1 Fibre reinforced composites are ”tailor-made” materials

A special characteristic of continuous fiber reinforced compounds is their anisotropic properties. Only along the fiber direction do the maximum mechanical characteristics - like solidity and stiffness - exist.

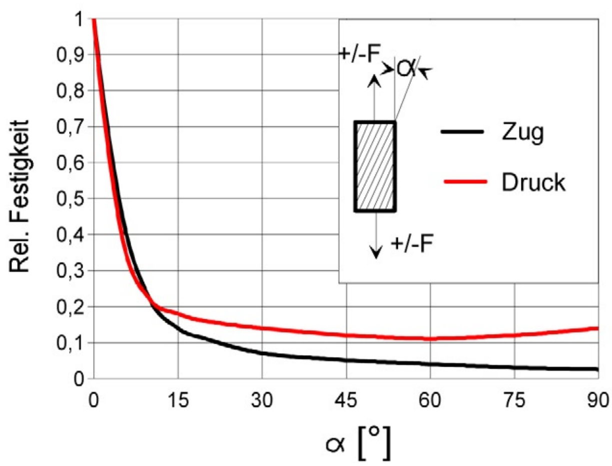

Bild 1: Abhängigkeit der relativen Festigkeit vom Winkel zwischen Kraft- und Faserrichtung

Already the small differences between fiber orientation and the angle of maximum stress can enormously reduce the load carrying capacity (s. Fig. 1). Therefore, designers attempt to arrange the fibers in such a way that they follow the stress field in the composite component under end-user conditions. This is what is meant by the term “tailor-made” material. Using analytical and numerical calculation methods the stresses in components can be determined qualitatively and quantitatively.

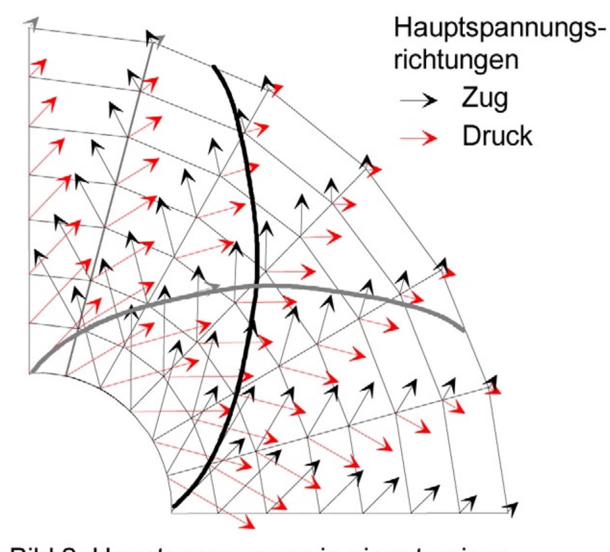

Bild 2: Hauptspannungen in einer torsionsbeanspruchten Scheibe (Viertelsegment)

The example in Fig. 2 shows the calculated stress distribution in a torsionally loaded disc.

The FE-analysis generates a vector plot of the principal stresses. The direction and size of the vectors indicate a stress field aligned fiber orientation along the two drawn curvilinear patterns which intersect in an angle of 90°.

Such an optimal stress field aligned fiber orientation results in fibers being placed alternating under +45° and -45° over the whole disc area. In the center area the loads are higher than at the outside so that the thickness of the disc should smoothly change from thick at the centre to thin at the outside edge. With conventional semi-finished reinforcements such as fabrics, multi-axial warp knitted fabrics, and braids, this is only partly possible.

2 Manufacturing of 2D-Reinforced Fiber Preforms for Fiber Compound Components Using the Tailored-Fiber-Placement Technology

A number of textile reinforcements are available on the market which are made using many different manufacturing techniques. These textile reinforcements can be e.g. woven, braided or knitted.

Fibers in reinforcements for advanced composite components should be arranged in the following way:

- stretched (without waves and twists),
- aligned to the stress field,
- constantly stressed (local thickness of the component corresponds to the local load).

Conventional semi-finished reinforcements can sometimes comply with these requirements. However if the component has complicated shapes and load paths then the optimum fiber orientation is not economically feasible.

That is why the Institute of Polymer Research of Dresden developed the Tailored-Fiber-Placement-Technology (TFP-Technology), which allows the results of a stress and strain calculation to effectively transfer into a textile reinforcement structure. The process is based on the well-known embroidery technique. By using CAD technique the desired fiber course is converted into a software pattern which, fed to an embroidery machine, takes care that reinforcement fibers, e.g. rovings, are stitched upon a base material (s. Fig. 3). Examples are presented in the collection of applications s. Point 6.

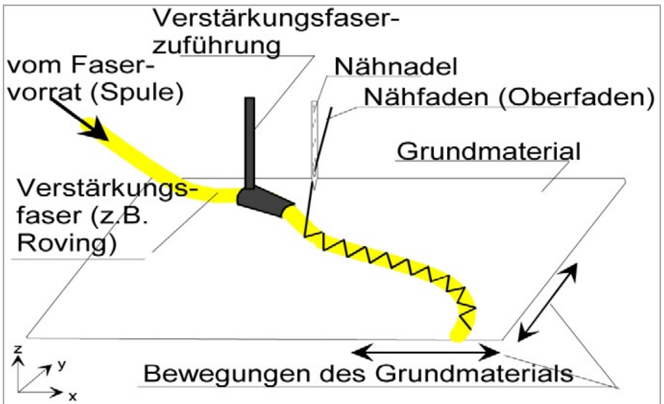

Bild 3: Prinzip der Herstellung von Tailored-Fiber-Placement-Preforms (ohne Darstellung des Unterfadens)

The TFP-technology has several advantages compared to other textile technology:

- the angle of fiber placement during the lay-up process can be varied freely between 0° and 360°,
- repeated fiber placement on the same area allows for local thickness variations in the fiber preform suited for the fiber composite component,
- the conversion of the desired fiber orientation in a fiber placement pattern for the embroidery machine requires minor development times and costs,
- the process allows a near-net-shape production, which results in low waste and optimal fiber exploitation,
- the possibility to process a variety of fibers such as natural, glass, aramid, carbon (high strength and high modulus) and ceramic fibers.

3. Consolidation of TFP-preforms

The consolidation of TFP-Preforms to composites can be done with conventional processing techniques such as resin transfer molding, vacuum bag molding, pressing and autoclaving. In case of thermoplastic composites the matrix material and the reinforcement fibers can be placed simultaneously e.g. in the form of films or fibers. The base material can then be a thermoplastic foil which melts during the consolidation process and becomes part of the matrix. This type is ideally suited for deep-drawn TFP-preforms.