A MOLDING FLIGHT SIMULATOR

Looking for an easy way to determine how process parameter changes affect temperatures, gate freeze, and other factors? Good, because there's new software on the market that helps you do just that.

Ask yourself this: If I speed up fill rate, what will that do to my thin-wall part? Wouldn't it be nice to know the answer to such a pressing question in a matter of seconds, without wasting your precious time and money on trial runs?

Donald C. Paulson, chairman of Paulson Training Programs Inc. (Chester, CT), says he has a better idea. It's called SimTech 2004, an interactive Windows-based program with a GUI that looks just like a molding machine.

SimTech 2004 is designed to analyze the effects that all variables in the entire molding process have on any given part. And you can set it up to do test flights using the same materials, molds, and machines you've got out on the floor (see January 2003 **IMM**, p. 67 for an initial report).

It costs $5000. Does it work? What happens if you increase the fill rate on a thin-wall part, for instance? We asked Paulson to pilot us through a high-speed SimTech test flight. Please fasten your seat belt.

Shear Speed

"Plastic flow causes shear heating and molecular orientation within the plastic," says Paulson. "Such a molding evaluation as this one examines that very short period of time when both shear heating and cooling occur during moldfilling."

As he begins keying in the molding conditions for the test runs, he explains that the entire filling process often takes less than a second in the real world, but that analyzing it involves a very complicated set of equations.

Factors involved include runner, gate, and cavity dimensions; the effects of viscosity change; flow rate; and melt and mold temperature.

SimTech software is designed to perform more than 50 million complex calculations on each cycle simulation in just a few seconds, so there shouldn't be any filling analysis problems.

At left is a graph of plastic pressures vs. time at three locations in the mold: before the gate (blue), after the gate (green), and at the far end of the cavity (black).

In this simulation result, SimTech plots plastic temperature vs. time at the surface and the inside of the flow front as the cavity fills, packs, and cools.

The Flight Plan

"We'll run a fast fill rate and a slow fill rate for a 10-inch part to determine how they affect melt temperature and fill properties," he says.

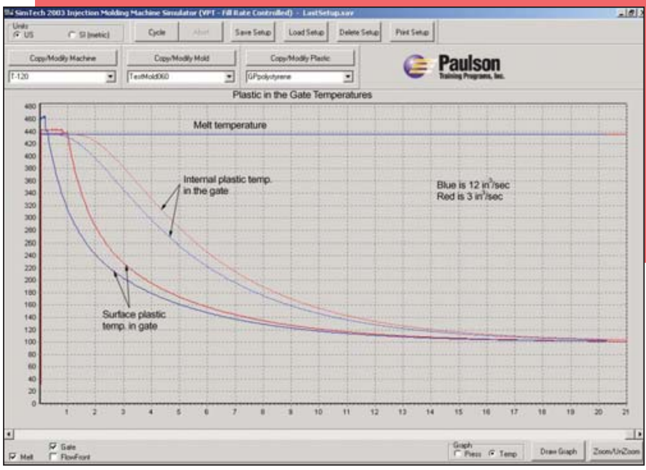
Here are the molding conditions he's keyed in for our test flight:

- Fill rate setting test 1: 3 cu in/sec.
- Fill rate setting test 2: 12 cu in/sec.
- Cavity dimensions: 2 by 10 by .060 inch thick.
- Gate size: .060 inch (diameter) by .060 inch (length), end gated.
- Material: polystyrene (Dow Plastics' Styron A-Tech 1120).
- Machine: 120 tons.
- Barrel temperatures: Three barrel heating zones and one nozzle zone set at 440F.
- Pack and hold pressures: 6000 psi.
- Pack time: 1 second.
- Hold time: 3 seconds.
- Backpressure: 1000 psi (plastic pressure).
- Screw rpm: 100.
- Shot volume: 2.51 cu in.
- Velocity-to-pressure setting: 96% of full cavity.
- Mold temperature: 100F.
- Mold closed time: 20 seconds.
- Mold open time: 1 second.

First Results

In a few seconds, the software calculates that the melt temperature for this simulation will be 435F. It also shows us that the actual fill times will be 1 second at the 3 cu in/sec rate, and .27 second at 12 cu in/sec.

What are the temperature changes caused by shear heating and mold



A third result shows a graph of plastic temperature vs. time at the surface and the inside of the gate as the plastic fills, packs, and cools.

cooling? Regarding the fast (.27-second) fill simulation, Paulson refers to temperature graphs showing an average melt temperature increase of 15 deg F, from 435F to 450F, in the gate.

"Plastic temperature was also calculated in the cavity during filling," he says. "When the plastic reached the far end of the cavity, its average temperature was 465F, an increase of 30 deg F. SimTech calculated the plastic temperature increase during flow through the cavity due to shear."

As far as the slow (3-cu-in/sec) fill rate results go, we see that when the cavity filled in 1 second, gate shear only caused the melt temperature to rise 4 deg F to 439F; and melt temperature at the last place to fill in the cavity had cooled to an average about 415F.

Conclusions Drawn

So, as we touch down we ask our pilot, What conclusions can we draw from our SimTech test flight?

First off, he tells us the simulation shows that when filling a mold quickly, significant plastic heating in small gates occurs, and also in thin-wall cavities. This could this be one cause of plastic degradation. "While this is well known, the amount of shear heating is difficult to measure," Paulson says. "One study using a rheometer showed hot regions more than 150 deg F above the melt temperature."

Our simulation also showed us that gate freezing takes longer when the fill rate is slow. "This is because the plastic can't freeze in the gate while it's flowing. If you've ever experienced gate discharge when you reduced the fill rate, this is the cause," he says.

What's Your Problem?

In our test flight part, shrinkage increased by .001 in/in at the higher fill rate. At a higher plastic temperature the molecules are further apart, and therefore there are fewer of them in the cavity and more shrinkage occurs, Paulson explains, adding, "If the cavity is a thin-wall container, it is likely part ejection will be more difficult. The molder can offset increased shrinkage by increasing the packing pressure. In molding machines that do not have velocity-to-pressure transfer, the opposite happens: Cavity pressure increases when shear heating occurs."

Paulson says we've also learned that cavity pressure loss decreases at higher fill rates. Higher fill rates reduce shrinkage variations down the length of the molded part and should reduce warp. However, he reminds us that faster fill can increase molecular orientation.

Finally, he says we've learned it's likely that shear heating is a major factor in filling cavities for very thin walls.

If you'd like to see this simulation, complete with outputs and graphs, go to the Paulson Training Programs website listed below.—*Carl Kirkland*

Editor's note: If you've got a pressing molding problem you'd like SimTech to solve, let us know. Or, perhaps you've got one you've already solved and want to see what SimTech has to say. E-mail your problem to editorial@immnet.com by August 17. We'll pick out the best, leave the rest to Paulson, and publish the results.

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