A Bike Frame from an Injection Molding Machine

Controlling Complex Development and Manufacturing Processes, Using Simulation

The toolmaker Siebenwurst uses injection molding simulation to optimize part design and production processes in its routine workflows. Among other things, Simcon's software ensures the quality and dimensional accuracy of the plastic frame for the first series-produced injection molded e-bike.

The frames give the e-bikes an extraordinary design, with robustness comparable to steel or aluminum © Nuvelos

The small river Altmühl flows peacefully through the valley of the same name in the Bavarian Upper Palatinate. When visitors enter the production hall of the model and mold maker Christian Karl Siebenwurst GmbH & Co KG in Dietfurt, Germany, they quickly leave this tranquility behind. More than 400 engineers and technicians work here, serving the most prestigious OEMs and suppliers to the German automotive industry. Every year, they design and manufacture around 150 injection molds, mainly for instrument panels, window frames, radiator grilles and many other large plastic components. Other clients of this high-tech supplier include manufacturers of household appliances and companies in the field of climate and environmental technology.

The company, which was named Toolmaker of the Year 2018, has recently created the backbone for the first series-produced e-bike: an injection molded plastic frame (**Title figure**). Siebenwurst manufactured the components for the start-up Nuvelos (**see Box p. 27**), a fully owned subsidiary of the automotive supplier Rehau. Apart from their extraordinary design, the bicycles made a name for themselves especially with their composite frame, which performs at on the same level of strength as aluminum or steel frames. This is also an achievement of the development team led by Frank Bäcker, Head of Development and Design at Siebenwurst.

Two Halves of a Shell, Glued together

Bicycle frames are a rather unconventional product for toolmakers. But: "The principle that complex thermoplastic support structures replace traditional aluminum or steel components is becoming increasingly common in the automotive in- »

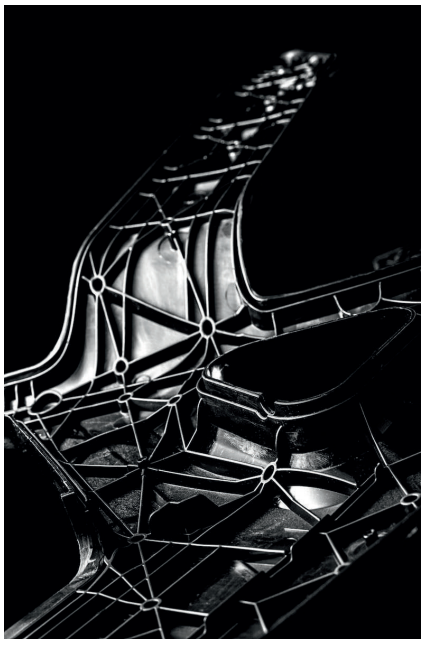

Fig. 1. In the dimensionally stable hollow structure of the frame made of a thermoplastic fiber-plastic composite, the battery, cable and motor can be integrated into a novel, flat design © Siebenwurst

dustry. Often, this is also in combination with overmolded steel insert elements", the industrial engineer Bäcker explains.

The asymmetrical frame is composed of two injection-molded half-shells (**Fig. 1**), which are joined to form a robust structure, and an additional organic sheet glued into the battery compartment. "The components consist of a polyamide with a 50% glass fiber content. To ensure that they meet the requirements perfectly and can be injection molded without defects, we first tested all relevant aspects in a feasibility analysis using simulation. This is how we optimized mold, component and process."

Simulation Reveals Distortion Problems and Gap Formation

To simulate and optimize, the experienced mold designers deploy the software solution Cadmould 3D-F, by simulation specialist Simcon kunststofftechnische Software GmbH, Würselen, Germany. The results were valuable: the simulation showed that shrinkage and warpage would have caused problems in the initial design of the frame halves. Gaps of up to 5 mm would have arisen at the mounting points of the headset and rear wheel.

Cadmould simulation was then used to test numerous compensation measures. At the same time, it was necessary to maintain a balance between the strength of the frame and the use of materials. After all, lightweight construction is at least as important for bicycle frames as it is for vehicles powered solely by engines. By optimizing the mold design (**Fig. 2**), and by modifying and repositioning reinforcement braces in the part, the designers were able to find a solution. Doing this in a simulation environment helped avoid time-consuming and cost-intensive physical correction loops, down the line.

