

# Coal Combustion in a Rotary Kiln

*A number of complex, interacting phenomena are at work in the rotary kiln described in this example. Heat, supplied by a coal flame, is delivered to a moving bed of solids. As the solids absorb the heat, a reaction takes place that releases additional heat. Other effects such as turbulence and radiation are also included in this comprehensive FLUENT simulation.*

Rotary kilns are commonly used in the cement, mining, and chemical industries, among others. These cylindrical kilns are used to dry material that is transported along the bottom of the kiln as it rotates slowly about its axis. CFD can be used to understand both the combustion and heat transfer phenomena in rotary kilns, and to improve the efficiency of these units. In this example, coal combustion provides the source of heat above moving clinkers (chunks of solids) in a kiln. The simulation includes the effects of turbulence on the motion of the coal particles, and radiative heat transfer from the flame to the kiln walls and moving material as well.

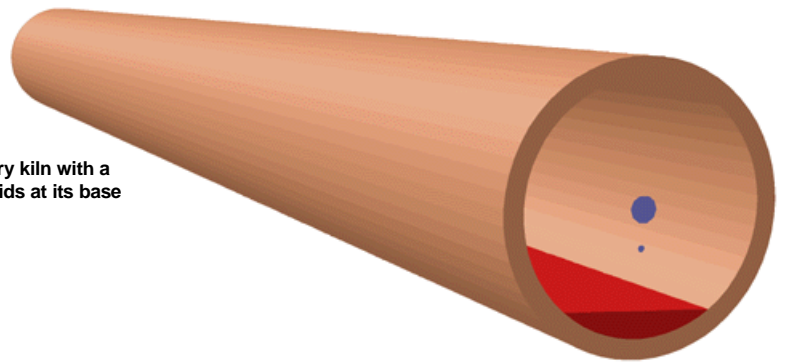


Figure 1. The rotary kiln with a moving bed of solids at its base

A 50-meter long, 2-meter diameter rotary kiln is shown in Figure 1. Coal particles along with cold air (350K) enter the kiln from the center jet (shown in blue) which is surrounded by a hot air (850K) inlet. A smaller air inlet positioned below the coal and air inlet also supplies cold air to the kiln. The red slab at the bottom of the kiln represents the

bed of clinkers, which moves slowly in a direction that is opposite to the flow of gas in the combustion space on top. The kiln has a finite thickness wall through which heat is conducted to the outside.

The coal trajectories and interaction with the surroundings (heat, mass, and momentum transfer) are simulated by the discrete phase model, a Lagrangian particle tracking scheme. The eddy-dissipation combustion model is used for the coal combustion. A one-step global reaction between the coal volatiles and oxygen in the air generates carbon dioxide and water vapor. The coal combustion model, which is a built-in feature

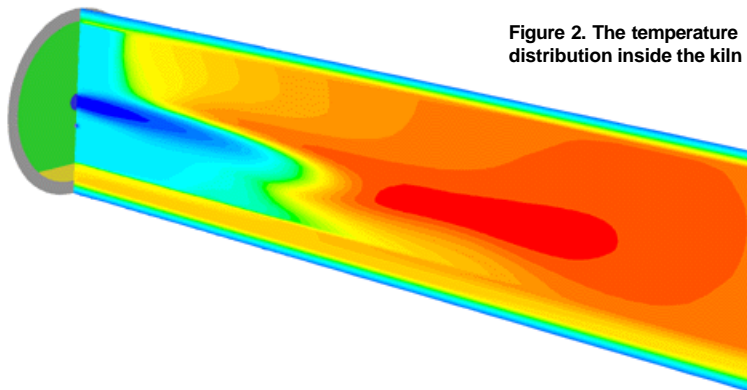


Figure 2. The temperature distribution inside the kiln

of FLUENT 5, includes the burnout of the residual char particles, as well as the initial devolatilization of the coal.

