Blade Reliability Initiative

Paul Veers
Sandia National Laboratories

Blade Workshop
Albuquerque, New Mexico
14-May-2008
Reliability is the key focus of the industry

Vestas, 3rd quarter report, 2007

- At EWEC 2008, the industry CEOs spoke with a common voice that the focus would be on improving the reliability of the current product line rather than innovating on the product.
- Reliability is a system issue
- Reliability solutions are effected at the component level

Vestas CEO quote (Windpower Monthly): “Our number one goal is no longer market share, it is reliability.”
“80% of the blades that require repair have never been flown.”
Gary Kanaby, Knight & Carver Wind Blade Division.

- Blades are being delivered to the site in a condition that often requires additional treatment of quality issues before they can be installed.
- Rare installations need to have all the blades replaced after the discovery of a batch problem.
- Blade failure can cause extensive down time and lead to expensive repairs.
- **Blade reliability issues need early attention because of the lost production and cost of significant failures.**
“Delphi” Expert’s Group Assessment of Issues

- Experts from Industry, consulting, academia, and national labs convened to identify critical issues (few numbers)
- Collected expert knowledge as a basis for planning to address blade reliability needs
Preliminary Survey of Operators - 2008

- Five Plants – over 400 turbines
- Mostly 3+ years old
- About 80 blade replacements – 40 (half) at one plant
- Replacement times range from 2 weeks to 2 months

Blade Issues Cited:
- Manufacturing Issues – waviness and overlaid laminates
- Bad bonds, Delamination, and Voids
- Leading Edge Erosion
- Trailing Edge Splits
- Lightning – Comments:
  - At one plant - Every blade has been struck at least once
  - Many repairs and replacements
  - Scorching and splits
  - Manageable problem (relative to gearboxes)
Major Issues for Improved Blade Reliability
Identified by the “Delphi” Group

Six *threads* of issues

1. Infusion Quality
2. Bonding Quality
3. Inspection Capability
4. Environmental Protection
5. Multiple Assembly Plants or Assembly Lines
6. Certification, Tracking and Feedback
1. Infusion (composite fabrication) Quality

- Complete infusion, voids
- Fibers moving during infusion prior to curing (waviness)
- Material drop off – Detailing
- Speed of production creates problems
- Scaling issues

Waviness

Delaminations

Carbon Spar Cap

1/2 meter
2. Bonding Quality

- Typical Blade Bond Lines
  - Difficult to control
  - Blind bonds
  - Scaling effects
- Shear-Web Bonding
- Bond-Line Voids
- Bond-Line Weakness (without major voids)

**Commentary from a Blade Manufacturing Manager**
- “The most difficult part of manufacturing process is trying to bond the two shells together.”
- “Trailing edge defects can grow to full blade failure.”
- “Bonding problems are the biggest issue.”
3. Environmental Protection

- Leading edge erosion
- Moisture intrusion
- Freeze/Thaw cycling
- Root fastener corrosion
- Lightning
  - Big issue
  - Many blades are repaired
  - Some operators consider it manageable - when compared to other components, such as gear boxes
4. Inspection Capability: Factory and Field

- Existing inspection methods can detect bond line gaps and major delaminations
- Every blade manufacturer has inspection methods but some problems are still getting through
- Need to know what inspection methods are effective at finding the flaws that affect early failure.

Phased Array UT Inspection of an Aircraft Vertical Stabilizer Specimen
5. Multiple Assembly Plants

- Not covered in standards
- Production start-up (infant mortality)
- Local practices and corporate cultures
- Process qualification – metrics, procedures, etc.
- Bad batches of blades
  - lead to major plant development delays and cost overruns
  - May not be reflected in operator surveys because they are incurred before the transfer of responsibility from developer to operator
6. Certification, Tracking and Feedback

Example of a Mature, High-Reliability, Structural Safety System

- Involves regulatory authorities in the operations of the fleet, AND ...

- Specific requirements would probably be too expensive for wind turbine application, BUT...

- Continuous feedback to Manufacturers
- Drives component specification

How do we define a structure that provides the benefits without the unnecessary overhead and excessive cost?
Blade Reliability Initiative – Three Phases

**Discovery** – Define the nature and extent of the issues:
Focused on field work and full-scale testing

**Evaluation** – Characterize the issues and evaluate mitigation:
Focused on laboratory testing and inspection

**Resolution** – Validate the methods of resolving specific issues:
Targeted R&D to solve specific problems
Discovery Phase

What is causing early field failures and unreliability?
Field experience – Manufacturing Output
The inspection link between the two

- National Reliability Database analysis
- Operator surveys
- Field failure assessments and root cause analysis
- Manufacturer inputs
- Evaluate Current inspection capability
- Full-scale blade testing: Fatigue tests reveal hidden flaws
  - Production blades
  - Detailed inspection
  - Typical manufacturing quality resulting capability
Evaluation Phase

Pursuing specific findings from the Discovery Phase. Fully define the issue.

- Improvement and validation of analytical modeling and failure of as-built blades
- Subcomponent testing of troublesome details
- Evaluating the impact of defects (coupon and substructure)
- Targeted Inspection method improvement
  - Specimens with well characterized flaws
  - Actual flawed blades
  - Blind trial opportunities for commercial inspection providers and blade manufacturers
Technology for inspection is evolving for new aircraft

- The Boeing 787 is 50% composite material in structural elements
- Composite Inspection is growing in technical sophistication
- Tied to damage tolerance

Composite Structures on Boeing 787 Aircraft

Nondestructive Inspection

Detectable Flaw Size

Damage Tolerance

Allowable Flaw Size

- Carbon laminate
- Carbon sandwich
- Fiberglass
- Aluminum
- Aluminum/steel/titanium pylons

Composite Structure Breakdown:
- Composites 50%
- Aluminum 20%
- Titanium 15%
- Steel 10%
- Other 5%

Nondestructive Inspection Chart:

- Allowable Flaw Size vs Detectable Flaw Size

- Damage Tolerance Scale
Example: Fabricated flaws for validation of inspection

Flaw templates - ensure proper location of flaws

Sandia’s AANC

Flaws inserted
Resolution Phase

Pursue design changes to eliminate the root causes “Failure Modes and Effects Avoidance”

**Outcome: Definition of the Critical Issues**

- Confirm the level of quality required to preempt the delivery of flawed blades to the field
- Validate the inspection methods capable of certifying the required quality

**Long-Term Effect: Drive the R&D agenda**

- R&D will be issue specific and led by manufacturers
- Innovation will have a reliability driver
Questions?

Thank You