Tight Tolerances, Short Development Times

Sigmasoft Virtual Molding Puts Decision-Making for Mold and Process Design on a Sound Footing

Why get caught up in a never-ending cycle of corrective measures when simulating injection molding long before production commences represents a more reliable approach to mold and process design? A virtual injection molding process which has been on the market for the last year and has now passed the first proving trials with converters provides that footing.

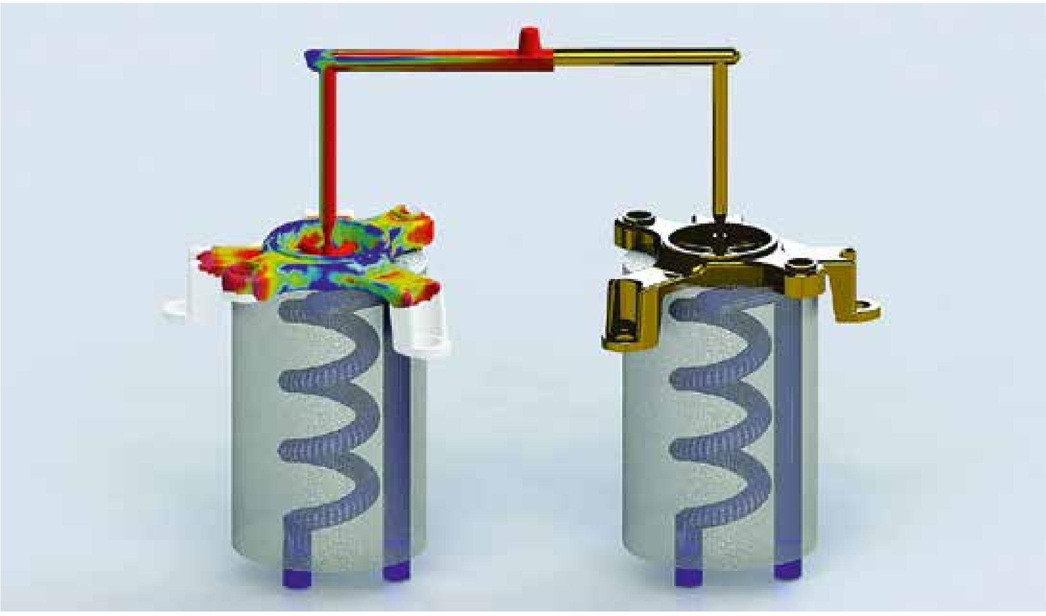

Fig. 1. Motor mounting part made from a glass fiber-reinforced (30 %) PA66. The fiber orientation is simulated (figure: Kalypso Ultra Technologies and Sigma Engineering)

Like other industries, injection molding is coming under increasing pressure to deliver results faster. Scarcely any time is now available for iterative work – molds must function perfectly from the get-go. Not only that, since parts are growing in complexity at the same time, experience is proving to be of limited benefit. Gaining a thorough understanding of how the various mold components interact is therefore all the more important. The same goes for questions about how best to configure the cooling system, what is the right mold material for specific applications, and how reliably can the molded parts be ejected.

The answers to these very questions are provided by Sigmasoft Virtual Molding (supplier: Sigma Engineering GmbH, Aachen, Germany), a software program that acts as a virtual injection molding machine. Nowadays, it is possible to extensively test a mold's configuration on the computer before the mold itself is made. There is no longer any need to await the results of first trial-and-error experiments aimed at uncovering and correcting problems. This gives converters the confidence to undertake new projects, while deepening their process understanding and building up new skills at the same time.

Advance Evaluation of the Processing Concept

Sigmasoft Virtual Molding was launched onto the market at the K 2013 plastics show. It plugs all the data on the mold and the molding compound into a computer simulation that replicates the rheological and thermal processes occurring in the injection molding process for several production cycles. As it also takes account of the physical properties of all system components, it affords a way of evaluating the performance of a given processing concept in advance. »

