Cold model testing of an innovative dual bubbling fluidized bed steam gasifier

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Highlights

- A cold model of an innovative dual bubbling fluidized bed has been realized
- PTV analysis showed that bed circulation rate is more than double of the minimum required
- Tests demonstrated that gas leakages between the two reactor chambers are negligible

1. Introduction

Dual fluidized bed steam gasification is a very promising process to produce a rich hydrogen syngas from biomass wastes, although several issues have to be considered in the reactor design. In particular bed material circulation should be enough to transport heat from the combustor to the steam gasifier, and siphons/loop-seals should be properly designed to avoid gas leakages between the two reactors (such as N_2 from the combustor to the gasifier). The aim of this work is to evaluate these aspects for an innovative pilot scale dual bubbling fluidized bed gasifier (100 kWth as biomass input) by means of cold modelling tests. The gasifier is realized in HBF 2.0 project financed by the Italian Ministry of Economic Development.

2. Methods

The reactor, shown in Figure 1, consists of two adjacent fluidized beds: (i) the gasification zone (external cylinder) and (ii) the combustion zone (internal cylinder) fluidized by steam and air respectively. The two chambers are connected with two orifices at a proper distance to allow bed material circulation: to avoid gas leakages, two loop seals fluidized with steam are included. The fluidized beds operate at different temperature and superficial velocity (u_s): (i) the fast bed (combustor) T~1173 K and u_s = 5-10 u_{mf} and (ii) the slow bed (gasifier) T ~1073 K and u_s = 2-3 u_{mf}. Due to differences in height and void fraction, pressure gradients are established at the lower and upper orifice. For this reason a circulation of bed material is established and heat is transported between the combustor and the gasifier: (i) sand and residual char in the slow bed flow into the fast bed through the lower orifice and (ii) hot sand is recycled back into the slow bed through the upper orifice**.** The char combustion in the fast bed supplies the heat transported by solids.

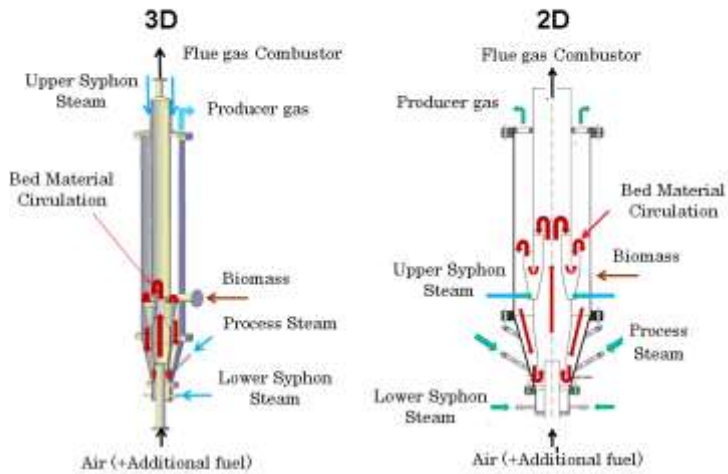

Figure 1. – 3D and 2D sketch of the new dual fluidized bed gasifier concept

A cold model of the gasifier has been realized adopting scaling rules proposed by Foscolo et al.[1], to operate the system at ambient temperature with air. Thanks to the cold model it was possible then to test the hydrodynamic behavior of the bed and evaluate experimentally:

- the gas leakages between the two chambers, injecting a known flow of CO_2 with the air for fluidization, measuring the volumetric fraction of CO_2 at their exit, and applying mass balances for the gas species;
- the bed material circulation rate to verify that is higher than 50 kg_{oliv}/kg_{bio}, using Particle Tracking Velocimetry analysis (PTV) on the upper siphon. The algorithm developed by Shindler et al.[2] was used to evaluate the Lagrangian vertical velocity of the sand throughput that overflows periodically from the upper siphon.

3. Results and discussion

Figure 2a shows a frame obtained by the PTV with velocity vectors, while Figure 2b shows the extrapolated v_z >0 at the outlet of the siphon during tests for the case of a $u_{s(combustor)}$ equal to $7u_{mf}$:

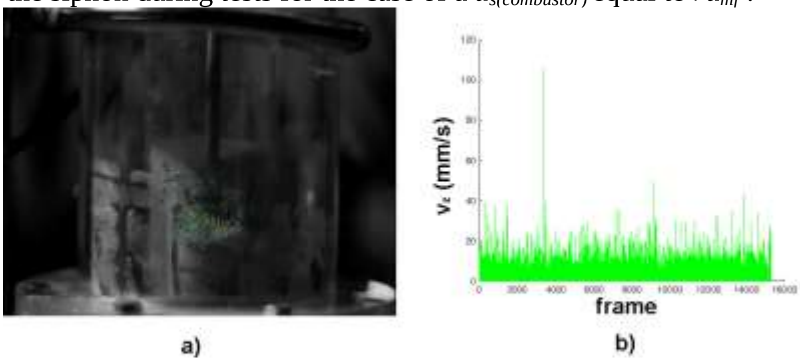

Figure 2. – PTV results: a) frame with velocity vectors b) vertical velocity extrapolated from different frames

The estimated bed circulation rate of the real reactor is 130 $kg_{oliv}/kg_{bio.}$ Figure 3 shows CO_2 concentration at the exit of the external cylinder vs that injected in the internal cylinder

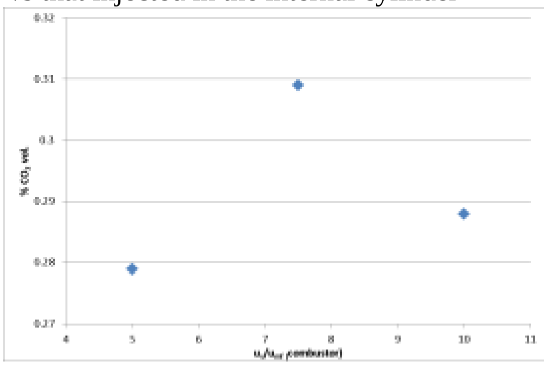

Figure 3. – measured CO_2 concntration at the exit of the external cylinder (gasifier) vs that injected in the internal cylinder (combustor)

Similar results were obtained when CO_2 was injected in the external cylinder and measured at the exit of the internal cylinder. The amount of CO_2 is close to the zero of the on-line analyzer (0.3%). Mass balance calculations showed that gas leakages are negligible.

4. Conclusions

Cold model analysis of an innovative dual bubbling fluidized bed gasifier (100 kWth) was carried out to verify: (i) bed material circulation rate and (ii) gas leakages between the two reactor chambers. Experiments carried out by PTV showed that the solids circulation rate is more than double of the minimum required for autothermal behavior, demonstrating that the gasifier is well dimensioned. Furthermore gas leakages between the two reactors are negligible demonstrating that siphons can properly operate for their scope.

References

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Keywords

Dual fluidized bed gasifier, Cold modeling, bed circulation rate, gas leakages between fluidized beds.