CFD *for* Injection Molding

Plastic parts designers need to ensure that injection molded parts are fully formed and contain no visual defects. Specialized injection molding tools have been used to meet these goals for a very long time and have continued to mature. However, these tools require their own licensing, user training and support. In almost all cases, when specialized tools are optimized for injection molding, they become very limited for use in other engineering applications. Schneider Electric engineers have validated the use of ANSYS general-purpose computational fluid dynamics (CFD) software, which is already extensively used at Schneider Electric, for mold-filling simulation. They have also shown that ANSYS CFD can interface with a wide range of other simulation tools.

By **Carlos Marquez**, Thermal Domain Leader,
CAE R&D and 3D Simulation
and **Silvestre Cano**, Rheology Domain Leader
Schneider Electric, Monterrey, Mexico
Omar Rodriguez, CFD Specialist
Grupo SSC, San Miguel de Allende, Mexico

Manufacturability ranks second to function as a design concern for injection molded plastic parts. During the design process, engineers need to know how a part's material, geometry, gate locations, runner system, wall thicknesses, injection flow rate and other parameters will affect the cycle time and quality of the finished part. The cost of the tool required to mold the parts is typically tens to hundreds of thousands of dollars. It is expensive to try to fix problems or optimize the design once a trial is underway, so simulation is required in the mold-filling process to identify quality issues and optimize productivity before building the injection molding tool.

Schneider Electric is leading the digital transformation of energy management and automation in homes, buildings, data centers, infrastructure and industries. For more than 180 years, Schneider Electric has innovated at every level, developing connected technologies and solutions for safety, reliability, efficiency and sustainability, and to ensure that "Life Is On." The company's engineers wanted to determine whether injection molding simulation could be

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performed with the already deployed general-purpose ANSYS Fluent CFD software used throughout Schneider Electric for a wide range of simulation tasks. If it could, the team would be able to meet their injection molding simulation needs while consolidating software tools. They could save costs by decreasing the number of licenses required, reducing the learning curve to increase team efficiency and alleviate additional training needs, and shrinking IT overhead.

DEFINING MATERIAL PROPERTIES

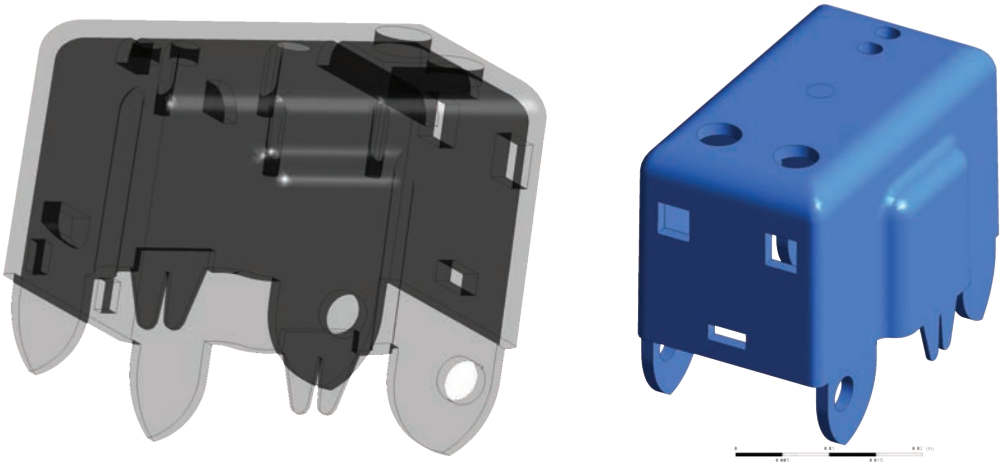
When simulating injection molding, engineers must account for the material properties of the polymer. Polymers have a high resistance to flow (viscosity) that is shear-dependent (meaning that portions of a fluid flow at different relative rates). The higher the shear, the lower the viscosity becomes, so typically polymers can be described as shear-thinning non-Newtonian fluids. This high shear rate occurs when the polymer is squeezed or forced to flow through narrow gaps.

This viscosity–shear-rate dependence makes the flow prediction of non-Newtonian polymers somewhat nonintuitive. For example, when the molten plastic is injected through a small gate into a large mold, the material flows outward to the walls of the mold. The outer layer flows more slowly than the inner core.

To leverage ANSYS CFD to simulate mold filling, Schneider engineers began by gathering physical properties on the plastics frequently used by the firm, such as the relationship between shear rate and viscosity. They fit the data to a non-Newtonian model and created a user-defined material in Fluent that represents each of the six primary materials used for injection molding at Schneider: polypropylene, polycarbonate, polyamide, polyester, polyethylene, polyphenylene and polyoxymethylene. This methodology could also be extended to other plastics if needed.

