From a Different Angle

ORW Technology Enables Multi-Axial Local Reinforcement for RTM Structural Components

In the manufacturing of RTM structural components, semi-finished textiles can be locally reinforced at different angles using a special weaving procedure. This allows the mechanical properties to be improved in highly stressed areas.

Glass-fiber-reinforced headlamp bowl with local carbon fiber reinforcement. It was possible to enhance the mechanical properties according to the load orientation through the multi-axial integration of carbon fibers into the basic glass fabric (© Fraunhofer ICT)

The requirement profile of textile-reinforced structural components is increasingly complex, in terms of fiber orientation according to the load transmission, tailored joining techniques and functional design. There is concurrent a growing demand for the cost-efficient design and manufacture of these structural components. As the load within a fiber composite component can vary significantly, it often makes sense to integrate local reinforcement into highly stressed areas. This can be achieved by a complex stitching process, or by integrating the reinforcement as an insert into the layer structure before infiltration. Semi-finished textiles are generally used for non-local reinforcement in composites, because there is no economically viable weaving technique for the local integration of reinforcing fibers.

Multi-Axial Fabric Reinforcement

Open reed weave (ORW) technology, developed by Lindauer Dornier GmbH, which was used in an industrial research and development project on multi-axial high-performance woven structures, offers high potential for the development of multifunctional, multilayered structures. In contrast to the current state of the art, this weaving technology enables the complete or local integration of fibers during the weaving process within one process step, including orientations deviating from 0° (**Fig. 1**). This is achieved by adding a third and fourth weaving axis to the weaving machine. Technically this requires an open-top reed and two needle bars, which are installed onto the front weaving shaft, and which can each be laterally displaced as required using a linear drive (**Fig. 2**).

For the first time, ORW technology makes it possible to manufacture a multi-axial reinforcement fabric, in which high-strength or highly rigid (and therefore expensive) reinforcing fibers (e.g., carbon »

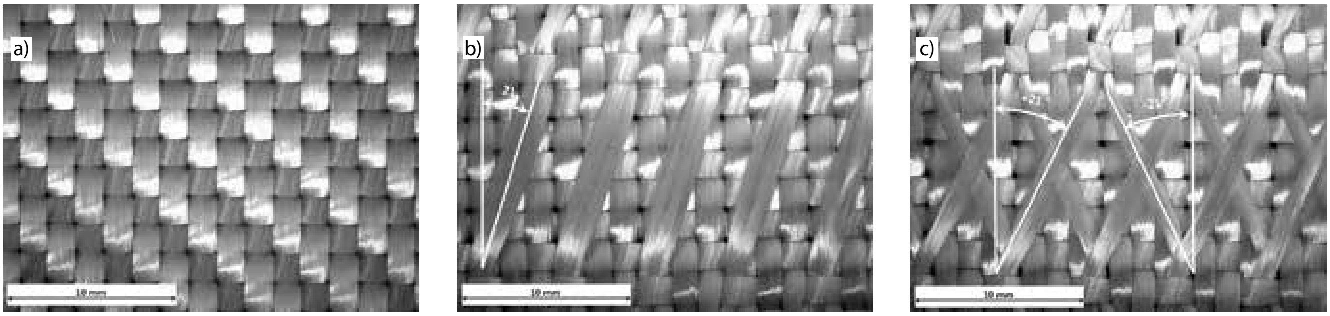

Fig. 1. Reinforcing fabric made of glass fibers without (left) and with multi-axial reinforcement: a) bi-axial base fabric; b) tri-axially reinforced fabric, angle +21°; tetra-axially reinforced fabric, angle ±21° (© ITV Denkendorf)

