Fire Tests for **Molten Metal Converters**

Numerical simulation helps engineers peer into a metallurgical converter in which high temperatures and adverse conditions make realistic measurements impossible to perform.

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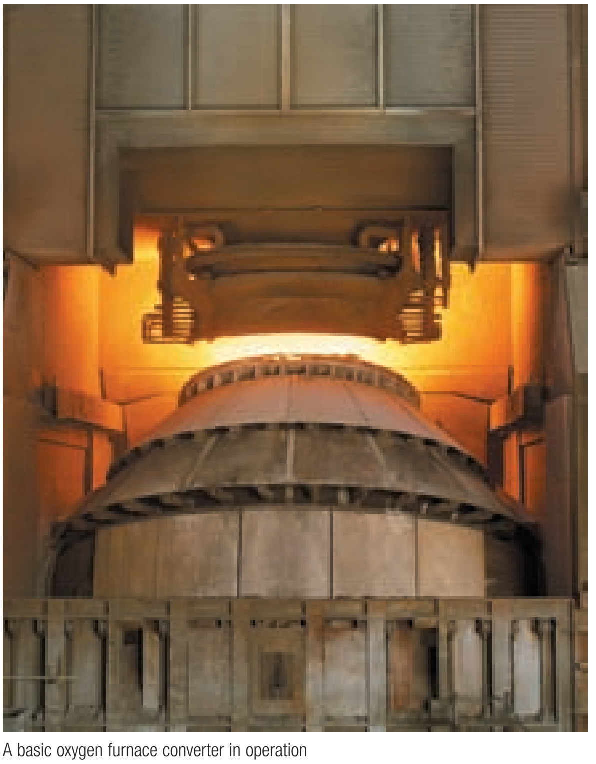
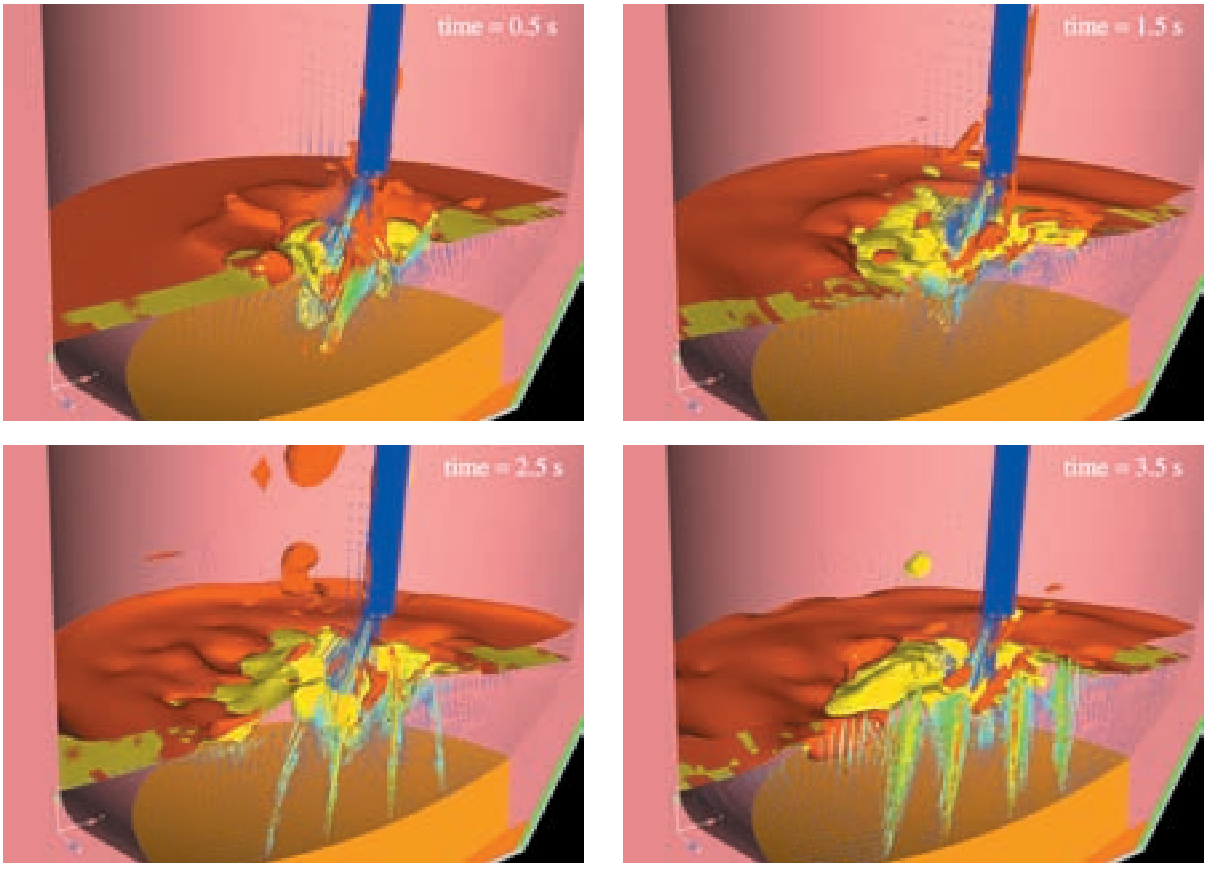