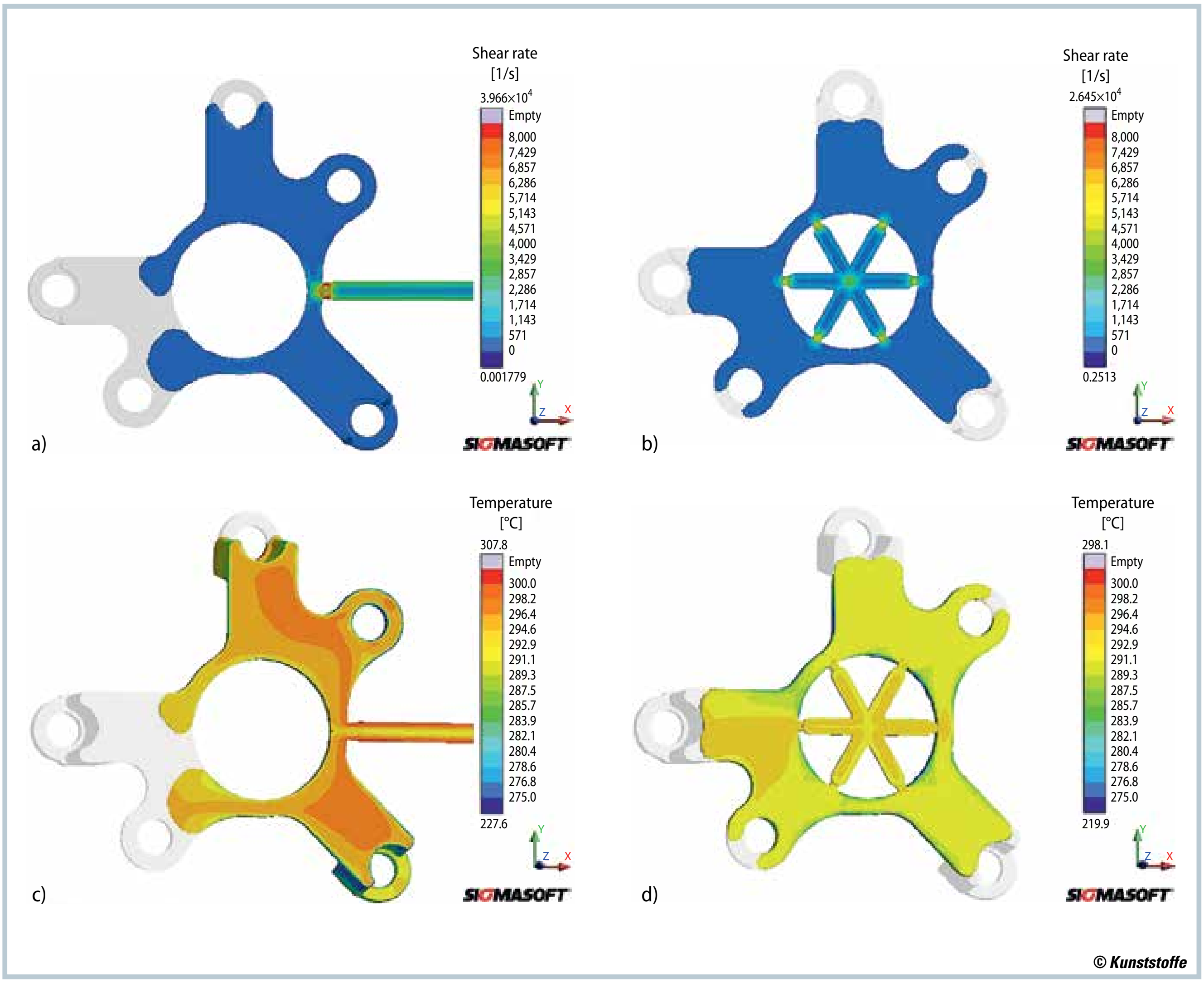

Fig. 2. Shear rate and melt temperature in a side-gate (a and c) are significantly greater than in a star-shaped gate (b and d) (figures: Sigma Engineering)

The traditional approach is to decide on the concept for the part and the mold, drawing on experience and possibly availing of mold-filling simulations. The mold is then fabricated and machine-tested. This usually marks the start of an iterative process for sizing the gate and finalizing the process parameters, as well as eradicating any manufacturing flaws. Although this process can take several weeks, pressure to start production is often the factor determining which process window should be used. That process window is often far away from the mold's optimal operating point, though.

Sigmasoft Virtual Molding adopts the exact opposite approach: performing the iterative process at the start of the design process and before the mold is made. Nowadays, simulations can be performed so quickly that the design and production conditions for a complete mold can be determined in just two to four days, during which time the relationships can be understood and the correct processing point for a part identified.

Early adopters of this virtual technology report that this has given them a "new understanding" of the injection molding process. This understanding inspires confidence in toolmakers and converters by providing a sound basis for their decision-making that will simplify and speed up the design of future molds.

