IMPROVING EFFICIENCY IN IRON ORE SINTERING

Process engineers are using multiphysics simulation to pave the way for the mass production of steel to be faster, more economical, and environmentally friendly.

by ZACK CONRAD

At the heart of manufacturing is a perpetual effort to simultaneously improve both efficiency and quality, and the steel industry is a prime example of this. As steel production entails a lengthy chain of processes, there is ample opportunity for advancements to be made. The VDEh-Betriebsforschungsinstitut (BFI), one of Europe's leading research institutions in the development of iron and steel making technology, is currently using multiphysics simulation to optimize their configurations and achieve these improvements.

⇨ PREPARING THE SINTER FOR THE BLAST FURNACE

A significant step in the steel production line is the sintering process, where a mix of fine iron ore and other materials is prepared for a blast furnace to melt out its base metal, eventually allowing for production of the steel's final form. Sintering involves using high temperatures to bake a powdered mix until it fuses together, creating a porous mass, which is then placed in the blast furnace. As shown in Figure 1, the initial mix, consisting of iron ore fines, coke (fuel), and flux (lime stone), is fed into the plant and ignited, while air is sucked from below the mix to accelerate the coke combustion downward and boost partial ore melting & solidification, calcination, and drying.

Increases in efficiency, especially in manufacturing, often manifest themselves via decreases in completion time. "If we can speed up the process and reduce the time it takes to complete, the efficiency will increase," explains Dr. Yalcin Kaymak, a researcher at BFI. "A higher efficiency will then increase our productivity, conserve energy, and even reduce emissions." In sintering processes, a decrease in completion time is achieved by speeding up the combustion of the mix. The overall efficiency also depends on factors such as the permeability and porosity of the mix, flow rates, temperature field, and overall sinter strength. Dr. Kaymak, Dr. Hauck (BFI), and Dr. Hillers (Shuangliang Clyde Bergemann) study the effects of all of these factors in their numerical simulations.

A possible solution that BFI explored is the aeration of the raw mix during feeding using horizontal and/or vertical permeability bars (Figure 2). As the conveyer belt moves, horizontal permeability bars create a horizontal, oval-shaped locally aerated region. The vertical permeability bars cut the packed bed to create a roughly rectangular aeration region. In this case, the affected region is a vertical plane following the vertical bar axis. The permeability bars increase the porosity of the bed, thus improving the air supply to the fuel, speeding up combustion and increasing the efficiency. The focus of the simulation was to determine the optimal configuration of the bars that will yield the most substantial increase in porosity.

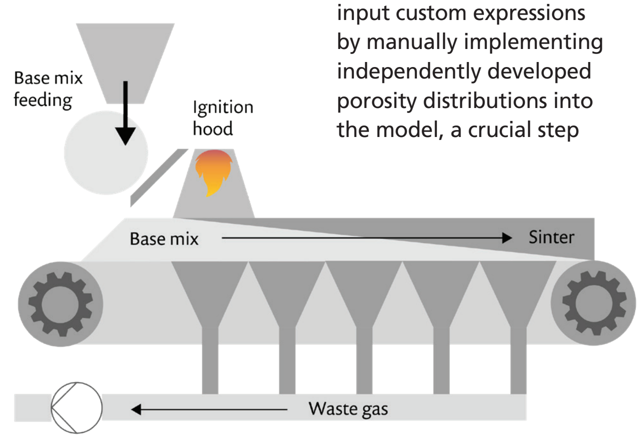

FIGURE 1. Sintering process scheme.

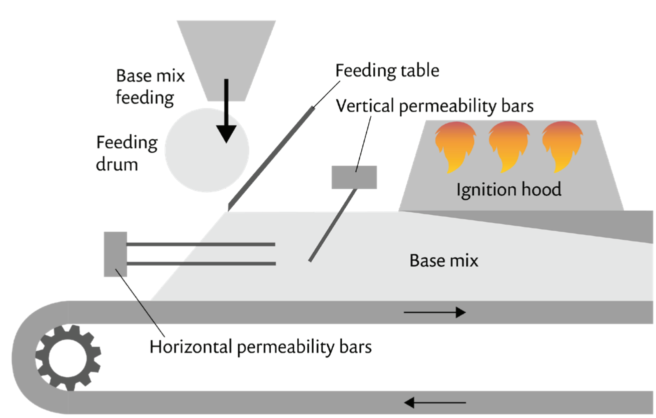

FIGURE 2. Sintering process schematic with permeability bars added.

⇨ MULTIPHYSICS MODELING OF THE SINTERING PROCESS

The mathematical model needed to simulate a combustion process in iron ore sintering is truly multiphysics, consisting of numerous subprocesses that involve heat transfer, chemical reactions like melting and solidification, and porous media flow. To effectively integrate these physics, multiphysics simulation is used. "COMSOL Multiphysics is fast and offers a lot of flexibility," says Dr. Kaymak. "You can edit expressions and control the mesh according to your needs." Full advantage is taken of the flexibility to input custom expressions by manually implementing independently developed porosity distributions into the model, a crucial step

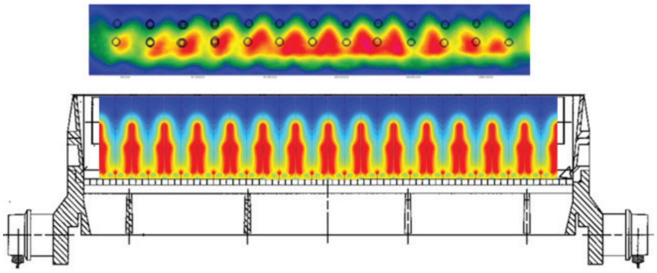

FIGURE 3. Measured (top) and simulated (bottom) high temperature zone at discharge.

