Optimizing Screen Protection During the Manufacturing Process

Kornerstone Materials Technology (KMTC) optimizes glass manufacturing processes by using multiphysics simulation technology, fostering collaboration across company departments with simulation apps.

by VALERIO MARRA & LEXI CARVER

Nowadays, smartphones and tablets have become inseparable parts of our daily work, learning, leisure, and entertainment. The screen of a mobile device has a protective top layer that is known as the cover glass. The cover glass is mainly used for screen protection, offering highly visible light transmittance and an elegant appearance.

Cover glass is a high-end product, with prices tens or even hundreds of times higher than that of traditional soda-lime glass. The high price is due to the extremely challenging manufacturing process. Things get more complicated due to the different behaviors cover glass exhibits under different conditions. These particularities challenge a company's product and development department to perform at its highest caliber.

Kornerstone Materials Technology Co., Ltd. (KMTC) specializes in displays, touch component products, and high-tech material development and production (Figure 1). "Our products focus on cover glass used in electronic devices such as smartphones and tablets," explains Frank Hong, R&D manager at KMTC. "To meet the growing diversified needs of our customers and to cope with the opportunity and challenge of the touch display industry, KMTC is taking advantage of multiphysics simulation to evaluate and optimize the glass manufacturing process."

⇨ MULTIPHYSICS IN GLASS MANUFACTURING PROCESS

The display glass production industry is dominated by three major manufacturing processes: float glass, slot down-draw, and overflow down-draw. Within these three, the overflow down-draw process is the most widely used technique. In this process, an ultrathin glass sheet forms naturally in air as two overflowing molten glass regions join together (Figure 2, left). The glass produced has flat surfaces and dust-free cutting areas. It does not require grinding or polishing to fix characteristic differences on the glass surface.

As a pioneering company producing high-alumina cover glass, KMTC has enhanced the application of overflow technology to the domestic leading level. "Our unique process can produce the glass without any mark or damage on the surface during the forming process," says Hong. "The surface of the formed glass substrate is smooth, pure, and flawless, meeting the demands of the consumer electronics market."

During the overflow down-draw process, highly viscous and homogenized molten glass flows from a melting furnace through a platinum channel and then to an overflow forming block made from refractory materials (Figure 2, left). The molten glass flows down either side of the block under the influence of gravity (Figure 2, right). The glass regions rejoin at the bottom of the block and continue downward, guided by a plate, and cools in the air to form an ultrathin glass sheet.

The sheet thickness is controlled by the inlet flow and the guiding plates, which also determine glass output. Temperature is monitored closely since it affects glass viscosity and flow velocity, and must be carefully controlled to avoid warping. The complete glass manufacturing process is a multiphysics problem involving fluid-solid-thermal-electric coupling.

Engineers at KMTC use multiphysics models to evaluate the electric heating efficiency of the glass melting systems. They also use apps built from their models to simulate the real-time manufacturing processes. The resulting data is used as guidelines for manufacturing processes adopted by the production department.

Their models, built in the COMSOL Multiphysics® software, include coupled fluid, structural, thermal,

FIGURE 1. 3D cover glass allows designers to deliver better displays for smartphones and tablets.

