Man standing beside the pig iron channel, adjacent to where the hot metal flows

Blast Furnace Air Pre-Heater Gets a Thermal Boost

Engineers use CFD to improve heat exchanger performance.

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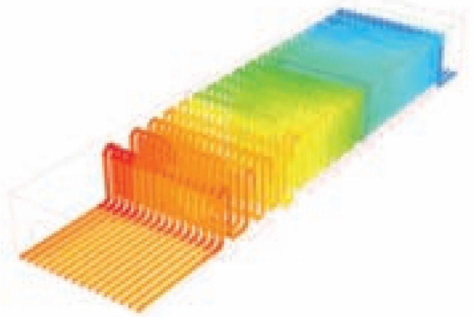
The blast furnace is perhaps the oldest, but still most widely used, technology for extracting iron from iron ore. Inside the brick-lined furnace, a combustion process takes place producing a raw form of iron (pig iron) that subsequently can be refined to more useful forms through other processes. Since the combustion of fuel can be made more efficient using pre-heated air in any combustion process, heat exchangers often are positioned before the blast furnace.

Vallourec & Mannesmann (V & M) Tubes, the largest manufacturer of seamless steel tubes in Brazil, together with engineers at Federal University of Minas Gerais (UFMG) and ESSS, a leading ANSYS software distributor in South America, used FLUENT software to analyze the air flow inside a heat exchanger used in one of V&M's blast furnaces. The main objective of the analysis was to verify the flow configuration in the current geometry and suggest possible improvements that would increase the exit temperature from the air pre-heater.

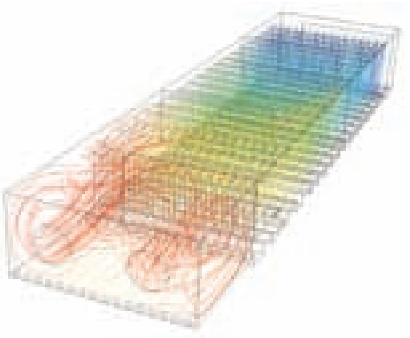
The heat exchanger consists of an array of tubes, each of which is a linear series of U-bends. The tubes are heated by the combustion gases in the furnace. In the steady-state CFD simulation, the standard k-ε model was used for the turbulent flow and the discrete ordinates (DO) model was used to account for radiation heat transfer. Combustion was not modeled. Instead, the combustion gases were approximated by air of comparable temperature. The air inside the tubes was modeled as well.

The heat exchanger is large (15 x 4 x 2 m^3), but the existing geometry is symmetric, so only half of the original geometry was analyzed using a tetrahedral mesh of about 6 million cells. To reduce the cell count, the tubes were modeled as zero-thickness walls and the shell conduction boundary condition was employed to account for the thermal mass of the tube material. Following the CFD simulation, the surface temperature predictions were used as input to ABAQUS™ to obtain the deformations and thermal stresses on the tube array that would arise from such a severe thermal load.

The analysis of the heat exchanger showed good agreement with experimental data. In particular, the results reproduced experimental observations that the tube-side air was not being heated properly. One reason for the problem was the tendency of the combustion gases to flow over the U-bends of the coils, resulting in limited surface area for heat transfer. To improve the combustion-side flow, modifications were suggested, such as the inclusion of baffles to promote cross-flow of the combustion gases through the coils. A new simulation was performed on the entire (non-symmetric) geometry of the newly proposed design using about 12.5 million cells. The results showed that the new configuration increased the exit air temperature significantly because the baffles successfully modified the flow of the combustion gases through the coils, improving the heat transfer. The modifications have been approved by V & M Tubes and will become effective in the blast furnace design revamp in 2007. ■



Temperature inside the heat exchanger tubes as the air flows toward the front left; the heated air is subsequently used for combustion in the blast furnace.



Pathlines, colored by temperature, show the improved flow of combustion gases through the heat exchanger tube array and the resultant transfer of heat to the tube array.