

Savings from Submerged Combustion Melting



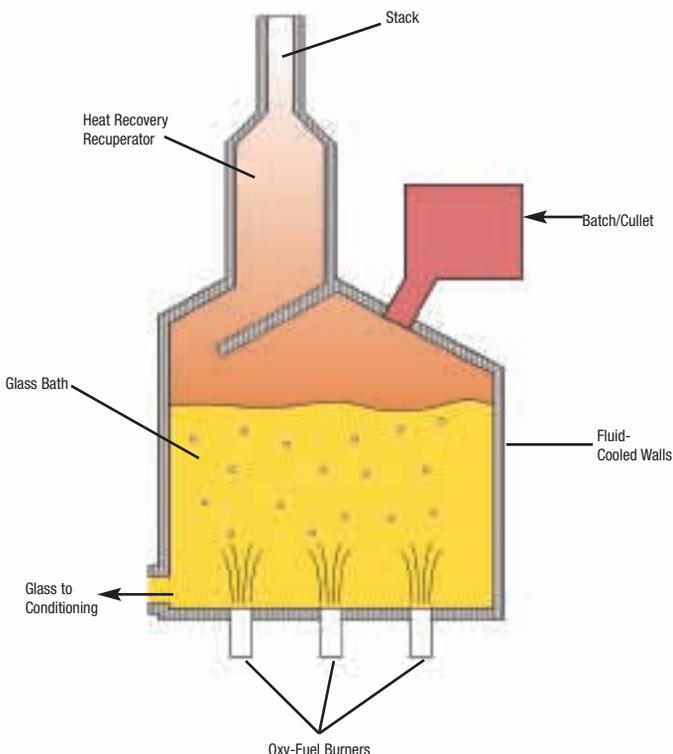
Simulation helps glass manufacturers understand complex phenomena in next-generation melter technology.

By Bruno A. Purnode, Owens Corning Science & Technology Center, Ohio, U.S.A.

The glass industry annually produces 21 million tons of consumer goods valued at \$28 billion. Energy costs for this volume of goods account for approximately 15 percent of production costs. Theoretically, glassmaking requires about 2.2 million BTUs of energy per ton of glass, but usually more than twice that amount is actually used due to various system losses. Given this reality, the industry is constantly seeking and developing new ways to lower capital and energy costs. Owens Corning has been melting glass for more than 65 years yet has not stopped working to find better and more sustainable ways of doing so. Over the last 14 years alone, Owens Corning has reduced its global energy intensity by 40 percent through a variety of glass melting innovations. With the possibility of reducing capital cost expenditures by more than half, submerged combustion melting (SCM) technology offers the potential to meet this goal.

SCM was first commercialized a decade ago in the Ukraine for production of mineral wool. The process takes fuel plus oxidant and fires them directly into the bath of the material being melted. The combustion gases bubble through the bath, creating an intense transfer of heat between the two phases. Meanwhile, forced convection-driven shear effects provide rapid particle dissolution and enhance temperature uniformity in the bath. Batch handling systems can be simple and inexpensive because the melter is tolerant of a wide range of raw material sizes; the systems can also accept multiple feeds and do not require perfect feed blending.

Presently, very little is known about the physics of the submerged combustion process because experimental or field data is not easily accessible in such a melting system.



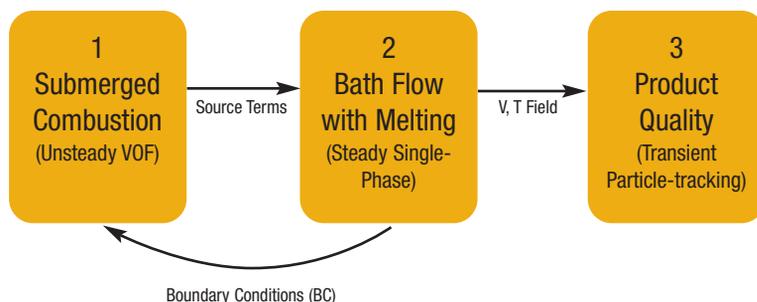


Illustration of the three-step CFD analysis strategy used to analyze the SCM process

Therefore, in order to support submerged melter designs and to better understand the complicated melting phenomena, an important modeling effort using FLUENT computational fluid dynamics (CFD) software was initiated at the Gas Technology Institute (GTI) in Illinois, U.S.A. The simulation effort, which included model development support from ANSYS, Inc., was part of a larger U.S. Department of Energy-sponsored project being conducted in partnership with a consortium of glass companies, including Owens Corning. The project's goals were to design, demonstrate and validate the melting stage of a next-generation melting system.

