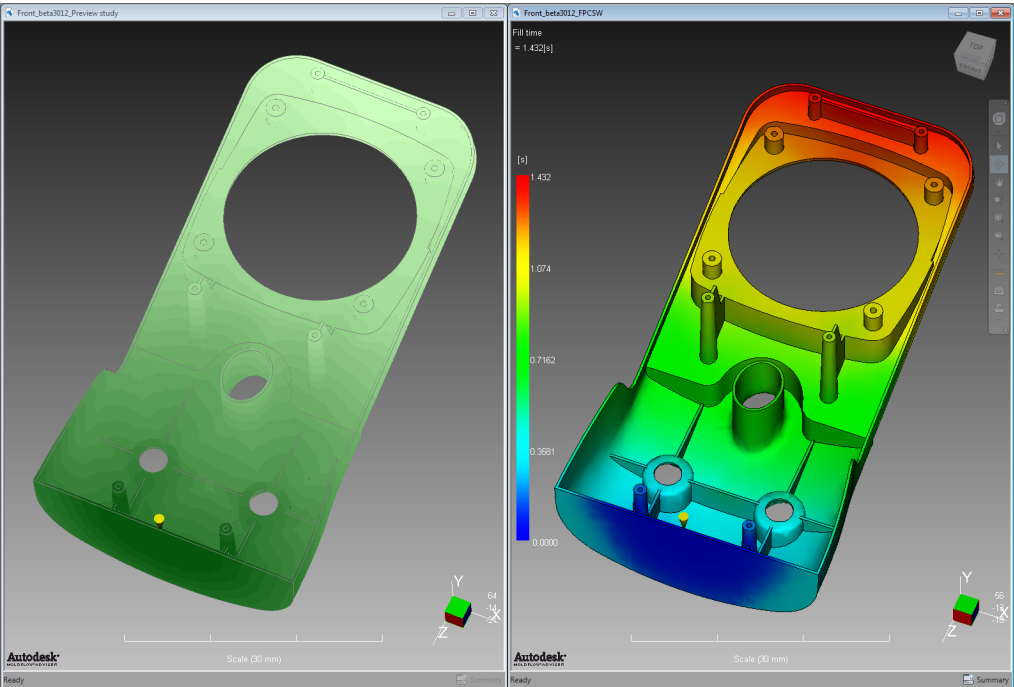


# Real-Time Plastic Injection Molding Simulation



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Companies involved in designing and manufacturing plastic parts face increasing pressure to get innovative products to market faster. Best-in-class manufacturers have responded by integrating simulation into the product development process, making it possible for simulation to help drive design. Making simulation an integral part of the design process allows manufacturers to find problems with plastic part and injection mold designs earlier, minimize the number of physical prototypes required to optimize designs, and thereby speed the product development process.

Despite these advantages, simply integrating simulation into the process isn't enough to keep companies competitive. In addition, they must fully adopt simulation-driven design by taking advantage of drastic improvements in simulation technology.

Autodesk is revolutionizing simulation-driven design and changing perceptions of what can be achieved during product development. In fact, Autodesk's newest technology accomplishes something once seen as impossible: *real-time simulation*. This paper discusses some historic simulation challenges and shows how Autodesk has overcome them with real-time simulation technology.

## Simulation Challenges

Designers and engineers use simulation tools to help validate educated, intentional guesses based on years of experience with design and intelligent 3D CAD software. But not even the most experienced professionals make perfect assumptions every time. Simulation increases decision-making confidence and provides insight into what, where, and how to adjust in-progress designs.

This cycle of making and validating decisions throughout the design process is called simulation-driven design—and it's being used more and more by leading manufacturers. Hardware and software advances have continued to reduce simulation times from days to hours to minutes, making it possible to explore and validate more design iterations in less time, and to significantly increase ROI by optimizing product designs and finding problems before manufacturing.

Until recently, however, the very fact of simulation times has kept simulation-driven design from reaching its full potential. It can still take hours to set up, perform, and interpret each simulation—a situation companies have been willing to tolerate because it beats the alternatives.

Ideally, manufacturers would be able to get instantaneous, seamless feedback on manufacturability and quality *during* the design process. Such real-time feedback about product performance would allow designers and engineers to instantly understand the impact of each design decision on the manufacturing process.

