Getting Warpage under Control

With Sigmasoft Virtual Molding, F. & G. Hachtel Manufactures Accurate Parts from the First Shot

"Think of it like this: the clip is bent when it leaves the machine, and you can see it straightening as it cools", states Georg Schlöser. "And that is how we calculated it", he adds satisfied, since he analyzed the required shrinkage allowance with Sigmasoft, so that the mold could deliver dimensionally true parts from the first shot.

Georg Schlöser is responsible for simulation and process development at F. & G. Hachtel GmbH & Co. KG. The family-owned company is not only an injection molder with its own tool shop, but its engineering department also supports customers throughout part and mold development, for all the steps from the first idea down to the processing and analysis. The company's aspiration is no less than to build molds that work straight away, and thereby instantly produce dimensionally true components.

To support this goal, the company offers a solid foundation of experience achieved by over 600 built molds of all possible types. At the same time, Hachtel applies state-of-the-art technologies. There are good reasons why the company's mission statement is "we understand technology". To achieve the ambitious production goals, employees must first understand all the processes relevant to part production, and be able to optimize them. This is made possible through process simulation: it allows the production process to be realistically modelled and a profound process understanding to be gained at the design stage. The necessary measures to achieve process optimization can therefore be taken at an early stage.

The value of this approach is tested at the end of the development process with non-destructive validation of the parts by means of computer tomography (CT). On the five machines that the company now owns, the specialists gain a true insight. This is paying off.

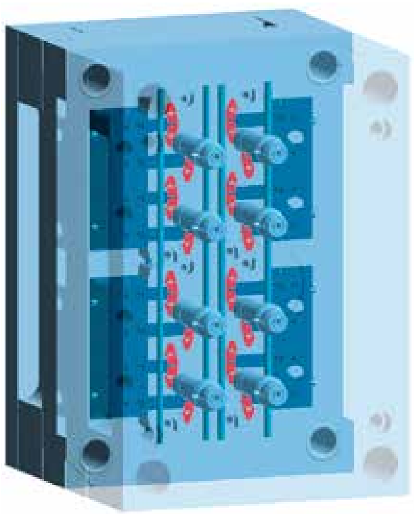

Fig. 2. The hot runner manifold and the slides influence the mold cooling and must therefore be considered in the simulation (© Sigma Engineering)

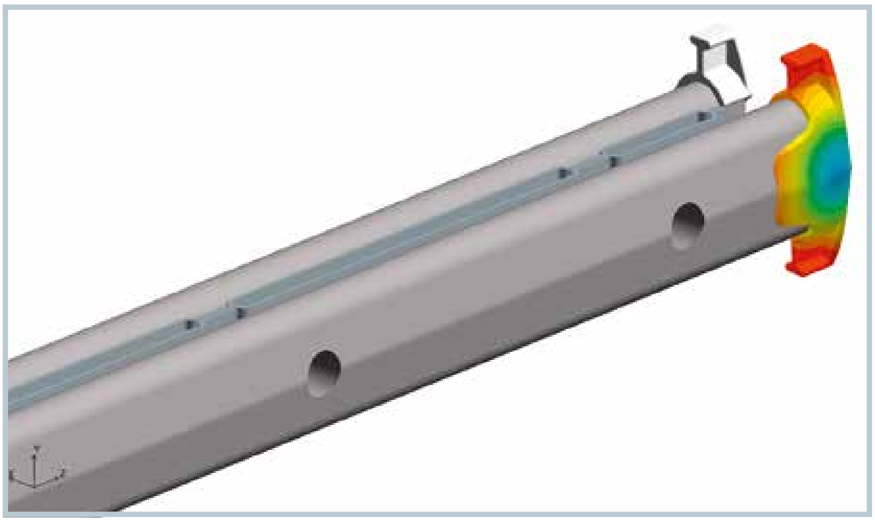

Fig. 1. The clip fixes a basket on a slide. For assembly, dimensional accuracy is imperative (© Sigma Engineering)

Warpage Is to Be Expected

For example, during the production of the clip (**Fig. 1**), which fixes a basket on a guide rail. To ensure problem-free assembly, the dimensions have to be kept within strict tolerances. The clips are to be produced from a talc-filled polypropylene with high rigidity and dimensional stability in a 16-cavity hot runner mold. The required core slides complicate the mold cooling (**Fig. 2**). The geometry of the part, however, gives reason to expect a significant warpage. If time-consuming iterations of the mold and trial-and-error during start-up are to be avoided, it is necessary to use a simulation tool, to realistically reproduce the injection molding process and to optimize the mold even before the tooling.

