DECEMBER 2023

RubberWorld

135 years

THE TECHNICAL SERVICE MAGAZINE FOR THE RUBBER INDUSTRY VOLUME 269, No. 3

Molding of fluoroelastomers

Liquid silicone rubber molding:
Building confidence through simulation

Molecular Rebar with Aflas:
Improved physical properties for performance applications

Molding Suppliers Directory

www.rubberworld.com

@rubberworld

Building confidence in liquid silicone rubber molding through simulation

by Harshal Bhogesra, Moldex3D Northern America, and Robert Jovingo and Kevin Barbee, Shin Etsu Silicones of America

The effective development of components is becoming more reliant on simulations. Allocating resources to precise, early stage design simulations can result in substantial savings by reducing the need for iterative loops in the prototype phase, streamlining the validation process for overall mold design. This study aims to demonstrate how Moldex3D simulations can be utilized to preemptively address these challenges during the product development phase.

Moldex3D recently decided that it could further promote its capabilities to help the molding industry, and joined with Shin Etsu Silicones of America and partner M.R. Mold & Engineering, and determined they could lead the efforts in understanding molding issues. Shin-Etsu provided an optical liquid silicone rubber (LSR) grade that was utilized for looking into tooling, filling and curing defects. It was determined that it would be best to use a showcase mold that was built to highlight most of the molding issues that could occur, including air traps, jetting, imbalances, short shots, flashes and uneven curing that could typically be seen in day-to-day LSR molding operations, and how they could be solved through Moldex3D simulations. A four-cavity tool in a horizontal press was utilized, where two cavities are facing towards the sky and the other two are facing towards the ground. Since LSR has lower viscosity, the influence of gravity during molding was highlighted. This tool was already built, so the focus was on how these molding challenges could be solved through Moldex3D simulations. If this problem been known earlier during the development phase, a different direction would have been taken.

The partners then set out to run a number of simulations that would help them focus on issues that do occur, and how the simulations would aid them early on to prevent these issues. During the first simulation, air was observed being trapped in the middle of the part, as shown in figure 1. Even though there was enough venting in the parting line, sometimes because of the gate location, air is entrapped in the middle of the cavity and does not make it to the vents to escape. Even with vacuum, these late fills can create issues as gas is released from heating the LSR, and these volatiles leave residue on the surface of the mold. This could also lead to potential knit lines in some designs, so it is important to review gate locations, size, melt viscosity, fill time, etc., earlier during the product development phase through simulation, and find a way to eliminate these issues. In this case, if the fill pattern and air entrapment had been known through simulation, before building the tool, there is a good possibility it could have been gated differently along the circumference of the part

