Experimental investigations of coal ashes for the VerSi Project

Matthias Dohrn, Michael Müller

Institute of Energy and Climate Research, Microstructure and Properties of Materials (IEK-2), Forschungszentrum Jülich, Germany

Modelling combustion behaviour inside a power plant has been under investigation for several decades. The complexity of coal and ash composition, as well as many other parameters such as flue gas composition, temperature, air-coefficients, boiler design, and many more cause lots of studies which have tried to find a suitable model. Most of the resulting models are only compatible with the coals that were used to validate it or vice versa.

Project VerSi focuses on the special case of modelling slagging and fouling during pulverised coal combustion with focus on flexible operating modes and co-combustion. The aim of this project is to produce an engineering tool to accurately predict deposit formation inside a boiler. Besides live analysis in power plants, small scale experiments have been performed to better understand the mechanisms of deposit formation. Within the present work, basic characterisation of hard coals is used, as well as complex experiments with detailed post-processing.

First, proximate and ultimate analysis of the hard coals was completed in order to realise a qualitative and quantitative x-ray diffraction analysis of the coals and corresponding ashes annealed at 450 °C. To differentiate recrystallisation, decomposition and melting effects, those ashes have been heated up and signals like weight loss, temperature changes in contrast to a reference, and data from a mass spectrometer have been collected.

Second, a furnace flushed with artificial flue gas is used to simulate boiler conditions, including cyclic temperature changes from 600 to 950 °C reproduce load changes in colder boiler regions. Pressed ash samples of hard coals from around the world have been prepared to obtain same initial sample conditions and to be easily evaluated before and after the experiments. Weight change, density change and compressive strength have been measured to detect interactions between flue gas and sample, sintering effects, and deposit densification.

These hard coals vary regarding their ultimate analysis, especially in sulphur content and ash content. Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-OES) reveals major differences in iron, alkali, and silicon contents. For this reason, every hard coal has its key minerals which are mainly responsible for sintering behaviour. Accordingly, the load change experiments give rise to the assumption that the most important factor is the peak temperature and minor differences arise from chemical and mineralogical composition. In addition to this, it is important to point out that the number of cycles is not as significant as having cycles in general.

To sum up, the results will be used to validate a new model that considers all temperature zones in a combustion chamber. This model already contains a silicate iron bypass, to inhibit thermodynamic equilibria with respect to kinetic effects. It is suitable for the addition of mass fractions calculated from CFD to predict the spatial distribution of the deposits. Additionally, viscosity calculations will be included to determine a sticking factor for the wall and boiler tubes.