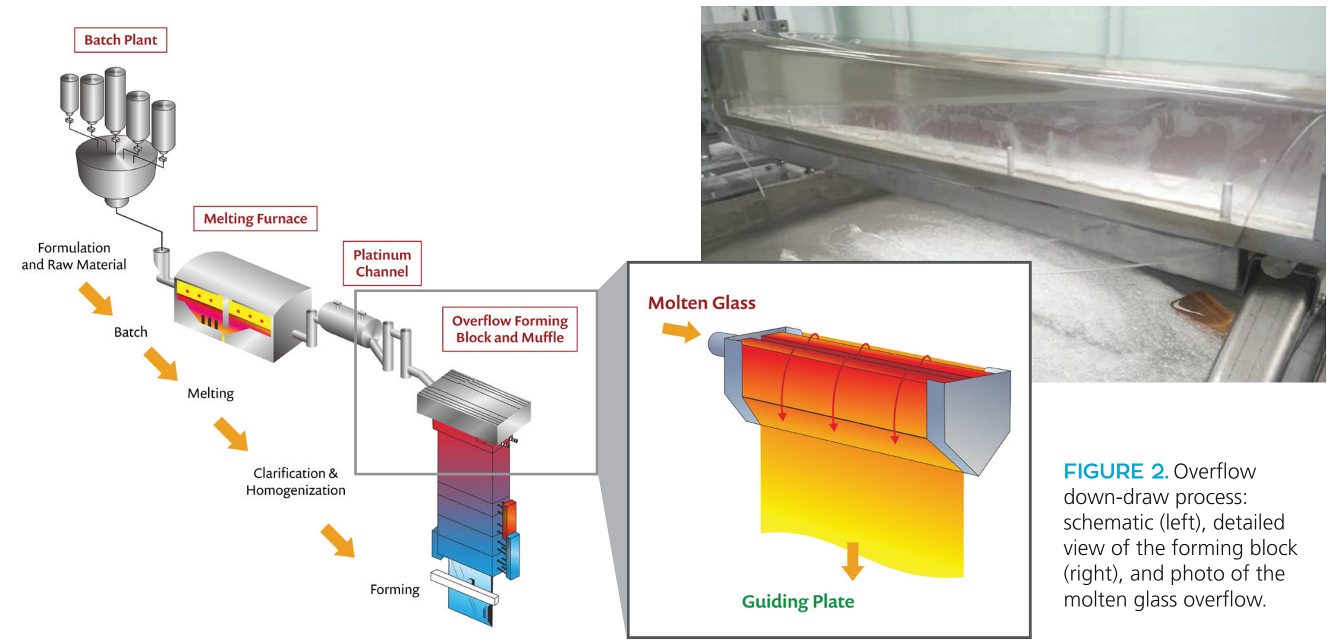

FIGURE 2. Overflow down-draw process: schematic (left), detailed view of the forming block (right), and photo of the molten glass overflow.

and electrical phenomena. The team performs fluid and heat transfer simulations of molten glass to calculate the thickness distribution on the outflow glass surface before cooling, and the strains generated during the forming process (Figure 3). "The software makes it possible for us to input our own constitutive equations or vary parameters such as inlet velocity or tilt angle of the forming block, and to optimize process conditions before mass production," explains Hong.

Multiphysics simulation results are used to predict the glass sheet quality, based on factors such as the thickness, uniformity, smoothness, and defects of the final sheet, as well as to optimize the device and process conditions. "COMSOL allows us to solve multiphysics problems with the needed level of customization," says Hong.

⇨ SIMULATING THE ELECTRIC HEATING SYSTEM

When the molten glass contacts the refractory materials of the forming block, its composition changes to include air, which can introduce bubbles and change the weight of the final glass sheet. The presence of the platinum channel compensates for this by allowing preconditioning such as refining, homogenization, stirring, and temperature adjustment before the glass meets the forming block. Each section of the channel can deliver molten glass with different viscosities thanks to real-time temperature control by an electric heating tube using controlled AC (alternating current).

There are two types of AC heating tube structures in the channel — a straight tube with nonuniform wall thickness and a Z-tube with uniform wall thickness (Figure 4). "Using COMSOL Multiphysics we are able to evaluate the current density distribution on tube walls and the heating effects of both tube structures," says Hong.

The multiphysics model includes Joule heating by coupling electric currents and heat transfer. The governing equations are discretized with the finite element method and solved using a frequency-stationary study. The computed results include the AC heating effects and surface current density distributions, as shown in Figure 4. The results showed Hong's team how the heating effects differ between the two tubes. Experimental validation demonstrated that the simulation results were in good agreement with real-world measurements.

⇨ SIMULATION APPS ENHANCE COLLABORATION

"To build such specialized models, simulation expertise and knowledge of the system being simulated is required," explains Hong. The most efficient way to share this knowledge with others in the company is to take advantage of the Application Builder tool available in the software. Simulation specialists can customize their models so that only

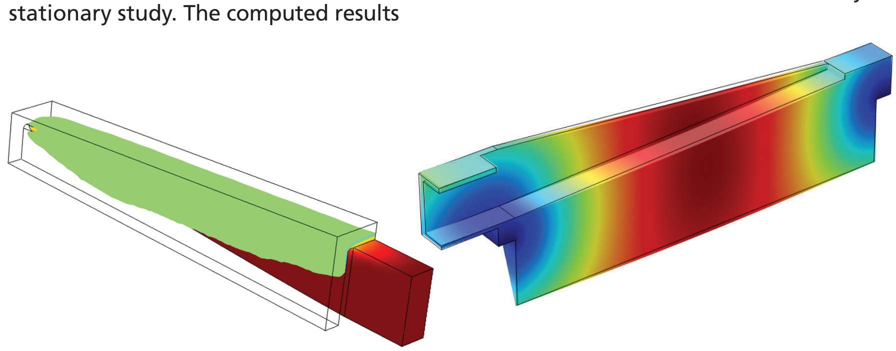

FIGURE 3. Simulation of the molten glass overflow process in COMSOL software. These results show the flow region of molten glass (left, in green) and strain in the forming block (right).

