Fuel flexibility of an open top pilot plant gasifier

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Gasification systems allow the combined heat and power (CHP) production using the gas produced in the gasifier. The interest of investors for biomass gasification system is still strongly depending on the specific boundary conditions – the access to biomass at reasonable costs, the heat demand high enough to allow the exploitation of the gasifiers' heat output and mainly the regulatory framework in terms of feed-in tariffs for investment incentives. Over the last twenty years, considerable improvements have been made to small-scale biomass gasification technologies. Small-scale gasifiers coupled with internal combustion engines have been successfully commercialized with electrical and overall efficiency of about 20 % and 80 %, respectively.

Several biomass can be fed into gasification systems (processing residues, agricultural residues, forestry residues, energy crops and internationally traded feedstock such as wood pellet and wood chips). However, in order to guarantee proper operation of the plant, small-scale gasifiers have usually narrow ranges of process conditions, using mainly feedstock of uniform characteristics - e.g. in terms of moisture and granulometry - and working predominantly at steady-state operation [1].

The main aim of this work is to investigate the flexibility of a gasification system at laboratory scale.
In order to achieve this goal, feedstock characteristics and gasification plants behavior were investigated in different conditions. Different kinds of feedstock have been gasified in form of pellets and wood chips.

In particular, some types of biomass were tested: standard pellets made with conifer wood (soft wood standard pellet - SWSP), standard pellets made with beech and oak wood (hard wood standard pellet- GWSP), torrefied pellets at different temperatures (250°C and 270°C – T250 and T270) and conifer wood chips with different bark content from 8% to 80% (CB08, CB30, CB80). Finally, the gasification system was tested by recirculating the produced char in different percentages of 10% and 5% (RC10 – RC05). All the characteristics in terms of moisture and ash content, elemental analysis (Carbon, Hydrogen, Nitrogen and Sulfur) and the lower heating value are analyzed (Table 1).

Table 1. Average feedstock characteristic in terms of moisture average content on wet basis (w.b.), elemental analysis and Lower heating value on dry basis (d.b.)

Feedstock type	Moisture [%wt]	Ash [%wt]	C [%wt]	H [%wt]	N [%wt]	S [%wt]	LHV [MJ/kg]
SWSP	7.4 ± 0.3	0.3 ±0.03	51.1±0.36	6.1±0.05	0.08±0.02	0.26±0.21	42.1±0.5
HWSP	7.9 ± 0.04	0.9±0.04	49.8±0.05	5.9±0.04	0.14±0.01	0.00±0.00	17.5±0.2
T250	4.5 ± 0.14	0.8±0.04	50.6±0.28	5.6±0.05	0.14±0.02	0.00±0.00	17.9±0.4
T270	4.1 ± 0.13	0.7±0.04	53.2±0.30	5.3±0.09	0.16±0.02	0.01±0.00	18.5±0.6
RC10	6.0 ± 0.3	0.6±0.02	55.5±0.07	5.5±0.01	0.12±0.01	0.06±0.01	38.1±0.1
RC05	6.4 ± 0.3	0.6±0.01	53.6±0.06	5.7±0.01	0.14±0.01	0.08±0.01	39.8±0.1
CB08	10.9±0.48	0.7±0.03	49.2±0.27	6.2±0.07	0.10±0.01	0.20±0.01	43.6±0.3
CB30	10.7±0.31	1.5±0.02	49.5±0.19	6.1±0.09	0.25±0.01	0.25±0.02	42.6±0.2
CB80	7.8±0.23	3.3±0.02	50.1±0.20	5.8±0.19	0.30±0.01	0.20±0.02	40.3±0.2

