Molds for Orthoses

3D-Printed, Not Machined

Molds for orthoses are usually machined. That is not optimal – neither for the patient nor for the manufacturer. Within the scope of a study, Lehmann & Voss therefore investigated whether 3D printing is an alternative – both ecologically and economically.

3D-printed laminating standard for the production of CFRP orthoses. © Adviva

Orthopedic items such as orthoses (**Fig. 1**) are always patient-specific, and must therefore be produced individually. Hereby, the respective optimum fit must be created to meet the special ergonomic requirements. Therefore, when modeling the patient's 3D-scanned structures, the know-how of an orthopedic technician as well as the expertise of a biomechanist are required to produce a surface-optimized model. In general, there is only one aim: to create cost and handling-optimized laminating standards (laminating molds or laminating tools) for the production of sophisticated orthoses made of carbon fiber-reinforced plastic (CFRP).

One method for producing such molds is to machine (mill) them from semi-finished material, usually blocks made of construction foam (**Fig. 2**). The procedure is well established in practice, and has been proved during many years. But it also has a few disadvantages that are noticeable economically as well as ecologically. For example, construction foams are usually made of thermosetting polyurethane (PUR). Machining them is not critical, but large amounts of fine and finest dusts are generated in the process. The result is considerable cleaning work in rooms and filter systems. Moreover, the light dusts can lead to quality reductions in the laminated components due to foreign material enclosures, for example caused by carryover during CFRP prepreg processing.

What's more, the mold blocks to be machined must be cut to size in preparation for the milling process. Hereby, and apart from additional dust, block cutoffs are produced. Dust and block cutoffs, as well as the laminating molds that must be disposed of at the end, are classified as hazardous waste. This means that after expiry of the legally specified storage time, the manufacturer must ensure that the waste is disposed of separately and correctly – a costly side effect.

PET Filament instead of PUR Foam

3D printing with filaments opens up the possibility of clearly unraveling the processing and production chains. In principle, and thanks to the generative procedure, no production wastes and residual material are created. The material used is limited exclusively to manufacturing the mold. Similarly, contamination of the surrounding area is practically excluded. Additional costs due to quality reduction as well as time-consuming

Fig. 1. The spiral "PowerSpring" orthetic supports natural movements, thereby assisting the patient to achieve the self-set goals faster and better. © Adviva

cleaning are eliminated. Something that sounds good in theory, must also be convincing in practice. This view was shared by material producer Lehmann & Voss, and orthoses manufacturer Adviva. In a joint case study, they investigated the production process of a mold using 3D printing. Luvocom 3F PET CF 9780 BK (**Fig. 3**), a carbon fiber-reinforced filament based on polyethylene terephthalate (PET), was selected as material. PET is featured by high strength as well as temperature and chemical resistance.

The strength and also the surface hardness of molds made of this material entail an additional advantage: The component is easy to handle, as it is insensitive to damage. This not only supports an undisturbed laminating process, but also has a positive effect on the article's transport and storage. Process-related requirements, such as thermal stability and freedom from moisture for the curing process in a vacuum oven, are fulfilled entirely by the printed laminating molds.

Because minimum use of material is already an issue during design of the model – supported by the high strength of the selected 3D printing material – it is possible to work with a minimum amount of infill (supporting structure in the component). Consequently, the amount of waste material is even lower. As the PET filament is a thermoplastic, it can be collected separately for subsequent recycling. After the components have been ground, they can be used to produce new technical items, e.g. with injection molding. If the method becomes established, pure-grade material recovery can be organized in this application, so that recycling is no problem.

Optimization of Component Mechanics

Apart from the material, the study also focused on component mechanics. In order to check operating performance, and to optimize the pressure settings for the mold, SmartSlice for UltimakerCura was used – a software plug-in developed by Teton Simulation. SmartSlice uses experimental material data to analyze the structural performance of printed FFF (fused filament fabrication) parts. Hereby, variables such as orientation of component build-up, material anisotropy, loading, and limitations are taken into account, including pressure settings such as filling density, filling pattern, and shell thickness. The plug-in's main purpose is to ensure that the printed component meets the performance »

Fig. 2. In the store for thermosetting construction foams. © Adviva

Fig. 3. The Luvocom 3F PET CF 9780 filament is suitable for lightweight but simultaneously strong components. © Lehvoss

Info

Text

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Company Profile

The **Lehvoss Group** under guidance of Lehmann & Voss is a group of companies which develop, produce, and market special chemicals and minerals for various user industries. The company was founded in 1894 as a trading house in Hamburg. During more than 125 years, the owner-run company has evolved into a global organization – with close, long-term business relations with well-known suppliers, and with own production sites in Europe, the USA, and Asia.
www.luvocom.com

Adviva is a private health company that was founded in Heidelberg in 1997 and offers medical products, orthopedic and rehabilitation technology. The focus of advice and services is on orthopedic insoles, orthotics, prostheses and positioning systems, a large selection of medical, rehabilitation products and wheelchairs as well as video-supported adViva movement analysis.
www.adviva-info.de/en

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Read the German version of the article in our magazine ***Kunststoffe*** or at ***www.kunststoffe.de*** requirements while simultaneously reducing printing time and material consumption to a minimum.

The first step in the SmartSlice workflow involved selection of the material (Luvocom 3F PET CF 9780 BK) from the material database, and the definition of performance requirements and application cases. Because the milled foam molds are sensitive regarding surface damage, an important requirement for the printed component is to prevent damaged during handling. To ensure this, a safety factor of 3.5 was defined, i.e. the component must withstand 3.5 times the assumed working load, before is permanently deformed or yields. Regarding loads and limitations, the surface to which the clamping device is attached, was fixed in a simulation process, and three different loads were applied to the mold's surfaces.

