Cracking Product Development

When Traditional Approaches Meet their Micromechanical Counterparts

In the realm of virtual product development, the idea of the cycle has been around for many years. But where does the cycle begin? When we take a closer look at this concept, new aspects rightly start to emerge. For example, whether it is possible or necessary to augment or expand existing, hitherto proven mechanisms so that goals can be achieved, or perhaps even surpassed – and, if so, how this is to be accomplished.

Driving forces and the potential for further development have become more and more prominent in lightweight construction in recent years. This is due not least to pressure primarily emerging from within the automotive industry to reduce CO_2 emissions. In this connection, injection molding processes and workflows, too, are increasingly becoming the focus of a need for change. On one hand, products are becoming ever more complex and, on the other, questions have been raised about the key elements of the manufacturing process, such as a reduction in the number of production steps, demanding design requirements and high expectations imposed on the product's mechanical properties.

An important role here is also played by plastics foaming (both chemical and physical). The introduction of this technology necessarily entails investments, not only in machinery, but also in infrastructure, product development, staff training and the ensuing restructuring of workflows. The changeover to this process can therefore be viewed with a certain amount of ambivalence, especially as history shows that the adapting of components to existing molds designed for compact injection molding has met with very mixed success.

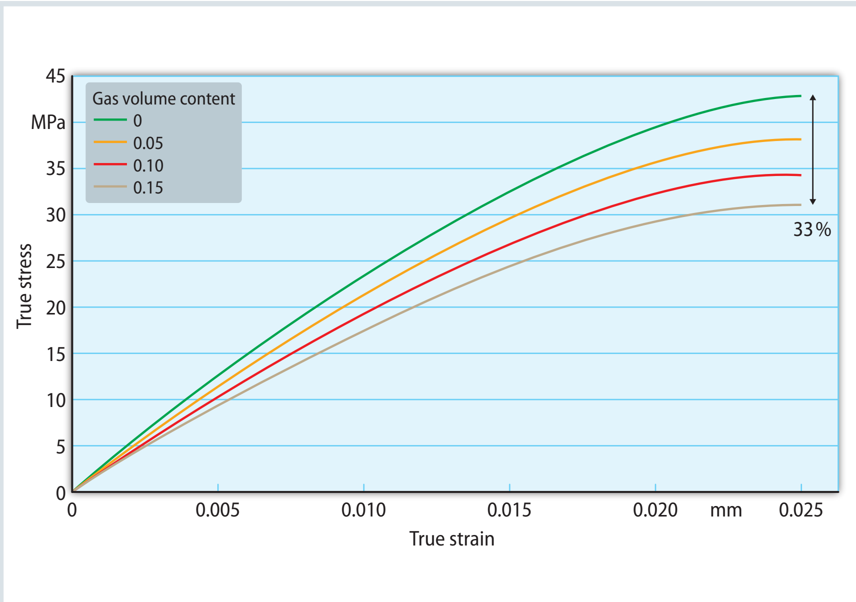

Fig. 1. Stress-strain diagram as a function of microstructure. Shown are three different porosities (5 to 15 %) relative to the compact material Source: SimpaTec; graphic: © Hanser

Separate Development Steps

But, from the development perspective, what is the current situation with regard to foamed components? Up to now, tasks and steps have usually been considered in isolation. Thus, one development step leads straight from the designer to the tool designer, while another leads to a simulations department that simulates mechanics independently of any analysis of the process. The outcome is that simulation of the manufacturing process is usually performed within product design and/or tool design which is then faced with meeting the production challenges. Part of product design, for example, entails revisiting the wall thickness ratios of base bodies and ribs. And in tool design, too, adjustments have to be made, e.g. with regard to the positioning of the gates.

However, product development is also interested in how foamed products behave under mechanical load and how they should be designed. Traditionally, these approaches have been pursued in separate departments – a consequence of their different specializations.

For some years now, foam injection molding has increasingly been the focus of fiber-reinforced plastics processing. The "usual" separate product development steps are encountered here as well. But is this an efficient use of the technology's potential? Or is a rethink needed? And if so, what are the technical and, above all, the temporal and financial implications of these adjustments?

The first step towards answering these questions is to assess the current status. This reveals that the tools needed for effecting an improvement often already exist. The question is not about how to use these tools. Rather, it is more about how the results are evaluated, how they are used and how and to whom they are communicated.

