Co-firing of Alternative Fuels in Cement Kiln Burners

The production of cement is an energy intensive process, where, traditionally, 30% of operating costs have been related to fuels. By increasing the use of alternative fuels in the industry, the operating costs can be significantly decreased. In addition, use of refuse derived fuels may limit the need for landfilling, and partly biogenic fuels can reduce CO2 emissions from the industry. The utilization of alternative fuels in the cement rotary kiln appears to be mostly based on a trial and error approach. Fairly little systematic knowledge of the impact that these fuels have on flame behavior and cement clinker quality is available in the literature. This thesis attempts to give an increased fundamental understanding of these impacts. This is done through a literature survey highlighting the known challenges of alternative fuels firing, experimental studies conducted at full scale cement plants investigating the effect of cofiring on the kiln flame, and laboratory characterization of alternative fuels. Furthermore, a model is developed to describe the combustion in the cement kiln.

Alternative fuels for the cement industry can be both solid and liquid. Some of the most widely used are shredded tires, meat and bone meal, and solid recovered fuel (SRF). SRF is a fuel derived from the mechanical treatment of non-hazardous municipal or industrial waste. Compared to fossil fuels, most alternative fuels have a larger particle size, higher volatile and moisture contents, and a lower heating value. This makes their use in cement kilns challenging, as burnout takes longer, and flame temperatures are reduced. An increased understanding of these issues, and how to overcome them, are necessary to further increase the utilization of alternative fuels in cement kilns.

An experimental study was carried out at three different cement plants. The kiln flames were observed with a specially developed camera, which can be inserted in the kiln hood close to the burner and allows for detailed imaging of fuel and flame behavior. The difference between fossil fired flames and flames cofired with alternative fuels were studied. It was found that addition of alternative fuel to the flame would delay ignition by 1-2 meters and lower flame temperatures. At one plant the burner was changed. The design of the axial air injection was changed from an annular nozzle to multiple jet nozzles. The new burner decreased the ignition length of the flame and increased the dispersion of alternative fuel in the kiln, which led to a higher clinker quality.

Additional measurements of the new burner were performed to study the impact of burner settings. Swirl air level and direction of the axial air, were found to impact the ignition of a petcoke flame. The air could also be used to disperse the SRF into the secondary air stream to aid ignition and burnout. The burner settings were linked to the cement clinker quality by means of a statistical analysis tool (Partial Least Squares Regression), which showed that the increased dispersion of SRF would increase the alite content of the clinker, indicating a higher quality.

SRF from two of the test plants and an additional plant was collected for fuel characterization. The fuels were classified using a wind sieve setup, which showed a distinction between light fuels used in the kiln and heavier fuels used in the calciner. A characterization of fuel composition, particle size distribution, and shape was made on two SRF samples. This resulted in a simplified description of the fuel that can be implemented in computational models.

A one-dimensional model was developed for the rotary kiln. The model describes and links together the fuel combustion, gas mixing, heat transfer, and clinker chemistry. The model calculates temperatures in the gas phase and clinker bed through the kiln and the clinker composition is given as output. Thus, the impacts of co-firing different alternative fuels can be studied. It is also possible to explore methods to reduce the negative effects of co-firing. The model was used to study the influence of SRF co-firing in the kiln. It was found that increased shares of SRF, reduced flame and bed temperatures, which caused an increased free lime content in the clinker, indicating a decrease in clinker quality. These effects could to some extent be avoided by increasing the energy input to the kiln. An increased dispersion of SRF near the burner was also found to be beneficial, confirming the conclusions from the industrial tests.