Braided Reinforcements Enable Nimble Automation of Composite Molding

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Overview

• Explanation of Braid’s Tailorability
• Description of Braid Types/Architectures
• Advancements in Machinery/Design Possibilities
• Overbraiding and Overbraiding Applications
• Braided Sleevings/Near Net Shape Preforms
• Quasi-Isotropic Architecture – Benefits in Manufacture and Performance
• Automation
Smart Fiber Placement Through Braid

Lower Finished Part Costs Realized Using Braid’s Inherent Automation

Because each individual tow of yarn is controlled individually, a braid can be optimized to enable:

- better mechanical properties
- faster, simpler builds
- thinner, lighter, tougher laminates
- reduced manufacture time
Braid Can Be Tailored To Optimize Specific Property Requirements:

- Stiffness – Axial, Transverse, Shear
- Strength – Axial, Transverse, Shear
- Coefficient of Thermal Expansion (CTE)
- Compression After Impact (CAI)
- Reduced Interlaminar Shear Stress
- Burst Pressure
- Twist/Bend Coupling
- Fatigue
- Resistivity/Conductivity
- Fiber Volume Fraction
- Porosity

Braid Can Be Tailored For Useability
Braided Products

- Sleevings – biax and triax
- Flat tape – biax and triax
- Unidirectional – sleeving and fabric
- Fabrics – biax and triax in various widths
- Overbraids – complex geometries
- Contoured Braids -constant thickness or constant angle
- Preforms
- Fillets
• Flexible diameter, good conformability & drape
  • Fibers in the bias direction only
• Construction dependent fiber orientation ranging from 15 to 75 degrees
• Locked diameter or width
• Fibers in both axial and bias directions
• Fiber orientation ranging from 10 to 80 degrees
Range of Machinery

- 800 Carrier
- 656 Carrier
- 600 Carrier
- 500 Carrier
- 400 Carrier
- 336 Carrier
- 272 Carrier
- 232 Carrier
- 208 Carrier
- 192 Carrier
- 172 Carrier
Increase in machine size allows for the braiding of very large structures, and enables the production of high coverage braid with small unit cells and the appropriate fiber orientation. (A unit cell is a textile term describing the openings or voids between yarn crossings).
Overbraided Preforms

Reinforcements are tailored to the precise dimensions and structural requirements of the part

• Tailored to the shape of the mold; CNC allowing for thickness variations in the airfoil shape
• “Drop and shoot” dramatically reduces manufacture costs
Capstan Winding – Contoured Braids

The capstan winding process orients the braided sleeve in the circumferential direction of the structure. Use of a wheel with complex geometry allows this Contour to be built into the braid as it is pulled through the formation plane. Since the radius changes as layers accumulate, each layer on the wheel has a different contour.
Containment Systems

Triaxial braids and manufacturing efficiencies found with capstan winding optimize the design/manufacture of jet engine fan cases. Braided composite fan cases are up to 30% lighter than metal fan cases and strong enough to contain a released titanium blade.
Frame Preforms
For the 787 Airframes

The axial fibers in the braid are contoured to follow the shape of the airframe meeting stiffness requirements of the part and optimizing the use of carbon.
Braided Sleeving - Predictable & Repeatable

A sleeving takes on the exact shape and dimensions of the part over which it is pulled. When a braided sleeving is pulled over a part with changing cross-sections the fiber orientation, the thickness, and the yield of the braid vary at each point along the length of the part. These variations are predictable and repeatable and lend themselves to easy and precise manufacture of composite parts.
Braided Sleeving Applications

This side impact airbag is stowed in an elongated configuration, and upon inflation, the airbag self-deploys expanding in diameter and shrinking in length. This tubular airbag provides full coverage at a low angle for the bladder at the inflated diameter, so that it can handle internal pressurization without damage. Small yarns on a 600 carrier braiding machine achieved the design criteria.
• Quasi-Isotropic Reinforcement in a Single Braid Layer
• Symmetric and Balanced with One Ply
• Simplifies Design & Manufacturing Efforts

33% Uniform Stiffness In All Directions
Every Ply Balanced & Symmetric

1 layer braid

8 layers tape

- Allows for decreased layup time
- Reduced thickness, less weight
- Simplified laminate design
- Faster, simpler build
Impact Video of Aluminum Panel

A fracture in the .071” thick aluminum panel propagates rapidly resulting in extensive damage.
Braided Composite Panel

0±60° Architecture
Impact Velocity Below Penetration Threshold

Braided panel absorbs high impact energy without permanent deformation
Uniform lamina stiffness properties in all directions result in efficient energy distribution during impact
Braided fibers within a composite arrest the fracture leaving undamaged composite with structural integrity right up to the edge of penetration. This is particularly important when post-impact secondary loads are a concern. Interlaminar shear stresses are reduced dramatically since there is no mismatch of properties between ply interfaces.
Quasi-isotropic architecture eases engineering concerns granting a constant, drapable fiber architecture.

Dieffenbacher Demonstrator
- Good Drapability
- Stack of 3 Plies

Robust Fiber Architecture
- Cutting & Handling Operations – High Process Reliability
Customization (Hybrid Materials)

Widths To Optimize Utilization
Areal Weights / Thickness
Yarn Type
Hybrids
Fiber Orientation
Strategic Axial Placement

Huge material costs savings
& layup costs savings

Uniform Tool Surface – CTE is maintained with single balanced lamina
Automated Layup of Pressure Vessels

Braided design and manufacturing process for pressure vessels achieving benign, repeatable failure modes. The preform allows contouring materials over the tank end-domes, application of hoop fibers through the cylindrical tank portions, and technology for the placement and application of materials.

Manufacturing efficiencies enable 20 minute cycle times from beginning of wind to out of mold.
Hybrid Architecture

Unidirectional + Biaxial fibers for hoop section

Biaxial fiber-end domes

Fabric end-contouring

Biaxial fiber-end domes
Using the inherent interlocking of fibers in a braid architecture, failure modes were developed that are much more benign than those achieved with filament winding.
Vessels are pressurized with liquid nitrogen (-320F) and shot with a 50 caliber bullet. The 800 grain bullet at 2600 ft/sec has approximately 15,242 joules of energy.
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Braid Optimizes Fiber Architectures
Unlike Any Alternative

Mass production of composites using expensive fibers is made cost-efficient with the use of braid. Optimal utilization of fibers results in reduced waste, reduced layup time and optimized architectures.