Simulation and exergy analysis of a novel small-scale biomass gasifier: A "Multi-Box" application

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Extended abstract

Several models have been developed in order to describe the process of biomass gasification, a respectable amount of which concern the specific case of downdraft gasifiers. The high interest in modelling downdraft gasifiers is due to the fact that they are so far the most applied technology in the market. Nonetheless, biomass gasification is a complex process, influenced by various parameters. Thus, the development of such models should enhance the traditional "black-box" modelling approach and give answers about the different steps involved in gasification.

Biomass gasification is not a homogeneous process and it is characterized by a wide range of operational conditions; in downdraft gasifiers four major different process zones (i.e. drying, pyrolysis, oxidation, and reduction) can be recognized. The local functions of state (i.e. enthalpy) and the products from specific zones of downdraft gasification (i.e. products of complete combustion) are not taken into consideration from black- box models. Furthermore, other products i.e. tar, can't be described from the

typical solid-gas reactions systems. Intermediate reactions act as nested ‘niches’, the equilibrium of which defines drastically the composition of the final products. Thus this ‘niches’ should be identified and analysed individually. This procedure could be named as a “multi-box” approach, where every ‘box’ contains a thermodynamic intermediate equilibrium. A basic scheme of the model can be shown in Figure 1.

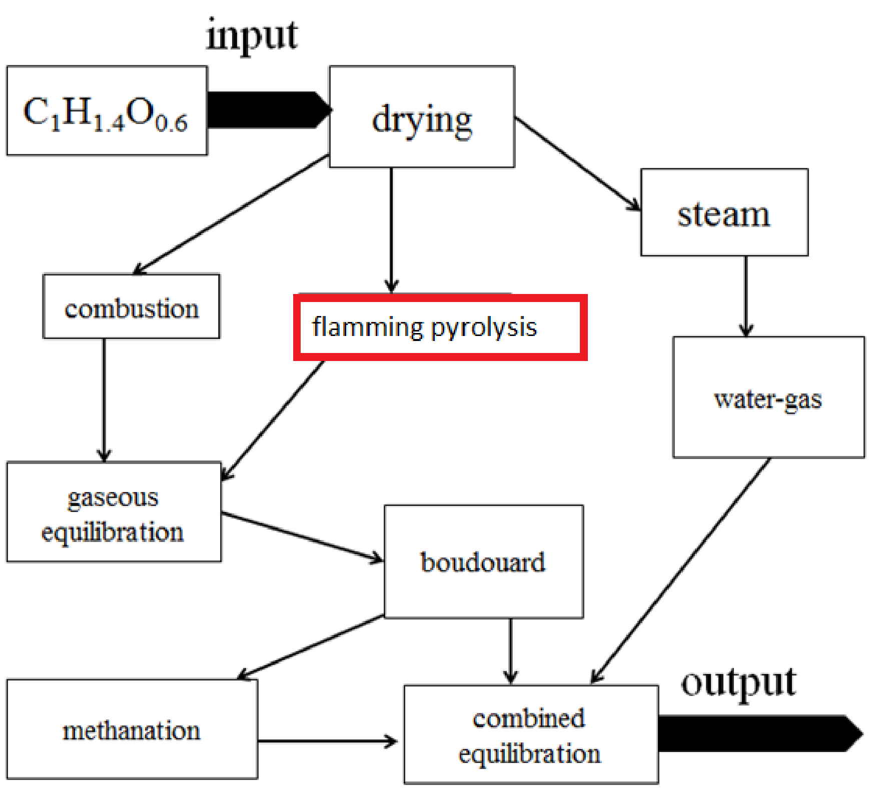

Fig. 1. Basic breakdown of the model with the necessary adjustments for the simulation of a rising co-current gasifier.

The “multi-box” could potentially be applied to describe and test a wide spectrum of operating conditions. Moreover, alterations in the sequence and the nature of the reaction mechanisms are relatively easy and straightforward to be performed. The model was initially developed to simulate downdraft gasifiers but the ‘boxes’ can be restructured in a way that make the model suitable for the analysis of various designs, like updraft gasifiers. An interesting case of a novel and innovative design is the rising co-current gasifier which combines the zone separation of the downdraft design and several innovations in respect to the method of air-input and the upward movement of the material in the reactor.

