Manufacturing Blades for Turbine Reliability

Sandia Wind Turbine Reliability Workshop
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Presented by Gary Kanaby
Overview

- Review the major blade challenges facing turbine reliability.
  - Designing blades that can be built as designed
  - Building blades that survive
  - Design blades that reduce loads on the turbine
- Discuss possible areas for improvement
- Research opportunities
Challenges

- **DESIGN FOR MANUFACTURABILITY:**
  - How do we make sure that the blades can be built as designed?

- **BLADES BUILT TO SURVIVE:**
  - How do we build reliability into the blade?

- **REDUCE LOADS ON THE TURBINE:**
  - How do we reduce blade mass and moment?
  - How does aero elastic tailoring reduce loads on the turbine?
Megawatt Class Turbines
25 Years of Blade Scaling

60 meter blades for a 5 MW turbine.

9 meter blades on a 100 kW turbine.

Source: Euros
Blade design and testing requirements:

- Blades along with the rest of the machine have standards
- Not detailed
- Not prescriptive
- All certified machines have testing requirements
- All processes to be tested
- Quality measures built into each process
- Committee now writing new standards (TC–88)
Design Development

IEC 61400-1 → Design & Process Development → Prove Process by Prototype Fabrication → Static test → Fatigue Test → Field test → Prototype Testing

IEC 61400-23 Lab Testing → Fatigue Test → Static test

Manufacturing to Survive

Major challenges facing megawatt-scale wind turbine blade manufacturing:

- Material handling and placement
- Resin Infusion
- Bond assembly
- Reducing variability
- Increasing repeatability
- QC/QA
Dry Material Placement

- Properly place 1000–2000 kg of dry fabrics each shell mold.
- Dry fabrics must remain in position during vacuum bagging and infusion.
Resin Infusion

- Must distribute 500–1000 kg of resin throughout the mold.
- Need to fully infuse all fibers with resin.
- Must maintain vacuum over large surfaces.

Source: Sandia National Laboratory
Fiber Flatness & Straightness

- Dry fibers can shift during vacuum infusion.
- Waves and wrinkles degrade ultimate strength and fatigue life of the laminate.
Dry Fiber

- Defects in the vacuum pressure or the resin feed system can create dry spots in the blade laminate.
Bondline Control

- Megawatt scale blades may require 200–300 meters of adhesive bond.
- Bondline thickness is critical to blade structural performance.

Source: LM Glasfiber
Automation Increases Reliability

- Blades do not vary due to human variability
- Process is repeatable

Source: Composite Systems, Inc
Build in Quality

ISO Quality Management System:

• A system that assures that you follow a quality system
• Does not include specific measures
• Manufacturer determines the quality by controlling important processes, specifications and tolerances

Advanced Inspection Tools:
Identifying Defects

- Need to identify and repair defects in the factory.
- Ultrasound
- Infrared thermography
Load Reduction for the Turbine

Blade mass & moment:
- Better blade design tools and testing allows for the margin of safety to be lessened
- New materials can be used in smaller quantities
- New processes can reduce total material mass

Blades that shed loads by twisting or bending
- Prototypes have demonstrated the ability of blades to shed loads by twisting
- Many blades are made less ridged absorbing energy during gusts by bending
Solutions

- Better IEC standards
- Assure that blades are built as designed. Eliminate “open loop” manufacturing process changes.
- Blade designs that manufacturing processes can achieve
- Perform extended testing of new blade designs: static, fatigue and field
- Trial fit before bonding
- Blades can be bladder molded and/or infused in one piece eliminating the bonding process
- Fabrics can be pre-impregnated at the factory site
- Blades can be built out of smaller subcomponents
- Build a two-piece blade that can be shipped more easily
- Automation
Research Possibilities

• Rapid blade design tool incorporates:
  ▪ Performance, Structure, Materials and Manufacturing processes
• Multi-piece blade that is easier to build & transport
• Advanced fabrics—better properties and easier to infuse
• Low cost S–glass and/or carbon fiber
• Component construction methods
• Automation of fiber placement working toward a fully automated process
• Automation of quality & manufacturing processes
• Automated inspection that may include x–ray or other techniques
• Condition monitoring and smart blades
• Aero–elastic blades
Wind Energy Services Company
Gary Kanaby
GKanaby@moldedfiberglass.com
www.windenergyservices.com

MFG automated spray booth South Dakota

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