Numerical Simulation of a Rotary Kiln

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Objectives
A rotary kiln is a long cylindrical equipment slightly inclined tilted on its axis. The objective of this rotary kiln is to drive the specific bed reactions, which, for either kinetic and thermodynamic reasons, require high bed temperature. The energy originates with the combustion of hydrocarbon fuels via a main burner at the hot end.

In 1979 the Almatis cement plant (Rotterdam) was built. The kiln was designed to produce Calcium Aluminate Cement (CAC), a very white, high purity hydraulic bonding agents providing controlled setting times and strength development for today’s high performance refractory products. The design of the kiln was based only on a downsizing of typical Portland cement plants.

- Increasing market demand for high purity cement
- Unscheduled shutdown due to ring formation
- Restrictive emission regulations (i.e. NOx)
- Future project to expand the plant by building a new kiln
  - have triggered Almatis’ management to increase it’s knowledge base on kiln processes.

The model is used to understand in more details what happen inside such a ‘black-box’ and help to control the standard production procedure but in particular underline critical aspects. In the next stage the model will be used to optimize the kiln production and to test solutions for a new equipment.

Physical Phenomena

Turbulent non-premixed combustion
Heat transfer in the gas
Heat transfer in the lining
Granular flux

The Model

Turbulent combustion results from the two-way interaction of chemistry and turbulence. When a flame interacts with a turbulent flow, turbulence is modified by combustion because of the strong flow accelerations through the flame front induced by heat release, and because of the large changes in kinematic viscosity associated with temperature changes.

The grid was done using polyhedral elements: 2.8 Millions of elements

Some results:

Counteracting ring formation: different configurations of the kiln was tested to find the best one to reduce such negative effect.

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Practical Applications

Counteracting ring formation: different configurations of the kiln was tested to find the best one to reduce such negative effect.

In severe cases, ring grows rapidly and can cause unscheduled shutdown of the kiln in less than a month. Depending on the severity of the problem, maintenance labour, make-up lime purchase, and lime mud disposal can bring the cost of a ring outage very high due to several days production loss.

Here an example of a severe ring formation that was observed in our kiln.

As presented it is evident that we reduced the peak temperature and the incident radiation only by increasing the A/G ratio.

This setup was tested during a severe ring formation and as the images below shows, after a few hours we destroyed the ring. With a lower temperature the liquid phase shows, after a few hours we destroyed the ring. With a lower temperature the liquid phase

We are using now this model to find out other configurations that can prevent or counteract ring formations in the kiln but also that can reduce NOx production.

References

Counteracting Ring Formation in Rotary Kilns by Fuel-Air Composition, M. Pisaroni, D. J. P. Lahaye and R. Sadi.