Combustion of solid alternative fuels in the cement kiln burner

In the cement industry there is an increasing environmental and financial motivation for substituting conventional fossil fuels with alternative fuels, being biomass or waste derived fuels. However, the introduction of alternative fuels may influence emissions, cement product quality, process stability, and process efficiency. Alternative fuel substitution in the calciner unit has reached close to 100% at many cement plants and to further increase the use of alternative fuels rotary kiln substitution must be enhanced. At present, limited systematic knowledge of the alternative fuel combustion properties and the influence on the flame formation is available. In this project a scientific approach to increase the fundamental understanding of alternative fuel conversion in the rotary kiln burner is employed through literature studies, experimental combustion characterisation studies, combustion modelling, data collection and observations at an industrial cement plant firing alternative fuels.

Alternative fuels may differ from conventional fossil fuels in combustion behaviour through differences in physical and chemical properties and reaction kinetics. Often solid alternative fuels are available at significant larger particle sizes than solid fossil fuels due to the cost of downsizing. Through theoretical evaluation it is found that the devolatilisation of large fuel particles is mainly limited by internal heat transfer and the char oxidation is dominated by external O$_2$ diffusion at conditions relevant to suspension fired combustion.

An experimental combustion reactor for simulating suspension fired combustion of large, single particles is established and experiments are performed to investigate conversion pathways, ignition, devolatilisation, and char oxidation times of pine wood, and three types of dried sewage sludge as function of particle size and shape, O$_2$ concentration, and gas temperature. Results show that the main factors affecting the time of devolatilisation is the gas temperature and particle size and shape. Factors affecting char oxidation rates include gas temperature, O$_2$ concentration, and particle size and shape.

A one-dimensional mathematical model of the rotary kiln flame is developed to evaluate the influence of fuel properties and combustion system parameters on the fuel burnout and flame temperature profile. Two alternative fuel cases are simulated; dried sewage sludge and refuse derived fuel firing. Firing sewage sludge or refused derived fuel with large particles and high moisture contents at conditions similar to a coal fired flame results in an elongated flame and a burnout time exceeding the available time in suspension. Fuel pretreatment, i.e. grinding and drying, is insufficient to ensure the dried sewage sludge to be converted within the available time in suspension, however a partial particle downsizing without drying can be allowed for refuse derived fuel firing. By increasing the entrainment rate of secondary air, the primary air percentage, the excess air ratio and applying O$_2$ enrichment it is found that full conversion of the large alternative fuel particles may be reached.

The simplified mathematical model may serve as a tool for predicting the effect of introducing new fuels on burnout behaviour, and flame properties such as flame length and gas temperature profile in a rotary kiln flame.