Increasing Yield in Glass Fiber Manufacturing

Reducing Incidence of Glass Fiber Breakage During Manufacture

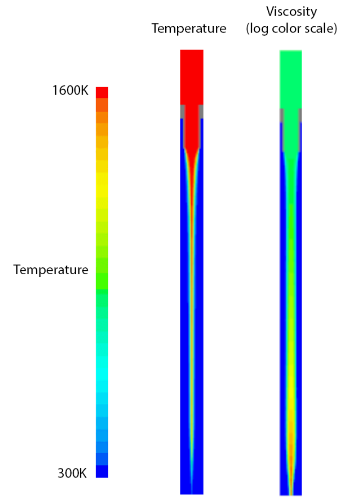
Modeling Fiber Pull Process Shows Cause of Breakage

Glass fibers for fiberglass and other fiber-fill applications involve pulling of molten glass fibers—4,000 at a time per pulling station—through tiny extrusion nozzles. If even one of these fibers break as the glass changes phase from a viscous honey-like liquid into a solid fiber, then the entire 4,000-fiber station must be restarted. It takes over an hour for the operator to manually reset the station to begin producing fiber again. If this process could be improved, then the annual industrywide savings could reach up to $8.5 million with energy savings of 1.7 trillion BTUs.

Researchers at Lawrence Livermore National Laboratory (LLNL) teamed with PPG process engineers through a project funded by the Department of Energy High Performance Computing for Manufacturing (HPC4Mfg) program to use supercomputers to determine how fibers break during the complex transition from molten glass to solid fiber. Understanding the mechanism of fiber breakage will help PPG process engineers modify the process to reduce breakage and increase yields.

Using Models Instead of Sensors in Extreme Manufacturing Environments

The high temperatures in the furnace and the small size of the delicate fibers make measurements of the process difficult to obtain. PPG engineers worked with LLNL researchers to build a model of the glass fiber-pulling furnace. Using in-house capabilities, PPG engineers developed an initial coarse-grained model without individual fibers. LLNL researchers ported this model to a commercial code, Star-CCM, and a laboratory-developed code, ALE3D—both running on supercomputers. This allowed the engineers and researchers to model temperature distribution across the entire 4,000 fiber-pull furnace. As a result, engineers could see non-uniformities in the temperature distribution and glass flow of the furnace for the first time. The team discovered that the glass enters



This LLNL model relates local glass flow and temperature to the mechanics (pull rate and stress) of the fiber-drawing process.

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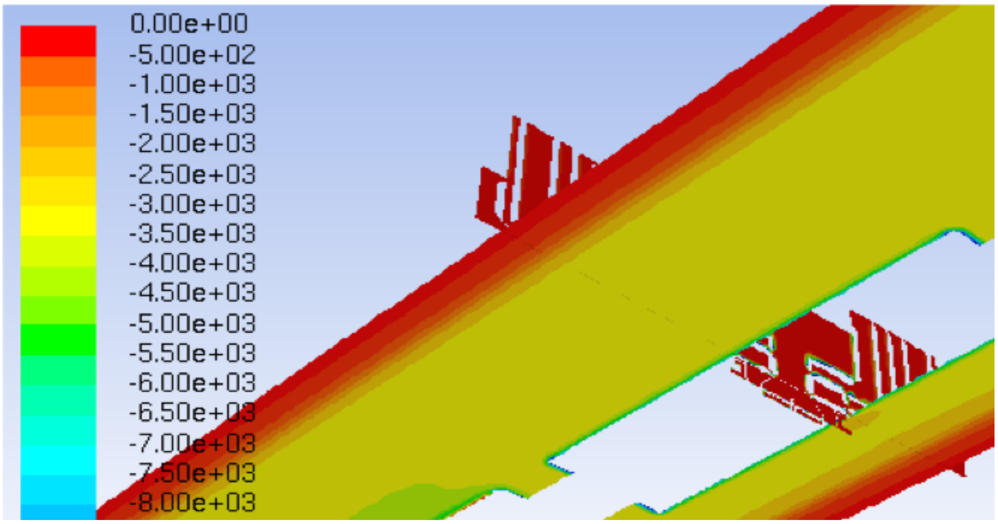
at a single temperature but loses more heat than expected through the flow channel and the bushings as it traverses the furnace.

LLNL researchers also used advanced simulation codes to model the actual drawing of the glass fibers. This process is very complex with many factors such as air currents, radiant heat transfer though transparent media, and glass phase transformations—all of which affect the geometry and stresses in the glass. While the modeling predicted the reduction of fiber diameter throughout the process, achieving accurate diameters that matched operational sizes would be the subject of future effort. In addition, with continuing work to add advanced adaptive meshing, the fiber model could provide the local stress in a fiber during perturbations—such as sudden temperature or air flow variations. This was not possible with the analytical models previously used to study fiber behavior.

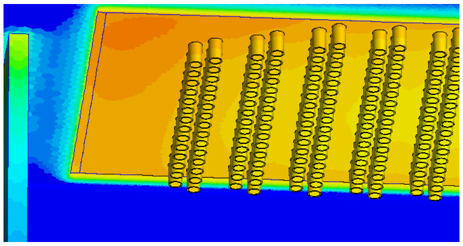
Process Improvements Through Combined Computational and Experimental Efforts

Future experimental efforts coupled with computational efforts will investigate a range of likely sources of fiber breakage in the glass flow due to airflow instabilities or particulates in the glass melt, and could resolve the question of the source of fiber breakage. The range of possibilities could be narrowed by careful experiments such as high-speed photography, then followed by a well-focused modeling effort to better understand the problem.

This work has the potential to allow large savings in energy and reduce wasted materials. PPG has estimated that improving the fiber yield by a single percentage point would give an additional $1 million in salable product per year.



Computational Fluid Dynamics models developed jointly by LLNL and PPG provide local glass flow and temperature conditions around the bushing, a plate containing an array of fine metal tips used to draw glass fibers.



Local heat variations among the fine drawing tips (where the glass flow narrows into tiny extrusion nozzles) are related to furnace conditions.

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