Figure 1 - air trap comparison between actual part and simulation

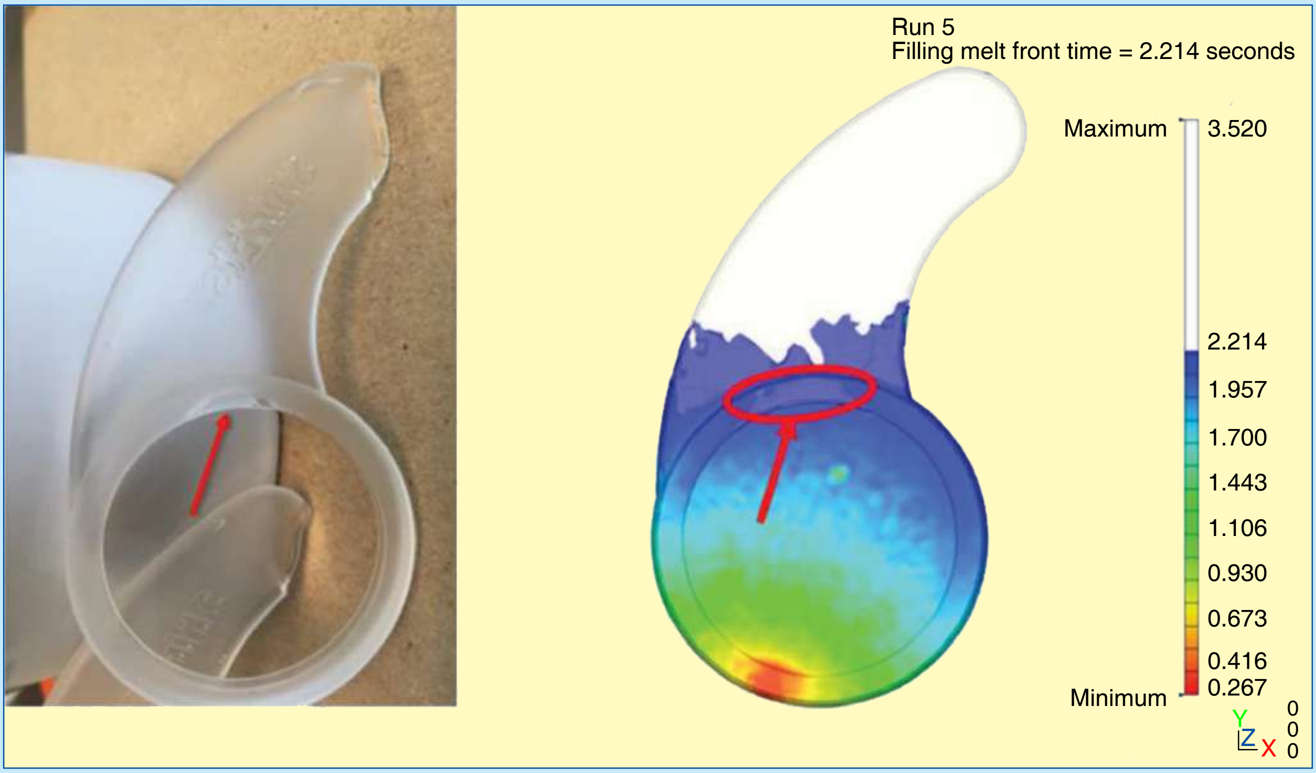


Figure 2 - inconsistent jetting comparison between actual part and simulation

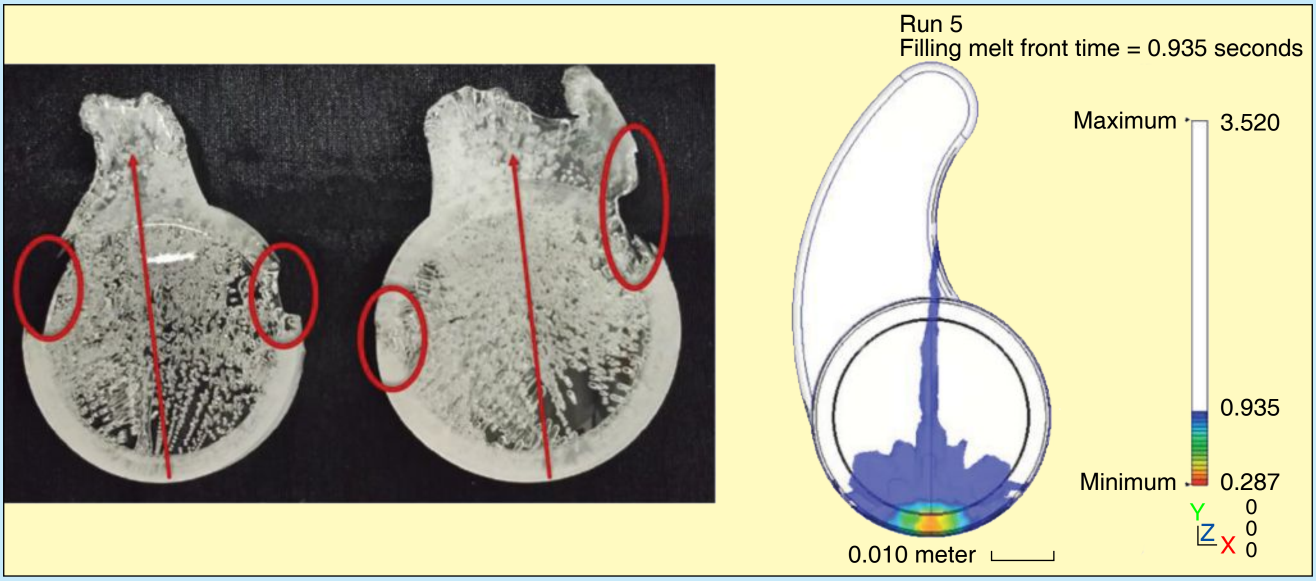


Figure 3 - imbalances during filling because of gravity and lower viscosity of liquid silicone rubber

