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Oxyfuel combustion of lignite in a non-stoichiometric operating two burner arrangement

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HIGHLIGHTS

- ▶ Investigations on oxycoal combustion in a non-stoichiometric two burner arrangement.
- ▶ Significant reduction of recirculation while fulfilling all requirements on temperature limitation.
- ▶ Comparable NO and CO emissions to the stoichiometric air-like oxyfuel process.
- ▶ Negligible differences in combustion characteristics when changing between wet or dry recirculation.

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ABSTRACT

Next to the recirculation rate and that way the oxygen concentration in the oxidizer, the stoichiometry offers an option to control flame temperatures in oxyfuel processes. While using both, non-stoichiometric flames and recirculated flue gas as in the concept of controlled staging with non-stoichiometric burners (CSNBs), the recirculation rate could be reduced drastically. Reducing the recirculation rate in the oxyfuel process is a viable option for more efficient steam generator concepts. The auxiliary power demand, the size of the recirculation equipment and the steam generator size is reduced. The investigations in this paper focus on the interaction of two non-stoichiometric operating pulverized fuel oxycoal burners as used in the CSNB concept. Two different staging strategies have been investigated in detail as well as the influence of dry and wet flue gas recirculation. For that purpose species concentrations have been measured along the flue gas path in the combustion chamber. Additionally emissions at the combustion chamber exit as well as mass and energy balances of the process are reported. The species concentration profiles demonstrate the functionality of the CSNB concept. Either way the oxygen excess or the hydrocarbon excess of the first flame level could be balanced by the contrarily operating second flame level. The staged CSNB concept with low recirculation rate shows comparable combustion performance with the unstaged oxyfuel process with high flue gas recirculation. However the influences of the individual burner performance and the flue gas mixing, especially in the second burner level, is emphasized in the CSNB concept. In concerns of NO_x emissions shows the arrangement, first sub- then over-stoichiometric combustion lower values because the initial NO formation in the first level is much lower. In case of over- and then sub-stoichiometric arrangement the NO reduction by the second sub-stoichiometric flame is low. In case of wet flue gas recirculation with increased vapor concentration in the flue gas atmosphere the heat transfer in the combustion chamber is slightly higher compared to the dry oxyfuel case.

1. Introduction

As shown in several pilot plants, the oxyfuel process, that burns coal in mixture of pure oxygen and recycled flue gas, is a feasible option for sequestration of CO_2-emissions from large scale coal fired power plants [1–3]. Burning coal with pure oxygen, as in the zero recycle oxyfuel process, leads to very high temperatures of up to 3000 °C [4]. In case of boiler applications these temperatures have to be controlled. Boiler materials and the ash melting and ash evaporation behavior limit maximum flame temperatures. Without the temperature moderating nitrogen from the air, flue gas from the combustion chamber end has to be recirculated as thermal ballast. Several review articles are published on this topic [3,5–8]. Depending on coal quality and recirculation parameters, matching similar adiabatic flame temperatures as in air-blown systems needs a recirculation rate from 60% to 70% of the total flue gas at combustion chamber end.

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The concept of controlled staging with non-stoichiometric burners (CSNBs) offers a firing strategy that allows a reduction of the recirculation rate while fulfilling all requirements opposed due to temperature limitations. While avoiding the nearby stoichiometric burner operation, peak flame temperatures are lowered. In the case of over-stoichiometric combustion the excessive oxidizer operates as thermal sink and in case of sub-stoichiometric burner operation the release of the combustion enthalpy is obviated. Problems with melting and evaporation of ash components, as well as inadmissible high peak heat-fluxes are in that way avoided. To ensure complete burn out at the combustion chamber exit over- and sub-stoichiometric burners are combined such that the global stoichiometry in the combustion chamber is slightly over-stoichiometric. Fig. 1a shows the idea of the CSNB combustion concept. More details to the CSNB concept can be found in Becher et al. [9] and Bohn et al. [10]. Becher investigated the CSNB concept with natural gas burners and showed the feasibility of the concept. Additionally he focused on the different radiation behavior of the oxyfuel gas flames. Bohn transferred the CSNB concept to coal and investigated in a first step the combustion characteristics in a single non-stoichiometric operating pulverized fuel (pf) flame. Based on this background the combustion characteristics of lignite in a non-stoichiometric operating two burner arrangement is examined.

