Optimization of fiber reinforced composites by roving based modelling

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ABSTRACT

In lightweight constructions made by fiber-reinforced plastics, the strong anisotropy of the material properties has to be considered. Stress adaptive curvilinear fibers following pre-calculated paths (e.g. according to the dominating load direction), lead to significantly increased mass specific stiffness and strength values compared to standard multiaxial stacked laminate constructions. Furthermore, less fiber material is necessary. For the production of curvilinear fiber patterns, the Tailored Fiber Placement (TFP) technology was developed at the "Leibniz-Institut für Polymerforschung Dresden e. V." [1-3]. The TFP procedure generates preforms by placing bundles of fibers, the so-called roving, in an embroidery machine based process on top of a base material using a sewing thread in a zigzag stitch pattern. The excellent flexibility of this technology is accompanied by a high accuracy and reproductive results.

Since TFP is a technology with many degrees of freedom, generating optimized fiber layouts is particularly challenging. The local density and fiber orientation may change on very small scales resulting in a variation of laminate thickness and a changing stiffness matrix due to the anisotropic material characteristics of fiber-reinforced plastics.

By using an algorithm that generates a finite element model for arbitrary roving placement path information, an optimization algorithm is developed. This so-called Direct Fiber Path Optimization directly operates on the roving path information. A spline parameterization of the roving path, that incorporates all production boundary conditions such as fixed areas or symmetries, represents the optimization variables.

As a first example, a gradient free optimization algorithm is employed and the fiber layout of an open-hole tensile specimen is optimized. The resulting part stiffness and strength significantly outperforms state of the art principal stress oriented fiber layouts. Experimental results show almost the same tensile strength as a reference specimen without a hole and parallel fibers.

REFERENCES

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