably high costs, typically in the order of 150 €/ton [2].

The aim of the present work is to investigate a viable and practical solution in fixed-bed gasification systems for reducing the amount of generated char and at the same time increase the efficiency of the whole conversion process, recirculating the char inside the gasifier in order to increase its residence time and conversion yields.

Gasification tests were performed in an open-top gasifier installed at the Free University of Bolzano. This specific pilot-scale gasification plant is a downdraft system, where both gas and feedstock move downward as the reactions proceed. The core of the gasification system is a stainless-steel cylindrical reactor with a diameter of 120 mm and a length of 1000 mm. The air required for gasification is partly drawn from the top, and the remaining from the air nozzle at the combustion zone. The required suction for this process is obtained from the water spray nozzles / engine suction / blower. It can be used in double stage stratified gasifier configuration where primary air is coming from the top while secondary air flows through a nozzle located 670 mm far from the reactor's top.

In order to investigate the effects of char recirculation, two set of tests have been performed, using ENplus A1 (ISO 17225-2:2014) certified spruce pellet as fuel:

- Case A: The gasifier is operated in order to achieve a char yield of about 10 % when the fuel is only biomass (2^{nd} air injected = 10 NLPM, blower SP = 40 Hz, ER < 0.25 when the fuel is only biomass)
- Case B: The gasifier is operated in order to achieve a char yield of about 5 % when the fuel is only biomass (2^{nd} air injected = 26 NLPM, blower SP = 40 Hz, ER = 0.25 when the fuel is only biomass)

For both the cases, the gasifier has been firstly operated using only pellets (subcase 0) and then recirculating the char produced during the test (subcase R), reintroducing it together with the standard pellets from the top of the reactor.

The char recirculation obviously increases the char yield calculated as ratio of output per unit of input, without differentiating if the input is biomass or char (Fig. 1a). Nonetheless, taking into account that part of the output is recirculated as input, the results show that char recirculation allows a significant reduction of the overall char yield (in the order of 40 - 60 %, Fig. 1b), without significantly impact the process if this is well tuned up. The producer gas composition and LHV remain almost constant in all the investigated cases, while the Cold Gas Efficiency (CGE) tend to decrease (Fig. 1c). Nonetheless, considering the overall effect, CGE slightly increases in case B, where the process is better tuned up (Fig. 1d).

To supplement the analysis and identify the maximum attainable performance of the system, a thermodynamic equilibrium model has been developed and validated against the experimental results. For the baseline scenario (i.e., standard operation without char recirculation), the gasifier was operated under several different parameters, i.e. under different load factors and with varying equivalent air scenarios.

From the results of this work it is possible to conclude that char recirculation could be a feasible and attractive solution to improve the conversion yields in fixed bed gasifiers, although this is currently not allowed by the legislation. For a complete viability assessment of co-gasification of biomass and char in the existing fixed bed technologies further investigations are required, in particular in relation to three main aspects: the effect of granulometry (char in powder form could negatively impact the process in case of recirculation), the long term effect (reiterating the recirculation for a long time could also negatively impact the process) and the impact of the proposed strategy on the emissions.

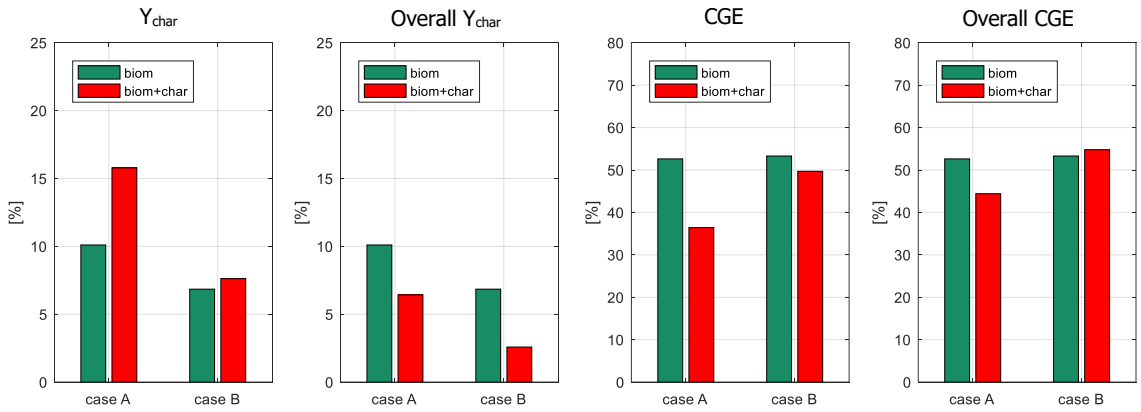

Figure 1. Effect of char recirculation on (a) the char yield, (b) the overall char yield, (c) the CGE and (d) the overall CGE.

References

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The abstracts will be reviewed by members of the Scientific Committee of the THESSALONIKI 2020 Conference.