As nearly all pilot facilities operate with a top down fired single burner arrangement the interaction in an arrangement of a non-stoichiometric multi burner oxyfuel setup is not investigated so far. When staging becomes a topic, than only in concerns of NO_x-reduction. In concerns of primary NO_x-emission control three staging strategies are discussed for coal combustion. The internal staging within the burner for special adapted low-NO_x burners, the fuel staging or reburning and the air-staging [11,4,12]. While low-NO_x-burners are a viable option for any combustion concept the differences between fuel- and air-staging and the CSNB combustion concept will be highlighted in the following. Fig. 1 compares the three concepts in a simplified way. In fuel- and air-staging there is one set of burners operating either way slightly over- or sub-stoichiometric. Usually the oxygen excess or deficit

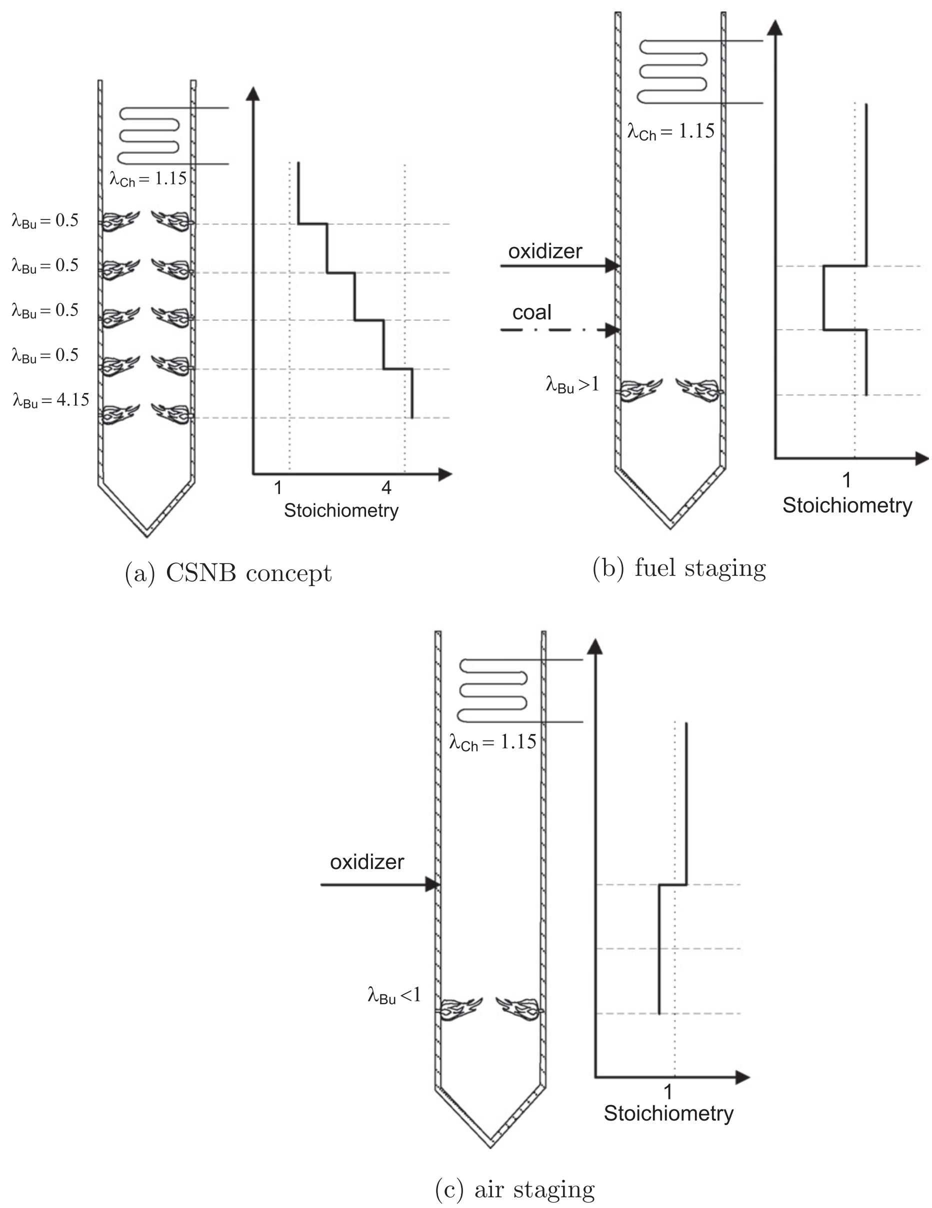

Fig. 1. Simplified sketches of the CSNB (a), fuel- (b), and air-staging (c) combustion concepts.