New developments and applications of textile reinforcements for composite materials

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A more extensive use of fibre-reinforced composites can be achieved by the reduction in production costs. The friction spinning process can be effectively used to produce hybrid yarns with integrated matrix material. Two-dimensional textile preforms can be manufactured in a rational way as knitted multiaxial layers or as woven narrow fabrics. Fibre reinforcements for three-dimensional composites with varying cross-sections can directly be produced without a laying process by a new knitting method or a 3D-rotational braiding procedure. The above technologies have been discussed in this paper.

Keywords: Advanced composites, Textile reinforcements

1 Introduction

The Institut für Textiltechnik (ITA) of the Aachen University of Technology, Germany, is developing new techniques for the production of composites. The potential of conventional fibre laying and wrapping technologies is largely exhausted. A further rationalization in production of long fibre-reinforced composites can, for example, be achieved by the combination of the matrix material and the reinforcement fibres in one yarn and preconfectioned textile reinforcements can be realized.

2 Spun Textile Prepregs

So-called friction-spun hybrid yarns in core-cover structure, i.e. with a complete covering of the brittle filament core with thermoplastic staple fibres, are produced by friction spinning. With this method a textile prepreg is achieved as a yarn. The cover protects the core of filaments against mechanical damage during subsequent textile treatment. The integration of the thermoplastic matrix material into the textile semifinished yarn allows to rationalize the production of fibre-reinforced composites, because soaking with resin is no more necessary. The hybrid yarns are produced on a DREF-3 spinning machine by Dr. Ernst Fehrer AG, Austria, modified by ITA¹, as shown in Fig. 1. A glass-, carbon- or aramid filament yarn (1) is fed in a rectilinear way via a tensioning unit (2) into the spinning device. The straight path of the yarn ensures that no filament damage occurs. Above the friction drums (3) there is a drafting device (4) with an opening unit (5). Here, the material, to cover the filaments, is supplied as slivers (6). Polyester (PET), polyetheretherketon (PEEK) or liquid crystal polymer (LCP) are the possible materials for use. In the gusset between the friction drums the spinning takes place covering the filament yarn completely with thermoplastic staple fibres. The core-cover ratio can be adjusted in a wide range. The filaments are processed untwisted and

![Fig. 1—Modified friction spinning device DREF-3 for production of hybrid yarns](image-url)
completely straightened, which allows them to realise their maximum strength potential. Finally, the hybrid yarn is wound on a bobbin (7).

Hybrid yarns were subsequently processed on weaving-, braiding- and knitting machines as well as in pultrusion at ITA. The textiles were then consolidated. A fast production and a very good fibre-matrix compound under avoidance of air inclusions has been achieved because of the already integrated thermoplastic matrix material.

3 Two-Dimensional Textile Reinforcements

ITA is working on the optimization of techniques for the production of sheet-like reinforcement textiles with fibre load bearing orientations for high-loading.

3.1 Warp Knitted Multiaxial Layers

With the multiaxial warp knitting process (Liba system) up to seven sheets of parallel high performance fibres can be laid in defined angles of orientation and fixed by knitting (Fig. 2). Sheets of filament yarns (1) are pulled off a bobbin creel (2) and are fed to the machine which has pin chains (3) at each side. Several weft insertion systems (4) spread out the sheets of yarn on top of each other in angles of 90° and ±30° to ±60° related to the working direction. Above or below the layers, an additional covering (5) and an extra layer of yarn in 0°-orientation (6) can be added. A further sheet of yarn (7) is fed to the knitting unit (8), where the layers of yarn are fixed by a loop system. After that the knitted multiaxial layers (WIMAG) (9) are wound up (10).

The production of WIMAG is very productive as a delivering speed of up to 60 m/h can be reached. The properties of drapeability and strength can be varied in a wide range by changing the number and orientation of the layers. Hereby, a construction of the textile to meet requirements of further processing and strain in the final composite can be realized. At the Aachen University of Technology a motorcar wheel and panels for aircrafts were, for example, made of composites using WIMAG.

3.2 Special Woven Narrow Fabrics

The cutting and laying of textile reinforcements are very expensive processes and can, for some geometries of construction, completely be avoided by the proper choice of production method. A recent development by Jacob Müller Forschung AG, Switzerland, allows the production of profiled woven fabrics. At the beginning the textile is manufactured in a special weave construction as a flat fabric on a narrow fabric loom. After that it is cut open at the sides so that, for example, an I-beam-profile fabric is obtained.

The fabric shown in Fig. 3 was produced and consolidated from friction-spun hybrid yarn in cooperation with Jacob Müller Forschung AG and ITA. In this kind of production the protecting function of the fibres spun around the filament core has a favourable effect, because no damage caused by friction between yarn and healds can occur during the weaving process. The integration of matrix material into the yarn allows the consolidation of the composite by pultrusion or moulding directly after weaving. Such components

Fig. 2--Multiaxial warp knitting machine (Liba system)

Fig. 3--I-beam-profile narrow fabric partly cut open and the resultant consolidated composite
4 Three-Dimensional Textile Reinforcements

Often fibre-reinforced composites with large extensions and changing cross-sections along their longitudinal axis are wanted. Using special textile manufacturing techniques, such components can be produced as prepregs without having to drape textiles into form.

4.1 Three-Dimensional Raschel-Knitted Fabrics

With the raschel technique, modified by ITA, shaped knitted fabrics with variable cross-sections can be produced so that a spaced three-dimensional textile is obtained. In Fig. 4, the top shows the construction of the double-walled knitted fabric with a variable cross-section. The two biaxial reinforced facing surfaces are connected in altering distances with plush threads by moving the segmented raschel elements during production. After subsequent soaking with resin and consolidation of the walls and foaming out the space between the walls a very firm and lightweight construction is obtained. This can be used as a preconfectioned monocoque element with integrated stringers by the aircraft- or shipbuilding industry.

4.2 Three-Dimensional Braids

Apart from a variable cross-section, the integration of fastening elements is often desirable. A newly ITA-developed rotational braiding machine allows to vary the braided cross-section during processing and to incorporate inserts in the textile semiproduc. In contrast to conventional braiding machines, the transfer of the bobbins from one horngear to the other is not caused by a positive mechanical drive. The way of each bobbin is controlled by electrical switches below the horngears which allow to change the geometry of the braiding during the process by varying the movement of the bobbins around the stationary threads and the number of involved bobbins. Collision of bobbins is avoided with the help of a special software program. Fig. 5 shows a three-dimensional rotational braiding machine for industrial use, manufactured and distributed by Herzog GmbH, Germany. The photograph shows at the bottom the braiding area with 50 bobbins. Above the braiding point the textile semi-finished structure in the form of an I-beam can be seen.

5 Summary

The reduction in manufacturing costs of advanced composites is possible by two ways:
- optimization of traditional textile technologies, and
- development and application of new textile production techniques for advanced textile structures.

The results are:
textile reinforcement structures with load-bearing fibre orientations adapted to the special demands of composite components, and lightweight composites with excellent mechanical properties.

There is a high potential for advanced textile structures, discussed in this paper, as reinforcements of composite components.

References