The development of the model has the scope to assist the design optimization of gasifiers. The performance of the multi-box was assessed applying real operating data (i.e. biomass composition, equivalent ratio, operation temperatures), measured during a monitoring activity that have been performed by the authors on a rising co-current gasifier in the North of Italy. The values that are returned from the model are compared with the actual measurements as shown in Figure 2.

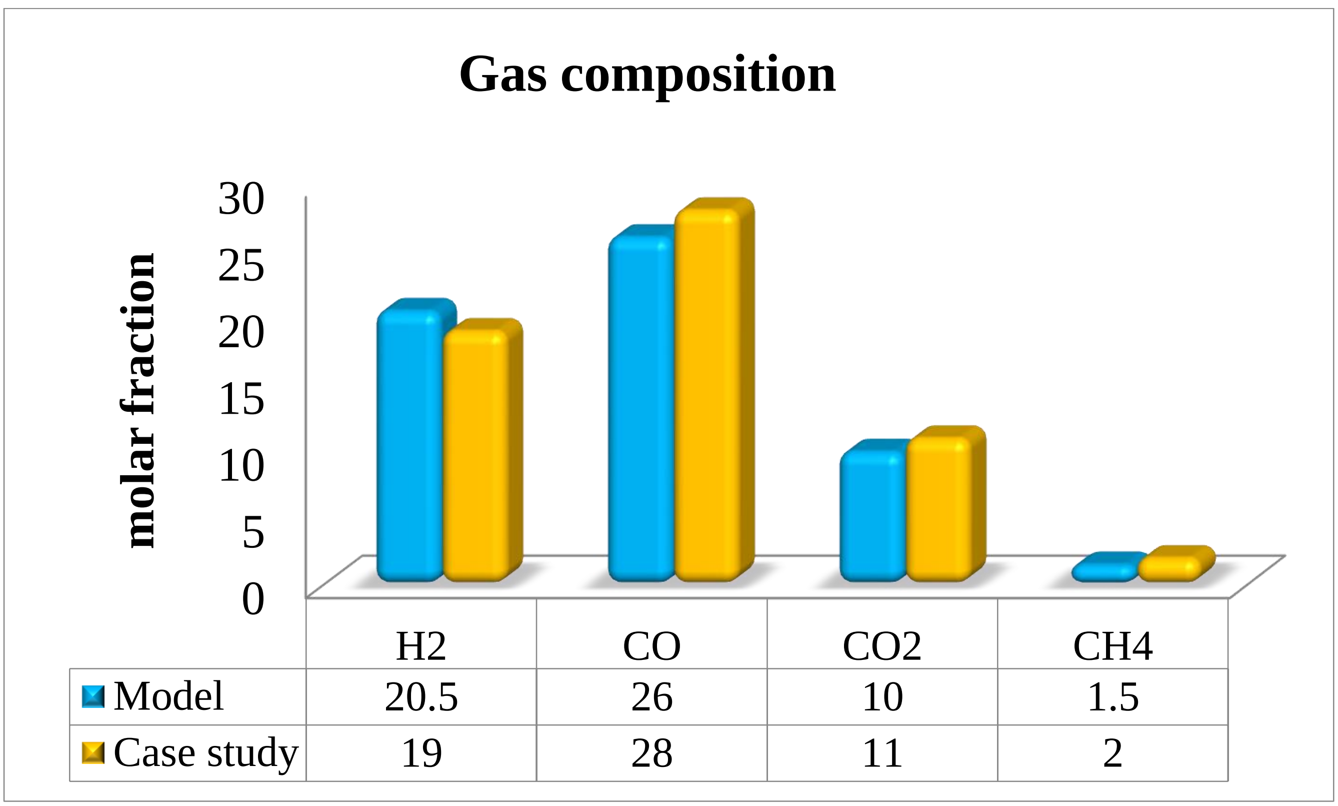

Fig. 2. Comparison of simulated gas composition and real case gas composition.

The ‘Multi-Box’ model returns gas compositions very close to the real measurements. Also, the model solves the problem of methane composition and returned char yield, which have negligible returned values for the case of ‘black-box’ modelling. Also, a secondary scope of the model is to identify and assess the processes within the gasifier and the gasification plant that dissipate the exergy. This becomes possible due to the nature of the ‘Multi-Box’ model which is able to calculate the intermediate equilibriums.