Case Study: 3D printed molds for orthotics

A cooperation of adViva, Teton Simulation, Ultimaker and LEHVOSS Group

Introduction

Additive manufacturing processes, colloquially 3D printing, are predestined for the production of safety components and small series, but especially for production in "batch size one".

In the production of orthopedic aids, which are always patient-related, there is almost always a batch size of one. The aim is always to create an optimal fit that meets the special ergonomic requirements. When modeling the 3D-scanned structures of the patient, the know-how of the orthopedic technician or the specialized biomechanic is incorporated in order to generate a surface-optimized model.

The whole thing ultimately pursues one goal: the creation of cost and handling-optimized lamination standards (lamination molds or lamination tools) for the production of highly developed orthoses from CFRP laminates. The aim is to reduce the effort to a minimum of value-adding steps and to minimize throughput times.

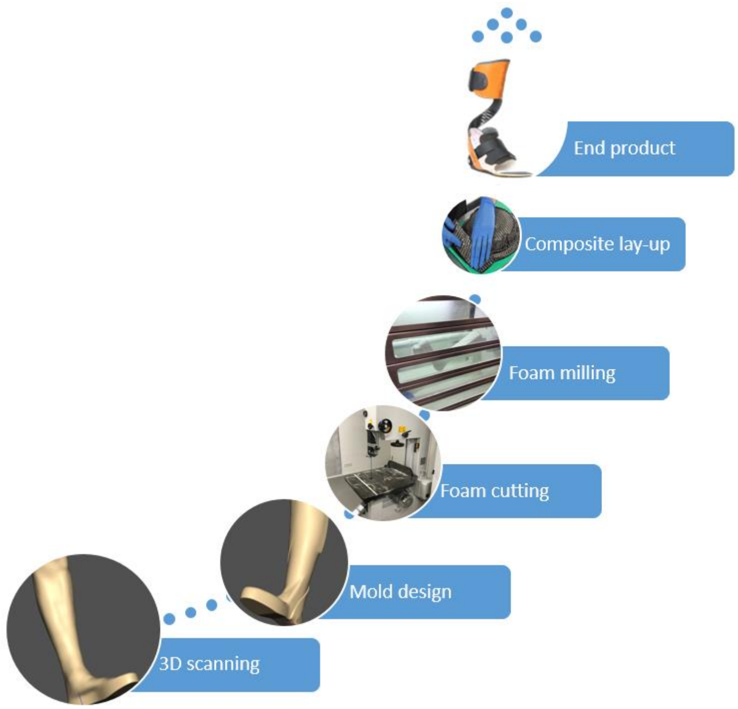

Figure 1. Classic production of orthotics

One method for producing such tools is milling from semi-finished products, usually block products made from toolmaking foams. This procedure is established in practice and has been tried and tested for many years. However, if you carry out a differentiated process analysis, optimization steps can be derived that are economically and ecologically noticeable.

The mentioned tool construction foams are usually made of thermosetting polyurethane. Their machining is not critical, but large quantities of fine and extremely fine dusts arise, which lead to considerable cleaning effort in rooms and in filter systems. Furthermore, these light dusts, when carried over into the CFRP prepreg processing, can lead to a loss of quality due to the inclusion of foreign material on laminated components. Particle carryover is generally difficult to control contamination of the work environment.

The foam blocks to be machined must be cut to size in preparation for the milling process. Here, in addition to other dust, there is also block waste. The dust, as well as the block waste and later the laminating form to be disposed of, are hazardous waste.

In this case, 3D printing by means of filament opened up the possibility of clearing up the process and production chain. In principle, this generative process does not result in any production waste or residual materials. The use of materials is limited exclusively to the tool to be manufactured. Contamination of the environment is almost impossible. There are no additional costs as a result of a reduction in quality or laborious cleaning of the work environment.

Figure 2 and 3. Foam warehouse and foam waste

The case study

For a case study, the material LUVOCOM 3F PET CF 9780 BK was selected with the company adViva. This is characterized by high strength and temperature resistance. In addition, it has good chemical resistance and is easy to print. The strength and also the surface hardness of the molding tool made of this material cause another major advantage. The component is very easy to handle because it is virtually insensitive to damage. This favors an undisturbed lamination process, but also the transport and storage of the item.