MOLD-FILLING TEST CASE

Schneider engineers selected an enclosure for a current transformer, used to measure alternating current, as a test case to evaluate the new methodology. In a current transformer, current in its secondary windings is proportional to the current flowing in its primary windings. The engineers imported a solid model of the enclosure into ANSYS DesignModeler. They eliminated details that were not relevant to the mold-filling simulation, such as chamfers and text embossing on the part, to optimize computational time. The geometry of the part was used to define the flow domain for the mold-filling simulation. Engineers defined a gate with a pressure boundary condition to shoot molten plastic into the mold. They created several user-defined functions (UDFs) to track important mold-filling parameters. For example, one of these functions tracks the unfilled area of the mold, providing a record of filling time and making it possible to stop the simulation when the mold is full to avoid wasting computational resources. Engineers ran the simulation from the beginning of the injection process to the point where the mold was filled with plastic. The simulation results correlated well with the results from the specialized mold-filling software.



CAD models of the switch enclosure

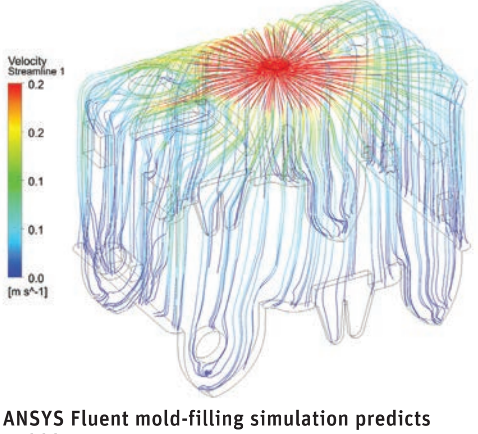
Schneider engineers simulated the part to improve the mechanical properties of the transformer enclosure. They simulated mold filling with several materials to determine the effect the material change would have on part quality and productivity. Simulation predicted the locations of weld lines (produced when two flow fronts meet and are not properly welded together); the engineers could then evaluate problems in weld line formation. If the temperature and pressure of these flow fronts are not correct, the mechanical properties of the current transformer can be compromised. Engineers evaluated different gate positions and runner system designs to ensure that the part fills evenly and to minimize runner volume to avoid wasting material and energy. They evaluated different process settings to minimize warpage and sink marks, and to improve the structural integrity of the part.

ANSYS CFD MATCHES SPECIALIZED SOFTWARE

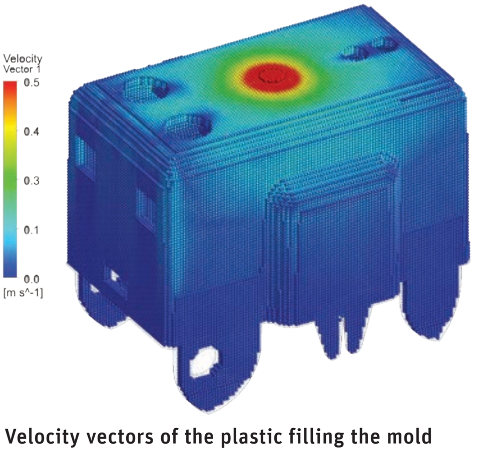
Engineers concluded that the general-purpose ANSYS CFD software provides the same accuracy as the niche tools that perform only injection molding simulation. This provides an opportunity to consolidate simulation software and could lead to substantial cost savings by reducing licensing, support and training costs. Using an ANSYS Workbench tool (ANSYS Fluent) for mold filling will also allow use of other ANSYS tools for other physics — such as structural integrity and electronics cooling — by leveraging a common model for multiple simulations. Finally, ANSYS CFD provides world-class parallel scalability that opens the door to cloud computing platforms.

Reference

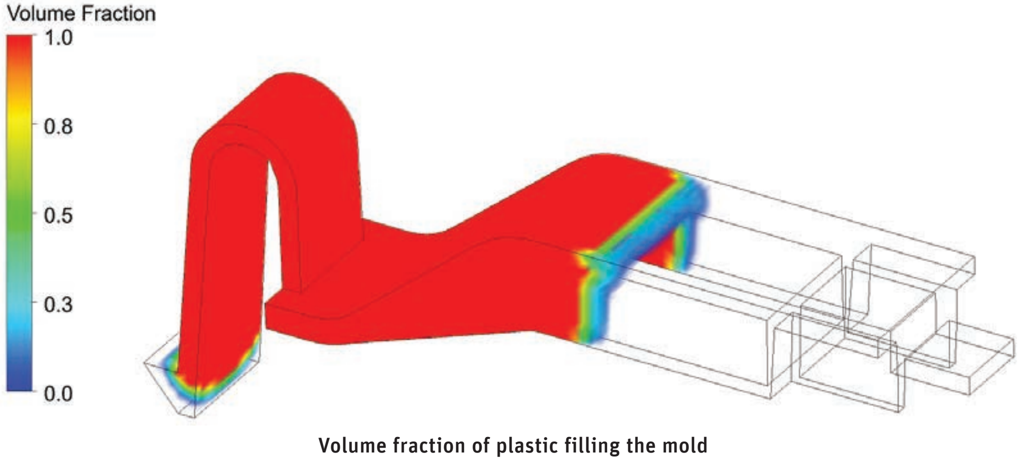
Schneider Electric, schneider-electric.com



ANSYS Fluent mold-filling simulation predicts weld lines.



Velocity vectors of the plastic filling the mold



Volume fraction of plastic filling the mold