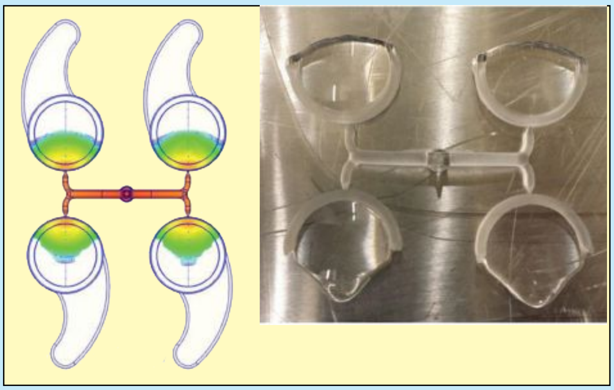


Figure 4 - imbalances could lead to flashing in the bottom cavities and non-fills in the top cavities

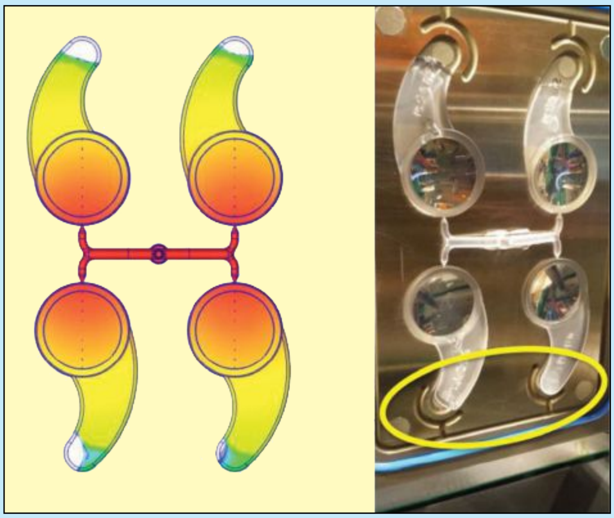
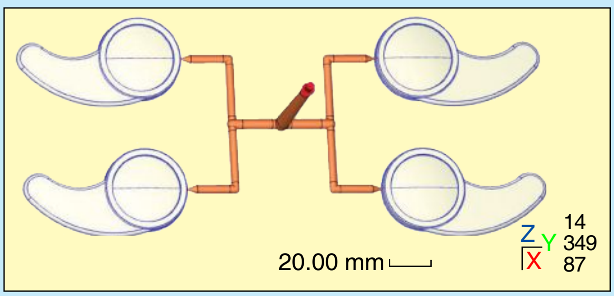


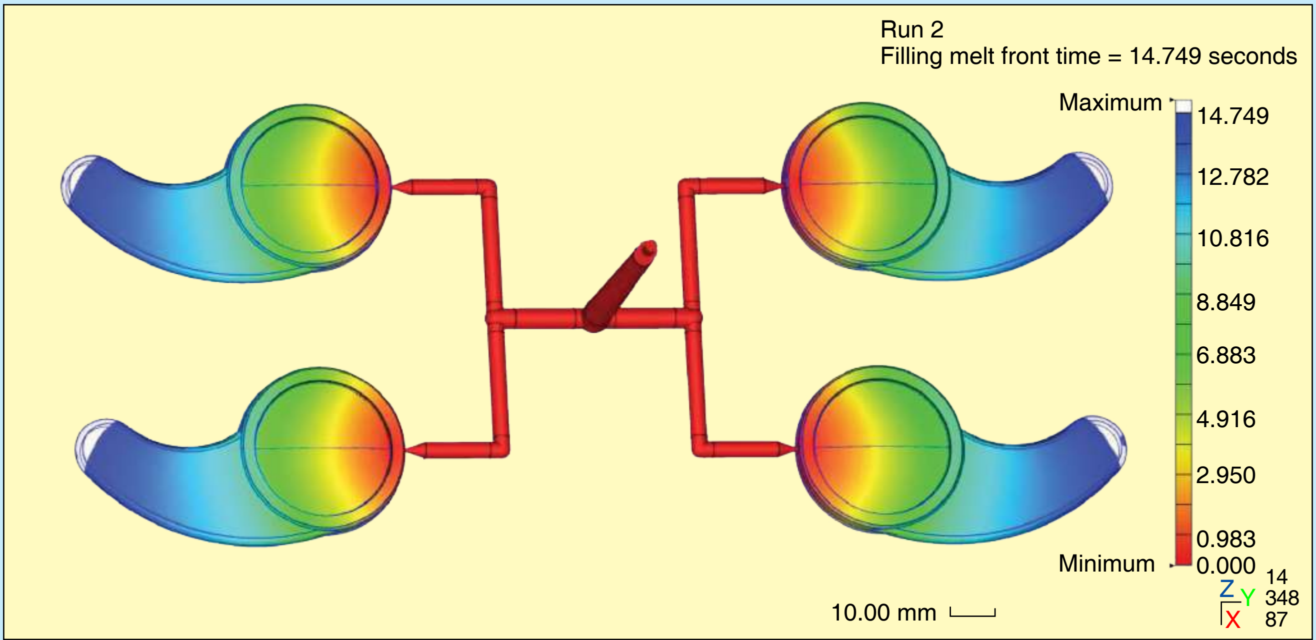
Figure 5 - part orientation idea for equal gravity influence on all cavities