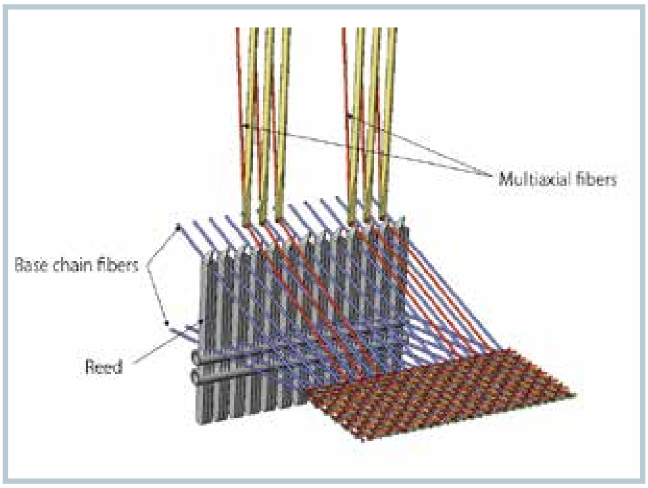

Fig. 2. Schematic diagram of the ORW concept (© Lindauer Dornier)

The Authors

Prof. Dr.-Ing. Frank Henning is the Head of the Polymer Engineering Department and Deputy Institute Director of the Fraunhofer Institute for Chemical Technology ICT, Pfinztal, Germany.
Dr.-Ing. Bernd Thoma leads the project group for high-performance fiber composites at Fraunhofer ICT.
Dipl.-Ing. Rainer Wendel is a researcher in the group for high-performance fiber composites at Fraunhofer ICT; Rainer.Wendel@ict.fraunhofer.de
Dipl.-Ing. Philipp Rosenberg is a researcher in the group for high-performance fiber composites at Fraunhofer ICT.
Prof. Dr.-Ing. Götz Gresser is Head of the Institute of Textile Technology and Process Engineering (ITV), at the German Institute of Textile and Fiber Research (DITF), Denkendorf, Germany.
Dr.-Ing. Hans-Jürgen Bauder is Head of the Weaving Technology and Filament Yarn Finishing Department at ITV.
Dipl.-Ing. (FH) Jürgen Wolfrum is a researcher in the Weaving Technology and Filament Yarn Finishing Department at ITV.
Metin Caliskan is a technician in the Weaving Technology and Filament Yarn Finishing Department at ITV.

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fibers) are locally integrated specifically into highly stressed areas, rather than throughout the material. More cost-effective glass or natural fibers can then be used in less stressed areas of the component. ORW technology provides the prerequisite for manufacturing a semi-finished textile which is specifically adjusted to the load of the component, and in which the additional reinforcing fibers are stably connected to each other within one textile layer.

For evaluation of the mechanical properties of the components, in a collaborative project the Fraunhofer Institute for Chemical Technology ICT, Pfinztal, Germany, and the Institute of Textile Technology and Process Engineering ITV, Denkendorf, Germany, manufactured, infiltrated and subsequently characterized fabrics with multi-axial fibers at an angle of ±21° and ±41°. Each of the laminate plates consists of four textile layers, but

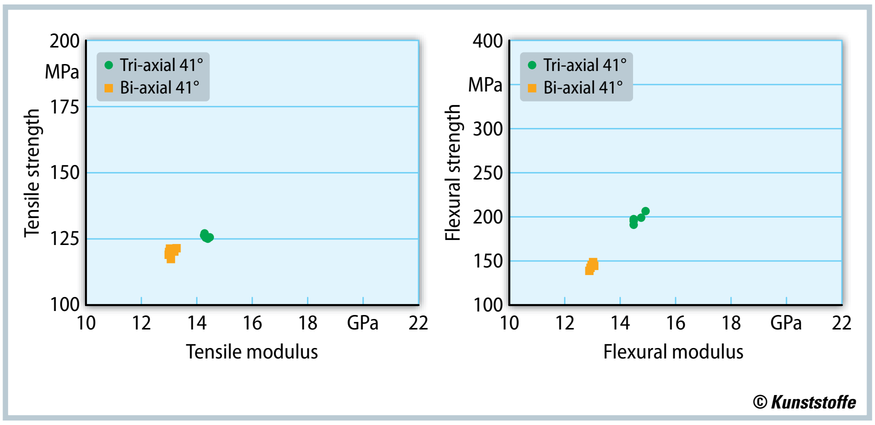

Fig. 3. Comparison of the tensile and bending properties of composites without and with multi-axial reinforcement at 41°. The properties in multi-axial direction could be further enhanced by increasing the amount of fibers per centimeter during the weaving process (source: Fraunhofer ICT)

only the two outer layers are reinforced with multi-axial fibers.