Entire Production Process in Focus

"Thanks to Cadmould, we can precisely determine filling and temperature behavior, filling pressure, cooling time and holding pressure on the basis of plastic material data, long before a single real component is produced," summarizes Daniel Maier, Project Manager R&D at Siebenwurst. The calculations help us to identify possible problem areas and potential for improvement at a very early stage. In addition, this helps to identify the best combination of component, tool and process (**Fig. 3**).

Siebenwurst also uses the simulation software to evaluate customer specifications such as injection concepts and points, and identify suggestions for better solutions, which are then developed with the customer. The production process is always thought through end-to-end – including part handling and machine requirements for filling pressure, clamping force and demolding.

By testing and comparing numerous variants quickly, easily and cheaply simulation practitioners can achieve the best machine capacity and performance. "Our users simulate the effects of changing parameters like number, dimensions or position of injection nozzles or the flow paths – and so they get the learnings and benefit without having to modify a physical mold." says Barbara Schumann of Simcon.

Component Changes during the Design Phase of the Tool

More often than not, Siebenwurst accompanies and supports their clients' project development from the very beginning. This means that the tool designers ongoingly evaluate feasibility of the 5 to 40+ tonne tools, from the very beginning, in parallel to product design. A constant exchange of information and sophisticated time management are crucial for successful simultaneous engineering, with overlapping process steps.

This method also enables the toolmaker to quickly and efficiently adapt to part changes during the design phase of the tool, thus enabling shorter product cycles and an increasing number of variants, according to the requirements of the customer. Even production machine capacity planning and raw materials and standard part procurement are already done during the design phase. This collaborative and parallel process makes it possible to achieve the very best products, together.

At Siebenwurst, design and production are consistently planned centrally using a system in which every design, every production step, and every individ-

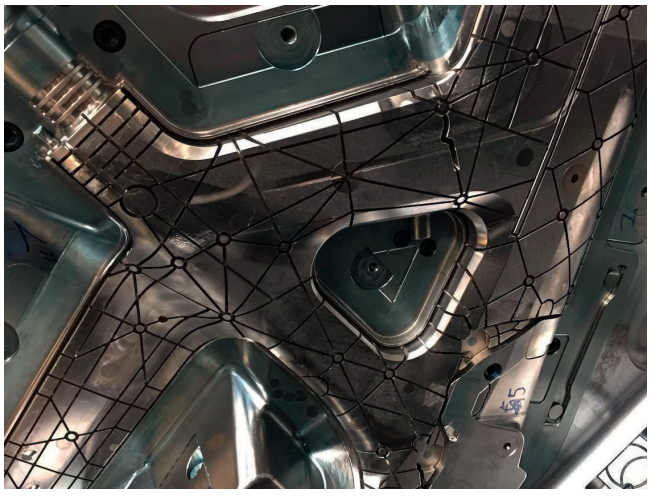

Fig. 2. Shrinkage and warpage during injection molding were calculated by simulation and the position and wall thickness of reinforcing struts inside the frame were improved © Siebenwurst

