GREEN, INDIVIDUAL SKI-SHOE-LINER - APP AND 3D-PRINTING TECHNOLOGY

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Abstract. Additive manufacturing processes open a wide range of opportunities for new bionic designs and integrated functions as well as more customer related individualized products. Besides these positive effects additive manufacturing helps reducing the use of resources in different ways from reduction of forms and dies to a higher grade of identification with personalized products to get longer product lifetimes. This paper presents a resource saving, customer related way to get best fitting ski shoe liners tailored to the specific requirements of the customer. Starting with a new kind of app for smartphones which allows scanning the feet at home, to the realization using Fused Filament Fabrication, a 3D-printing process using the material extrusion technology to print the ski shoe liners individually in size, geometry and comfort properties.

Keywords: 3D-Printing Ski Shoes, Individual Ski Shoe Liner, Smartphone Scanning APP

1 INTRODUCTION

Ski shoes and especially the liners have an impact on comfort, health and risk of injuries during the skiing season. Customers tend to use good fitting ski shoes and liners longer when they fit. A nonrepresentative evaluation of random interviews with different users as well as an expert from Steinbach Alpin from ski industry observe a longer lifetime if ski shoes and liners are comfortable and fitting. Nowadays there are some technologies to fit especially liners but also the ski shoe shell. Sport stores offer the opportunity to adopt the geometry of the shoes and liners using thermal forming processes at a serial shoe and liner. Another way to get better fitting shoes and liners are given by injecting Polyurethan foam into the gap between foot and outer shoe [2]. All these methods need to be turned out having the customer at the store. In some case there is a need for the customer to have more than one visit at the stores. Another opportunity to create individualized ski shoes and liners are presented by company Tailored Fits [3]. The feet are being scanned in a foot scanner, then 3D-printed in Switzerland and send back to the store for picking up by the customer.

The procedure presented in this paper is related to the ski shoe liners only. For the scanning process a smartphone app was created. Customers are required to make photos of their feet. From the photos a 3D-model of the feet is created by applying photogrammetry algorithms.

The 3D-model of the feet is a representation of the inner surface of the liner. Based on a manual design procedure a 3D-model of the liners is merged with the 3D-model of the feet. From this CAD-model a 3D-printable g-code is generated. To increase the comfort of a customer, elastic properties of the liners can be adapted by applying infills. For production no dies or forms are needed. The consumption of material and energy is minimized.

Main Contribution:

- Smartphone App for home use
- Web based data platform
- Slicing and 3D-printing – procedures for FFF-3D-printing

2 METHOD

This section details the end-to-end process of scanning the customer's feet (Section 2.1), designing and preparing (Section 2.2) the liners and finally printing (Section 2.3) the liners.

2.1 SCANNING

A mobile app was created to provide customers a convenient and reliable process to create a 3D-model of their feet. Therefore, customers must take photos of their feet from different angles. The photos are uploaded to a server software, which construct the 3D-model by using photogrammetry algorithms.

A major challenge for constructing a high-fidelity 3D-model is to ensure that the photos created by customers are of appropriate quality. As the photogrammetry algorithms have high requirements on the processing hardware, easy to calculate heuristics were determined to ensure the quality. Image blurring, brightness and contrast were identified as suitable.

For detecting image blur, existing algorithms were used [4][5]. The hyperparameters of the algorithms and threshold values were tuned based on an empirical assessment of a self-created dataset of valid and invalid images. The validity of the images was set in accordance with the outcome of the photogrammetry algorithms. Figure 1 gives an overview of images with different quality metrics and a validity indication.

Figure 1: Images with different blur, brightness and contrast parameters. Threshold values are used to indicate the validity of the image for 3D model generation.

Allowing for a convenient and guided process for the customer to scan their feet, auditory signals are used within the app. That is, a customer is guided to create a photo from every angle of a foot. For each position the app creates candidate photos and evaluates these along the mentioned heuristics. If a position has appropriate photo quality a signal is given to the customer to move the smartphone to the next position.

2.2 DESIGN AND PREPARATION

The STL-data resulting from scanning are used to design the liner considering the inner shape of the outer ski shoe where it should fit in and exporting it to a STL-Format again. This STL file contains all geometry related data like as a filled volume and a closed surface. In the next step the data will be imported into a slicing software which divides the geometry into slices and generates program code for the printer as a so-called G-Code.

