COMPOTECH
Structural Composite Tubes

Technology Overview

Introduction

CompoTech places equal importance on every aspect of its technical capability, from the initial design and engineering through to materials selection and production process. Much research has been carried out into all of these areas to ensure customers receive a structural composite tube that will perform to the highest standards, whatever the application.

CompoTech has developed its own fibre laying process for structural composite tubes, which is particularly suitable for components which require high bending stiffness and stability. This is called the zero degree axial fibre laying process.

To ensure that this new process is successful in the many applications in which it is used, CompoTech has developed its own technology tools, which include:

- Design methods and software
- Axial fibre laying machinery
- Axial fibre laying process
- Testing methods
- Quality assurance

Each of these tools is described in further detail overleaf. For more detailed information about the zero degree axial fibre laying process, please refer to CompoTech's 'Advantages of Axial Fibre Laying' document, which can be found on the Downloads page of the CompoTech website:
www.compotech.com

Design methods and software

CompoTech's approach is to encapsulate all aspects of the process for maximum results. This starts with interpreting the customer's initial request and fully understanding the end goal; continues with the use of the latest design methods, bespoke design software, purpose built machines and control software; and concludes with product testing, manufacture, quality control and final delivery.

CompoTech’s designers have extensive experience of understanding, analysing and solving very complex composite problems, including their practical application and interaction with, and design of, components made from other materials.

CompoTech uses two basic groups of software for designing and analysing fibre layed structures, which were developed by CompoTech in close collaboration with the Czech Technical University in Prague.

The first group of software analyses stresses and displacements of cylindrical, fibre layed, laminated composite shells. Two approaches have been developed:

The first is simple linear shell theory based on Kirhoff's conditions of shell deformation, known as Classical Laminating Theory. CompoTech has developed its own method of unit forces distribution in the cross-sections of tubes. This enables different loads such as bending moment, torque, axial force or thermal load to be solved together. Because this method is based on plate theory, the advantage is a simpler and more precise two-dimensional data preparation, and the possibility of solving several loading states at the same time. This method is powerful enough for most composite tube applications and has been verified by full destructive tests on test samples.

The second approach is based on the theory of the cyllindrically anisotropic elasticity. Using Lekhnitskii's stress functions, a closed form solution for calculating stresses and displacements was found. The advantage of this approach is the exact and precise calculations of three-dimensional stresses in a fibre layed tube. It particularly enables the analysis of the stress gradients through the thickness of a laminate, which may be very substantial in the form of interlaminar stresses for thicker sections of composite tubes. The disadvantage is a more complicated three-dimensional lamina data preparation and the possibility of solving only one load state - bending moment. CompoTech is currently working on a solution using this method for three load states: bending, torsion and axial force.

The second group of software solves and analyses stresses and displacements of fibre layed, laminated composite shells of generally noncircular cross-sections. The principle of this model is the integration of stiffnesses of elements in a cross section. The stiffnesses are calculated as a transformation of Classic Laminated Theory into a geometric three-dimensional expression. The mathematical model for composite beam analysis is a very close replica of each command in the manufacturing process. Special software was developed to calculate deflection curves and deformations of beams or spars. The main advantage is that the way mathematical models are built from elements is identical to the way in which the structure is made, offering accuracy and time saving in pre processing data entry and in transferring results directly into the production code. In order to analyse the details of CompoTech products, such as contacts or joints with other components, FEM software is used in collaboration with Czech Technical University in Prague.

Axial fibre laying machinery

CompoTech has developed and built its own fibre laying machines, including control software, systems, and supporting machines, which, in conjunction with extensive design and engineering capabilities, enable CompoTech to offer a high quality solution to customers.

CT 5000/190-98 is a light single spindle machine designed for production of lighter products up to 30kg in weight, 5000 mm in length and 190 mm in diameter.

CT 8000/450-01 is a two spindle high productivity machine designed for production of heavier tubes up to 400 kg of weight, 8000 mm of length and 450 mm of diameter when using both spindles; or up to 1500 mm diameter when using only one spindle. It is specifically designed for a high torque of up to 250 Nm and for up to 10 tows of fibre to be laid under high tension simultaneously. This creates an excellent fibre and resin consolidation, resulting in a very high performance laminate.