to see if it would help air to escape through the vents and not be built up in the middle of the cavity. Through design of experiments (DOE) and optimization at Moldex3D, objectives and variables can be assigned, and Moldex3D technology can provide the answer. For example, testing personnel can mark specific areas in a simulation and request the software to eliminate any regions where air may be entrapped. Variables could include plans for location of 20-30 gating ideas and determine which one is the most optimum. Simulation will run all those gating designs automatically, ingeniously learn from previous iterations and funnel the team towards the final solution. In this case, it would have found the optimized gate to eliminate air traps, before cutting the tool steel.

It was then decided that, based on the previous issue of air entrapment, operators might try to fill this part faster. The fill time of 3 seconds resulted in jetting. This occurs when the viscosity is low, and velocity is high. The material flows from a

Figure 6 - balanced filling in all cavities with horizontal molding machine



small gate towards the larger wall thickness. The melt front is unstable during this time, and the material jets into the open space towards the opposite wall, as shown in figure 2. It can also lead to inconsistent air bubbles and entrapment inside the parts, which would be hard to eliminate.

Jetting can be reduced or eliminated by slowing down filling, which will lead to lower shear, or by changing the gate location/style, which will change the flow pattern. It is important to run simulations before cutting the steel to optimize gating and eliminate this jetting issue in production. It might, at this juncture, be best to provide a gate that would allow the melt front to impinge the wall at angle, so it hits the wall rather than have the material flowing into an open space. In this case, it was too late, since the mold was already built, so the only option was to slow down the filling. The fill time was increased to 15 seconds, which reduced the jetting, but led to another issue: imbalanced filling. Due to gravity, the top two cavities facing the sky filled evenly, while the bottom two cavities facing the ground developed a sagging issue due to the influence of gravity and low viscosity of the LSR. Gravitational influence increases with the

Figure 7 - balanced filling progression in all cavities with vertical molding machine