With two multi-axial fibers (300 tex glass fibers) per centimeter in the direction of loading and 600 tex glass fiber rovings in the basic fabric, the additional fiber volume content of the multi-axial fibers in the plate is only 4 %. The determined tensile and bending properties of the bi-axial base fabric and the tri-axial reinforced fabric (angle 41°) are compared (**Fig. 3**); the testing direction corresponds to the 41° angle. However, this small proportion of glass fibers is sufficient to enhance the tensile and bending properties in the direction of strengthening.

Significant differences are observed when comparing the mechanical properties of the components with integrated multi-axial fibers at an angle of 41° to those with an angle of 21°, although the number of fibers remains the same. Reinforcement at an angle of 21° increases (presumable due to the smaller ondulation of the fibers) the tensile and bending strength as well as the tensile and bending modulus (**Fig. 4**). Here, too, the testing direction corresponds to the angle. A further increase is expected if a 6K carbon fiber roving is used instead of a 300 tex glass fiber direct roving and/or if the fiber density in the multi-axial area is increased. The latter, however, requires a redesign of the ORW installation of the weaving machine.

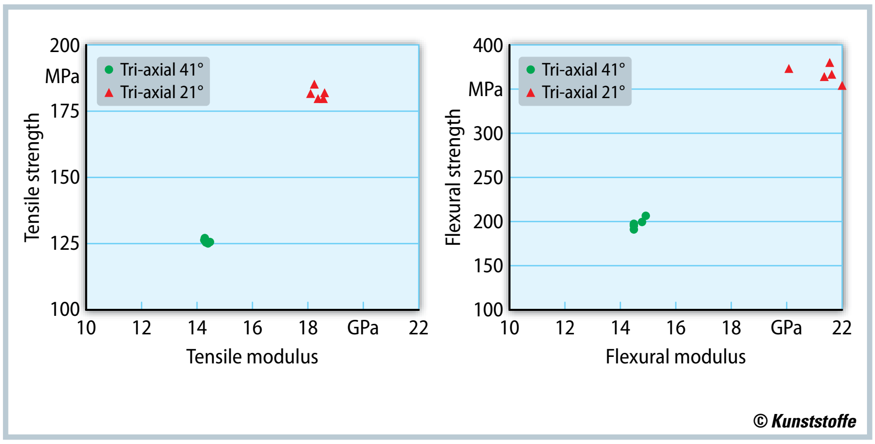

Fig. 4. Comparison of the tensile and bending properties of composites with multi-axial reinforcement at 41° and 21°. One reason for the improvement of the mechanical properties is presumably the smaller ondulation of the fibers at 21° (source: Fraunhofer ICT)

The Challenge of Reshaping

Using a so-called headlamp bowl from a car trunk lid as a case study (**Title figure**), researchers were able to demonstrate the further processing of a fabric that was reinforced multi-axially using ORW, to create a complex fiber composite component. A glass fiber semi-finished product was locally reinforced with carbon fibers (**Fig. 5**). In preforming, the process step of draping constitutes a new challenge. Because of its inhomogeneous structure, the hybrid fabric, which consists of glass and carbon fibers, shows a different draping behavior than homogeneous carbon fiber or glass fiber layers.

For this reason, in initial experiments, wrinkles developed in the fabric, and fiber loops appeared in the area of the local carbon fiber reinforcement. For prevention of these problems, the integration and layout of the local carbon fiber reinforcements in the semi-finished textile were adjusted step-by-step. The RTM process was selected for the infiltration of the preforms. It enables the production of composites with complex geometries.

Conclusion

Based on the headlamp bowl geometry, it was demonstrated that ORW enables the reinforcement of even complex structural components close-to-contour and according to the load orientation. It is therefore possible to improve component properties significantly, while reducing the processing efforts and the costs. ORW is a textile production technique which, together with the RTM process, is a promising tool for the development and manufacturing of new and cost-effective constructions for textile lightweight designs. ■

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Fig. 5. Steps for the further processing of a fabric, which was reinforced multi-axially using ORW, to produce a finished fiber composite component: two-dimensional pre-cut fibers (left), fiber preform (center), infiltrated RTM component (right) (source: Fraunhofer ICT)