A basic oxygen furnace converter in operation

In a steel mill, partially processed iron from the blast furnace is transported to a basic oxygen furnace, also known as a converter, to produce liquid steel. The converter is a refractory-lined steel vessel with a holding capacity of up to 400 tons of molten metal at temperatures above 1600 °C (2900 °F). In the converter, several jets of oxygen are blown onto the melt surface, and the subsequent oxidation process helps remove undesired secondary elements such as carbon, manganese, silicon, phosphorus and sulphur. Efficient mixing of the melts is helped by additionally introducing inert gases, such as nitrogen or argon, from the floor of the vessel, where they bubble to the surface. Optimization of the converting process depends on a number of variables, but operating trials and parameter studies on water models cannot be carried out realistically using experimental methods. Steel producers as well as steel equipment manufacturers therefore are switching to numerical simulations of the process to optimize the quality of the final product while minimizing the time and cost of steel production.

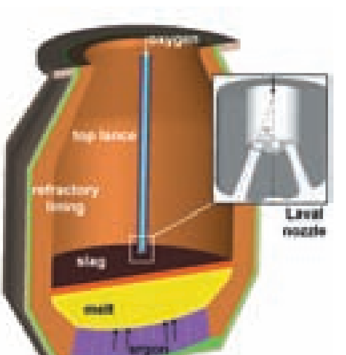
SMS Demag AG, Düsseldorf, is a leading installation builder for the steel and non-ferrous metal industries. Besides making individual components, SMS Demag plans and builds complete production lines and turnkey plants. It is a part of the SMS Group GmbH, which has interests in metallurgy, forging, casting and rolling technology, engineering services, and plastics engineering. At SMS Demag, a group of experts has been successfully working in the 100-employee Central Development area, studying the mutual relationships of individual process parameters with FLUENT software and using them in industrial applications. The bandwidth stretches from long-term development projects to project-related orders and fault analysis on operating plants. Using CFD, the flow and thermal mechanisms taking place in the melt can be analyzed in detail and displayed, thus considerably facilitating the understanding of the process. Three-dimensional projections have been used to augment spatial visualization. The Cave Automatic Virtual Environment (CAVE) at RWTH Aachen University in Germany is used for particularly important projects, such as the demonstration of complete virtual plants.



Instantaneous images of the molten metal (yellow) and slag (red) free surface after 0.5, 1.5, 2.5, and 3.5 seconds of operation, showing the penetrating oxygen jets and resulting flow field

One of the primary objectives of the CFD work has centered on the blowing of oxygen into the converter and the subsequent phenomena induced by this process. The oxygen is delivered into the converter by a top lance, which terminates in a fitting that contains several Laval nozzles. Each nozzle produces a jet at approximately twice the speed of sound. The jets penetrate deeply into the melt and create oscillation blowing cavities with large reaction surfaces. The top lance is designed to avoid undesirable effects, such as metal back-splashing, which leads to increased wear. The inert gas conduit on the floor is designed to avoid plugging so that sufficient gas can continually be introduced to the melt to achieve the desired agitation.

The process being simulated is a hot, highly turbulent, ever-changing multiphase flow. The model generation begins with ANSYS ICEM CFD Hexa for the creation of a 500,000-cell hexahedral mesh with aligned cell layers. In addition to making use of models for turbulence and heat transfer, the numerical simulation couples together two multiphase models in FLUENT software: the volume of fluid (VOF) model for tracking the evolution of the free surface of the melt and slag, and the discrete phase model (DPM) for tracking the trajectories of the inert gas bubbles used for mixing. A Linux® cluster of up to 10 computers was deployed for two weeks to perform a 20 second-long simulation of the 20 minute-long blowing process. The high computation times are due, for the most part, to the complexity of the physical models rather than the size of the mesh. User-defined functions (UDFs) were employed to couple the models together and incorporate effects such as a varying drag coefficient for the bubbles.



The geometry of a converter, showing the refractory lining and oxygen top lance, terminated with an array of six Laval nozzles. The steel melt is agitated by argon bubbles released from several locations on the converter floor. During the conversion process, a slag layer forms on the melt surface.

The results provided information about the design of the nozzles, the penetration of the oxygen jets into the melt, the effectiveness of the agitation scheme and heat transfer into the refractory walls. Despite the comparatively short span of the simulation, the results to date have been sufficient to make clear decisions about the basic sequences in the melt and to introduce optimization measures. Thus, each converter can be adapted to the individual requirements of the customer. ■