54   INJECTION MOLDING   **Simulation**

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Systematic Approach to a Precision Polymer Gear Wheel

Optimizing a Tricky Component Geometry Using Sigmasoft Virtual Molding

A great deal has already been reported about the use of Virtual Molding software to plan and analyze injection molding processes from start to finish. However, many people are unaware that this tool can be used to optimize functionality at the design stage. MS-Schramberg, a company specialized in magnets, has a track-record of developing precision polymer parts for the automotive industry. The following practical example of a gear wheel demonstrates how the efficiency of component optimization can be boosted through the use of simulation.
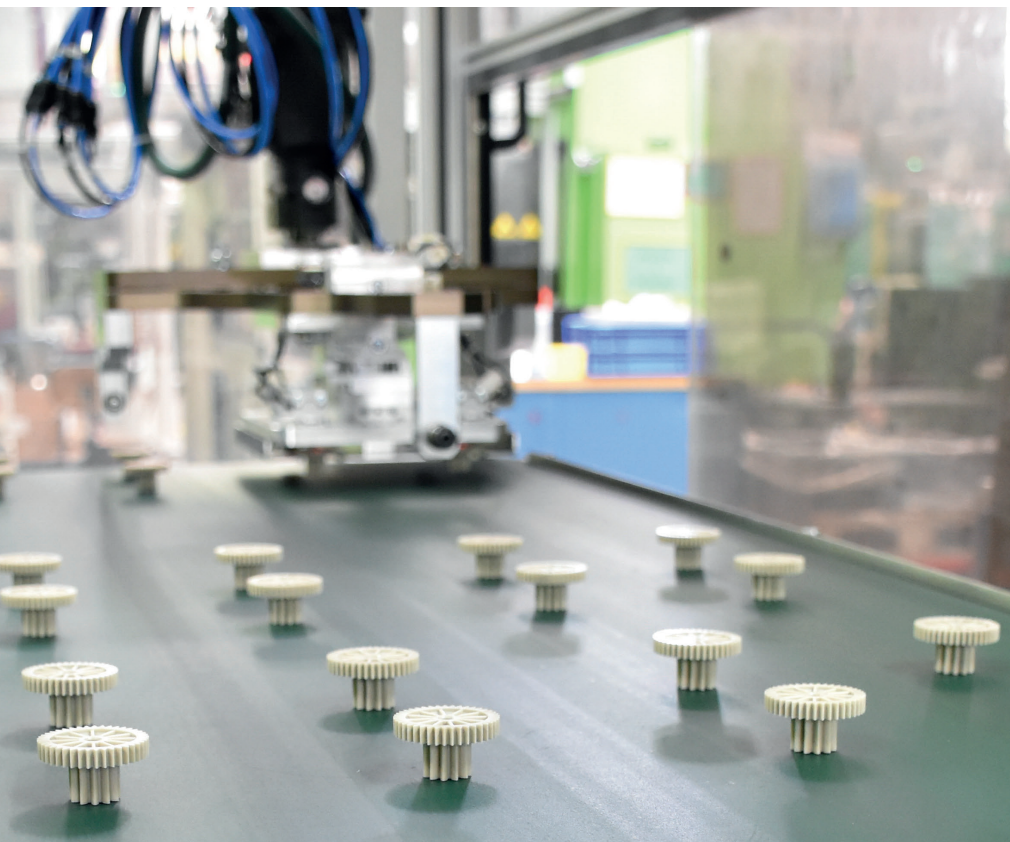
After component optimization, the gear wheel lay within the desired tolerance as soon as it went into series production © MS-Schramberg

The customer not only specified the geometry of the component by a 3D model but also the polymer to be used, namely a polyphenylene sulfide reinforced with 40 % glass fibers (PPS-GF40). More particularly, the component has a diameter of around 30 mm and weighs about 5 g. In the real world of injection molding production, deformation resulting from material buildup, fiber anisotropy and shrinkage poses a risk to the functionality of this gear wheel. A gear wheel that undergoes just radial deformation can be allowed for or corrected relatively easy in the injection mold. However, one that is deformed both radially and axially, as expected in this example (**Fig. 1**), is difficult to correct in practice and therefore requires careful advance planning.