The next step investigated which build orientation provided the best performance using the least amount of material. During this phase, the standard printing profile for CF 9780 was used. As shown in **Figure 4**, three build orientations were tested: Side, back and upright. The Software calculated a minimum safety factor of more than 3.5 for every build orientation. This means that all components exceeded the strength specifications, this finally signifies the parts are over-dimensioned.

Final result for this phase: The upright orientation is best, as it requires the least printing time and material. Therefore, to save time and material, further investigations were only conducted with this orientation. In particular, a validation with two walls and 20 % filling density (infill) – the recommended minimum values for these two parameters – was carried out. The results showed that two of the three simulations exhibited a minimum safety factor of less than 3.5. Regions with a lower safety factor were recorded in SmartSlice (**Fig. 5a**). It was also shown that the region near the end of the clamping rod had a potential for yielding. Therefore, a modifier network (**Fig. 5b**) was inserted here to strengthen the component locally with additional material. As shown in **Figures. 5c and 5d**, the component is only printed completely (100 % infill) in the layers located within the modifier network. Outside the modifier network, the filling density is 20 %. In a further validation, the component finally met the strength requirements using a minimum quantity of material and printing time.

In total, the component was validated for about one hour in SmartSlice, and then optimized in terms of printing time and material consumption. Compared with the standard printing profile and the knowledge that Adviva prints about 100 molds per month, the company saves about 50 days printing time per year, plus 13.2 kg material per year. A printing time of 50 days corresponds to an annual increase of machine output of 70 additional molds. ■

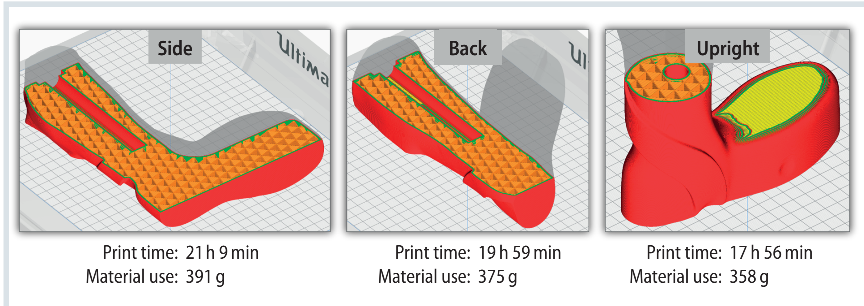

Fig. 4. The Luvocom 3F PET CF 9780 filament is suitable for lightweight but simultaneously strong components. © Teton Simulation

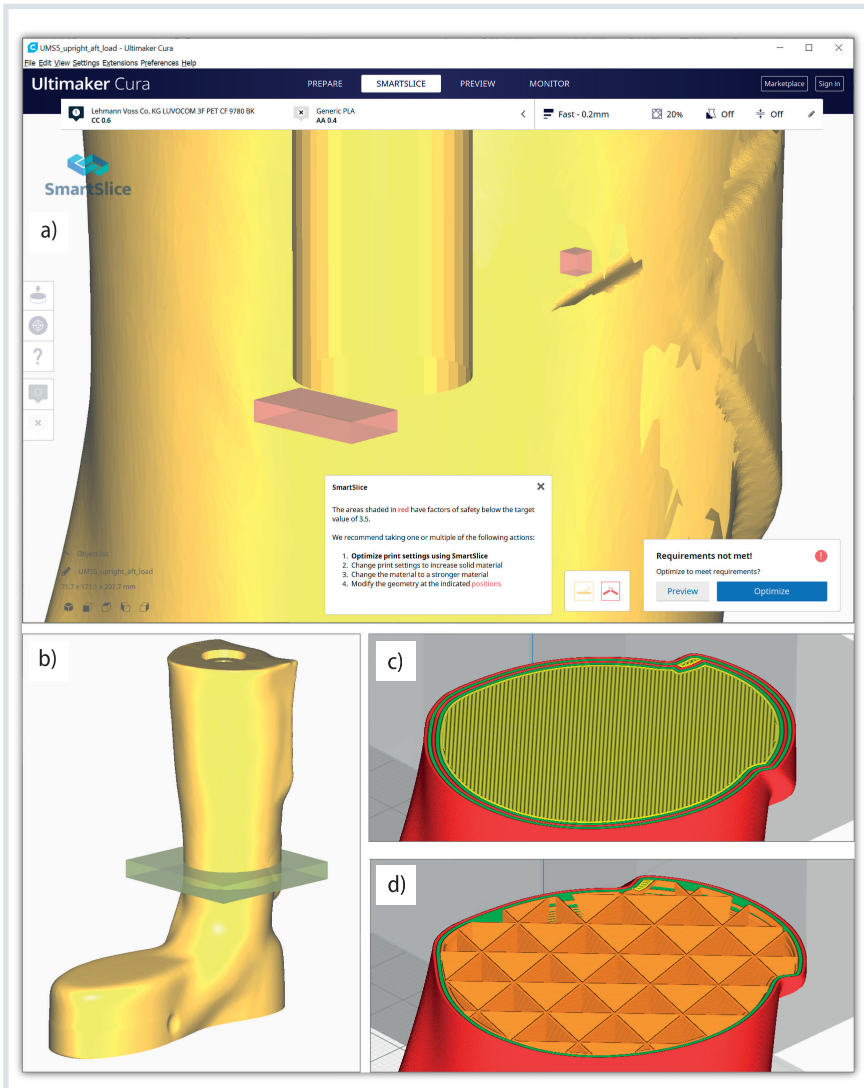

Fig. 5. (a) Areas (red), in which the calculated safety factor is lower than the requirement of 3.5, (b) modifier network, (c) sectional view showing the layers in the modifier network, and (d) sectional view showing the layers outside the modifier network. © Teton Simulation