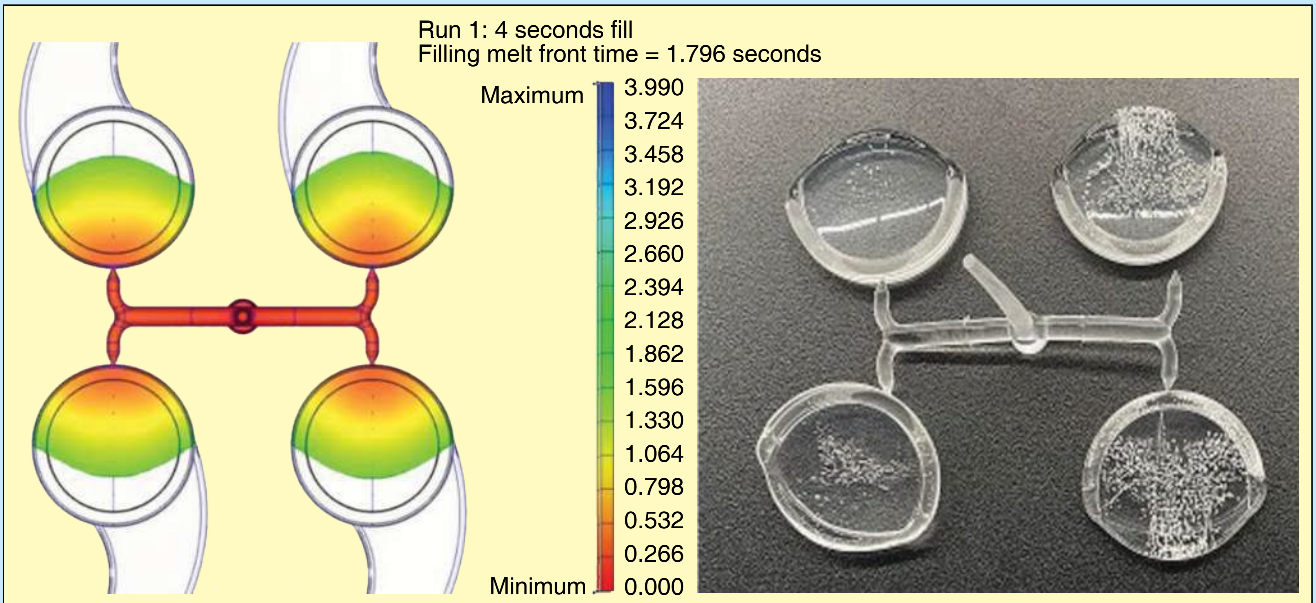


Figure 8 - balanced filling further progression in all cavities with vertical molding machine; actual production

