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Oxyfuel Combustion of alternative fuels based on results from a circulating fluidized bed pilot rig

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1. Introduction

Application of pure oxygen in industrial furnaces has the potential to provide concentrated CO_2 exhaust streams for carbon capture and, additionally, adds a relevant degree of freedom to the combustion process because of the variable oxygen content of the synthetic air mixture (combustion gas). With respect to fluidized bed combustion, OxyFuel has been investigated e.g. by Alstom [1] and results from pilot test rigs have been recently reported by Czakiert et al. [2]. The main advantage of fluidized bed boilers is the relatively isothermal combustion chamber due to the heat capacity of the bed material. It is possible to extract heat directly out of the fluidized bed material. This means that the oxygen content in the combustion gas may be increased without increasing the combustion temperature. Less exhaust gas needs to be recycled. The Oxyfuel process offers a supplementary degree of freedom, in the terms of O_2 concentration in the feed which allows improved operation especially for low calorific fuels.

Oxygen enrichment of combustion air has been applied for low heating value fuels like sewage sludge in bubbling fluidized bed combustors [3].

The present project is to some extent a combination of the above approaches and paves the way for capture ready waste incineration with immediate economic benefit. Such benefit comes e.g. from the avoidance of fossil fuel co-firing when converting low calorific fuels.

In a final stage of development with infrastructure for CO_2 compression, transport and storage, the technology offers the potential of below zero emission spots if the fuel mix has a non-fossil carbon content.

First operating results for the combustion of sewage sludge could be obtained. Variation on O_2 excess and water content were performed and the specific results on CO_2, CO, NO_x and O_2 concentration in exhaust gas are presented. An Oxyfuel model implemented in the IPSEpro environment [4] was used for parameter evaluation by means of reconciled calculation.

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2. Experimental

In order to have a scale-up ready technology, the reactor type was set to be a Circulating Fluidized Bed (CFB) reactor. The fuel output was set to be 100 kW thermal, which is a typical size for test rigs. Fig. 1 shows the setup of the main components of the pilot rig. In this type of reactor a solid inventory of silica sand is fluidized with gas entering at the bottom of the reactor. A gas/solid mixture is produced that entrains the fuel and assures good mixing. The design of the pilot rig has been presented by Höltl et al. [5]. Cold flow model results have been summarized by Guío et al. [6].

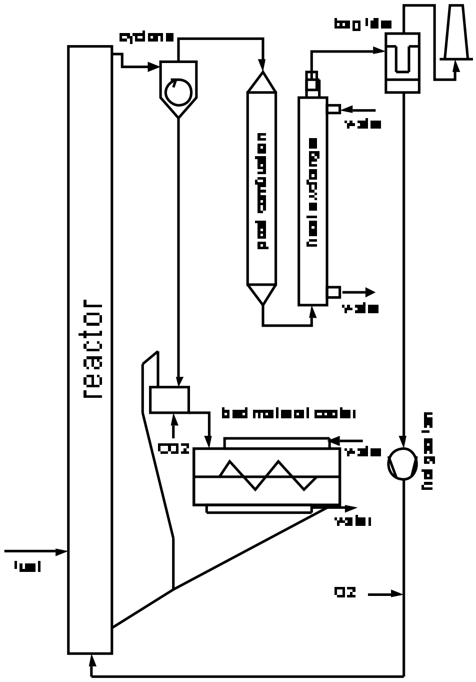

Fig. 1 Principal setup of the test unit

3. Results and discussion

For this experimental campaign Oxyfuel combustion of sewage sludge with his high ash and water content (ash 30%wt. dry and water content up to 70 %) were investigated. A maximum thermal fuel power of 47 kW was achieved and the combustion of sludge with 40 % water content could be attained. High CO concentrations during the start up phase are observed due to low temperature in the post combustion chamber. Once the post combustion chamber obtained a temperature above 600 °C a significant decrease of CO concentration took place. As can be seen in Fig. 2, a maximum CO_2 concentration of 90 % dry basis could be attained and once the Oxyfuel combustion started, a several decrease on O_2 content in exhaust gas could be reached. High NO_x content during start-up phase due to thermal NO_x from the start-up burner could be lowered after switching to Oxyfuel mode and continuously reducing the thermal heat input from the start-up burner. Measurement validation by mass- and energy balance checking indicates water content in exhaust gas of 30 % during the entire sludge-feeding period.