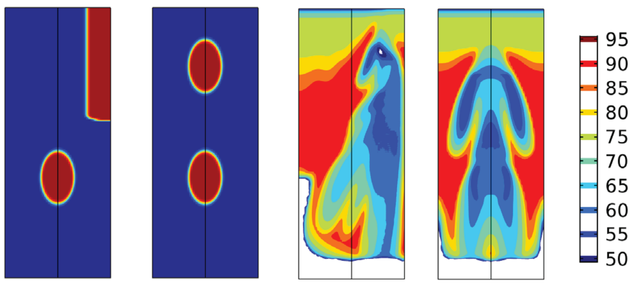

FIGURE 4. Quality estimations for two permeability bar configurations.

in characterizing the local permeability of the base mix. To determine these distributions, experimental air velocity measurements of specific configurations are used. By allowing air to flow through the mix, the resulting air velocities can be measured and the porosity distribution can then be defined and input directly into the software.

After meticulously studying the porosity distribution and implementing it into the overall model, a transient sinter process can subsequently be simulated, yielding a temperature profile definition and a thorough investigation into various configurations. Additionally, the global ordinary differential equations feature for time integral operation is used to compute numerous relevant quantities, yielding a comprehensive characterization of the configurations' effects on the process. These quantities include the total energy inlet and outlet, moisture content, total inlet substances, total energy inlet at the ignition hood, total outlet substances, and total gas volume.

Because combustion is such a significant part of the sintering process, the temperature profile of a certain configuration has a direct impact on completion time and sinter strength. The cold strength is a key indicator when assessing sinter quality, since high strength for sinter means that it can withstand harsh conditions in the blast furnace process. The sinter strength is measured by tumble tests and usually raises with the time spent above the melting start temperature. Thus, the information about the local time-dependent temperature profiles can be used to estimate the local cold strength. This results in a quality distribution through the cross section, as shown at the top of Figure 3.

To validate the simulation results, temperature profiles were compared with plant discharges observed with infrared thermography and proved to be strongly substantiated. The small circles in the measured thermography in Figure 4 show the position of horizontal permeability bars. It can be easily recognized that the permeability bar locations coincide with low temperature regions. The same trend is also computed in the simulation models.

⇨ RESULTS AND FUTURE WORK

The simulations demonstrated that with the optimal configuration of permeability bars, the sintering speed can be raised by up to 40%. Said optimal configurations consist of either two stacked rows of horizontal bars or vertical bars with horizontal bars in between. The configuration with two rows of horizontal bars can be seen in Figure 5. Now, as BFI seeks to add further complexity and broaden the scope of this model, the next step is to ensure quality and strength is maintained during the sintering process.

To generate additional accuracy and capabilities, plans are in the works to expand the model to encompass phenomena such as diffusion and dispersion in the convection equations and NOx emissions. It is also planned to use the Application Builder tool to create and implement user-friendly simulation apps to aid the plant operators. Experts can customize the interface and control the inputs and outputs that the app displays, empowering individuals without a simulation background to focus solely on relevant parameters

"COMSOL Multiphysics is fast and offers a lot of flexibility."

— YALCIN KAYMAK, RESEARCHER AT BFI

when running the apps. These apps can subsequently be deployed with COMSOL Server™ product to people throughout the organization, spreading the power of multiphysics modeling. Of particular interest to them are the specific energy flow, bed temperature, exhaust gas temperature, coke consumption, calcination, sulfation, condensation, and sinter quality. "Operators do not have the simulation experience or know the details of the software," explains Dr. Kaymak. "But with a user-friendly app, they can be creative with the parameters that are more important specifically to them, model quick changes, and see the effects right away." ❖

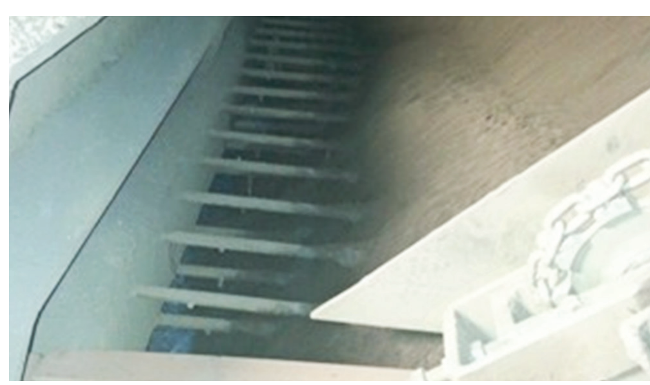

FIGURE 5. Sinter plant feeding system in operation with two rows of horizontal permeability bars.