Estimation of Corrosion Risks Caused by Alkali-Species in Oxyfuel Processes

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Abstract

On one hand the work has been concerning the OXYCOAL-AC process, a power plant concept that is developed by RWTH Aachen. It is based on an oxyfuel process with a high temperature oxygen membrane for the oxygen supply. On the other hand a pressurised pulverised coal combustion process (PPCC) under oxyfuel conditions has been investigated: POxycoal. In Oxyfuel processes the combustion of the fuel takes place in recirculated flue gas that has been enriched in oxygen. Thus the processes allow easy CO_2 removal from the exhaust products.

The change in atmosphere for combustion of fossil fuels in oxyfuel processes in comparison to conventional power plant processes evokes certain corrosion risks for metal and ceramic materials that are induced by the changed chemical composition of the produced flue gas, ashes and slags. For example, low melting alkali and alkaline earth carbonates may occur below 900 °C resulting in hot corrosion, problems in ash filtration, and fouling of a membrane, that is used for the oxygen supply of the process. The formation of alkali containing sulphates induces high temperature corrosion on metal materials, such as the commonly used nickel-base alloys. There is also the possibility of the formation of alkali metal containing slags that may lead to filter plugging (which will be not discussed here).

To estimate the occurrence of these corrosion reactions thermodynamic modelling calculations have been done for the mentioned processes. Input data for the calculations were the chemical analyses of different German hard and brown coals. Different oxygen/fuel ratios λ show the influence of stoichiometric and non-stoichiometric combustion.

Different temperature and pressure conditions of the processes have been computed with FactSage to determine the composition of the flue gas and the ashes as well as the precipitation temperatures of alkali metal containing ash phases like sulphates, chlorides and carbonates.

To improve the simulation of the OXYCOAL-AC process a more complex thermodynamic process model has been designed with SimuSage. The whole process including the flue gas recycling and the enrichment in oxygen of the flue gas at the membrane could be calculated to simulate long operation times. In addition, the corrosion of metal materials has been examined by inserting nickel into the cooling section of the flue gas.

The results of the calculations indicate that the lower the oxygen content of the combustion gas becomes, the more moves the chemical character of the produced ash from a sulphate dominated system to a sulphate-chloride system. Additionally, the silica and aluminium content of the used coal type plays a significant role concerning the formation of these ash phases. The formation of alkali metal containing carbonates occurs under sub-stoichiometric conditions if the content of silica and aluminium of the brown coal is low. The calculations concerning the interactions between metal materials and the hot flue gas show that there is a certain risk of hot corrosion under stoichiometric combustion conditions and of sulphidation of nickel-base alloys under sub-stoichiometric conditions.

For the POxycoal process the calculations show clearly that the concentration of sulphur in the recycled flue gas causes a risk of sulphate induced high temperature corrosion for nickel-base alloys which is provoked by the precipitation of sodium sulphate at temperatures that are higher than the eutectic melt of nickel sulphate with sodium sulphate.