Virtual Injection Molding as a Core Technology

Kalypso Ultra Technologies Inc., based in Ottawa, Ohio, USA, specializes both in product and mold development and in the use of DMLS (direct metal laser sintering) and additive manufacturing to optimize thermoplastic applications and specialist processes, such as LSR, metal and micro-injection molding. This leads to enhanced design flexibility, particularly in the integration of conformal cooling concepts. What sets Kalypso apart is its integrated approach, consisting in the use of photorealistic models, 3-D-printed part designs and informative "full motion" simulations to perform detail modeling and to provide advance insights into the entire process. It summarizes these results on information sheets for use by process setup. The converter can thus be confident that parts will be made flawlessly, regardless of product complexity.

Shawn Schnee, Managing Director of Kalypso, is a plastics engineer with more than 20 years' experience in the industry. After several unsuccessful attempts, he was about to give up on injection molding simulations and revert to trial and error. However, he reconsidered when he

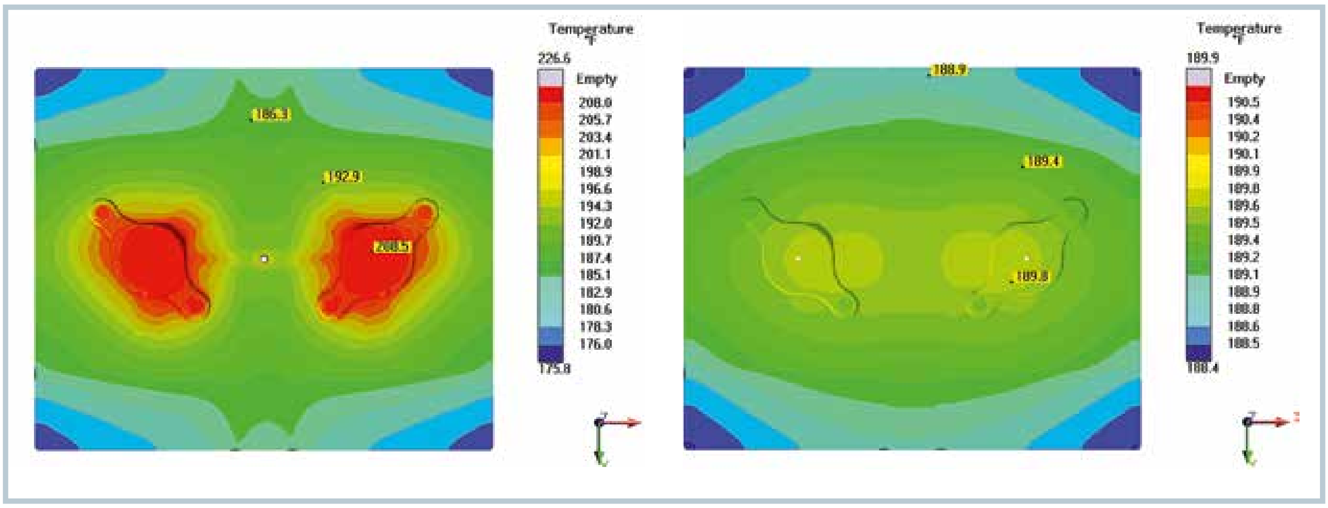

Fig. 3. Mold wall temperature: Cooling using a bubbler leads to hot spots (left) (see Figure 4) which can be eliminated by conformal cooling (right)

(figures: Sigma Engineering)

learned of Sigmasoft's Virtual Molding technology, and decided to give computer-assisted analysis another chance.

Today, Kalypso deploys virtual injection molding as a core technology because it is capable of accurately simulating the various relations existing between the key factors involved in injection molding. The entire process is reproduced over several cycles, allowing the performance of the proposed mold parts to be analyzed in a production window – much as if the machine itself had been used, but without the outlay entailed in making the actual mold.

Kalypso uses Sigmasoft Virtual Molding to design and coordinate the various parts of new molds. The company's specialists plug in all the physical properties, material properties and process interactions, so that they can analyze the relationships between the cooling circuits, hot runner system and thermocouples in advance. Schnee says that to neglect any one of these critical variables is to run the risk of costly mistakes and weaken the accuracy of the computer-assisted analysis.

