SmartFlow analysis optimizes silicone and rubber tooling design

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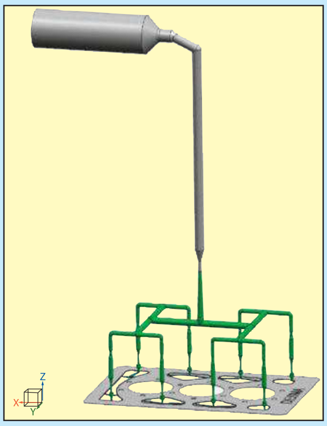
Klockener Desma Elastomertechnik GmbH, located in Fridingen, Germany, builds machinery and molds, and develops production cells for rubber and silicone processing. This company, founded in 1965, has a history of mold and cold runner development. Desma molds are in factories around the globe in various market sectors, including automotive, electrical, infrastructure, consumer goods and mechanical sealing applications. Today, Desma produces molds and tooling at factories in Germany; Hebron, KY (Desma USA's NAMC Division); Ahmadabad, India; and Wuxi, China. Each facility has a core competence in mold manufacture. In an effort to leverage global know-how, reduce design time and overall time for mold production, a decision was made to invest in mold flow simulation capabilities.

Mold design processes today benefit from sophisticated design software that creates 3D models easily exported to manufacturing, CAM programming and metal cutting. But regardless of the software sophistication, basic decisions early on are driven by practical knowledge and elastomer experience. These decisions include parting line location, gate types and expected filling behavior of the material. Such decisions drive the final mold concept and subsequent design steps. While Desma has the ability to apply the collective experience of its global teams to mold projects, the ideal mold design is not always created at first pass, often due to polymer characteristics or other unforeseen factors. Traditional mold making typically requires optimization that involves injection testing on production equipment. Then, based on performance, modifications to the mold are made to create a stable process. This endeavor consumes time and resources.

Figure 1 - rubber flow path from injection unit to article



To increase value in this situation, Desma created a process for flow analysis called SmartFlow. Over the last year, Desma developed a polymer library of common materials used by common customers to better create SmartFlow analysis. In addition, Desma merged engineering data from their entire injection unit database (screw geometry, injection barrel diameter and various orifice measurements) into the SmartFlow platform for improved test accuracy. Finally, Desma created a process map of their current control system screens of critical data to minimize the risk of data transfer mistakes when conducting SmartFlow trials.

Most mold flow software on the market comes with a range of machines to select from when performing the analysis; but most existing platforms are from the plastic industry and are not helpful in the analysis for elastomers. SmartFlow has analyzed all of the Desma injection units so that, depending on the project, a proper injection unit can be selected. Each injection unit may have a different screw size, barrel diameter and nozzle length. All are factors that contribute to different heat histories input into the material. For the most accurate analysis, all criteria need to be considered (figure 1).

The first step in the SmartFlow analysis starts with the compound. For an accurate analysis, there needs to be proper material testing or characterization data available. Once compound characteristics are determined, SmartFlow software can calculate. Most existing flow analysis on the market today starts with various thermoplastic material characteristics and/or is limited to LSR (liquid silicone rubber) data. To provide value, Desma is creating a polymer characterizations library for various types of elastomers.

To collect the compound data required for the SmartFlow analysis, the compound must be evaluated by a laboratory using ASTM and ISO testing standards. SmartFlow testing includes compound reactive viscosity, curing kinetics and pvTc, which is volume based on temperature, pressure and cure degree. Establishing reactive velocity and curing kinetics is important for understanding the filling and curing characteristics of the compound. The specific volume with curing is important for the compressible simulation. All factors contribute to the accuracy of the simulation, which shows how the material will fill into a cavity, and what possible defects might appear.

If a customer has internal testing capabilities, a list of material properties can be provided that are required for SmartFlow analysis. In most cases, Desma recommends established test laboratories around the globe that provide material characterization services.