The presence of extremely complex physics and chemistry, as well as the widely disparate time scales between the combustion gases and the glass flows, made solving the full problem impractical. Therefore, the simulation team from GTI, the consortium companies, Owens Corning and ANSYS established a pragmatic, three-stage modeling strategy in order to find a compromise between faithfully describing the process physics and maintaining a reasonable computational cost.

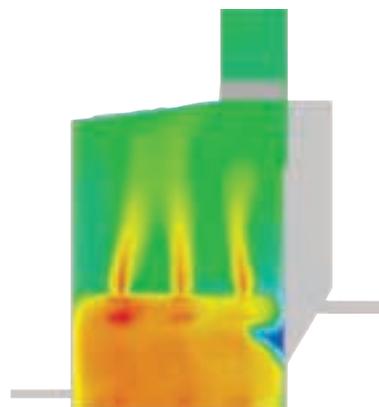
The first CFD modeling stage was a 2-D axisymmetric analysis, which solved the full transient, two-phase gas-liquid submerged combustion problem for a single-burner region. This analysis used the volume of fluid (VOF) multiphase method in FLUENT software to track the gas phase bubbling through the liquid phase; it also used the eddy dissipation model to simulate the combustion. With the eddy dissipation model, the reaction rates were assumed to be controlled by

the turbulent mixing, allowing expensive kinetic calculations to be avoided. The team simulated the turbulence itself with the realizable $k-\epsilon$ model and modeled radiation using the discrete ordinates (DO) method, since this is one of the most versatile of all the radiation models and also has a reasonable computational cost.

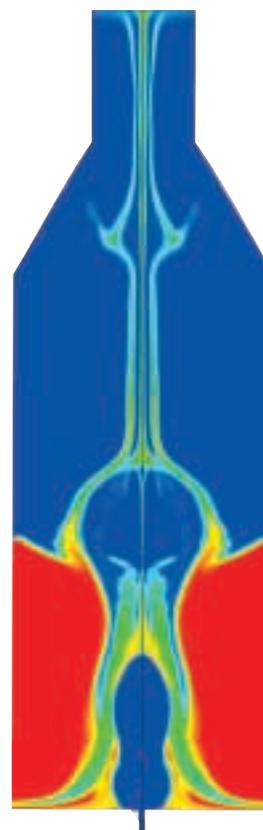
In the second modeling stage, the CFD group focused on the overall flow and heat transfer in the melter. They extracted equivalent momentum and heat source terms derived from time-averaged VOF results from the first modeling stage and used them to generate a set of user-defined functions (UDFs) to represent the momentum and heat sources in the second stage. The group then used the UDFs to model a subsequent 3-D steady-state, single-phase analysis of the entire multi-burner melter.

The third modeling stage consisted of a 3-D transient tracer species analysis. In this final analysis, the CFD team used the velocity and temperature fields from the second modeling stage to analyze the transport and dissolution of the batch by calculating the residence time distribution.

Preliminary trials in the one-ton-per-hour pilot-scale melter seemed to validate the staged modeling approach. The research team successfully compared temperature, velocity, pressure and residence time simulation results to measurements in fully instrumented submerged melter trials conducted by GTI. A complete validation of the model will be done in the coming months as more trial results become available.



Glass temperature in the plane of the burners. An increase in temperature can be seen from lower-temperature areas in blue on the batch inlet side (right) to the more intense red areas on the glass outlet side (left).



Single-burner (bottom center) multiphase combustion simulation results showing mass fraction of glass (solid red) and gases (solid blue)

Mathematical modeling of the submerged combustion process using the FLUENT product has been an integral part of the SCM project. Simulation has led to a better understanding of the complex glass and gas flows and thus has been used extensively for designing the melters as well as for guiding their operation. This constitutes a first step toward the industry's goal of reducing cost and energy usage with a next-generation melting system. ■