The gasifier used for the experiments is an open top pilot-scale gasifier installed at the Bioenergy and Biofuel Lab of the Free University of Bolzano. The gasifier is an open top downdraft system, where both gas and feedstock move downward, i.e. co-current configuration, as the reactions proceed. The peculiarity of this gasification reactor consists of the possibility to insert the gasifying agent in two separate sections of the reactor. A first flow of air enters from the top of the reactor and participates at the gasification reactions while a second flow of air can be introduced in the lower part of the reactor where there is the reduction zone where only the char produced in the upper part of the reactor is subjected to conversion. By increasing the flow of secondary air, it is possible to achieve partial combustion of the char bed. This allows on the one hand to decrease the final char yield and, on the other hand, to increase the temperatures in the reduction zone (due to the char oxidation) with a net increase in the conversion of solid carbon to carbon monoxide at the expense of the carbon dioxide production due to the Boudouard reaction. In addition, the secondary air influences the equivalence ratio of the gasification process, which is defined as the ratio between the air supplied and the stoichiometric air. Increasing the secondary air the equivalence ratio increases as well (Figure 1).

The results are presented in Figure 1 in terms of equivalence ratio of the process, the char yields and the cold gas efficiency. The char yield is the ratio between the char mass flow rate and the input feedstock mass flow rate. The cold gas efficiency is the ratio between the output power - considering only the contribution of the lower calorific value of the producer gas - and the input power relevant to the biomass.
The obtained results suggest that it is possible to control the gasifier via secondary air flow rate, in order to enhance its performance reducing the char production and enhancing the cold gas efficiency.

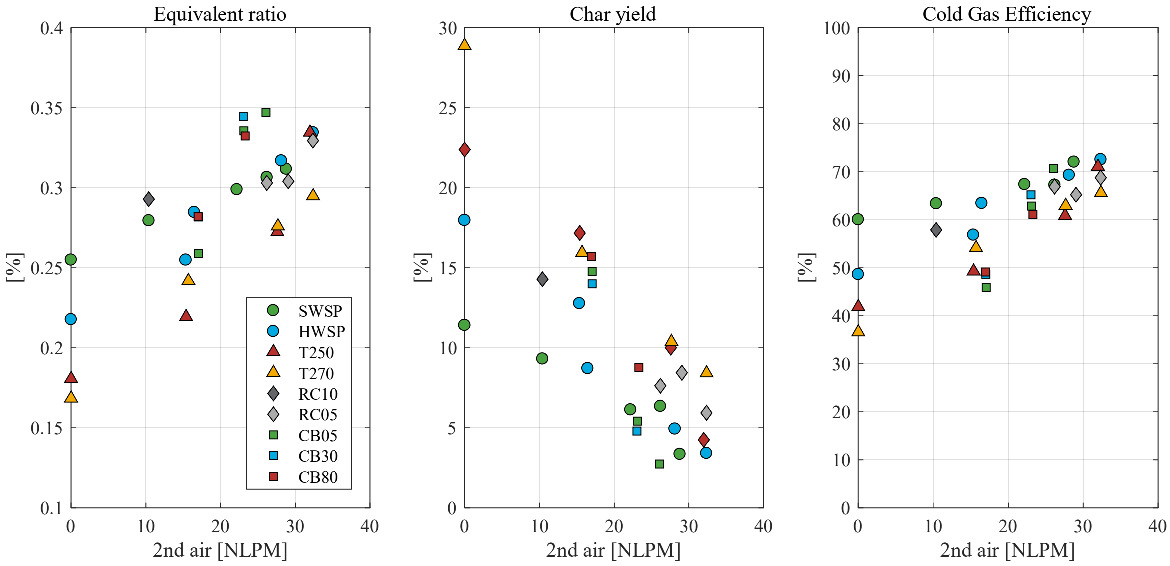

Figure 1. Effect of secondary air variation in terms of equivalence ratio (on the left), char yield (in center) and cold gas efficiency (on the right)

In conclusion, the fuel flexibility of the plant is evaluated comparing different biomasses utilized in the same reactor by varying the secondary air supplied. For all the analyzed tests, the equivalence ratio and the gasifier performance have the same trends. Increasing the equivalence ratio there is a decrease in the char yield and an increase in the cold gas efficiency. Therefore, secondary air flow rate allows to adjust and control the process conditions obtaining comparable conversion efficiencies using feedstock of different characteristics.

References

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