The goal of this project was therefore to optimize the component geometry – reducing axial gear wheel deformation – even before the injection mold had been made. This was done with the aid of Sigmasoft Virtual Molding software (supplier: Sigma Engineering GmbH, Aachen, Germany). The model was imported into the software, the corresponding negative cavity was created, filled with the designated polymer through manually defined sprue points under application of selected parameters (filling time, temperature, etc.) and then cooled.

Geometry Optimization Necessary

This highly simplified approach proceeds from a constant cavity wall temperature. The complete mold, with its various plates and circuits for heating and cooling, are only considered at a later stage. As a result, the high outlay on modeling and simulation is reduced and hundreds of scenarios can be simulated within very short time.

Axial deformation of the teeth was minimized by designing a full-factorial virtual test plan designed to evaluate the geometric variation possibilities within the legitimate design space:
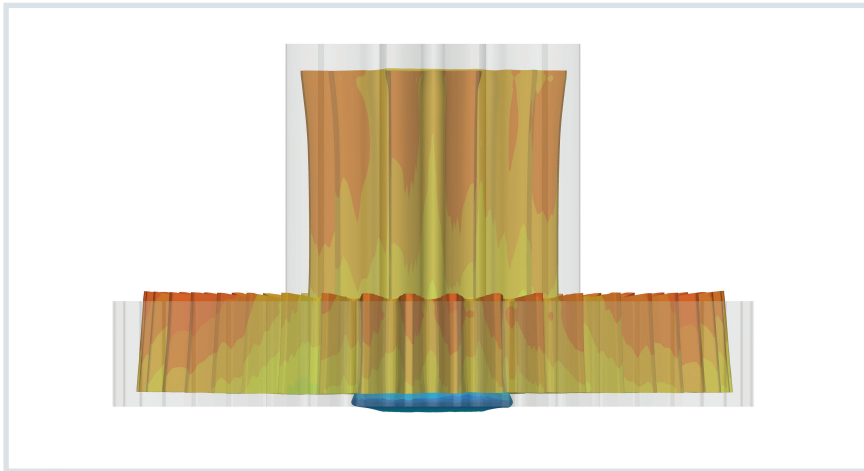
Fig. 1. The expected axial and radial deformation calls for careful component design (5:1 scaling)
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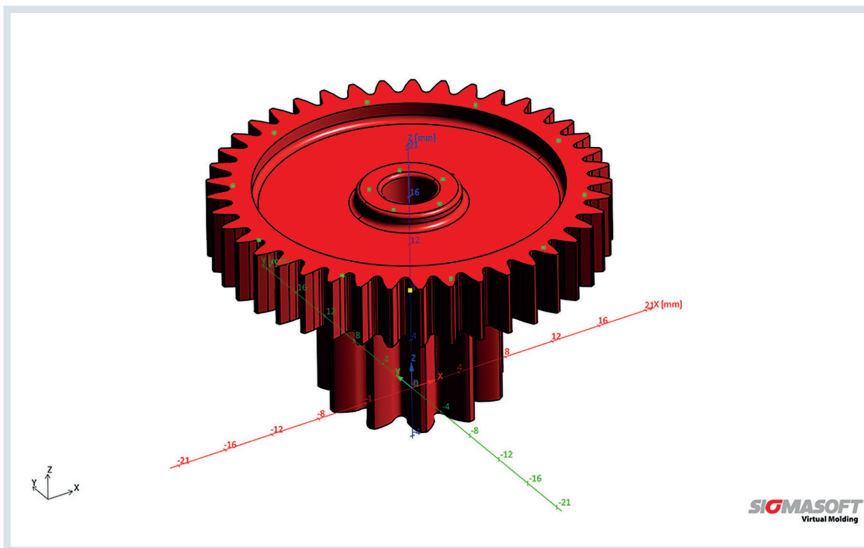
Fig. 2. The target criterion of the first optimization loop was a small deviation in the measuring points in the surface © MS-Schramberg

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Service

- six ribs on the bottom,
- six ribs on the top,
- clearance at the bearing seat,
- radius at the toothing.

