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# Design and operation assessment of an oxyfuel fluidized bed combustor

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ABSTRACT

Oxyfuel combustion is a promising alternative for $CO_2$ capture. While this has been proven in pulverized fuel (PF) burners, research in fluidized bed (FB) reactors is still scarce. Our work aims to increase the knowledge about this technology. To this purpose, a 95 $kW_{th}$ FB oxyfuel combustion test rig has been erected. Its main characteristics are described in this paper, giving detailed information on the subsystems: the FB reactor, the fuel and oxidant supplies, and ancillaries. Plant flexibility is emphasized. It allows to operate under different $CO_2/O_2$ ratios, and to recycle $CO_2$ from the flue gases. Both the processes design and monitoring are supported by simulations that have been validated against experimental data, regarding fluid dynamics, combustion, and heat transfer. Finally, the performance of the facility has been tested both with coal alone and blended with biomass. $CO_2$ concentrations over 90% (dry basis) in the flue gases have been obtained. Comparison of air and oxygen combustion tests and operational recommendations are discussed, confirming the feasibility of the FB oxyfuel technology for $CO_2$ capture purposes.



## 1. Introduction

In the last decades, fluidized beds (FB) boilers have established as a clean combustion technology, suitable for using a diversity of fuels. The current international concern about $CO_2$ emissions has led to research and development of capture systems, where FB is expected to play again an essential role.

In recent literature, several $CO_2$ capture systems based on FB have been proposed [1–5]. They are mainly based on a combination of several interconnected circulating fluidizing beds (CFB) with separation/regeneration processes for calcium and chemical looping. Nevertheless, oxyfuel combustion in FB for $CO_2$ capture has been barely studied so far. To the best of our knowledge, few institutions are working on oxy-firing fluidized beds, and they are mainly focused on CFB [6–12]. Outstanding oxyfuel reviews [13–15] concentrate on pulverized fuel (PF) applications, but the behaviour of FB combustion is completely different. In PF combustors, thermal radiation is the main contribution to heat transfer rates, being substantially affected by oxyfuel combustion [13]. Hence the simulation of this contribution deserves important efforts in the literature [14]. For FB applications radiation contribution diminishes and other mechanisms dominate heat transfer processes. Evidently, there is a common interest in emissions, both in PF [11–15] and FB units [6–9,11,12], but the pollutant formation and reduction/capture are considerably different. The same concerns arise for ash related issues, where the effect of temperature could be even more significant than the change from air to $CO_2/O_2$ atmospheres. As for the combustion performance, ignition and flame stability are essential to improve combustion efficiencies in PF, but not in the case of FB. The challenge for both applications is eventually the reduction in unburned rates but, again, the fundamentals are very different.

The traditional characteristics of FB combustion are promising for its application to oxy-firing for $CO_2$ capture. The possibility of using different kinds of (low cost) fuels could contribute to reduce the $CO_2$ capture costs. The problems with combustion temperature control and pollutant formation are easily limited in FB. And, finally, the difficulty of flue gas recirculation for temperature control in PF applications could be reduced in CFB by means of the bed material recirculation, since the specific heat of the solids is higher than that of the recycled flue gas. In this sense, it is expected that scale-up of CFB boilers operating under oxyfuel conditions will result in more compact units, with a significant decrease of heat removal per surface area. This will demand new designs of BFB external heat exchangers, to evacuate higher heat rates from the recycled particle flows, which will necessarily be operated under oxy-firing conditions to avoid dilution of $CO_2$ in flue gases.

Regarding oxyfuel in FB, the works by Czakiert et al. [6,7] have studied the fuel conversion in a 100 $kW_{th}$ CFB with increased inlet oxygen concentration, at different temperatures and fuel loads. Although fuel was fed in a pulse manner, the authors pointed out the relevance of the oxygen concentration and reported figures

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