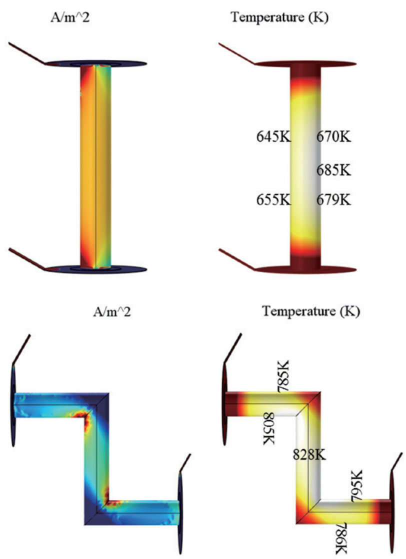

FIGURE 4. A simulation for predicting the state of the glass within a heating tube. Top: Straight tube with nonuniform wall thickness. Bottom: Z-tube with uniform wall thickness. Left to right: simulation results depicting current density distribution and temperature distribution.

chosen parameters will be accessible to the user. The individualized interface is based on the model, which can be distributed internally and allow colleagues to run complex analyses independently.

The simulation team reports to the R&D department of KMTC, but simulation apps extend their work to the engineering department as well. The next challenge is to make simulation accessible to customers directly. Then they can make detailed adjustments according to their design needs, without needing to be experts in the underlying multiphysics model.

The KMTC simulation team built an app to study the platinum channel. The app can be used for calculating fluid temperature and velocity, as well as stress distribution in the heating tube during manufacturing to predict the stress levels and final state of the glass (Figure 5). Input parameters available to the app user include glass temperature, velocity at the inlet, and heating power. A stationary analysis evaluates and optimizes the operating conditions, while a time-dependent analysis simulates the real-time manufacturing processes. The app provides the necessary data to define site instructions for production.

"It is very convenient for engineers to modify input parameters through the interface of the application to, for example, predict the state of the glass within the heating tube," says Hong. "This has simplified the designer's work, while improving the team's efficiency."

The overall simulation workflow has been streamlined. Simulation specialists work on a parameterized mathematical model with various design parameters added for later use, then turn the model into a simulation app, to deploy to other engineers. Designers who are not familiar with multiphysics simulation are empowered to solve practical problems with flexibility and efficiency.

The team deploys simulation apps to colleagues with the COMSOL Server™ product installed on a computing cluster, to support requests from the R&D and engineering departments. Users are able to run the apps based on customer demands and immediately provide insights into the manufacturing process. "Simulation apps are a great tool for the long-term development of the CAE simulation team as they take both cost and information security into consideration," says Hong. ❖

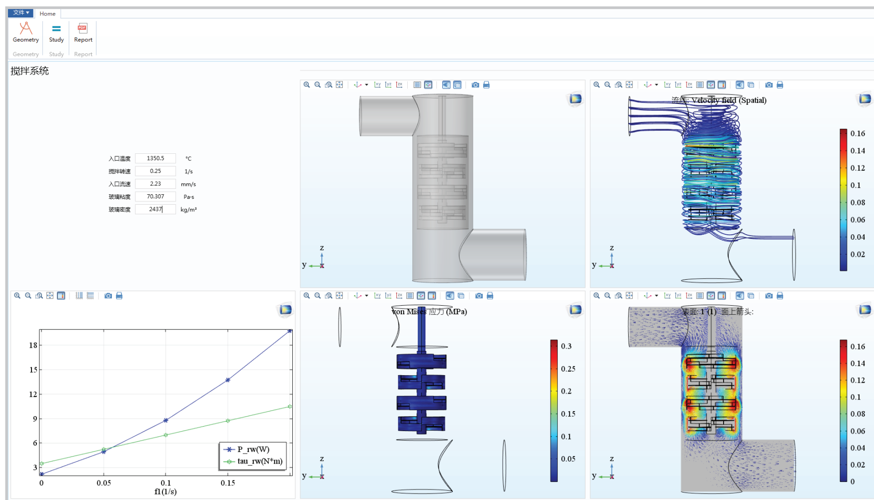

FIGURE 5. App used to predict the state of the glass within the heating tube. Users can change parameters such as glass temperature, velocity at the inlet, and heating power at different sections to investigate fluid temperature, velocity, and stress in the heating tube.

From left to right: Zhenlong Yang; Jiming Yang; Liyao Tao; Lixin (Frank) Hong: research and development manager at KMTC.