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A Novell Approach for Modelling Composites with a Variable-Axial Fibre Design

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In recent years the demand for energy efficient systems caused a boost of applications for modern lightweight structures made of fibre reinforced plastics (FRP). Next to classical fields of applications like aerospace and sports equipment also the automotive and machine building industry request FRP materials. Due to the high pricing of carbon fibres the efficient exploitation of its material characteristics becomes more and more important. By employing a variable-axial design strongly increasing stiffness and strength properties compared to classical FRP designs can be obtained for specific applications. Thereby variable-axial means changing fibre orientation throughout the part. The performance increase is obtained by guiding the loads almost exclusively along the fibre orientation and thus minimizing the shear load of the matrix material. For a technical realisation the Tailored Fibre Placement (TFP) technology, which was developed at IPF Dresden (Germany), is well suited. Basics and some applications of the TFP technology are described in Refs. [1-6]. With a good compromise of efficiency and flexibility this technology can be applied to produce small and medium sized variable-axial FRP parts.

However, the flexibility for highly optimised designs causes difficulties, which limit industrial applications so far. Generally, a variable-axial fibre pattern can imply a varying density of fibres, which causes a non-uniform thickness of FRP preform. This increase of complexity is a major drawback for the widespread use of such a technology. The knowledge of the thickness distribution and the local fibre orientation corresponding to an arbitrary fibre layout is essential for the part design process.

According to the state of the art a modelling of composite structures is limited to a stacking of unidirectional reinforcement fibres with a constant thickness and a constant fibre angle within each applied layer. Models for structural analysis for uniform spirals and single curved tapes of parallel fibres and constant thickness have been successfully applied additionally by an increase in modelling efforts [6, 7]. In each case an analytic description for the local preform thickness and the fibre orientation is known, which can be used to build appropriate finite element models for structural part simulation. However, the existing model limitations are too strong if one plans to apply optimization strategies to fully exploit the potential of FRP made by TFP and to adapt to given production requirements.

With this work we present an approach to model variable-axial FRP's solely based on the given fibre path information, the fibre properties, and the stacking sequence. The method is implemented in a standalone software tool to generate 3D FE-models from fibre patterns represented as 2D-CAD files of almost arbitrary design. A simplified mathematical description of the fibre pattern leads to an analytical result for the thickness distribution and locally averaged fibre orientations. The concept applies macro-scaled models, which incorporate the locale thickness and fibre orientation information on a per element basis. This means the node geometry is obtained by the thickness and the elemental coordinate system follows the averaged fibre orientations. Thus we obtain fast and sufficiently accurate simulations as experimental results demonstrate. Restrictions on the element size are illustrated by convergence studies of specimen in comparison to experimental data. The existence of such a model generator enables a full usage of flexible fibre layouts and an accurate evaluation of properties before the first prototype is fabricated. Furthermore, even iterative optimization strategies with feedback loops become possible.

REFERENCES

[1] Gliesche, K., Feltin, D.: Beanspruchungsgerechte Textilkonstruktionen für composite-Bauteile, *Technische Textilien/Technical Textiles*, Vol. **38**, page 1050, 1995.

[2] Mattheij, P.; Gliesche, K.; Feltin, D.: Tailored Fiber Placement - Mechanical Properties and Applications, *Journal of Reinforced Plastics and Composites*, Vol. **17**, pp. 774–786, 1998.

[3] Cherif, C. (Ed.).: Textile Werkstoffe für den Leichtbau, *Springer, Berlin Heidelberg New York*, 2011.

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

[5] Uhlig, K.; Spickenheuer, A.; Gliesche, K.; Karb, I. Strength of CFRP open hole laminates made from NCF, TFP and braided preforms under cyclic tensile loading, *Plastics, Rubber and Composites*, Vol. **39**, pp. 247-255, 2010

[6] Uhlig, K.; Spickenheuer, A.; Bittrich, L.; Heinrich, G.: Development of a highly stressed bladed rotor made of CFRP using tailored fiber placement technology, *Mechanics of Composite Materials*, Vol. **49**, pp. 201-210, 2013

[7] Gürdal, Z.; Olmedo, R.: In-plane response of laminates with spatially varying fibre orientation: variable stiffness concept, *AIAA Journal*, Vol. **31**(4), pp. 751–758, 1993