Wind Turbine Blades
Manufacturing Improvements and Issues

TPI Composites, Inc.
Structural Composites Division

Derek Berry

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Manufacturing Overview

• TPI Composites: Brief History

• SCRIMP Infusion Process

• Blade Manufacturing Improvements

• Current Issues
TPI Composites, Inc.

- Fabricating Composite Parts Since 1966
- Rhode Island Facility:
  - Warren (250,000 sq. ft., 23 acres)
- Joint Venture: Vientek Blade Manufacturing – Juarez, Mexico
Warren, Rhode Island Facility
Disney Imagineering
Airport Shuttles
Composite Bus
MHI 1-Megawatt Turbine
SCRIMP

- Seemann Composites Resin Infusion Molding Process
- Vacuum Bag Resin Infusion Process
- Patented Silicone Bags
- Materials Laid-Up Dry
- Virtually Eliminates VOCs
- Aerospace Quality – Large Structural Parts
The SCRIMP Process
The SCRIMP Process

- **Vacuum**
- **Resin Feed**
- **Vacuum**
- **Pervious Conduit**
- **Flow Medium**
- **Mold**
- **Resin Flow Front**
The SCRIMP Process
The SCRIMP Process
Manufacturing Improvements and Issues

• Blade Manufacturing Process Approaches
• Blade Construction Approaches
• Blade Manufacturing Verification Approaches
• Blade Design Approaches
• Current Blade Issues and Future Trends
Blade Manufacturing Process Approaches

• Silicone Bags
• Remote Build
• Heated Molds
Silicone Bag Technology

• Custom bag, formed to a part

• Patented product and process

• Resin feed conduit and distribution pattern built into the bag
Remote Build

• Original Intent
• Lessons Learned
• Robust Process Steps:
  • Material Cutting
  • Material Kitting
  • Laminate Schedules
  • Silicone Bags
Remote Build – Material Kits
Remote Build
Laminate Schedules

STEP 3 / LAYER 3:
- Apply the mat to the area shown above
- Apply 1/4" balsa to the area shown above
- Apply 3/4" balsa wide and over all balsa
- Use the HP balsa templates to cut the shape
- Butt the front edge along the line on the HP
- The balsa (1/4") should start at 180mm from the root
- Balsa (1/4") should not finish the HP
- The balsa should terminate 30mm from the HP

PUT 3/4oz MAT UNDERNEATH AND ON TOP OF ALL BALSA
Remote Skin Infusion Preparation

Remote Blade Assembly
Blade Construction Approaches

- LE Bond Line
- Spar Cap – Constant Width – Constant Taper
- Root Connection
Aerodynamicists?
Offset LE Bond

- High Pressure Skin
- Assembly Bond #3
- Assembly Bond #2
- Shear Web
- Assembly Bond #4
- Balsa Core
- Low Pressure Skin
- Assembly Bond #1
- Unidirectional Spar Cap
Preliminary 50m Blade Design
Planform and Thickness Distributions
Preliminary 50m Blade Design
Constant Spar Cap
Root System Study
Root Stud Testing at NREL

- Back to back root stud configuration
- Static testing
- Fatigue testing
Root Stud Fatigue Test
Load – Life Results

Tests performed at $R = 0.1$
Test Frequency = 5-Hz (4-Hz for 1999 Tests)
Post Mortem of Epoxy Bonded Stud
NPS-100 – Bonded Root Inserts
Blade Manufacturing
Verification Approaches

• Blade Sectioning
• NDT – UT: Bond Lines
• Testing
Blade Sectioning

- Laminate design
- Internal blade geometry
- Blade adhesive
- Chordwise CG
- Static Balance
- Manufacturing variations

Laminate Fabric Wrinkle
Blade Proof Testing
Blade Proof Testing
Blade Design Approaches

• Blade Materials
  • E-glass
  • Carbon / E-glass hybrid
  • S-glass
  • Carbon / Wood / E-glass hybrid (zebrawood)

• Blade Geometry
  • Thick Airfoils
  • Flat-Back Airfoils
Innovative Design Results
Alternate Blade Materials

Shell Weight Comparison for Alternative Spar Cap Materials
Examples of Thick Airfoils

Illustration of Blade Sections at 25% Span
Examples of Flatback Airfoils

FB–6500–2000 at 15% Radius

FB–4300–0860 at 35% Radius

FB–5100–1100 at 25% Radius

FB–3500–0560 at 45% Radius
Current Blade Issues and Future Trends

- Adaptive Blades
- Increased use of Carbon Fiber
- Split Blades – Spanwise Joint
- Pultruded Spar Caps
- Iterative Design Process