Hachtel decided in favor of Sigmasoft Virtual Molding. And for a good reason: the Sigmasoft simulation software considers not only the part geometry, but also each of the mold components and the complete production cycle, including all non-productive times. "For us, Virtual Molding does not just mean simulating mold filling, since simplified modeling of the mold is usually not enough to predict the temperature distribution within the part and the resulting warpage", explains Timo Gebauer, Chief Technical Officer of Sigma Engineering GmbH. "This is why we calculate temperatures in the complete mold. In the analysis, we include all process steps that have an influence on the heat balance in the mold and therefore affect the part temperature. This is done over a time frame of several production cycles, which also consider the heat up stage or process interruptions".

To determine the temperature distribution in the mold as accurately as possible, the flow of the heat-exchange medium in the cooling channels can additionally be computed, since the local heat removal depends on the flow behavior in the channel and on its geometry. In complex cooling systems this has a significant effect on the mold temperatures, which should be taken into account.

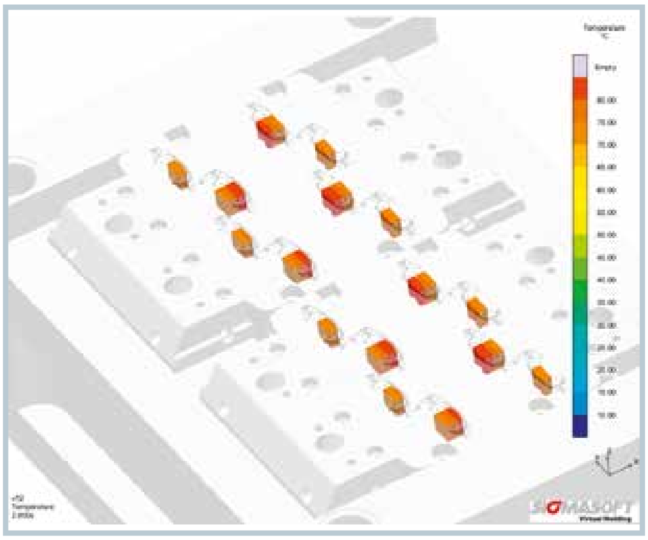

Fig. 3. Hotspots form in the slide cores with temperatures over 70 °C (© Sigma Engineering)

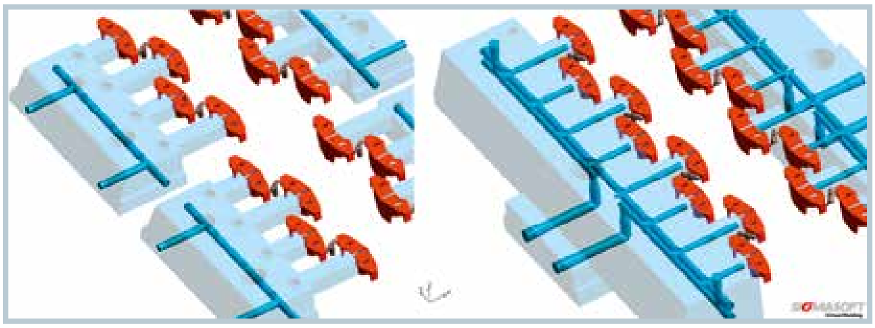

Fig. 4. Comparison of cooling concepts: Left the originally planned slides and cooling channels, right the optimized design with bubblers (© Sigma Engineering)

Mold Hotspots Are Not Identified in Filling Simulation

For the clip this means in practice that both the 60-minute heat-up and the warming up of the mold over several cycles were simulated. Because only when the mold has reached thermal equilibrium the boundary conditions for virtual production are exactly the same as those found on the machine during series production. During settling to equilibrium, the opening and closing of the mold, movement of the sliding cores and heat loss through the parting line are reproduced realistically. The hot runner manifold is also fully taken into account, as it introduces a significant amount of heat into the mold.

On this basis, the filling process, i.e. the propagation of the flow front in the cavity, is calculated in detail during the last simulated cycle. This calculation therefore relies on a realistic distribution of local mold temperatures and not on the assumption of a homogeneous temperature in the cavity. This analysis demonstrated that the planned mold cooling was not sufficient. The cores heated up from cycle to cycle, so that the local temperatures reached values of over 70 °C, while the set temperature was 20 °C (**Fig. 3**).