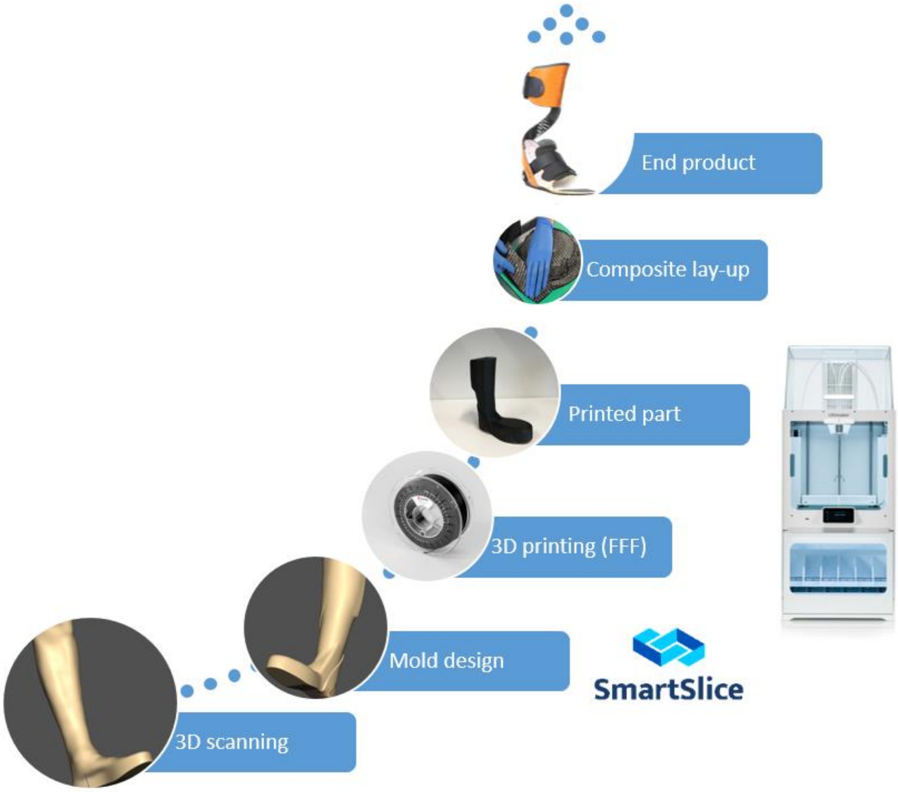

Figure 4. Novel production of molds

Process-related requirements, such as the required heat resistance and freedom from moisture for the curing process in the oven vacuum process, are fully met by the printed lamination forms. Additional LUVOCOM 3F materials are available to meet special requirements, such as increased crosslinking temperatures when using more reactive resin systems.

Figure 5. 3D printed mold, mold with handle, final CFRP orthotic

The end of the life of the lamination form is the expiry of the legally prescribed retention period. PU foam parts would now be sent to separate and expensive waste disposal for hazardous waste. Since minimal use of material is taken into account in the construction of the model - supported by the high strength of the selected 3D printing material - it is possible to work with little infill (support structure in the component). As a result, there is a further reduced volume of material as residual material. Since LUVOCOM 3F PET CF 9780 BK is a technically sophisticated thermoplastic, it can be collected separately and sent for technical plastics recycling. After the components have been ground, new technical parts can be created using injection molding, for example. When the process is established in this application, a sorted return of material can be organized and nothing stands in the way of recycling.

Optimizing the structural performance

SmartSlice for Ultimaker Cura, a software plugin developed by Teton Simulation, was used to validate in-service performance and to optimize the print settings for the mold. SmartSlice uses experimental material data to analyze the structural performance of as-printed FFF parts and takes into consideration variables such as the part build orientation, material anisotropy, loading and constraints, and print settings such as infill density, infill pattern, and shell thickness. The overall purpose of SmartSlice is to ensure the printed part meets performance requirements while minimizing print time and material usage.

The SmartSlice workflow began with selecting LUVOCOM 3F PET CF 9780 BK from the SmartSlice material database and defining the performance requirements and use cases. Because the foam molds dented very easily, a key requirement of the printed part is that it does not get damaged during handling. To ensure this does not happen, a factor of safety requirement of 3.5 was defined. This means that the part needs to be strong enough to withstand 3.5 times the assumed applied loading before it begins to permanently deform or yield. In terms of loads and constraints, the surface where the handle attaches was fixed (unable to move) and 3 different loads were applied to surfaces on the mold.

