COMPOTECH
Structural Composite Tubes

Advantages of Axial Fibre Laying

Introduction

During the last decade, performance composite components have been used in an increasing number of different applications, such as transport, marine and energy. One factor is the decreasing carbon fibre prices, which have created new demands for composite technologies. Industries can now adopt better materials to produce better performing products, whilst maintaining efficiencies of productivity and cost. Whilst various new processes have been developed to facilitate this surge in carbon fibre use, one of particular note is **axial fibre laying**.

Conventional filament winding

There are several existing techniques of axial fibre tube winding based on filament winding machines currently available on the market. However, these have some disadvantages, such as the need for a winding machine with more than three controlled axes, lower productivity and poor axial layer consolidation. As a result, it is more common for winding to be done at a very small angle of 5° or 7° or "Near Zero". The stiffness and strength characteristics are assumed to be very similar to the axial (or 0°) winding, but CompoTech has found that these differences are not negligible. There is there is a difference in stiffness between "Axial Fibre" and "Near Zero" winding of about 15 %, and the difference in strength can be up to 40 % depending on winding sequence.

CompoTech's axial fibre laying process

Taking into consideration the limitations discussed previously, CompoTech has developed a new processing technique to achieve:

- Maximum bending stiffness and strength of tube or beam
- Both thin and thick walled tubes and sections
- A process primarily for carbon fibre
- A productivity equivalent or better than conventional winding

The main principle of the CompoTech axial fibre laying process is a new approach to solving the precise fibre tow placement at the ends of the mandrel. Individual fibre tow pre tension can be achieved both in axial or off-axial layers. This technique combined with suitable layer stacking results in excellent laminate consolidation with a volume fraction of up to 70 % in a thin or very thick laminate, without further consolidation by additional external pressure systems.

This unique process has been developed over the last decade through extensive research and development, analysis and practical application, and can now offer:

- Constant thickness or tapered axial laminates along the beam
- Any convex closed cross-section
- Optimised axial fibre layed where most effective around the section
- High volume fraction and low porosity in both thin and thick walled structures
- Only two axis machines are necessary
- Option of wet or dry winding

Axial fibre versus “Near Zero”

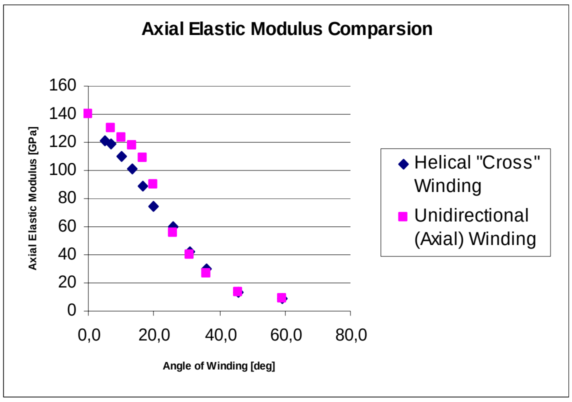

Figure No.1.

Figure No.2: Axial layer visible between the crossings of a partial helical layer.

As mentioned, one of the most common winding techniques in order to achieve maximum bending stiffness and strength is the use of close to 0° (usually 5°) helical winding with fibre tow cross-overs. In collaboration with the Czech Technical University in Prague, CompoTech tested over 300 tube samples, made from the same number of carbon fibre tows per layer, but with different winding angles. Two groups of tubes were made: one using a typical ‘near zero’ helical winding process with fibre cross-overs; the other using CompoTech’s axial fibre laying process, enabling either a perfect axial layer or unidirectional off axial layer. To accurately compare both techniques, all tubes were tested for axial stiffness and strength.

Figure No.1 clearly illustrates the difference between helical winding with cross-overs, and axial winding without cross-overs. The helical winding is less stiff in the axial direction, especially at low angles under 20°. When tested for strength, an even greater difference was recorded, with axial laying demonstrating up to 40% more strength that helical winding. It is clear that fibre tow cross overs decrease both the stiffness and strength of a layer.

Axial fibre laying applications

The axial fibre technique is advantageous for any structural tube or beam that requires the maximum possible bending stiffness and strength, such as:

Structural Components
Rollers & Drive Shafts
Hydraulics & Pneumatic Tubes
Robot Arms & Frames
Electrical Insulation Products
Marine Components
Sporting Equipment Parts

Photo courtesy of Vestas Wind Systems

The advantages of axial fibre laying can be illustrated by the industrial roller tube application:

A standard HS carbon fibre wound roller made by axial fibre laying can achieve up to 25% axial stiffness more than the one made by helical winding, with the same weight and radial characteristics. This gain can be also used in another way - a roller made by axial fibre laying can be wound with equal stiffness but with significant weight and cost saving.

One of the important parameters for correct axial layer consolidation is correct laminate stacking. This means that axial layers need to be locked between two other layers of off-axis helical winding. This effect is conveniently used in the case of thick walled tubes designed for maximum strength. In tests, for example, a circular rudder shaft made out of HS T600 fibre will usually achieve stress levels of over 1200 MPa in the axial layer. These shafts, with a wall thickness of over 20 mm, contain 84% axial fibres by volume.

Similar construction is used in a relatively thin walled drive shaft working with high speed of revolution, where an axial layer is locked between two 45° helically cross-wound layers. Axial fibres enable a cost effective design by combining high modulus fibre for axial stiffness to raise the critical speed of revolution, with cheaper HS fibres for the rest of the laminate transferring torque.

A very special feature of axial fibre laying is the ease with which axial fibres can be placed unevenly around the section. For example a box-section beam can be made with axial layers placed only on top and bottom of the beam to support bending moment and stiffness only in the desired direction. The same technique can be used on a circular mandrel, where the resulting outer shape is ellipse. This technique is very beneficial for mast sections, where sideway stiffness and fore and aft stiffness is controlled by specific axial fibre placement on the sides or front and back of the mast section.

UK office:
CompoTech Plus spol. s r.o.
10 Princes Esplanade,
Gurnard, Isle of Wight,
PO31 8LE, United Kingdom
T : +44 (0) 1983 290 323
F : +44 (0) 1983 290 218

www.compotech.com

Czech office:
CompoTech Plus spol. s r.o.
Družstevní 159
Sušice 34201
Czech Republic
T : +420 376 526 839
F : +420 376 522 350