Shattering Glass Tank Design Methodologies

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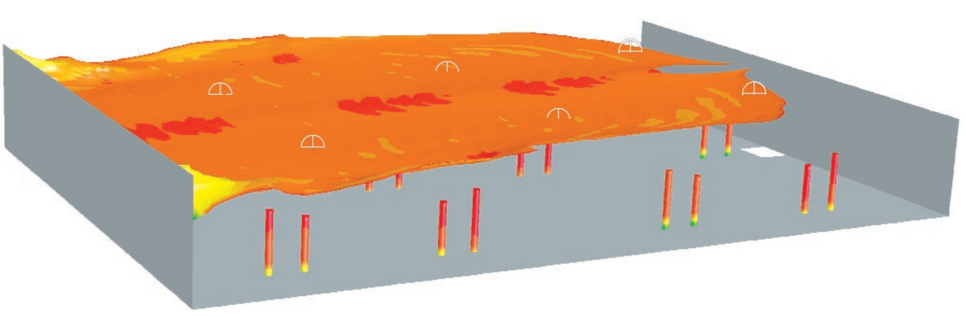

Simulation of a 120t/day electric cold top glass tank designed and constructed by Stein Heurtey (with courtesy of Akzo-PQ Silica); the horizontally fed batch (left to right), illustrated by a surface showing the batch-melt interface, extends nearly to the back wall of the tank but does not touch the electrodes; the half-circles indicate measurement points

Glass melting tanks are continuously operating reactors producing up to 1000 tons/day of glass at temperatures up to 1600°C. They have relatively simple geometry but complex heat transfer and glass melt convection. The transformation of the raw materials to the final glass melt passes through complicated thermo-chemical processes involving solid, liquid and gaseous phases. At Stein Heurtey, a worldwide supplier of thermal installations for the steel and glass industry, several detailed analyses of glass melting tanks have been performed using FLUENT, resulting in an improved understanding of many of the complex processes at work.

Typically, simulations of thermal installations are performed using several steps. First, the critical process parameters need to be identified. One of these parameters for glass tanks is the residence time on the critical trajectory through the melt volume. The critical trajectory, which has a crucial impact on the glass quality,[1] is defined either in terms of transit time, temperature, or shear flow history along its path. Second, the experimental and mathematical means for assessing the key process parameters have to be identified. CFD is often used to study the critical trajectories because glass tanks are very difficult to access for measurements. Third, the main factors that influence the key process parameters must be identified. For the critical trajectories, one such factor is the intensity of recirculation patterns in the melt. The batch blanket, which consists of the raw materials floating on the surface of the glass melt, acts as a heat sink during the process, and the heat flow just under the blanket has a strong influence on the recirculation of the melt.[2]

To simulate the critical trajectories, a large number of tiny particles are released in the batch blanket using the DPM model and the escape times at the glass tank throat are compared. The particle path with the shortest residence time represents the critical trajectory in terms of time. Flow field precision, the step size of the tracking calculations, and the fraction of recovered to injected particles are key numerical factors in determining the accuracy of the trajectory predictions.[3] A precise simulation of the heat sink under the batch blanket is a prerequisite, because this heat sink determines the recirculation intensity of the glass melt.

To address the modeling of the heat sink and other problems associated with the batch melting process, a collaboration between Fluent and Stein Heurtey was initiated. The target was to identify the requirements for batch blanket modeling and to develop the appropriate tools in FLUENT. Today, 3D batch models that include reaction kinetics, phase change, widely varying material properties, and free surface prediction can be solved using these tools. One Stein Heurtey glass furnace for which numerous measurements are available has been simulated in FLUENT. In this furnace, sodium silicate glass is melted by the dissipation of electric current fed through 24 electrodes in the glass melt. Having no combustion above the batch and melt, this type of furnace is called a cold top glass melter. The batch heat penetration and the kinetics of the batch reactions are taken into account in the simulation.[4] Predictions for the batch blanket thickness are particularly useful for assessing the remaining melt depth available for the electrodes. Electrodes that are too near to the batch corrode faster and may even be deformed by contact with the rigid batch. The 3D batch modeling tools now allow for optimization of the melt space and electrode arrangement under the batch blanket. Many other glass melting process issues can be studied using CFD as well. At Stein Heurtey, FLUENT has proved to be a very useful tool for problem solving and design improvement of its thermal installations. ■

References:

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4 Kuhn W.S., Marmonier F., Bessette D., Muralidharan, and Dutta A., "First principles batch modeling and validation on a large cold top sodium silicate melter," ICG Conference Extended Abstracts, Edinburgh, 2001.