The process support machines developed and built by CompoTech are a shrink tape wrapping machine, hydraulic extractors, computer controlled ovens and trimming / cutting machines. Other equipment includes a lathe capable of turning carbon tubes and shafts up to 3000 mm lengths and 450 mm diameter.

Axial fibre laying process

CompoTech's unique zero degree axial fibre laying process offers structural components and mechanical operations the following benefits:

- Maximum bending stiffness and strength
- Predictable and controllable high fibre content
- Consistent and repeatable thin or thick walled tubes and sections
- A productivity better than filament winding and pull winding

This is due to the optimisation of the axial fibre placement, which achieves high volume fibre fraction of up to 70% and low porosity, both of which contribute to the impressive stiffness and strength performance.

The laying of fibres in filament winding is carried out at a small 'helical' angle of 5° or 7°, which is often called 'near zero'. Although many people believe the strength and stiffness characteristics to be the same as zero degree (unidirectional) axial fibre laying, CompoTech's research has shown that there is a clear improvement of about 15% in stiffness and about 40% in strength of zero degree axial fibre laying over 'near zero' degree.

The CompoTech axial fibre laying process was developed and tested over a long period of time on many different applications, most of them taking advantage of CompoTech's superior bending stiffness and strength.

Applications differ in size: from a 56g, 200 mm long telescopic mountain bike fork tube to a 36 kg windmill tip shaft, 150mm dia x 2800mm length, with a wall thickness of 18mm; from a 190g kayak paddle shaft, 29 mm dia x 1200 mm length, to a 17kg double tapered spinnaker pole, 8m long, 195mm dia.

Applications are also different in cross section: from the 30 mm dia double tube aerofoil section of a 26 m long America's Cup headfoil, to the 17m D shape mast section of a 10m Thompson performance sportsboat.

Most of CompoTech's composite tubes have an average of 80% axial fibre volume to build up the bending stiffness and strength, and about 20% of off-axial fibres to perform well against other off-axial forces. The unique CompoTech method of applying load to the structure by winding in holes has been developed and tested on several applications such as wing spars and hydraulic cylinders.

CompoTech has also developed a system of lightweight and very stiff carbon fibre mandrels specifically for tooling. Ground steel rods or aluminium tubes with a concentricity of 0.2 mm/m are standard mandrels for winding high revolution shafts and rollers.

Testing methods

CompoTech works closely with the Department of Mechanics' laboratories at the Czech Technical University in Prague. The laboratories have state of the art testing equipment to perform numerous tests, from a simple static test to dynamic fatigue testing of large parts. Many different tests, from basic material properties to more sophisticated certification testing programs, have been developed to the requirements of CompoTech customers. Most of these are the bending test to failure, used to measure the bending stiffness and strength.

The Grant Agency of the Czech Republic has supported CompoTech and the Czech Technical University in a three - year research project, entitled "Analysis of the effect of manufacturing parameters on the behaviour of woven composites". The results of this project help CompoTech designers to better understand the performance of laminates, such as the cross wound layers and different winding patterns in relationship to the consolidation of axial fibres. The company will be integrating further new methods and computational models into its process in the near future.

Quality assurance

CompoTech understands that quality assurance systems are as important as the technology itself. With this in mind, CompoTech has developed a method of monitoring important technological parameters as an integral part of the production process. By putting these parameters back into the design software as part of the quality procedure enables CompoTech to control the critical technological parameters like fibre tension, impregnation, and speed of winding.

Applications

All of CompoTech's composite tubes are capable of directly and/or indirectly achieving some or all of the following:

Reducing...
- weight
- assembly time
- number of components
- cost

Increasing...
- performance
- longevity

They continue to be specified in many applications, but nearly all of them have this in common:

CompoTech can use the extra stiffness that is available with their unique axial fibre laying technique either to provide a stiffer tube or to give the stiffness specified with a thinner, lighter laminate at less cost than filament winding.

Applications include:

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

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