2nd Oxyfuel Combustion Conference

Experimental Verification of two 2.5 MW_{th} Oxyfuel PC Burner Designs

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Keywords: Oxyfuel, pulverized coal, burner

1. Introduction

The increasing energy demand and the high dependency of the energy sector on fossil fuels [1] necessitate the development of technologies, which support the reduction of greenhouse gas emissions. Carbon Capture and Storage (CCS) technologies represent an important contribution for the reduction of CO_2 emissions into the atmosphere [2]. One of the CCS technologies is the oxyfuel combustion, where the fuel is burned with nearly pure oxygen. Although the combustion of fuels with industrial-purity oxygen (90 to 99,9+% O_2) for several high-temperature applications [3] is already state of the art, new burners have to be developed for the combustion of pulverized coal in oxyfuel mode regarding technically feasible boiler temperatures, which ensure a stable and save operation [4]. Different factors (e.g. flue gas recycle ratio, oxygen concentrations, coal type) influence the design of an oxyfuel burner for pulverized coal [5].

Within the European Research Fund for Coal and Steel project "Friendly Coal", one task of the Institute of Thermal Engineering, Graz University of Technology, was the design of a 3MW_{th} pulverized coal burner for oxyfuel combustion and high recirculation rates [6]. In the course of an R&D cooperation with AE&E, the burner was further developed, mainly based on the results of the "Friendly Coal" burner tests and a validated CFD model [7]. Both burners were tested in collaboration with the International Flame Research Foundation at the test furnace of ENEL in Livorno [8]. This paper describes the basic design of the "Friendly Coal" burner and the further development as well as the results of the performed tests.

2. Basic burner design

The basic burner design strongly depends on the requirements of the planned boiler. Basic objectives are an appropriate shape and length of the flame, low carbon content in the ash, low emissions (NO_x, SO_x, CO), low excess oxygen content, high operating range, high flame stability and stable ignition [3,5]. In the case of a pulverized coal swirl burner for oxyfuel conditions different possibilities exist in order to achieve these objectives. The most important factors are certainly the swirl generation of the mixed oxygen and recirculated flue gas streams, baffles in

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order to enforce the inner recirculation, the oxygen injection and the overall staging of the streams. However not all of these components are stringently required for a swirl burner.

The burner design within the project “Friendly coal” focused mainly on the possibility to operate the burner with natural gas or pulverized coal with air or oxygen and recirculated flue gas (RFG) [6]. Figure 1 shows a scheme of the burner and its main components. A high variability concerning the amount of oxygen injection into the primary stream, the tangential velocity of the secondary stream and the position of the baffle at the inner circumference of the primary duct was chosen in order to figure out the optimum operating points for the different operational setups.

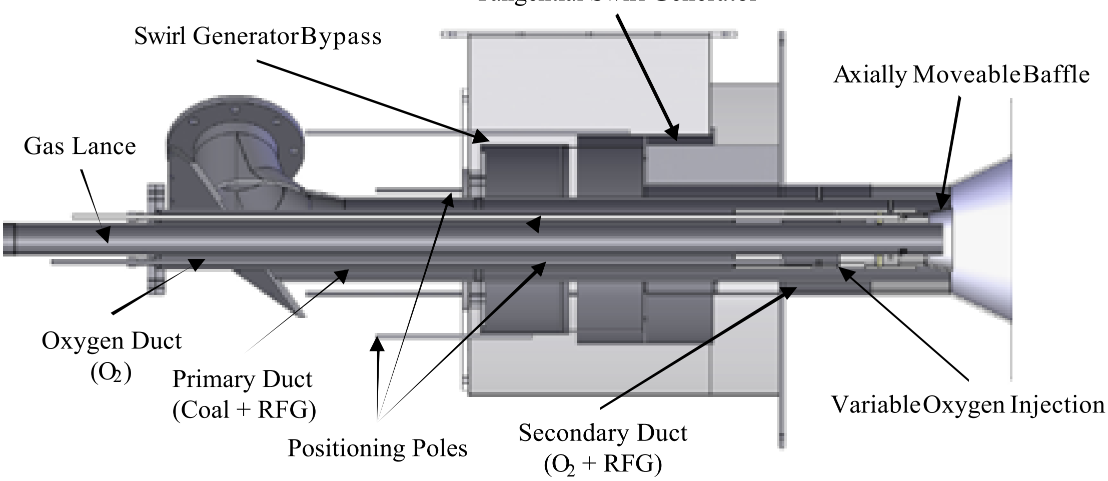

Figure 1: Scheme of the “Friendly Coal” 2.5 MW burner with its most important components

Based on the results of the tests and by the use of the validated CFD simulation models [7], the burner design was adopted and modified (Figure 2).