## Accurate, Real-Time Simulation

Relying on decades of expertise, the Autodesk team has met this goal with breakthrough technology that resolves some of the biggest challenges of plastic injection molding simulation. This technology does what was once thought impossible—provide accurate and real-time simulation results.

Here's how it works:

The revolutionary technology meshes the CAD model and determines a potential fill pattern based on part geometry and the location of at least one gate. Designers and engineers can specify gate location(s), or the software can assign them automatically.

The potential fill pattern is then used to develop a simplified (strip) representation of the part geometry. The technology creates strips that best represent variations in the part geometry and fill pattern.

Finally, a second, more-detailed filling simulation is performed on the simplified strip model to help predict the design's key characteristics, manufacturing defects, and more. The principles of Hele-Shaw flow approximations—a technique for solving problems in fluid mechanics—are used to model the plastic flow.

With this new technology in Autodesk® Moldflow® software, it takes only seconds to perform an initial simulation on even the most complex part design. Designers and engineers can use this real-time simulation technology to accurately discover:

- Fill pattern as a function of time
- Weld lines
- Sink marks
- Pressure required to fill a part
- Pressure distribution across a part

Let's take a look at key data from injection pressure predictions and plastic fill pattern validation benchmarks—confirming the accuracy of these real-time simulation results.

## Injection Pressure Predictions

Autodesk tested the accuracy of Autodesk Moldflow injection pressure predictions using an instrumented injection mold with three pressure transducers (see Figures 1 and 2). The test was performed using polypropylene (MT62CP from GS Caltex Corporation) with 25% mineral filler. The plastic melt temperature was 220° C (428° F) and the injection time was 1.586 seconds.

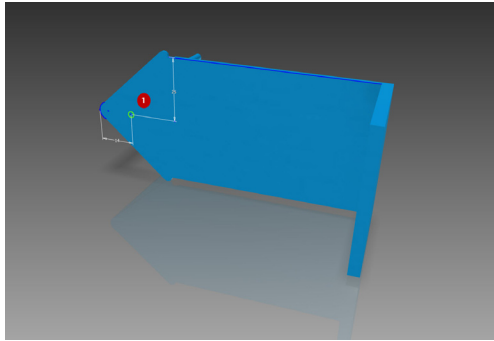


Figure 1

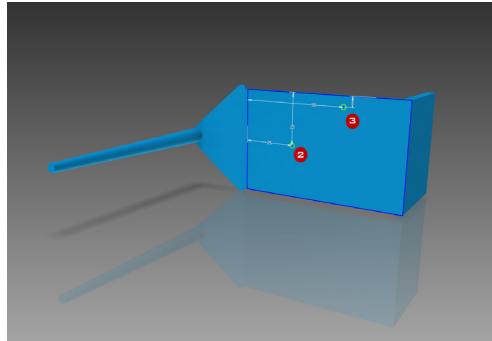


Figure 2

Autodesk compared Autodesk Moldflow simulation results—from a simulation that took just seconds to perform—with the pressure recorded in each transducer at the instant the part was completely filled with plastic. The pressures predicted by Autodesk Moldflow simulation technology closely matched the measured data (see Figure 3).

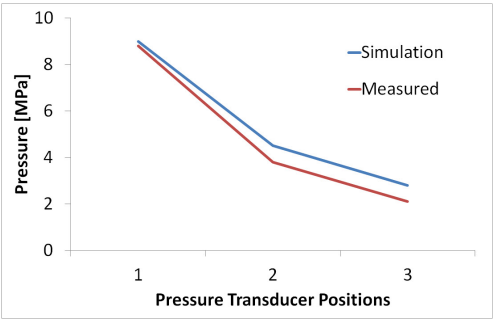


Figure 3

Plastic Fill Pattern Validation

Benchmark tests on a plastic fill pattern were equally accurate. The four arms of a part design (see Figure 4) had different thicknesses and widths, providing an ideal test case for studying unbalanced flow characteristics. The test was performed using ABS plastic. The plastic melt temperature was 235° C (455° F) and the injection time was 2.6 seconds.



Figure 4

At multiple stages of filling, simulations accurately reflected the filling pattern created by a plastic injection molding machine (see Figures 5a and 5b). Note that Autodesk Moldflow software accurately predicted the hesitation effect in the narrow arm. In addition, it indicated weld line locations that closely matched those of the actual injection-molded part.