Each of these four geometric changes was defined as an activatable input parameter for the optimization process, giving rise to 2^4 or 16 possible designs.

First Optimization Loop: What are the Major Influences?

Concrete implementation: in order that the axial deformation of the larger toothing could be determined, measuring points were defined on the toothing and the central running surface (**Fig. 2**). It was decided that the target criterion representing the optimum solution would be to minimize delta between the axial de-

formation of the outer and inner reference points as that would yield toothing of good flatness.

It emerged that ribs on the large surface and the radius on the toothing base offer the greatest potential for improvement. This still left plenty of room for optimization, especially regarding rib design, as so many variables are involved. So, a second optimization loop was then performed to determine the best rib design.

Refining the Result in the Second Step

Again, the aim here was to minimize the axial deformation of the toothing. In addition, for economy, the volume was designed to be as low as possible. The following were varied: »

Fig. 3. Plot of delta Z for the 245 variants against the experiment number (number of ribs increasing to the right) © MS-Schramberg

- the number of ribs: between six and twelve, in increments of 1;
- the height of the ribs: between 0.6 and 1.2 mm, in increments of 0.1 mm, and
- the width of the ribs: between 0.8 and 1.2 mm, in increments of 0.1 mm.

These 7 x 7 x 5 or 245 experiments, too, were subject of a fully automated Sigmasoft DoE (Design of Experiments) simulation. This was done by defining the variables and their values in terms of the respective increments. The entire simulation and evaluation were executed by the system overnight.
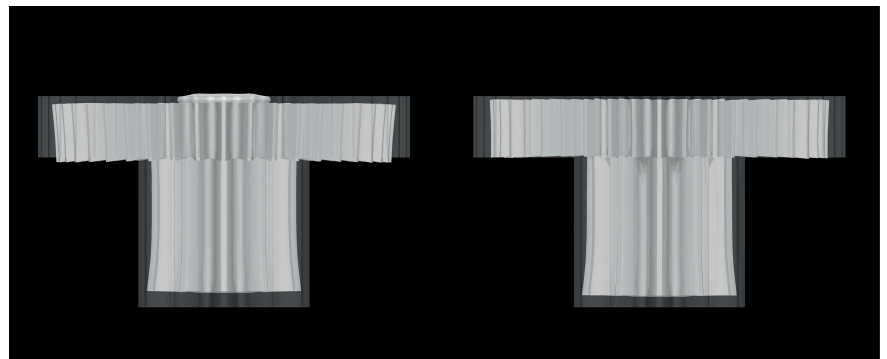
The outcome of the optimization was an enormous improvement – delta Z dropped by about 90% from 0.19 to 0.02 (**Fig. 3**). As expected, the solutions offering the greatest optimization potential were those which had the most ribs (twelve). These results were presented to the customer (**Fig. 4**). After approval had been given, the geometry was updated and the production mold was ordered.

How Many Sprues Are Needed?

Drawing on positive experience gained by MS-Schramberg in previous similar projects, all the simulations were executed with three sprues on the top. Here, of course, the positive aspect of more homogeneous fiber distribution and shrinkage had to be weighed against the higher mold costs and the cost of material losses. But, again, the simulation is expected to quickly yield an accurate answer. Fiber distribution is determined by the number of sprues (**Fig. 5**). In each case, differences in

the extent of filling lead to differences in shrinkage and warpage. This allows an accurate prediction to be made for each tooth on the circumference.