Choosing the Right Gate

In one of its projects, Kalypso was faced with making a motor mounting part from PA66 with 30% glass fiber reinforcement (**Fig. 1**). The part had critical dimensions in all five mounting holes as well as uneven variations in wall thickness. As a semi-crystalline fiber-reinforced material was being used, it was crucial to gain an understanding of how the mold and process design would influence fiber orientation and shrinkage (particularly with regard to post-crystallization). In this case, prior experience with similar shapes was of little benefit.

First, the designers used Sigmasoft Virtual Molding to optimize the gate concept (**Fig. 2**). The simplest solution envisaged an injection point on the part side, using a simple bubbler in the core center. This variant generates a large pressure gradient in the part, with the areas filled first cooling at a higher pressure than those filled last. As the freezing temperature rises with increase in pressure, the thermally induced stresses in this case varied along the part too, creating uneven shrinkage.

This insight came from a simulation that took 15 minutes to run. "Without the virtual analysis, several iterations and expensive mold modifications would have been needed," explains Shawn Schnee. A second variant based on a star-shaped gate was investigated. This new gate geometry yielded uniform pressure distribution within the part.

Thermal Design: When Is a Conformal Cooling worth It?

It was then decided to study the maximum shear at both gates, with a view to boosting the efficiency of the production process. The results clearly show that a single injection point induces greater shear at the gate (**Fig. 2a**) and causes the melt temperature to rise (**Fig. 2c**). The rise in melt temperature prolongs the cycle time on one hand, because it increases the temperature difference between the melt and the mold wall and, on the other, causes uneven distribution of the thermally induced stresses – with unwanted consequences for shrinkage. Greater shear also has the effect of damaging the glass fibers, thus impairing the resulting mechanical properties. The star configuration supports a wider process window for the injection profile because the shear rate at the gate is approx. 50% lower (**Fig. 2b**). There is also less shear heating, and the overall temperature distribution is more uniform (**Fig. 2d**). »

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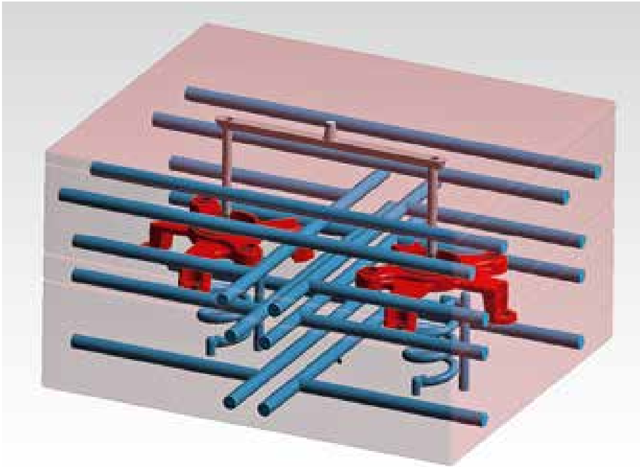

Fig. 4. Layout of the new cooling concept with conformal cooling in the cores. Due to the shorter cycle time, the higher mold costs are amortized very quickly (figure: Sigma Engineering)

The detailed analysis of the filling-phase interactions having been completed, the thermal response of the mold during the holding and cooling phases was investigated. This entailed conducting a multi-cycle analysis of 20 consecutive virtual production cycles.

A mold with two cavities was scheduled for this. These were originally to be filled via a bubbler in the core center. However, the simulation revealed a marked temperature gradient in the cavities, as well as hot spots in the mold (**Fig. 3, left**). While that was foreseeable, the temperature differences were unexpectedly high. One effect of this would be to substantially lengthen the cycle time. Another would be to make the temperature gradient steeper with each production cycle. Not only that, but part quality would suffer due to the thermally induced stresses.

A concept with conformal core cooling was analyzed by way of alternative (**Fig. 4**). Not only have the hot spots been eliminated, the temperature distribution on the cavity surface is extremely uniform (**Fig. 3, right**). As a result, the cycle time is much shorter than in the original concept. The accompanying higher productivity covered the extra cost of a mold core fitted with spiral cooling. The only justification for using a system that costs more to produce in terms of technology and finance would be better economics. The integrated approach employed by Sigmasoft Virtual Molding lends itself to determining these economics.

Having completed several projects successfully, CEO Schnee was so convinced by the targeted approach of Virtual Molding that he has integrated it into the development department of his company. In his words, it allows the user to “keep an eye on the bigger picture.” ■