FDM-STRUCTURES FOR THE PARTIAL REINFORCEMENT OF HYBRID STRUCTURES

The mechanical properties of thin-walled plastic components are limited. One approach of improving the strength is to apply individual adapted Fused Deposition Modeling (FDM) 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, due to the fact that 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 also considered.

PROJECT OVERVIEW

DURATION

07/2015 – 12/2018

PARTNER

Kunststofftechnik Paderborn (KTP)

FUNDED BY

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RESEARCHER

Research leader
Prof. Dr.-Ing. Elmar Moritzer
Research assistent
Andre Hirsch, M.Sc.

Deutsche Forschungsgemeinschaft
German Research Foundation

Objectives

The aim of the research project is the development and modeling of design and manufacturing guidelines for FDM reinforcement structures which are adapted to the load case and are to be used as partial reinforcement of hybrid structures. The research focus is on the strength optimization of the FDM reinforcement structure by means of a specific configuration of the manufacturing process in the FDM process. During the production of the FDM reinforcement structures, the process parameters are varied in addition to the building direction, as these have a major influence on the mechanical properties. Furthermore, depending on the shape of the FDM reinforcement structure, a targeted increase in strength or stiffness for the respective load case is to be achieved with the aid of topology optimization, whereby the generated structure is to have the lowest possible weight in order to save resources. In addition, the crack and fracture behavior is analyzed and the fatigue behavior of the FDM reinforcement structures is determined. Finally, the optimized FDM reinforcement structure in the composite system will increase the strength and stiffness of the base carrier. To achieve this, the manufacturing process of the hybrid structure must first be integrated into the existing GITBlow process.

Procedure

At the beginning of the research project, the analysis of the manufacturing restrictions for the FDM process was carried out. This includes the influenceable production parameters and the not influenceable production restrictions. The systematic determination and early analysis of these boundary conditions is necessary in order to clearly define the manufacturing limits for the subsequent investigations. In the next step, a statistical test plan with the Response Surface Method (RSM) was developed on the basis of the manufacturing boundary conditions. The analysis of the quasi-static strength values was initially carried out using various tests (tension, compression, bending, notched bar impact strength and torsion). This made it possible to determine the respective strength and stiffness values for the different load types, depending on the existing structure of the FDM component. Based on these results, mathematical models were determined for each of the five load types. The models were validated on the basis of the following target value optimizations. Furthermore, a topology optimization was carried out in order to optimize the FDM reinforcement structure according to the load case to achieve the highest possible specific stiffness.

As part of this research project, an extended strength verification and a service life estimation were also carried out with the aid of dynamic investigations. This allows statements to be made about the crack growth mechanisms and the influence of process-related defects or pores. Finally, a procedure for an automated insertion of the FDM reinforcement structures into the GITBlow process was developed. Subsequently, the hybrid components were manufactured using the standard parameters as well as the load case optimized process parameters. The investigations were completed by reviewing the manufacturing guidelines in the composite system and characterizing the bond strength between the FDM reinforcement structure and the GITBlow component.

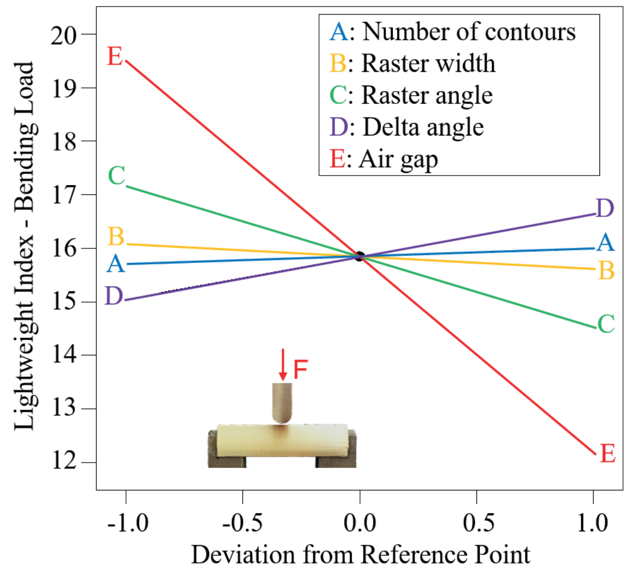

FIGURE 1 Model of the influencing variables on the lightweight index for bending load

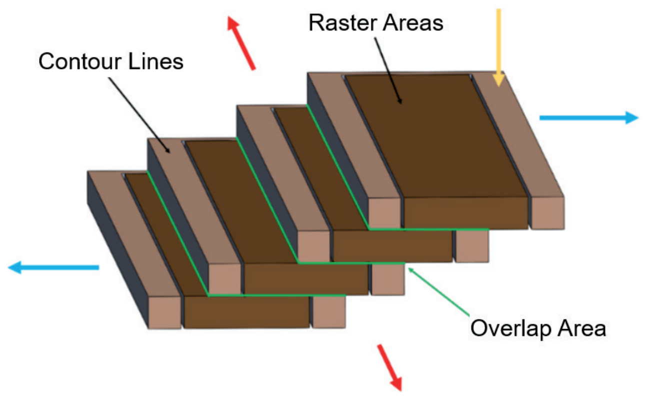

FIGURE 2 Schematic illustration of the layer overlap for peak overhang angles

Summary

Through the experimental investigations, a detailed understanding of the FDM process was developed. The combination of the summarizing manufacturing guidelines and the comprehensive process understanding enables the user to optimize the process design. In particular, FDM structures for the reinforcement of thin-walled plastic components are in the focus. However, the findings can also be used for the optimization of self-supporting, lightweight geometries and applications. In addition, the dynamic investigations revealed typical weak points and failure mechanisms of FDM structures, which should be taken into account during component design.

FIGURE 3 Finished hybrid component