The temperature distribution in the kiln is shown in Figure 2. In the gas space, the temperature is low near the injection site of the coal particles, but increases to about 2200K as a result of the combustion. In the clinker region at the base of the kiln, the temperature increases to about 1700K as the clinkers approach the exit, below the coal and air inlets. The temperature distribution is partly influenced by radiation through the use of the P-1 radiation model. To simulate exothermic reactions taking place inside the clinkers, a temperature-dependent heat source is added to the clinker region by a user-defined function.

The mass fraction of water vapor, shown in Figure 3, is high in the hottest region of the reactor. This quantity is a helpful indicator of where the core of the reaction is located.

The concentration of coal particles is shown in Figure 4. By the time the concentration has reduced to zero, the coal has experienced devolatilization and subsequent burning. This figure is therefore indicative of the efficiency of the burner to completely use the particulate fuel. Due to turbulence in the gas space, stochastic tracking is used to compute the particle trajectories. This special tracking model accounts for the random fluctuations of the gas as it exchanges momentum with the

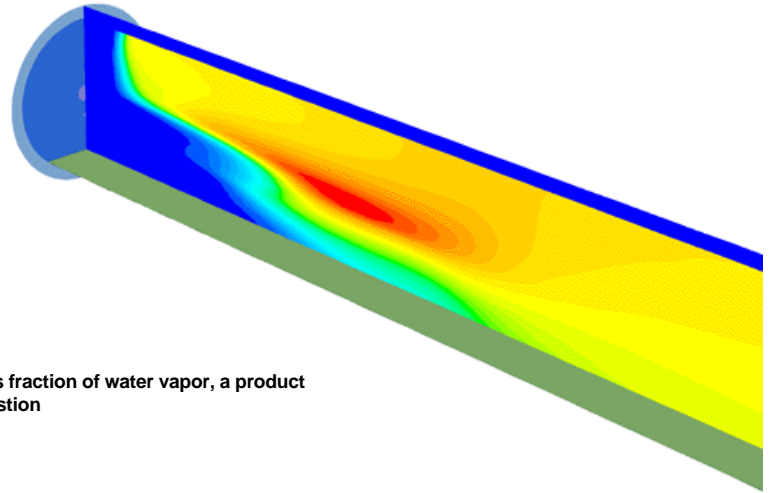


Figure 3. The mass fraction of water vapor, a product of the coal combustion

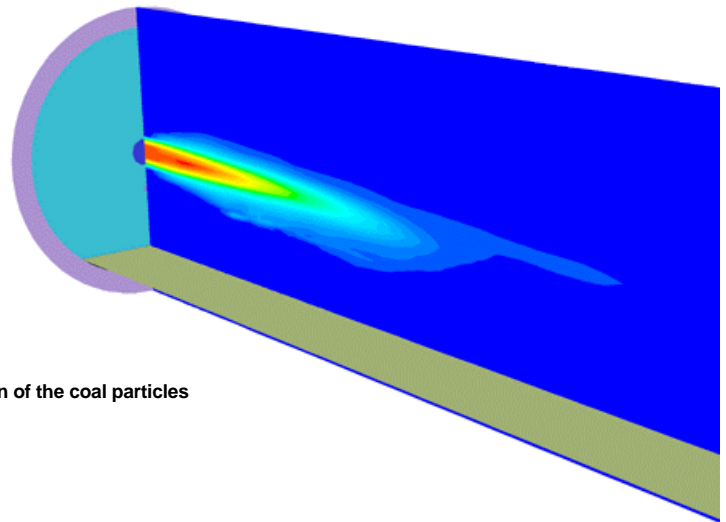


Figure 4. Concentration of the coal particles

particles.

Fluent's advanced discrete phase (particle tracking) and coal combustion models work together in this example to simulate coal combustion in a rotary kiln. Conjugate heat transfer with radiation is used to predict the temperature distribution in the moving bed of conducting solids as well as throughout the kiln wall. A temperature-dependent heat source is also added to the clinker region to simulate reactions taking place as the chunks of solid material move through the kiln. By taking advantage of all of these models,

CFD can be used to optimize many aspects of the operating conditions in rotary kilns.

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