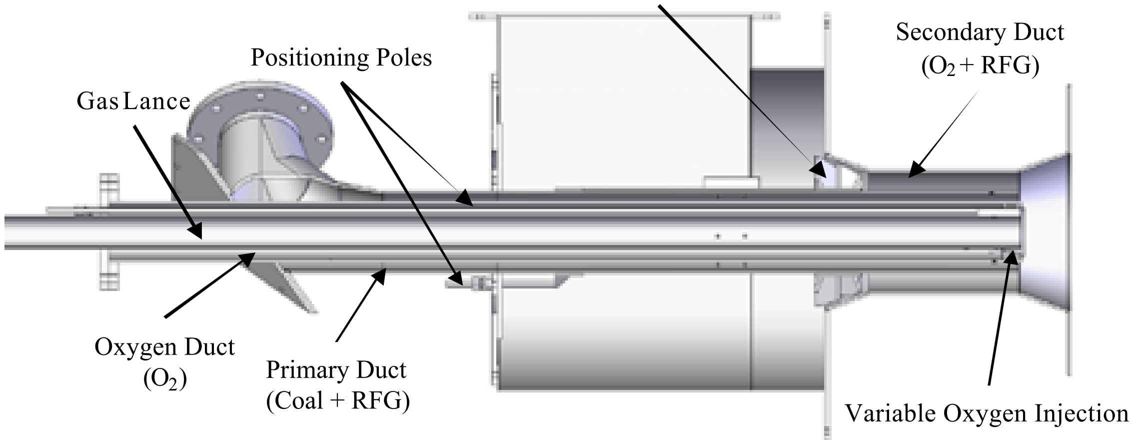

Figure 2: Scheme of the further developed 2.5 MW burner with its most important components

As one can see, the design of the swirl generator and the construction within the area around the primary outlet changed completely. This is mainly due to the fact, that the burner is especially designed for oxyfuel operation. During the tests, it was possible to define an appropriate range for the tangential velocity component. Consequently, the design of the swirl generator was changed, in order to reduce the pressure drop within the wind box. Additionally it turned out during the tests, that the amount of oxygen injection into the area of the flame core and the position of the baffle affect the NO_x emissions clearly. Due to security reasons, the oxygen injection required a relocation to the burner outlet. The new construction of the oxygen outlet allows the variation of the oxygen outlet velocity. Moreover, it enables the possibility to generate an inner recirculation of the hot flue gases within the flame core, depending on the injection velocity. Consequently, the baffle was omitted and the overall construction is simpler compared to the “Friendly Coal” design.

3. Test results

As mentioned before, the combustion tests were performed at ENELs test facility located in Livorno, Italy. Both burners were operated with a thermal load of 2.5MW (Indonesian Sebukusub bituminous coal) in oxyfuel mode with a flue gas recirculation rate between 61 and 63%. The excess oxygen amounted to approximately 3% on wet basis. With the aid of the thermodynamic process simulation program IPSEPro, it was possible to verify the operating conditions of the test facility and to provide adjustments for specific operating parameters. Figure 3 shows the two different flames of the burners in oxyfuel-coal mode and an installed burner at the test rig.

Figure 3: “Friendly Coal” burner flame (left), further developed burner flame (middle), installed burner (right)

In all test cases with both burners, the flame seemed to be stable, whereas in the case of the “Friendly Coal” burner, the flame was very near or attached to the burner outlet. Additionally the flame core temperatures (>1700°C) and the NO_x emissions (Oxyfuel: 390 mg/MJ; Air: 470 mg/MJ @ 3%O_2 on dry basis) were very high. Due to the reduction of the secondary stream velocity and the new oxygen injection mechanism it was possible to reduce both, the peak temperature (max. 1600°C) within the flame and the NO_x emissions (Oxyfuel:90 mg/MJ; Air: 100 mg/MJ @ 3%O_2 on dry basis) at the combustion chamber outlet. In both cases, the CO concentration lay within the range of 15 and 25 ppm at the combustion chamber outlet and the ash analysis showed that the unburned carbon in the ash was less than 1 wt%.

4. Acknowledgement

This work is partly carried out with a financial grant from the Research Fund for Coal and Steel of the European Community within the project “Friendly Coal” (RFC-CR-06007).

5. Literature

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