3D-printed parts are not solid inside if not needed. Inner structures so called infills are covered with closed surfaces. Many Slicers software offer the opportunity to adopt the structures of the volume locally as needed. The idea is to save material for improving printing time, reducing weight and adopting internal properties like damping, suspension as well as heat and sound conduction. Depending on the design and degree of infill (mass or volume %) different properties can be built in the structure besides using different materials. For slicing the software CURA from Ultimaker was used.

Figure 2 shows the liner with the different patterns used for creating hard (yellow) or soft (brown) areas. Infills can be chosen with homogeneous equiaxial properties like a) tri-hexagon, b) quarter cubes and c) zickzack all with 10% infill. But also, heterogeneous infill structures which are stiff in z-direction but soft in x- or y-axis are possible. A further adjustment setting is the density of the infill which also has an impact on stiffness, elastic strain and stress. The patterns and density can be adopted locally.

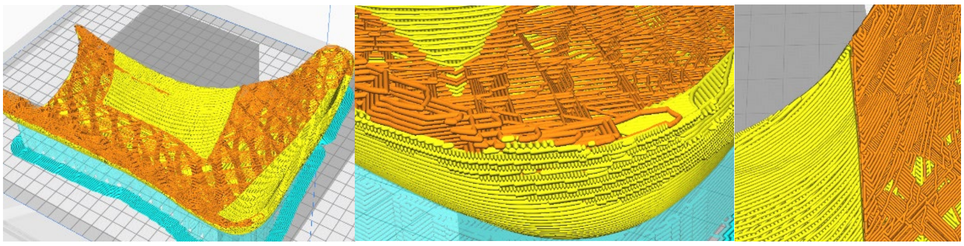

Figure 2: Patterns for infill in the liner a) overview about different patterns, b) transition area heel/sole, c) transition area shin, foot span – area brown (rough pattern/low density)- soft, yellow area (fine structure/high density) - hard

2.3 3D-PRINTING

To realize elastic properties of the liner, a 3D-printable thermoplastic Polyurethan is used. The material can be defined as block copolymer which consists of different sequences of hard and soft components. It behaves comparable to rubber and can be adjusted to different properties by varying the ingredients. For the tests a TPU 95A was used for part and support.

The 3D-printing procedure is a material extrusion process with a filament of 2.85 mm and a nozzle of 0.4 mm in diameter. The FFF-process (Fused Filament Fabrication) is a layer wise deposition process where the thermoplastic polymer, in our case TPU, plastifies while transported through a hot-end. For the tests an Ultimaker S5 was used.

3 TEST, EVALUATION AND DISCUSSION

For a defined setup of comfort properties an evaluation process should be turned out. The different deviations must be put in relation to the load to get an elasticity value for calculation of the compression of the infill depending on the weight and reaction forces during skiing. The material tests are aimed to get a calculation base for setting up the best fitting infill setup for different load cases regarding body weight and forces due to use case like casual or competition use. Table 1 shows the deviation of the cuboids (X100 * Y100 * Z30 mm) under a load of 98,1 N in z-orientation, parallel to gravity using a 100 * 100 mm square stamp.

Table 1. Elasticity of different infill patterns under a load of 98,1 N

Infill Type/Row	Deviation in z [mm]	Elasticity [mm/N]
Tri Hexagon 10%	20	4,905
Quarter-Cube 10%	21	4.671
Zickzack 10%	12	8.175

The tests show that roughly printed wide meshed patterns with a low-density lead to a soft behavior and wide deviations which lead to low elasticity rates. Highly narrow meshed patterns with high density implement a harder behavior. Depending on the orientation patterns like honeycomb or other non-equiaxial patterns show a different behavior in x, y and z directions. The choice of patterns, their orientation related to the load case and the density allow a wide variation of mechanical properties from soft to hard. This approach as well as the renounce of the usage of tools and dies as well as the opportunity to order from home reduces energy and material consumption and makes a contribution to sustainability.

4 Conclusion

The FFF process using TPU as printing material is a suitable procedure for printing liners for ski shoes realizing various localized mechanical properties for customer comfort. To give the customer a tool for making the best setup for his personal requirements must be developed and researched in further projects. The technology also saves resources – no tools and dies are needed for producing highly personalized items. For future work a further automation of steps in the overall process an elimination of manual steps should be realized. Scanning using video-technology, the automation of generating the CAD-Model from scanning data as well as the adoption of infill structures are aimed.

5 ACKNOWLEDGEMENT

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