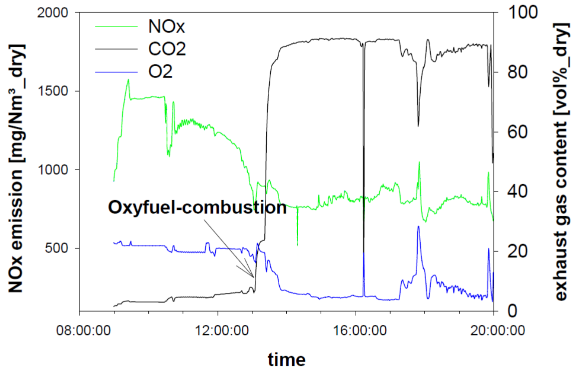

Fig. 2 gas measurement during experimental campaign

For steady state operation, a reactor temperature of 800 C° could be reached and CO concentrations for different O_2 excesses were evaluated. Fig. 3 shows the carbon monoxide content as a function of oxygen concentration in exhaust gas. A decrease of CO content is observed with increasing O_2 content. Therefore, good fuel burnout could be reached for an O_2 concentration of 7 % in the exhaust gas. Since separation of CO during compression and liquefaction of the CO_2 stream is possible, the optimum operating regime might likely be towards the CO-rich boundary in the case of oxyfuel combustion with CO_2 capture.

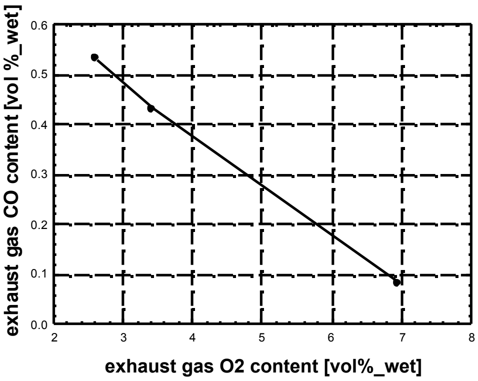

Fig. 3 CO content as a function of O2 concentration in exhaust gas at 800 C° reactor temperature

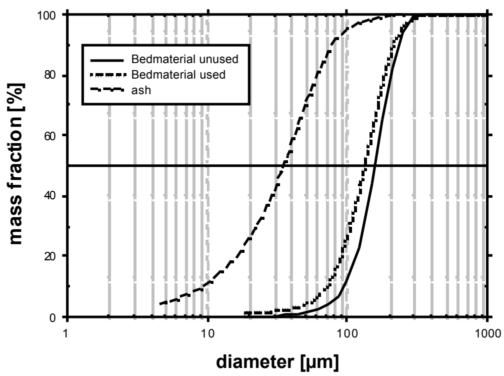

Fig. 4 particle size analysis

A particle size analysis was performed to assess attrition behavior and cyclone efficiency. Fig. 4 shows the results of the particle size analysis. The medium particle size of the unused bed material was 150 µm. Particles that have been collected in the bag filter after the cyclone show a medium particle size of only 35 µm indicating a favorable cyclone performance with the chosen design. The total loss of particles during the investigated test run was assessed to 70kg/MWh.

4 Conclusion

A 100 kW Oxyfuel pilot rig designed for the combustion of coal, sewage sludge, wood and other alternative fuels has been successfully put into operation. A first experimental campaign for the Oxyfuel combustion of sewage sludge with 40 % water content was performed. No nitrogen dilution of exhaust gas occurs in the pilot rig. The CO levels in the exhaust gas are higher than in comparable air-fired units with a significant trade-off between excess oxygen content and CO content. Since CO can be separated from liquefied CO_2 and recycled to the combustor, high CO values might be less problematic than high excess oxygen concentrations in case of zero emission applications. Taking still the non-optimal setup of the hot gas fan into account, there is room for improvement concerning recycle gas flow rates, oxygen concentration in flue gas and fuel power. Further work will focus on investigation of the Oxyfuel process for other alternative fuels such as biomass and domestic waste.

5 References

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