Fig. 2. Panel of a household appliance as an example of successful virtual product development © SimpaTec

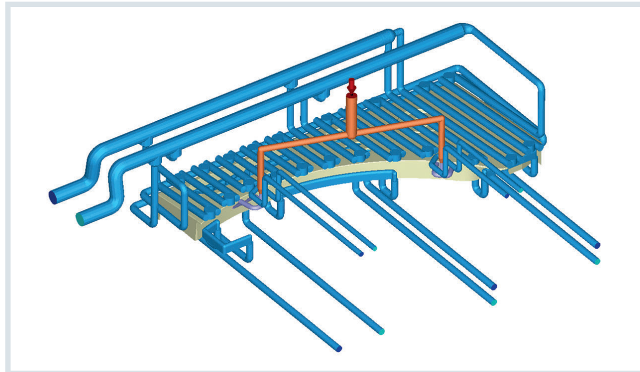

Fig. 3. Result of the process simulation for the temperature control system of the panel © SimpaTec

A fundamental aspect inheres in the usual approach taken to the mechanical design of products. Such an approach usually is based on the assumption that the mechanical properties are the same throughout the component. But this is precisely the crux of the matter, because to do so is to significantly reduce the possibilities of these technologies.

Mechanical Properties as the Crux

What potential is hidden in linking together these working steps – in the unification of two previously distinct components, in the examination of the process and analysis of the mechanical properties, in a cycle aimed at greatly enhancing the substance of virtual product development?

It may sound trite today, but consistency of design data is the firm foundation of all steps. Even today, the use of different CAD programs constitutes one source of challenges. Thus, every CAD kernel (not the CAD program) varies in the consistency of its details, and data import and export can lead to unwanted overlapping of surfaces and to other errors. As it is often the case that the CAD programs used for product design and for tool design are different, this is a common occurrence. However, specialized software is available for the necessary reworking or preparation of the data for simulation.

Process simulation serves as the basic tool for addressing challenges arising from the foaming process, product design, tool design and/or material. By performing calculations, analyses and optimizations, it simulates the entire process, from filling and cooling through to deformation. Common simulation results for foaming include two in particular that can exert a considerable influence on downstream development steps: the distribution of cell sizes and the cell density.

These two results not only allow conclusions to be drawn about "cosmetic" issues. More than that, they also reveal how pronounced the local edge layer is, whether more or fewer streaks can be expected on the surface and how much component deformation can be expected. Furthermore, they clarify process-related questions about the advisability of using variothermal temperature control.

Coupling of Process Simulation, Material Modeling and FEA

The successful coupling of what were previously two distinct components – process simulation and structural mechanics – in a single product development cycle hinges on the following step. For a long time, as already explained, these two methods for manufacturing safety-related products were left out of the equation, because integrated process simulation and mechanical simulation were deemed to be not possible. However, provided that certain aspects are taken into account, precisely this can be done. The description of the resulting cells can be transferred via porosity results obtained from Moldex3D, a process simulation program, to the Digimat software tool for the purpose of material modeling. The local differences in material characteristics arising from this are transmitted to the structural-mechanical simulation module: this is a step of considerable relevance (**Fig. 1**).

This step ensures that the local differences in the states of the material are taken into account and hence that the mechanical properties in the component can be targeted for correction. The geometric adjustments are then verified by running the process simulation again. Optimized process simulation results are repeatedly prepared for export to the mechanics module: the cycle has been closed. This process can be carried out manually, but there is also the option to more or less automate it. One advantage of optimization is that, aside from the »

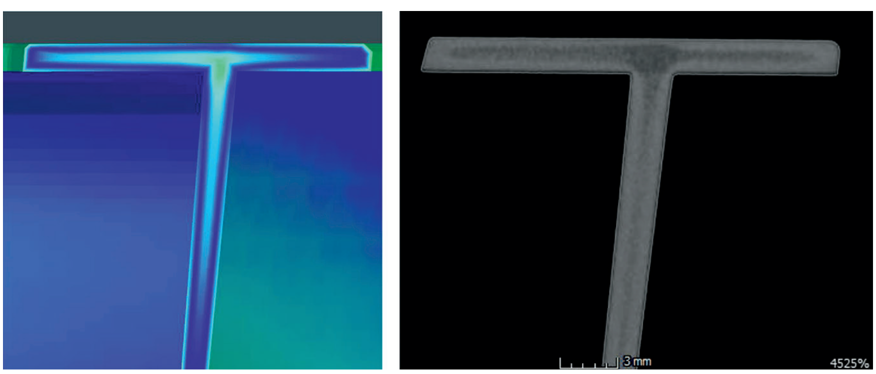

Fig. 4. Simulated cell structure (left) and CT image (right) of a rib: a high degree of matching is evident © SimpaTec