It is clear that such mold hotspots negatively affect the cycle times. And it is also clear that these weak spots in the cooling could not be found with a simple filling simulation. On the basis of the results of this first simulation the cooling concept was optimized. The two cores at one side were grouped together and it was then possible to cool them more intensively by means of bubblers (**Fig. 4**). In this way, it is possible to achieve a far »

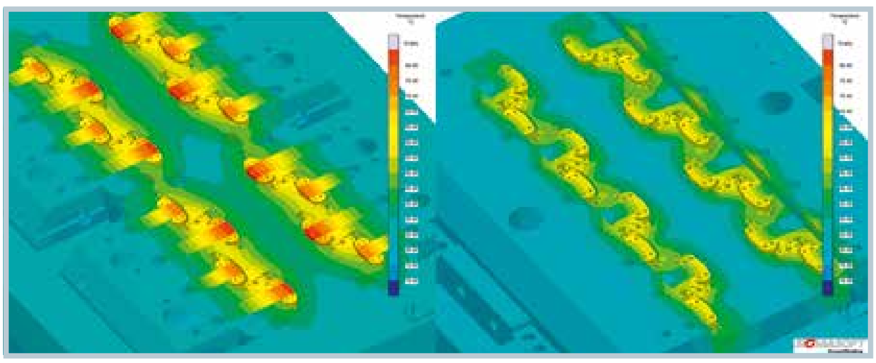

Fig. 5. Comparison of temperature distributions: Left the original concept with conspicuous hotspots on the slide cores, right the homogeneous temperature in the optimized design (© Sigma Engineering)

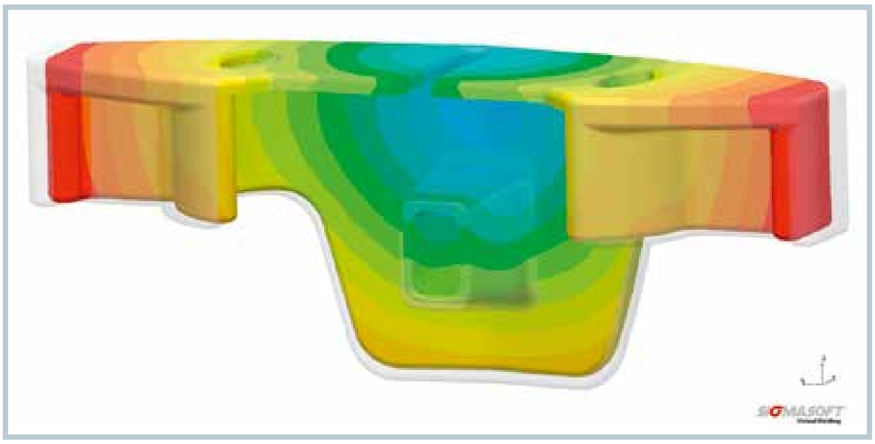

Fig. 6. The part geometry tends to undergo warpage (non-warped geometry shown transparent). Sigmasoft allows this problem to be mastered (© Sigma Engineering)

more homogeneous mold temperature distribution (**Fig. 5**). Temperatures are now consistently below 58 °C. With the new cooling concept it is possible to shorten the cycle time significantly. But not only this: it also improves the dimensional accuracy of the part.

Reliably Calculating the Necessary Shrinkage Allowance

With Sigmasoft it is possible to calculate the part warpage (**Fig. 6**), and again the principle of virtual injection molding pays off: in the calculation of the local material shrinkage, the realistic temperature distribution in the mold and the cooling history of the part are considered. The warpage simulation covers both the constrained cooling in the mold cavity, as well as the free cooling after the part is ejected.

One can learn from this "cooling history". For example, the fact that it is necessary to produce a bent clip, so that the clip has the required dimensions after cooling is finished. "We can work with the result," says Georg Schlöser. "For the clip we determined the necessary shrinkage allowance for the mold using the warpage simulation. This way we manufactured parts with the required quality right from the first shot". The final CT analysis of the first parts confirmed the simulation. Consequently, Hachtel saved expensive and time-consuming iterations to adjust the cavity geometry.

Summary

The virtual modeling of the injection molding process with Sigmasoft Virtual Molding provides realistic temperatures in the part and mold. Based on these results it is possible to reliably predict the part deformation. The test rig is therefore transferred to the desktop. This helps in all stages of the part and process development to avoid mistakes and to save resources, because iterations can be performed within a matter of hours on the computer. With this approach, Hachtel was able to produce an optimized mold for the clip, in which dimensionally accurate parts were produced under an optimized cycle time from the first shot. ■

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