The simulated axial deformation on the large gear wheel already lay within the target range when three gates were used, with four and five gates offering marginal improvements. For reasons of symmetry, five sprues would of course have been unsuitable for twelve ribs – in

this phase, the simulation was executed without ribs (**Fig. 6**). The next stage was to weigh the necessary functionality and economy against the desired and feasible degree of precision. In the end, the series was realized with three sprues, and was accompanied by a corresponding reduction in material consumption.

Just the Tip of the Iceberg

The case presented here is just one, often forgotten, way of using Sigmasoft software in component and process design. This simulation tool is successfully used, for example, in

- the inquiry phase to rapidly determine cooling times, pressure requirements or to identify critical hotspots early;
- component optimization, as in the case described above;
- mold design to resolve issues with flow paths, thermal layout and sprue positions;
- studies of the behavior of the molded part (weld lines, flaws, fiber orientation, shrinkage and warpage);
- process simulation – here the entire mold is operated over an arbitrary number of cycles. This grants a way of evaluating process capability and sta-

Fig. 4. Deformation of the customer model versus that of the optimized geometry, with 5:1 scaling. The greatest improvement was obtained with the model having the most ribs © MS-Schramberg
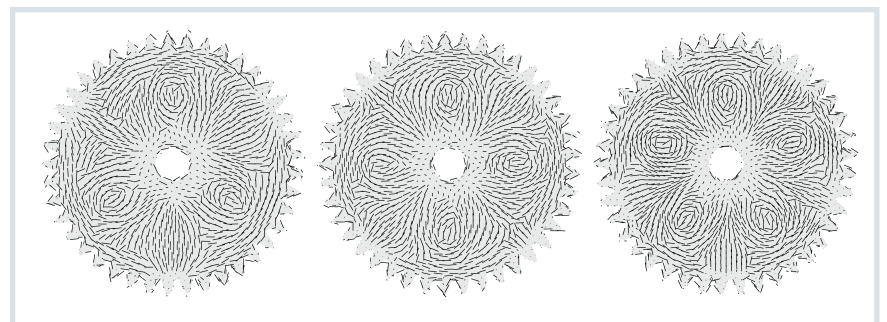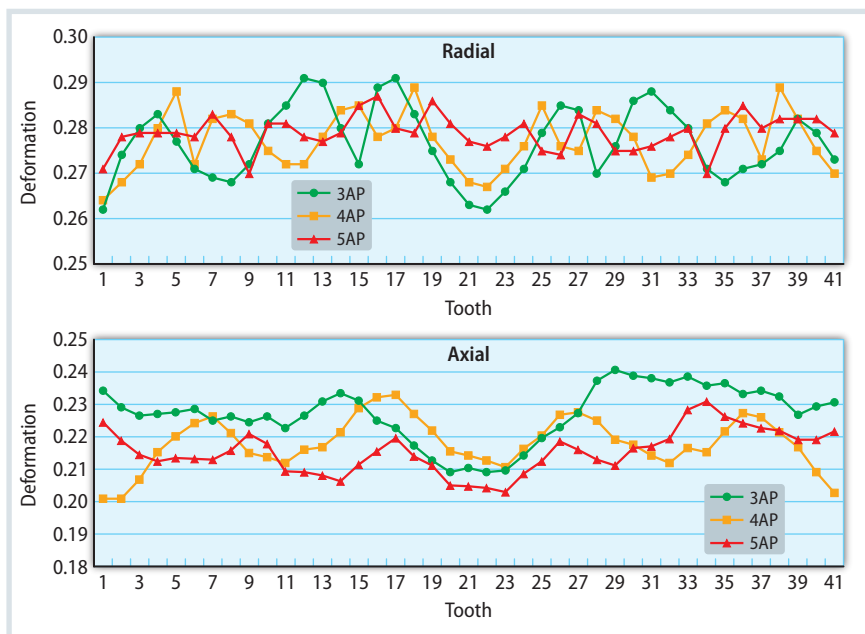

