Glass Furnace Model (GFM)

Argonne National Laboratory

Glass furnaces heating up more efficiently, thanks to new Argonne software

In the manufacture of glass, careful and exact control of energy, mass, and momentum is critical. If the material produced has a measurable defect or nonuniformity, it is not useable, the glass has to be recycled, large amounts of energy are wasted, and productivity suffers.

Similar problems exist for a wide range of companies that produce all glass products: bottles, windshields, even computer monitor screens. But now, thanks to award-winning software produced by researchers at the U.S. Department of Energy's Argonne National Laboratory, these companies have a tool to ensure their furnaces produce the highest quality glass possible.

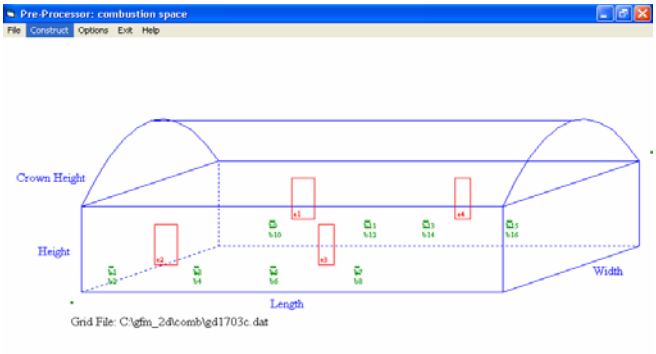
Glass is made in large furnaces in which burners inject fuel and oxidizer (either superheated air or nearly pure oxygen) into the combustion space, creating temperatures as high as 2400ºC. The intense heat melts sand, other constituents, and recycled glass in the chamber, turning it into "liquid glass that flows like cool honey," according to Brian Golchert, technical lead of process simulation and modeling in Argonne's Energy Systems Division. The viscous liquid is then stretched, rolled and formed into a desired configuration as it is cooled.

Argonne's software, called the Glass Furnace Model (GFM), allows manufacturers to create virtual furnaces on a computer to improve process design. Users diagram a main chamber, add any number of burners and exhaust ports anywhere in the chamber, and then evaluate in three dimensions how the resultant flow of energy and mass into and out of the chamber change with design and material properties.

In one Argonne study, the GFM suggested slight alterations to a furnace that would improve its efficiency by almost 5 percent. In fact, the GFM is so simple yet powerful that it was awarded an R&D 100 Award by *R&D Magazine* as one of the "most technologically significant new products" of 2004.

But to be effective, a furnace has to do more than just create ultra-hot air.

"It's not just the heat going in, but the distribution," Golchert said. "If you put the heat in the wrong place, you can end up with lower quality glass – you can get bubbles or grains of sand in the glass. You could have the right amount of energy but in the wrong places." The GFM is more than a simple heat transfer software package and it consists of three major computational modules: 1) A combustion space model, 2) A radiation heat transfer model and 3) A multiphase glass melt model. These modules can simulate the additional important phenomena occurring within the furnace that can impact the final glass product being produced. A more detailed presentation of the modules are provided at: http://www.softwareshop.anl.gov/gfm.html. The GFM code was written under a cooperative program, working with approximately 5 glass-producing companies in the U.S. The GFM can simultaneously model solids, liquids and gases, whereas other models can only represent a single phase at a time.



That's why Golchert says the GFM code needs to be run anew for every individual furnace configuration, because each furnace differs based on design and the products it yields. Different glass constituents lead to different densities, viscosities, thermal properties and so on, so each furnace and product batch has to be optimized differently to generate the best results.

The code is used to generate a computer simulation that allows engineers to "visualize" critical heat transfer, flow, and reaction patterns within the interior of a variety of glass furnaces. The simulation is used to conduct extensive experiments efficiently on the computer, by varying key operating and design parameters to determine their impact on overall furnace performance and lead to higher efficiency and increased productivity.

According to Paul Betten, Argonne's manager of software licensing and the ANL Software Shop, "Industry response to this newly available computer program has been overwhelming, partly because of its ease of use and partly because of its potential for energy savings in glass-making of all kinds." A software license for GFM is available at Argonne's Software Shop at http://www.softwareshop.anl.gov/.

The software's main screen shows the interior of a typical glass furnace. Natural gas burns over a patchwork of molten glass and islands of floating glass batch (sand, chemicals to control quality/color, and recycled glass). The menu bar provides access to a pre-processor that facilitates the creation of a model from furnace drawings and operating conditions, controls to run the simulations, and a post-processor that allows visualization of the computed results.

Golchert said making the software easy to use was a key. "Engineers have to keep track of where the mass, the momentum, and the heat are going," Golchert said. "So we designed the program so the engineer doesn't also need a degree in computer science to use the program."

"The program is important to the industry and I'm pleased we've been recognized for our work," he said. "I'm only disappointed because [the late] Dr. Shen-Lin Chang, who was instrumental to the success of this program, is not here to see the award, to see his work, and his talents showcased."

The glass furnace model was developed by Argonne scientists Brian Golchert and colleagues Steve Lottes, Michael Petrick, Chenn Qian Zhou and the late Shen Lin Chang.

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