Once material characteristics are defined, the next step is to integrate this information along with the molded article geometry into the SmartFlow software. The CAD data of the article must be high quality; otherwise it will take too long for the SmartFlow system to process the information. This is especially critical on freeform surface models, where it is important to make sure that the surfaces and body edges of the 3D model are closed. Otherwise, the SmartFlow calculation will create a mesh that is drawn over the model. The software has an automatic correction feature, but this has practical limitations if the CAD data are bad.

Based on the CAD data of the molded article geometry, the fill gates can then be placed at estimated positions. During the creation of the runner system, one can determine the size, radii, and whether or not the mold is filled by a cold or hot runner system. All factors contribute to the material flow and heat generation during the simulation. After the runners and sprue geometry are created, the engineer must apply a mesh to the entire article. The mesh creates layers that will be analyzed during the simulation. The finer the mesh, the more detailed the simulation will become; but also the longer the simulation will take to perform.

With SmartFlow, injection unit and machine size are selected from the library, along with estimated injection times and molding temperatures as a starting point. All injection units have their advantages and disadvantages in elastomer processing. The SmartFlow system has extensive data from all Desma FIFO injection units, ranging in volume from 350 cm^3 to 14,200 cm^3, and pressures up to 3,500 bar. Even within the Desma family of injection molding machines, there are differences between different types of FIFO injectors. For example, the FIFO-A design injection unit has a 90° transition from horizontal to vertical, where material dives into the center of the upper bolster. While this provides a very low working height of the machine, it provides a slight pressure drop of the material compared to the Desma FIFO-B design. Injection unit geometry is critical to result in an optimal SmartFlow calculation.

SmartFlow offers another benefit with a process overview that is mapped to the Desma DRC2030 TBM controller (figure 2). The process map allows the user to plug in the exact settings from their machine into the simulation as if they were standing at the operator panel. The process parameters created can be loaded 1:1 into the controller at a later point, and also transferred back into the SmartFlow filling simulation. The results are verified, and proven process settings can be immediately used in the actual tool startup. The DRC2030 TBM control unit is the link between the tests on the injection molding machine and the parameter input in the SmartFlow flow simulation.

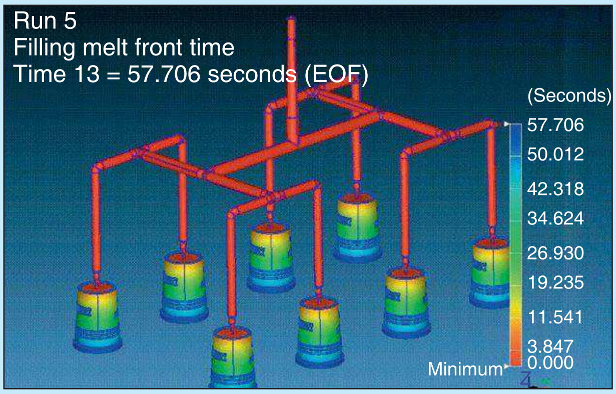
The final step is to estimate molding parameters for the SmartFlow simulation. With the material characterization data, process setting estimations and the importation of a proper CAD model, the SmartFlow process is set up. A typical analysis can take up to 20 hours using high quality CAD computing systems. In order for the computer to provide a stable simulation, it must have a Xeon processor which can support the required memory bandwidth and cache size.

The SmartFlow simulation will then analyze the material flow into the mold cavities. Multiple analyses are often performed so that, for example, injection locations and other factors can be evaluated using different parameters.

Critical determinations from the SmartFlow include filling melt front time. This is the length of time it takes to move the