Next, a build orientation study was done to determine which build orientation provides the best performance while using the least amount of material. During this stage, the default print profile for CF 9780 was used. As shown in Figure 6, 3 build orientations were considered: side, back, and upright. SmartSlice computes a minimum factor of safety that is greater than 3.5 for each build orientation. This means that all parts exceed the strength requirement which means the parts are over-designed or over-built. With print time and material usage being key concerns, the upright orientation is the best choice because it uses the least amount of print time and material.

The upright build orientation was then further examined by SmartSlice to reduce additional print time and material. Specifically, a validation that had 2 walls and 20% infill density, the minimum recommended values for these 2 parameters, was done and results showed that 2 of the 3 use cases had a minimum factor of safety less than 3.5. Regions where the factor of safety was low were plotted in SmartSlice (Figure 7a) and it was identified that the infill region near the end of the handle surface had the potential to yield, so a modifier mesh (Figure 7b) was inserted in these regions to add material and strengthen the part locally and only where needed. As shown in Figure 7c and 7d, the part is printed solid only in the layers residing inside the modifier mesh. Outside of the modifier mesh, the infill density is 20%. After adding the modifier mesh and running one more round of validations, the part met the strength requirement and used a minimum amount of material and print time.

In total, the part was validated and optimized to minimize print time and material after spending about 1 hour in SmartSlice. Compared to the standard print profile and knowing that adViva prints about 100 molds per month, SmartSlice saves 50 days of print time per year and 13.2kg of material per year. 50 days of print time equates to an increase in machine throughput of 70 additional molds per year.

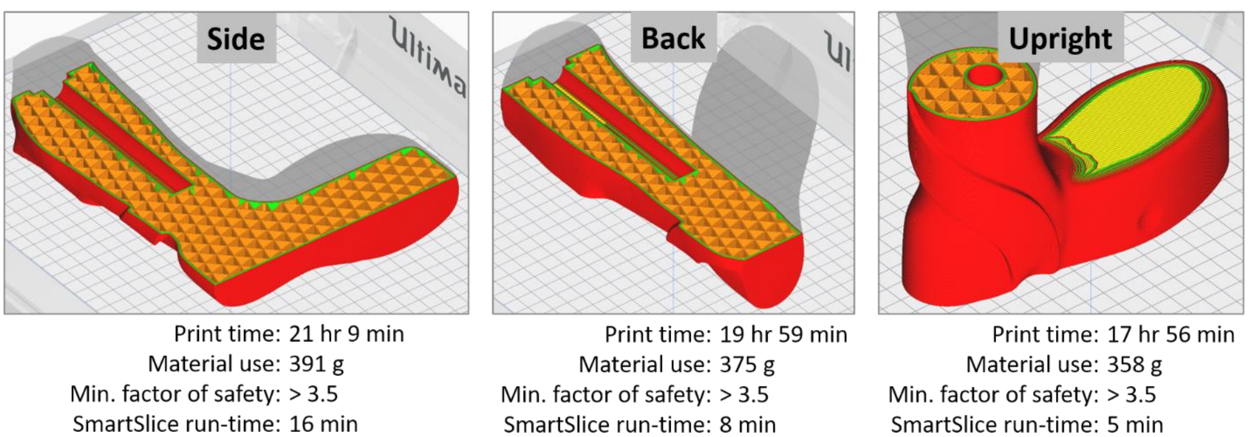

Figure 6. adViva mold shown in 3 different build orientations with results from each SmartSlice validation study.

