Modelling of a Heat Conduction Calorimeter Used in Cement Plant Automation

Cement is one of the most important materials used by mankind. To control the production quality of cement it is important to accurately measure the heat rate produced when cement is mixed with water. In this work we describe how instrument measurements can be used to understand the true heat rate. The results can hopefully lead to improved quality control in cement plants.

Inverse modelling, as the name suggests, is finding the relationship inversely from the known effect to the cause. When a sample of cement, mixed with water recently, is charged in a calorimeter, it already has a temperature higher than the instrument due to the reaction between the water and cement (hydration reaction). This temperature difference results in a heat rate that is added to the true heat rate from the reaction, that in turn is “lost” in the measurement. Imagine recovering the true heat rate from the measurement alone, it sounds naturally unintuitive but was shown to be possible in this work to some extent!

A calorimetric measurement looks like a bell curve that starts at zero, ascends to a peak value to later descend smoothly to low near-zero values. Physically and theoretically the true heat, that is to be recovered from a measurement, should start at a non-zero value, since the measurement begins when the reaction has already started. The true heat rate should then descend exponentially. The results showed a recovered true heat rate with such behaviour. However, it was not totally separated from the heat rate caused by the temperature difference that appeared early in the recovered signal as a “pulse”. Although one desires only the true heat rate, this initial “pulse” gives information about the initial temperature of the cement which also can be useful.

But how is measuring the heat rate interesting for cement production? To improve the quality of cement, ThyssenKrupp Industrial Solutions (TKIS) has automated the calorimetric measurement of heat rate from the hydration reaction in a robot called PolabCal. The robot operates inside a chamber of a temperature equal to that of the calorimeter, and charges cement samples in the calorimeter hourly to be used in cement control. For instance, if the peak of the measurement is deviated from a target value it indicates that a certain action at a certain phase of the manufacturing has to be taken, e.g more sulphate has to be added to the cement. The reason for using the recovered heat rate instead of the measurement is because it is believed that more information and more target values could be extracted from the true heat rate. This could hopefully allow us to compare the recovered true heat rate against more target values and improve quality control.

Different methods were used to recover the true heat rate. The first method estimates a mathematical relation from the cause to the effect. The relation is then inverted mathematically

to find the true heat rate from the measurement. The second method estimates the mathematical relation from the effect to the cause directly. The last method makes use of physical knowledge about the instrument to build a physical model that can be used to calculate the true heat rate from the measurement.