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FIBRE PATH OPTIMIZATION OF COMPOSITE STRUCTURES MANUFACTURED VIA TAILORED FIBRE PLACEMENT

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In lightweight fibre-reinforced composite structures, their intrinsic anisotropy needs to be addressed in order to fully take advantage their ability to withstand loading with lower safety factors. Stress adaptive curvilinear fibres following pre-calculated paths (e.g. according to the dominating load direction), lead to significantly increased strength- and stiffness-to-weight ratios when compared, for instance, to multiaxial composite laminates [1]. Furthermore, less fibre material is required. For the production of curvilinear fibre patterns, the Tailored Fibre Placement (TFP) technology was developed at the Leibniz-Institut für Polymerforschung Dresden (IPF). The TFP manufacturing process generates preforms by placing rovings through an embroidery machine based process on top of a base material using a sewing thread in a zigzag stitch pattern. As an automated fibre placement technology, the flexibility is accompanied by a high accuracy and reproducibility.

Since TFP is a technology with many degrees of freedom, generating optimized fibre layouts is particularly challenging. The local density and fibre orientation may change on very small scales, resulting in a variation of the laminate thickness and, hence, changing on the stiffness matrix. These points can be addressed by our novel self-developed automated model generator, which computes local geometric parameters, such as thickness and fibre orientation solely based on the fibre placement path information, and thus allows utilization of almost any optimization technique to enhance the fibre-placement pattern.

For structural design, topology optimization is often used successfully. However, for anisotropic materials, especially with continuous fibres, the applications involve several manual adaptations with unclear outcome and non-optimal results, e.g. the cross-section adaptation of the computed truss-like elements. Therefore, we present a procedure, which enables almost fully automatic adaptation of topology-optimized designs for composite structures. The flexible modelling generator allows evaluating possible realizations and with a genetic algorithm the optimal producible design is found. Overall, the combination of topology optimization and locally adapted fibre orientation allow a substantial increasing on the stiffness-to-weight ratio.

REFERENCES

[1] Spickenheuer A, Schulz M, Gliesche K, Heinrich G. Using tailored fibre placement technology for stress adapted design of composite structures. Plastics, Rubber and Composites 2008;37:227-232.