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Oxy-fuel coal combustion—A review of the current state-of-the-art

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ABSTRACT

Carbon dioxide emissions will continue being a major environmental concern due to the fact that coal will remain a major fossil-fuel energy resource for the next few decades. To meet future targets for the reduction of greenhouse gas (GHG) emissions, capture and storage of CO_2 is required. Carbon capture and storage technologies that are currently the focus of research centres and industry include: pre-combustion capture, post-combustion capture, and oxy-fuel combustion. This review deals with the oxy-fuel coal combustion process, primarily focusing on pulverised coal (PC) combustion, and its related research and development topics. In addition, research results related to oxy-fuel combustion in a circulating fluidised bed (CFB) will be briefly dealt with.

During oxy-fuel combustion, a combination of oxygen, with a purity of more than 95 vol.%, and recycled flue gas (RFG) referred to as oxidant is used for combusting the fuel producing a gas consisting of mainly CO_2 and water vapour, which after purification and compression, is ready for storage. The high oxygen demand is supplied by a cryogenic air separation process, which is the only commercially available mature technology. The separation of oxygen from air as well as the purification and liquefaction of the CO_2-enriched flue gas consumes significant auxiliary power. Therefore, the overall net efficiency is expected to be decreased by 8–12% points, corresponding to a 21–35% increase in fuel consumption. Alternatively, ion transport membranes (ITMs) are proposed for oxygen separation, which might be more energy efficient. However, since ITMs are far away from becoming a mature technology, it is widely expected that cryogenic air separation will be the selected technology in the near future. Oxygen combustion is associated with higher temperatures compared with conventional air combustion. Both fuel properties as well as limitations of steam and metal temperatures of the various heat exchanger sections of the boiler require a moderation of the temperatures in the combustion zone and in the heat-transfer sections. This moderation in temperature is accomplished by means of recycled flue gas. The interdependencies between the fuel properties, the amount and temperature of the recycled flue gas, and the resulting oxygen concentration in the combustion atmosphere are reviewed.

The different gas atmosphere resulting from oxy-fuel combustion gives rise to various questions related to firing, in particular, with respect to the combustion mechanism, pollutant reduction, the risk of corrosion, and the properties of the fly ash or its resulting deposits. In this review, detailed nitrogen and sulphur chemistry was investigated in a laboratory-scale facility under oxy-fuel combustion conditions. Oxidant staging succeeded in reducing NO formation with effectiveness comparable to that typically observed in conventional air combustion. With regard to sulphur, a considerable increase in the SO_2 concentration was measured, as expected. However, the H_2S concentration in the combustion atmosphere in the near-flame zone increased as well. Further results were obtained in a pilot-scale test facility, whereby acid dew points were measured and deposition probes were exposed to the combustion environment. Slagging, fouling and corrosion issues have so far been addressed via short-term exposure and require further investigation.

Modelling of PC combustion processes by computational fluid dynamics (CFD) has become state-of-the-art for conventional air combustion. Nevertheless, the application of these models for oxy-fuel combustion conditions needs adaptation since the combustion chemistry and radiative heat transfer is altered due to the different combustion gas atmosphere.

CFB technology can be considered mature for conventional air combustion. In addition to its inherent advantages like good environmental performance and fuel flexibility, it offers the possibility of additional

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