Fig. 5. Average fiber distribution for three, four and five sprues. This gives rise to different degrees of shrinkage and warpage © MS-Schramberg

Fig. 6. Visualization of radial and axial deformation per tooth on the large gear wheel with three to five sprues   Source: MS-Schramberg; graphic: © Hanser

Conclusion

The possibility of activating and parameter-izing individual geometry elements allow-ed a large number of geometric influences to be studied without a great deal of mo-deling effort. The two optimization loops led to a 10-fold reduction in axial de-formation of the large gear wheel. The influence exerted on efficiency by the number of gates was accurately deter-mined.

The simulations executed with Sig-masoft confirmed and extended the high level of development expertise pos-sessed by MS-Schramberg. The docu-mented simulations made a solid con-tribution to constructive discussions be-tween customer and supplier. The gear wheel went into series production with the simulated changes in a three-platen mold (**Title figure**). The optimized quality feature lay within the desired tolerance right from the start.

Although this report merely reveals how to simulate a resilient design with simple tools, Sigmasoft Virtual Molding is then used to design the injection mold and determine the best processing window. Should unexpected problems arise, the tool helps to systematically run through alternative settings, geometry or material changes to quickly arrive at the best solution. ∎

bility under series production condi-tions as early as the design stage.

The DoE method with autonomous opti-mization that was used here is available for each of these stages and offers a way of systematically and precisely studying all kinds of problems.

Sometimes, though, the results of fill-ing simulations are just a first step to-wards a reliable solution. Details relating to anisotropic material structure, fiber orientation or the deformed geometry after cooling, as determined with Sig-masoft, can be transferred to other FEA tools for a rigidity analysis, crash simu-lation or a service life simulation via the existing Sigmalink interface. This allows to determine the limits of a design with even greater precision in a follow-on analysis.

**Sorting Solution for Bottle-to-Bottle and Food Applications**

4-in-1 Sorter for PET Recyclers

With the Sortex A GlowVision sorting sol-ution, Switzerland-based **Bühler AG** intro-duces a 4-in-1 optical sorting solution that can be used for simultaneous color, polymer, foreign material and loose-label sorting.

In response to growing demand, the Sortex A GlowVision also offers a simul-taneous re-sort function, which delivers the highest ever reject concentration – according to the company, up to 40 % when the re-sort channel is deployed. The Sortex A GlowVision is available in three to five chute models on a five-module frame and features a custom-built inspection system designed spe-cifically for PET sorting.

Bühler expects great interest from PET processors who want to reduce con-tamination levels on key color and polymer defects. Thanks to its unique double-sided camera viewing technol-ogy, the Sortex A GlowVision provides good results, performing on a broad range of defects typically found in PET streams.

As as stated in a press release, the system deals effectively with opaque, white, and transparent colored flakes, as well as on polymer defects including polyvinyl chloride (PVC), polycarbonate (PC), polystyrene (PS) and polyamide (PA), not to mention a significant reduc-tion of loose labels.
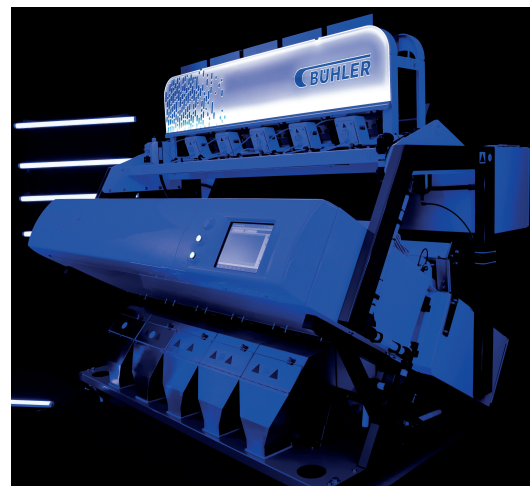
Sortex A Glow Vision is used for optical sorting
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