Figure 2 - Desma DRC2030 TBM controller and process map

Figure 3 - melt front time simulation



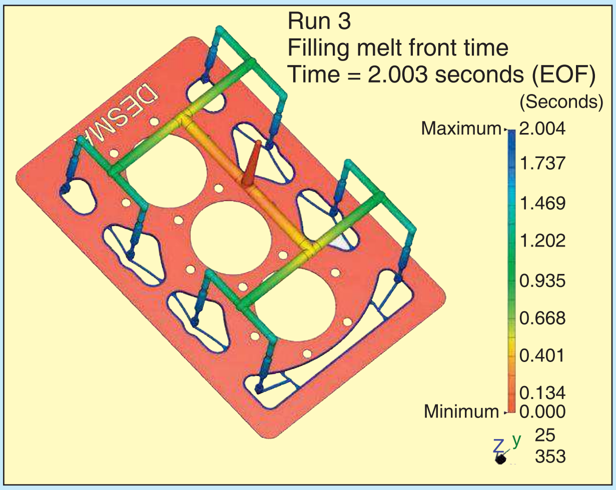
material from the injection unit to its final position in the cavity (figure 3). This information also helps to analyze the proper gate location to provide mold balance. It allows the engineer to visualize where possible flow lines and air traps could occur. The SmartFlow program performs multiple tests to estimate where possible air entrapment or knit lines will occur. The SmartFlow results also calculate the temperature and pressure distribution of the material during the injection phase, shear stress caused during the injection process, velocity, volumetric shrinkage and flow front temperature. Another interesting test performed by the SmartFlow is the particle tracer analysis that shows the position of each particle as it enters the runner until its final position in the article. This estimates how far the material must flow until its final fill point and the location.

After the calculation period is over, a SmartFlow report is generated that is used by Desma engineers to analyze whether or not the process parameters and mold details (such as parting line location, gate types, vent locations and overall expected filling behavior) are sufficient as proposed. SmartFlow software is used as an aid to or can entirely replace the prototyping phase tool development project. Just like in physical prototyping, SmartFlow data might lead designers to adjust gate location, size, vent techniques and/or suggest process setting changes. The SmartFlow analysis tool allows Desma engineers to construct molds for optimal productivity.

Recently, a SmartFlow analysis was performed on a multiple cavity, multiple deck mold intended to produce engine gasket seals (figure 4). In this analysis, Desma engineers focused on runner systems and gate sizes related to optimal balance and filling. Utilizing the SmartFlow test results, the original gates and runners were adjusted. To validate the findings and during the acceptance runoffs, short shots were completed to verify the accuracy of the analysis. Desma found the parts filled almost exactly in real life as per the SmartFlow simulation.

The SmartFlow simulation reduced the manual trial and error process typically needed to adjust the tool geometry. Simulating the molding process before creating a prototype or production mold is a huge cost savings. SmartFlow simulation allows engineers to test different gating locations for optimal solutions.

Figure 4 - gasket seal with multiple injection points



In traditional mold design methods, if initial gate or vent locations do not produce an acceptable part, tool modification is required. In this case, the mold must be removed from the injection molding machine and transported to the mold maker. A revised design must be created, including machining modifications. Depending on the scope of the changes, this process can take several weeks.

In this example, SmartFlow allowed the completion of the mold in an overall shorter time period, plus reduced the effort spent by the customer optimizing the tool on their production floor. This is because one of the targets of the SmartFlow was to determine process parameters such as mold temperatures, injection unit temperatures, injection speed and pressures, and cure time. Data from the SmartFlow simulation verified these critical parameters at very early stages of the project. This information was also used by the customer's operational teams to better determine production costs based on realistic cycle times.

This article lists several benefits of SmartFlow, such as verification of mold gates, determination of vent locations, early detection of molded defects and the determination of injection molding parameters. In some cases, SmartFlow may eliminate the need for a prototype mold; but in other instances a prototype program is required. If, for example, automation is considered, the SmartFlow cannot determine whether or not automation grippers can pick the part out of the mold, simulate adhesion testing or substitute for pre-production test parts.

Desma invested heavily in SmartFlow by training engineers in the USA, India, China and Germany to conduct simulations that produce actionable test results. Desma molds are capable of contributing to system safe molding processes. SmartFlow is another tool used to enhance Desma's products. The SmartFlow polymer characterization library, injection unit data used in the analyses and extensive knowledge of the entire elastomer molding process ensure SmartFlow results provide value for customers. SmartFlow analyses can be applied to hot runner, cold runner, cold or hot ITM pot, FlowControl cold runner, E-Drive cold runner or ZeroWaste ITM pot applications.