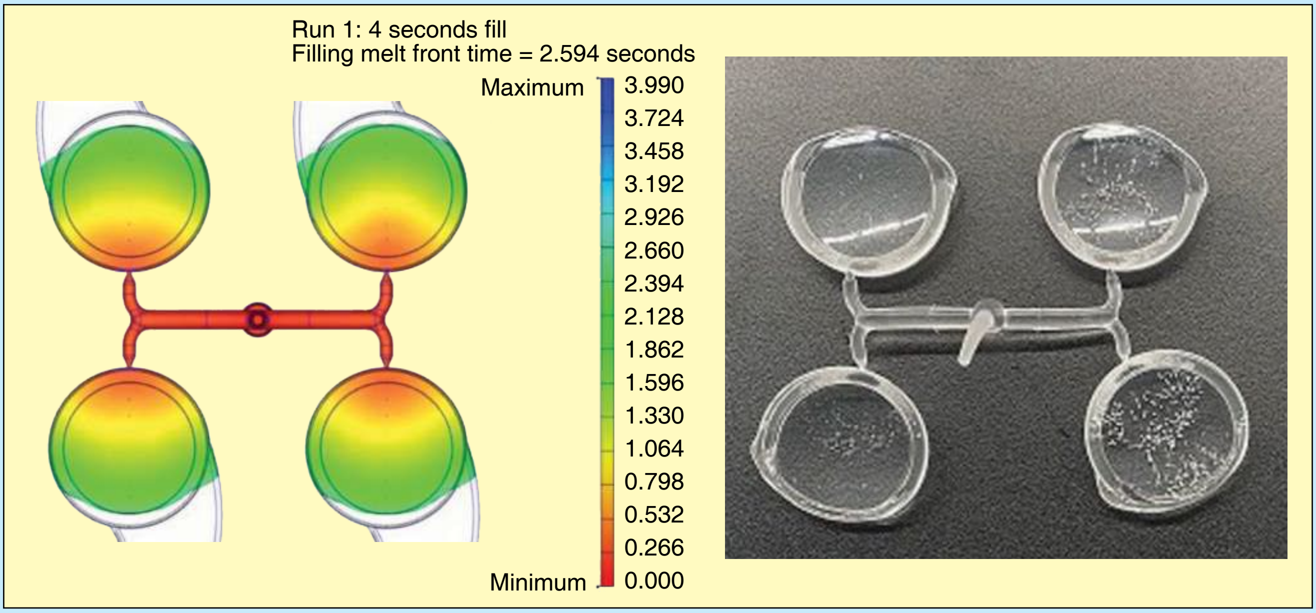


Figure 9 - curing conversion at the end of 60 seconds cycle; simulation

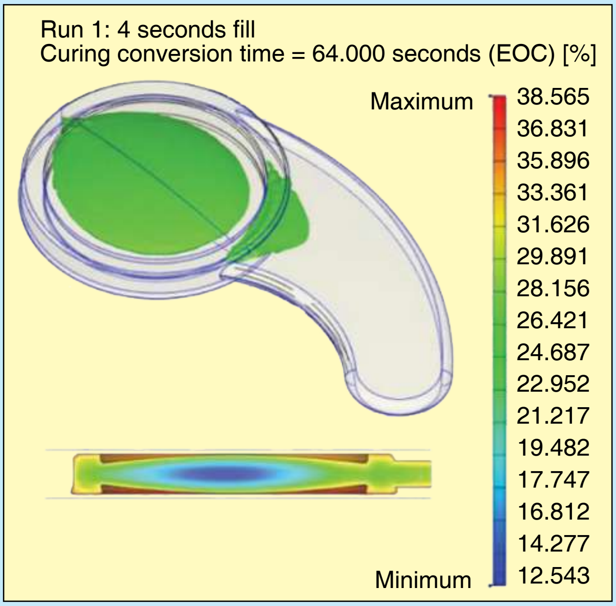
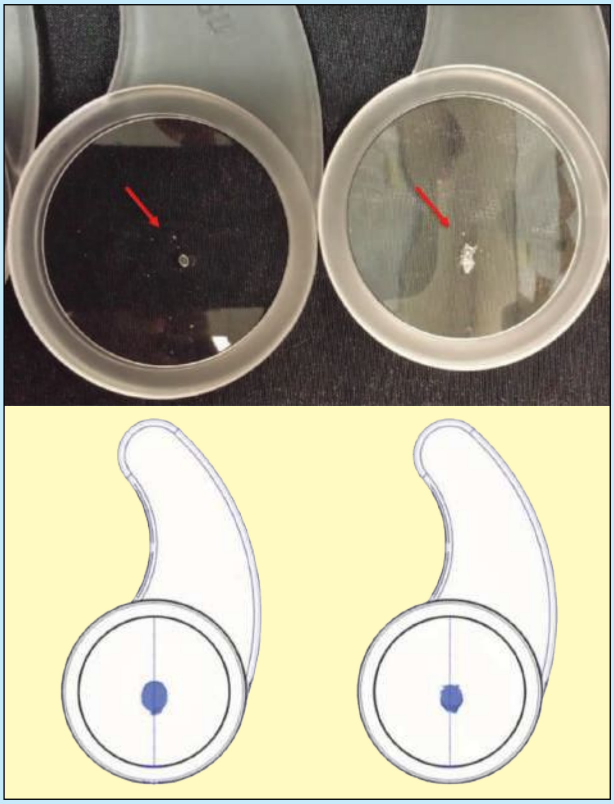


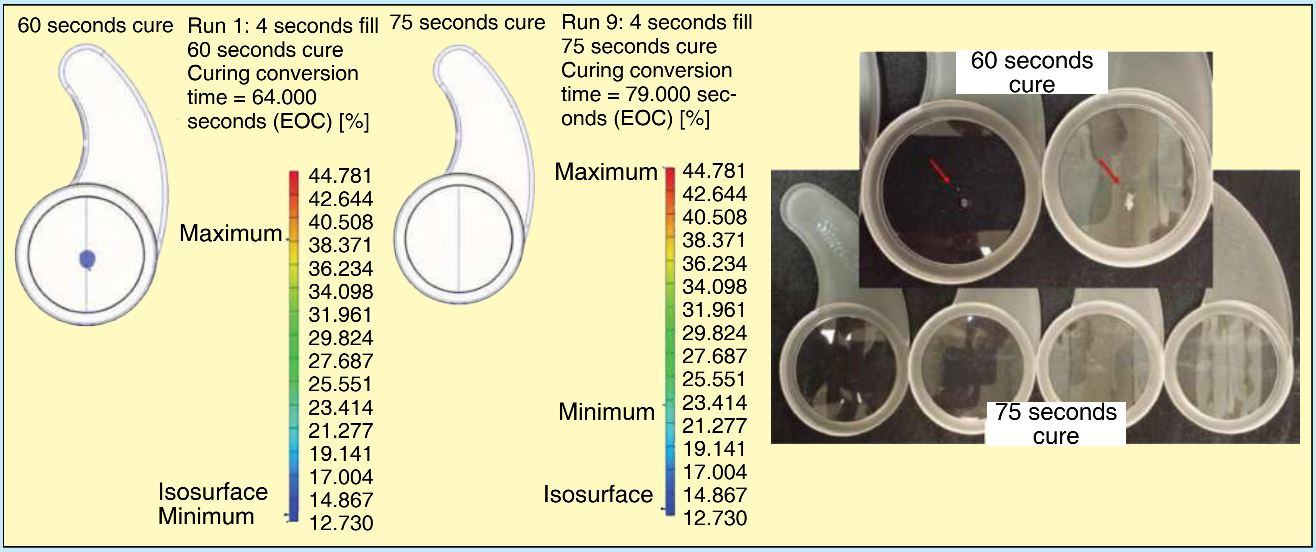
Figure 10 - voids comparison between actual and simulated parts