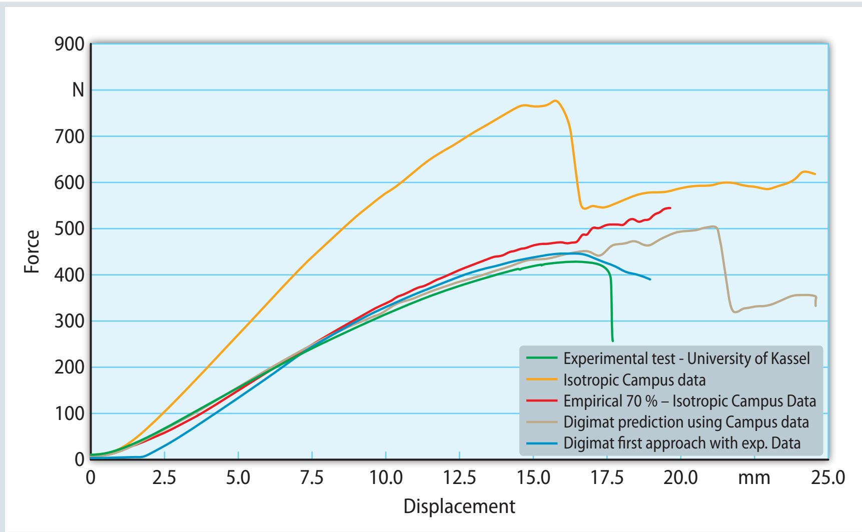

Fig. 5. With the aid of the material cards generated and computed in Digimat, a three-point bending test was simulated in the FEA software, and was also carried out in parallel on the real component Source: SimpaTec; graphic: © Hanser

traditional DoE approach, it also accommodates geometric adjustments, up to and including automatic topology optimization.

The question ultimately arises as to how much of this worth the effort. To explain the advantages in more detail, consider a real component, namely a panel (**Fig. 2**). During the process simulation, the complete temperature control and distribution system was calculated and analyzed, in addition to the component (**Fig. 3**).

Comparison of the simulated cell structure with a CT image shows strong agreement between simulation and reality (**Fig. 4**). The relevant porosity results from the foaming process were then transferred to Digimat. The material maps generated there were used to calculate a three-point bending test within the FEA module. This test was carried out on the real component in parallel.

The resulting force/displacement diagram clearly shows how much the isotropic approaches (shown in yellow) deviate from the real measurement (shown in green) (**Fig. 5**). This applies in part not only to the quantitative curve, but above all to the qualitative aspect of the failure. Moreover, this chart also shows the initial results (in blue) of the integrated simulation, which agree very well with reality.

Optimization runs were also carried out on the panel. The comparison started by assessing compact injection molding against foam injection molding. This led to a 10.1 % lowering of the component's weight. The product design then underwent an optimization step in which the rib structure on the underside of the panel was adjusted to the specified boundary conditions. This step lowered the component weight by a further 5 %. In addition, the optimization of the manufacturing process was integrated into the product development process. The outcome of this holistic approach was ultimately a 25 % weight reduction overall, combined with a 50 % reduction in production-related deformation and a 10 % shorter cycle time.

Conclusion

The holistic, virtual development of a product (**Fig. 6**) illustrates two key aspects. First, simulation employing the methodology shown can yield a holistic view of foamed components. Second, this approach harbors potential – not only with regard to lightweight construction – that is simply waiting to be exploited. ■

The Authors

Cristoph Hinse is Managing Director of SimpaTec GmbH, Aachen, Germany.
Tobias Schäfer, M.Sc., is an R&D Engineer Micromechanics & FEA at SimpaTec, Aachen.

Acknowledgment
The authors would like to thank the following for their support:
- the Institute for Materials Technology at the University of Kassel, Germany
- Ineos Styrolution Europe GmbH,
- F. & G. Hachtel GmbH & Co. KG
- and Volume Graphics.

Service

Digital Version
- A PDF file of the article can be found at *www.kunststoffe-international.com/archive*

German Version
- Read the German version of the article in our magazine *Kunststoffe* or at *www.kunststoffe.de*

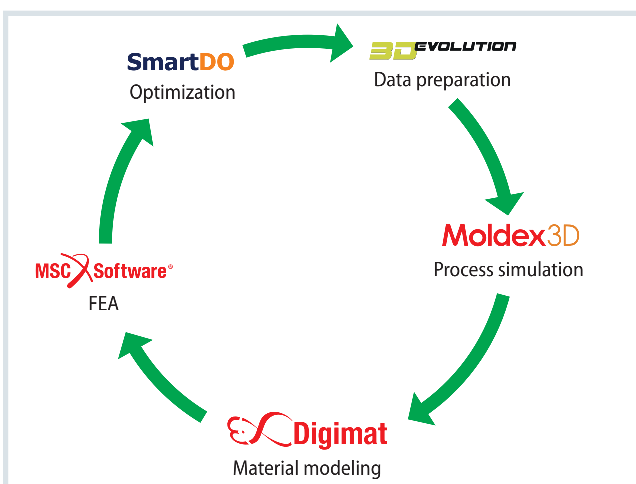

Fig. 6. Holistic product development leads optimization in a cycle Source: SimpaTec; graphic: © Hanser