3D Woven Textiles for Composite Applications

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Steve Clarke
T.E.A.M., Inc.
Rhode Island based small business specializing in Textile Engineering and Manufacturing formed in 1995

Pre-formers / Weavers of high end, difficult to handle fibers including carbon, glass, aramid and ceramic fibers

Customer base: Composites fabricators and end-users with applications in aerospace, military and industry

ISO 9001 and AS9100 certified

50,000 sq. ft. manufacturing facility built in 2008 and expanded in 2014
Textile Processing Capabilities

- Traditional ("2D") broad goods weaving
- Traditional ("2D") narrow tape weaving
- Braiding (16-288 carrier capacity); Sleeving, tubes, net shape preforms
- Jacquard ("3D") weaving; net shape preforms
- Jumbo Jacquard ("3D") weaving; Thick billets
- Needling, stitching, yarn winding, twisting and serving
2D Weaving

- Traditional Roll Goods
- Narrow Tapes <1” to Standard Fabrics >72” wide
- Carbon, Glass, Aramid and Ceramic Fibers
- Traditional Weaving Looms (Mechanical Control)
2D vs. 3D Weaving
2D Versatility: Traditionally, Jacquard weaving has been used to produce complex 2D patterns, such as tapestries and blankets.

3D Versatility: TEAM uses Jacquard loom versatility to produce complex 3D patterns, which allows for fabrication of:

1. Near Net Shapes
2. Thick Structures
3D Woven Near Net Shape Structures

- Near Net Shape Structures & Complex Geometries
  - Airfoils, Radomes, Tubes, Bifurcated Shapes, etc.
3D Jumbo Jacquard Weaving

- Large, Thick Structures
  8 ft long x 4 ft wide x >3” thick

- Computer Control of Every Unique Warp Fiber (up to 17,000!)
WHY 3D WOVEN COMPOSITES?

Advantages of 3D Woven Composites:
• Delamination resistance
• Damage tolerance
• Tailored x-y-z properties
• Reduced touch labor
• Reduced Finished part Cost
• Fast wet out for VARTM / RTM

Dis-Advantages of 3D Woven Composites:
• Trade-off of through thickness for in-plane properties
• In-plane fiber orientation limited (with some exceptions) to x-y
• High loom set-up costs affect R&D costs
Common Aerospace Applications

CFM Leap-X Engine
https://www.cfmaeroengines.com/engines/leap/

AE 3007 Engine
http://www.aircraftengines.com/pictures/AE3007

- 3D woven composite fan blades
- Contour woven composite fan case
- Ceramic matrix composites for hot section components
- Contour woven containment fabrics
- 3D woven composite vanes
Currently used in production PMC Guide Vane, Fan Blades, Fan Cases and Thrust Reverser Applications

Additional PMC Vanes and Blades are under development, as well as Ceramic Applications

Future opportunities for platforms and spacers, struts, seals, noise abatement systems and hangers
3D Woven Fan Blade Manufacturing Detail

Transform Customer’s Solid Models to a CAD Based Textile Preform Design

Woven Preform with Taper Prior to Edge Trim

Molded Root Section

Twist Imparted in RTM Tool
TEAM has woven 3D airfoil preforms for multiple engine programs since 1995

Over 300,000 3D Woven airfoils are flying today
3D Woven Cross-Sections and Rib Stiffened Structures
Examples of Possible X-Sections

Aircraft Engine Containment Case

Polar Woven Fabrics
Shaped Fabrics for Radomes, Tail Cones, Nozzles, Containment Cases, Fan cases, Exit Cones, etc.
3D WOVEN THERMAL PROTECTION SYSTEMS (TPS) AND STRUCTURAL SYSTEMS FOR HYPERSONIC AND RE-ENTRY VEHICLES

- A heat shield manufactured from HHEET will require seams.
- In FY13 preliminary arcjet testing was conducted to evaluate seams concepts, adhesive, stitched, etc...
- Test results are extremely promising and are providing guidance into the seam requirements.

**Performance combined with robustness makes HHEET an exceptional TPS**
Polar Woven Structures for Deployable Re-Entry Vehicles (NASA Proposal Z7.02-9630, Jan 2017)
3D Weave Preform Design Tools
3D Woven Frac Plugs
Braided Sleeving and Preforms

- Capable of braiding over net shape mandrels or making sleeving / roll goods
- 16 to 288 carrier machines
- Track record of braided product commercialization (Biomedical Structures, Inc.)
Novel Pinwoven Approach for Integral Mortar Fin (Scaleable via a Custom 3D Braiding Process)
Products, Applications and Processes

- **Aerospace**
  - Carbon fabrics for pre-preg & 2D lay-ups
  - Near net shape vanes, and airfoils
  - 3D fan-blades with taper, contour
  - Structural components: “T’s”, “I’s” “V’s”
  - High temp CMC’s for hot section applications

- **Military**
  - 3D woven preforms for composite armor applications
  - Various 3D woven airfoils

- **Industrial**
  - Fiberglass fabrics and hybrids for B&C, infrastructure, automotive and marine
  - Thick, 3D woven billets for oil and gas, chemical and petrochemical applications
  - Various braided and needled structures

- **Textile Preforming**
  - 2D weaving
  - 3D weaving – thick billets + roll goods
  - 3D weaving – near net shape preforms
  - Contoured, Polar and Steered weaving
  - Braiding – 24 carrier – 288 carrier
  - Pinweaving
  - Needling

- **Resin Infusion**
  - VARTM
  - RTM
  - Tackification and preforming