The mechanical properties of thin-walled plastic components are limited. One approach of improving the strength is to apply individual adapted Fused-Deposition-Modelling-structures onto the thin-walled components. To achieve an optimal reinforcing effect, the properties of the FDM-structure must be optimized first. This project will focus on the variation of the FDM process parameters, because they have the most significant impact on the mechanical properties. The results of the parameter variation shall provide findings to develop design and process guidelines for FDM-structures that are used for the partial reinforcement of hybrid structures. Besides the mechanical properties, the lightweight potential of the FDM-structure must be considered, too.

Objectives
This project aims to determine design and process guidelines for FDM-reinforcement-structures, which are aligned for specific load cases and shall be used for a partial reinforcement of lightweight parts. The reinforcement structure shall provide maximum increase of strength and stiffness with minimum increase of weight. To realize the maximum increase of the mechanical properties the inner structure is adjusted to the specific load case by using different parameters for the layer generation. In addition to this, the design of the FDM-part will be varied to achieve a weight increase as minimal as possible. The used material for the FDM-reinforcement-structure is Ultem 9085.

Procedure
The strength and stiffness for various inner part structures will be determined for the different load cases by using mechanical tests (tensile, compression, flexural, impact and torsional strength). As a result, a list of load specific designs and process guidelines for the FDM-structure will be compiled. Additionally a modeling of the mechanical strength of FDM-parts will be developed. The strength is modeled as a function of the inner part structure which is directly depending on the process parameters. The modeling shall support the strength analysis of the different load cases. At last, the design and process guidelines will be verified on a real lightweight part. This part will consist of two components, a GITBlow-part and the FDM-reinforcement-structure (Figure 1). To realize a joint between both parts, the FDM-structure is inserted to the injection mold first. Then the GITBlow-preform is inflated and adheres to the FDM-structure. The gain structure is only added to the thin-walled area of the GITBlow-part. For that hybrid component, different mechanical tests will be carried out.
Latest Results

In preliminary investigations, the manufacturing boundary conditions for the FDM-reinforcement-structure are investigated. The minimal negative air gap without an overfilling of the specimens and the maximum positive air gap for sufficient stability are determined. The investigations show that interactions between the different process parameters and the positioning of the seam out of stressed areas need to be taken into account. The highest mechanical properties can be achieved with the flat orientation of the FDM-reinforcement-structure in the build chamber. For the following investigations the flat orientation is used.

The investigations show that the mechanical properties of the FDM-reinforcement-structure depend on the filling parameters. For all load cases (tensile, compression, flexural, impact and torsional strength) a significant influence of the raster to raster air gap is detected. With a positive raster to raster air gap about 0.5 mm there is no force transmission in the component structure (Figure 2). This results in a failure of local stressed strands. Higher mechanical properties can be achieved by a negative raster to raster air gap about -0.03 mm caused by the force transmission through the layers. The experimental investigations show influences of the other parameters and interactions between them. Furthermore the FDM process parameters have an effect on the part weight and the lightweight potential of the reinforcement structure.

Outlook

In addition to the variation of process parameters, the design of the FDM-reinforcement-structure shall be adapted. The aim is a topology-optimized construction (FEM-analysis, Figure 3). The process principle of the Fused Deposition Modeling is the deposition of polymer strands in layers. As a result of this process characteristic the properties of FDM-parts are heavily depending on the fill pattern and the deposition orientation. This anisotropic material behavior has to be considered in the FEM-analysis. Moreover, extended strength verifications with dynamic tests are planned and the development of specific load design and process guidelines for the FDM-reinforcement-structure shall be continued.