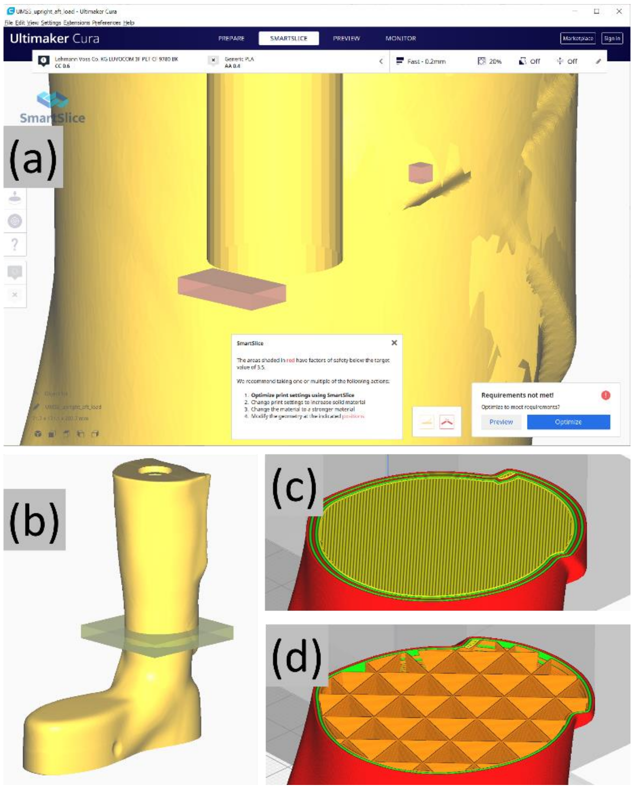

Figure 7. (a) Regions (red) where computed factor of safety is less than the requirement of 3.5, (b) modifier mesh, (c) slice view showing layer in the modifier mesh, and (d) slice view showing layer outside the modifier mesh.

About LEHVOSS Group:

The LEHVOSS Group under the management of Lehmann&Voss&Co. is a group of companies in the chemicals sector that develops, produces and markets chemical and mineral specialties for various industrial clients. Lehmann&Voss&Co., Hamburg, was founded in 1894 as a trading company. In its success story dating back some 125 years, the owner-run company has developed into a powerful global organization – with long-standing connections to prominent suppliers and with its own production sites in Europe, the USA and Asia. For more information, please visit www.lehvoss.de

With its product lines LUVOSINT® and LUVOCOM® 3F, the LEHVOSS Group is offering innovative and tailor-made plastics for 3D printing. These products have been adapted to the most common production processes, such as powder bed fusion, fused filament fabrication (FFF) and direct extrusion printing processes. The materials are distinguished by their good processing characteristics and excellent material properties. https://www.luvocom.de/en/products/3d-printing-materials/

About adViva:

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.

At the beginning of 2019 the adViva® AKADEMIE was launched with the aim of offering the company's competence in health issues a professional platform. In 2020 adViva started a holistic supply concept with adVPHYSIO, which is geared towards moving with aids. The company has also been committed to the Ethics Code of Walking Understanding® since 2020 and is a certified OT competence house. adViva is certified according to DIN EN ISO 9001: 2000 and DIN EN ISO 13485.

About Teton Simulation:

Teton Simulation develops software products that enhance the productivity of producing 3D printed parts. SmartSlice takes the guesswork out of optimizing a part for minimum print time and material use while ensuring that end-use performance requirements are met. The company's hallmark is providing software that is simple to use while providing very fast, reliable results. www.tetonsim.com

About Ultimaker:

Since 2011 Ultimaker has built an open and easy-to-use solution of 3D printers, software, and materials that enable professional designers and engineers to innovate every day. Today, Ultimaker is the market leader in professional 3D printing. From offices in the Netherlands, New York, Boston, and Singapore – plus production facilities in Europe and the US – its global team of over 400 employees work together to accelerate the world's transition to digital distribution and local manufacturing. www.ultimaker.com

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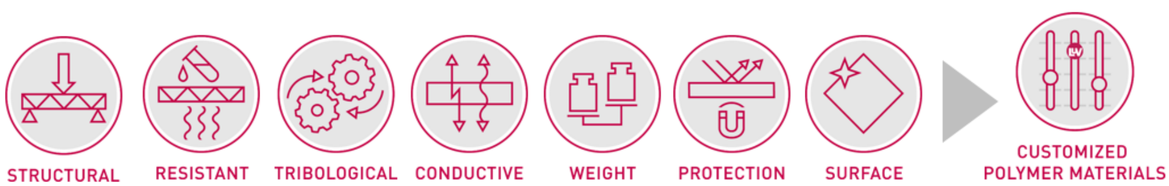
Our expertise in materials



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