longer fill time (slower filling), and this effect is more visible with the lower viscosity materials which are accurately captured inside the simulation, as shown in figure 3. This figure illustrates the imbalances between production and simulation, where the gravitational influence is captured by the software.

Sagging continues and leads to imbalanced filling, where the bottom two cavities fill faster due to gravity and slower filling/lower viscosity, as shown in figure 4. This then leads to high pressure and increases the potential for flashing in those cavities. This will also accelerate melt velocity to other unfilled cavities, and could lead to non-fills/short shots in the top cavities. This kind of imbalance between cavities or within cavities (in some

Figure 11 - voids comparison between actual and simulated parts; 60 seconds versus 75 seconds cure times



molds) could reduce the processing window. It is also important to evaluate mold temperature, as it would affect polymer viscosity/temperature and flow pattern. With longer fill time, this effect worsens the imbalances.

If the simulation had been run before this tool was built, testing personnel would have decided to orient the parts differently, as shown in figure 5, so the gravity influence is the same for all four cavities. It was too late at this point. Testing personnel did, however, check this by running the simulation to check if the theory was correct, and it was confirmed it was correct. This allowed a balanced filling in all cavities utilizing a horizontal molding machine, as can be seen in figure 6.

Since the tool in this showcase study was already built, the only option to avoid imbalances and jetting was to run it in a vertical press with the slower filling time. When the mold was run in the vertical molding machine, gravity influence or sagging were not seen, and there was a more balanced filling compared to the horizontal molding machine, as illustrated in figures 7 and 8, where the filling progression between actual production and simulation is shown.

Initially, the cycle time for this mold was 60 seconds. This resulted in late curing areas in the center of the part. Wall thickness is greater in that region, so a majority of the part cures at the end of the cycle, except the core of this thick section, as shown in figure 9. The longer filling time results then end up in two distinct regions of the fast cure: transparent and the much slower cure (green shaded).

It was then decided to evaluate if there may be enough residual heat in the part to fully cure outside the mold. In this case, there was not sufficient heat generated to effect an adequate cure. Since it is a clear LSR part, void related defects in the actual parts certainly could be seen, and were compared to the simulation, as shown in figure 10. If the simulation had been run before, testing personnel could have predicted it, and optimized the heater locations and power to facilitate curing in these thick sections.

At this point, the only option would be to increase the cycle time. It was then determined that if 15 seconds were added to the original cycle time of 60 seconds, it would lead to full cure within the parts, including the thicker section, and would as well eliminate the void related issues, as can be seen in figure 11.

Conclusion

In a collaborative endeavor involving Shin Etsu Silicones of America, M.R. Mold & Engineering and Moldex3D, this project explored the intricate challenges of molding optical liquid silicone rubber (LSR), and proposed innovative solutions. A key focus was a showcase mold featuring four cavities, strategically positioned to highlight the nuanced impact of gravity on LSR molding: two facing upward and two downward. Simulations revealed that altering part orientation can equalize gravity's impact, offering a preventive measure against imbalances. The study concluded by underscoring the paramount importance of conducting simulations before tool construction to proactively anticipate and effectively tackle molding challenges.