Photograph of Part



Simulation Results

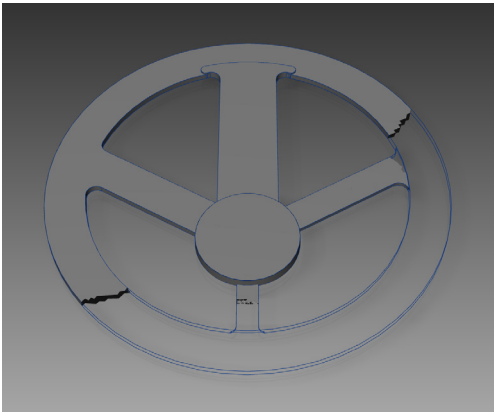


Figure 5a

## Photograph of Part

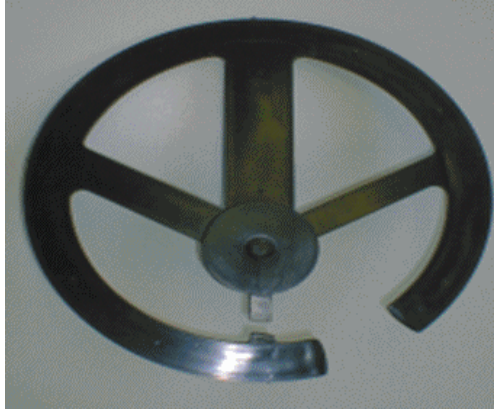
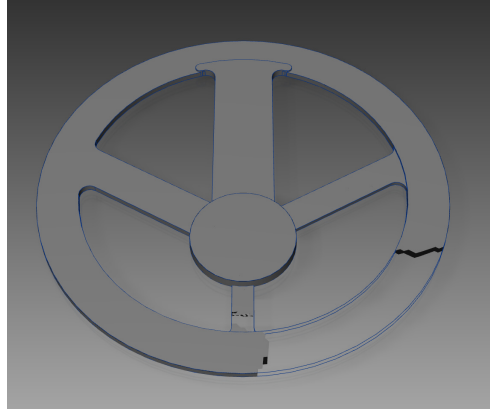


Figure 5b

## Simulation Results



## New Design Paradigm

The new simulation technology in Autodesk Moldflow software not only lets designers and engineers get accurate, real-time simulation results, it also displays indicators in the design workspace that highlight key aspects of manufacturability affected by design decisions (see Figure 6). Users of Autodesk® Inventor® and Pro/ENGINEER® software can continually assess how each design decision influences:

- Manufacturability—likelihood of defects and ease of part processing
- Costs—material, mold, and production costs
- Environmental Impact—carbon footprint, embodied energy, embodied water, and recyclability

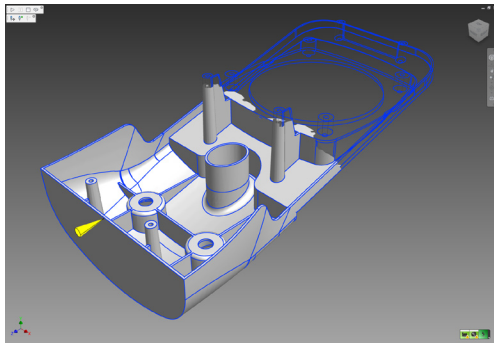


Figure 6

These indicators represent a new way of viewing, and using, simulation technology. Simulation becomes part of the design process, displayed as a series of gauges that provide integrated, real-time feedback. These gauges sit in the field of vision, issuing warnings whenever a design change could cause problems. Designers and engineers can know, as they design, whether they're creating potential manufacturing issues such as partially filled designs (short shots), unbalanced flow due to non-uniform thickness, poor or inadequate drafts, undercuts, or aesthetic and strength concerns resulting from the location of sink marks and weld lines. As a result, each plastic part design can be perfected more quickly—and with far greater confidence in its manufacturability.

## Conclusion

The benefits of performing accurate, real-time plastic injection molding simulation throughout the design process are clear. With this breakthrough technology in Autodesk Moldflow software, manufacturers no longer need to find time for simulation. Instead, they can validate and optimize designs throughout the design process, reduce the need for costly mold rework and physical prototypes, minimize delays associated with removing molds from production, and get innovative products to market faster.