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Experimental and numerical investigations on a swirl oxycoal flame

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ABSTRACT

The oxyfuel combustion technology has gained increased interest as a promising option for carbon capture and storage (CCS) in the last few years. The substitution of air by a mixture of recylced flue gas (RFG) and oxygen, however, is followed by changes in the process of pulverized fuel (PF) combustion as well as in the heat transfer inside the furnace. At RWTH Aachen University, research was conducted to investigate the underlying mechanisms governing the PF oxy-combustion and the impact of this process on burner and furnace designs with respect to industrial applications. Starting with experiments using a pulverized coal swirl burner designed for air combustion, measures were developed for an aerodynamical stabilization of an oxycoal swirl flame. Computational Fluid Dynamics (CFD), based on adapted models for PF oxy-combustion, was used as a design tool for development of swirl burner which was successfully tested in the oxycoal test facility at RWTH Aachen. This burner allows a stable oxyfuel combustion within wide range of oxygen content in the O_2/RFG mixture (from 18 to > 30 vol.-%). Further numerical simulations of a 1210 MW_{th} industrial boiler oxy-firing bituminous pulverized coal were performed with respect to retrofit. Comparisons made between air-firing and oxy-firing mode show that the radiative heat flux to the wall of a utility boiler is significantly influenced due to the changed optical properties of flue gases inside the oxy-firing utility furnace. A special focus was given to the oxygen concentration that is required to achieve similar heat transfer conditions as for conventional air fired furnaces.

1. Introduction

The combustion of pulverized coal using oxygen instead of air (oxycoal), diluted with Recycled Flue Gas (RFG), is an emerging Carbon Capture and Storage (CCS) technology with great commercial potential. Therefore, combustion science and modeling is needed to advance the oxy-firing technology and to optimize operations, particularly when this effort is linked to pilot-plant trials and the design of plants.

Several experimental investigations with oxy-firing p.c. burners report that flame temperature and stability are strongly affected [1–4]. There are pronounced differences in thermophysical and optical properties of CO_2 and air; it is therefore of vital importance to know the effect of CO_2 properties on flame stability and on heat transfer during oxy-combustion of pulverized coal.

Numerous works on this topic suggest a significant increase of the oxygen concentration in the O_2/RFG mixture (around 25–30% for wet recycle and 30–40% for dry recycle) to compensate for the higher heat capacity of CO_2. Achieving similar reaction rates and temperature levels like in a PF – air flame without significant changes to the flame aerodynamics [1,4–7]. This approach is based on the accumulated experience in burner aerodynamics in air-pulverized fuel combustion processes. However, the absolute value for oxygen concentration mainly depends on the burner, on the combustor design used, and on its operating conditions [8–10]. However, the level of oxygen concentration cannot only be determined by a stable flame and full burnout. It also depends on the requirements to achieve heat flux levels inside the radiative section of the combustion chamber. This becomes essential if a retrofit of existing combustion chambers with this technique is considered. In this case, the radiative flux levels to the chamber walls should be comparable to air-firing. Hence, detailed investigations are required in order to clarify the underlying mechanisms of oxy-firing of pulverized coal and thus to find the overall solution for the entire technical process. Within this aspect a series of test runs was performed at the oxycoal test facility at RWTH Aachen with the aim to achieve an experimentally confirmed database needed for development of a swirl burner able to operate at a wide range of O_2 concentrations (from 18 to 34% vol. O_2) under oxy-firing conditions.

Further numerical studies were conducted in order to investigate the qualification of the oxyfuel technology for full-scale facilities: the insights gained from the work on the test facility were

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