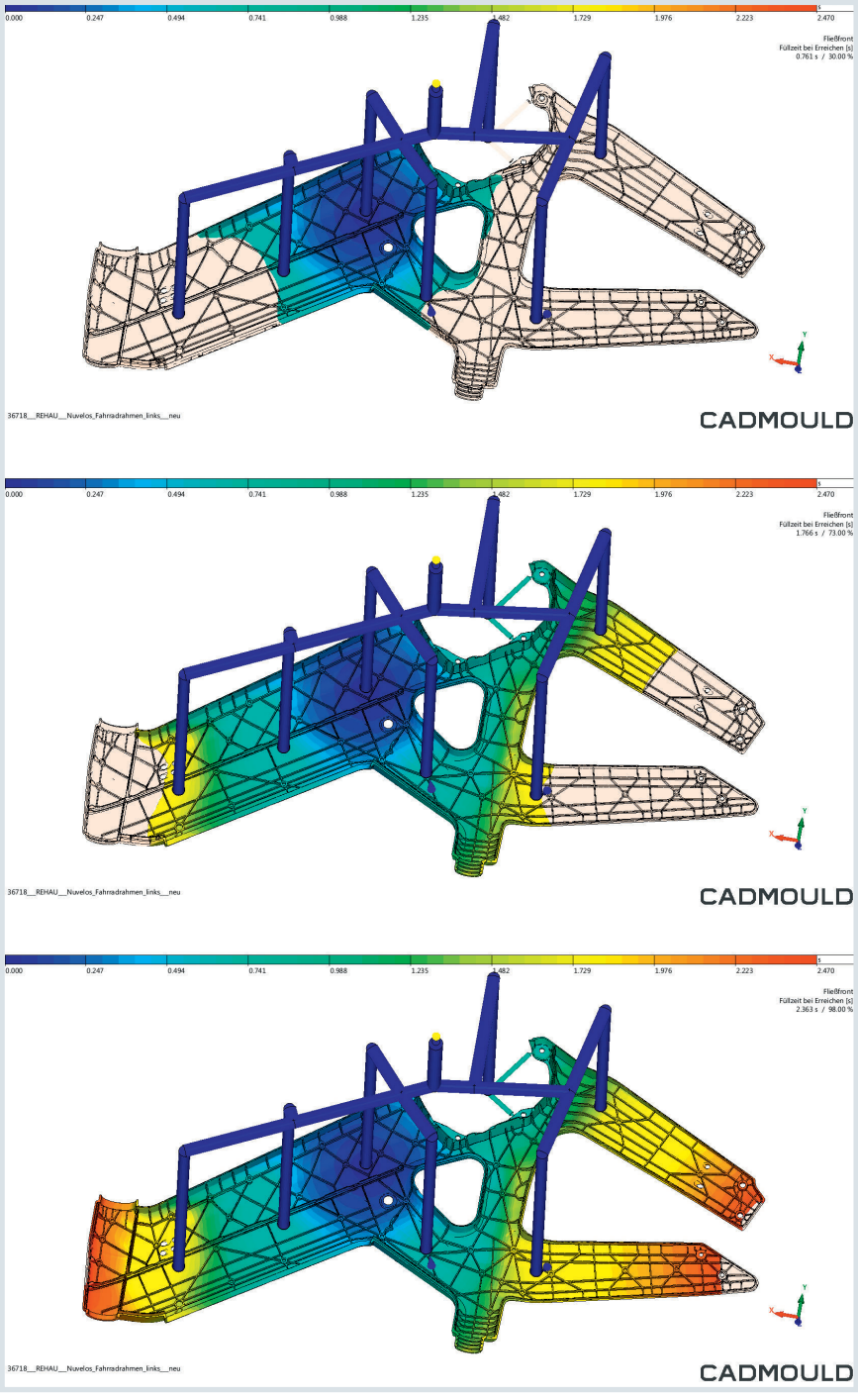

Fig. 3. Simulation of the cascade injection molding process, from left to right: filling level (30 %) just before opening the second stage; filling level (73 %) just before opening the third stage; filling level (98 %) when switching over © Simcon

ual part are represented and scheduled. The production control center includes a display of the real-time status of all projects. In addition to securing project deadlines, this also optimizes the continuous utilization of the more than 50 machines. Project planning for development, construction and sampling is based on weekly templates. These contain appropriate planning sequences and important milestones, depending on the tool size and current capacity utilization.

Evaluate Feasibility and Profitability

Precise organization and task control ensures optimal quality for every single tool that is produced in the Altmühltal – and ultimately, this is what made the success of Rehau's e-bike project possible. "Cad-mould has helped to make this possible. Simulation software has been an important component here and in all of our other projects as well. We use it throughout the entire process, from preparing a quote to the completion of a project," says design and development manager Bäcker. "Simulation software is essential for a thorough evaluation of the feasibility and profitability of projects." ■

The Nuvelos E-Bikes

Nuvelos is the e-bike project of automotive supplier **Rehau AG & Co.** The start-up was created in 2016 from the research project TherMobility ("Support frame structures made of fiber-reinforced plastics for single and multi-track vehicles"), funded by the German Federal Ministry of Economics. The first 3D-printed prototypes were produced in 2017. Following the design and manufacture of the tools for the frames, series production of the frame half-shells also started in 2019 at the model and mold maker Siebenwurst.

Nuvelos is the world's first serially produced e-bike with an injection molded frame. At the end of 2019, Rehau discontinued the product for other strategic reasons. In January 2020, the pedelec was awarded the pro-K-award gold. The riders of the 300 bikes produced therefore own a historic milestone in plastics processing, and a collector's item with high recognition value.

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Service

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