2009 NREL Wind Turbine Condition Monitoring Workshop

NDT, CM and SHM of Wind Turbine Blades at the National Labs

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Presentation Overview

- Wind Turbine Blade R&D
- Challenges
- NDT, CM and SHM Examples
Sandia Wind and Water Power Technology

- **Blade Technology**
  - Materials and Manufacturing
  - Structural, Aerodynamic, and Full System Modeling
  - Sensors and Structural Health Monitoring
  - Advanced Blade Concepts
  - Lab - Field Testing and Data Acquisition

- **System Reliability**
  - Industry data collection
  - Improve reliability of the existing technology and future designs

- **System Integration & Outreach**

- **Water Power**
Sensor-Related Tasks at Sandia Labs

• Laboratory and field Testing (Lead: Josh Paquette)
  – Blade model validation
  – Blade performance and diagnostics

• Blade Manufacturing (Lead: Daniel Laird)

• Reliability (Lead: Paul Veers)

• Next-generation of wind turbine blades
  – Sensor Blade Projects (Lead: Mark Rumsey)
    • Evaluate applicable sensing technologies
    • Address sensor-in-blade issues (Manufacturability, Reliability, Cost)
    • Determine sensor requirements for active aero blade
  – Active-aero Project (Lead: Dale Berg)
    • Develop/modify structural and aero models
    • Model and validate sensor/actuation performance
    • Research fast active devices to augment active pitch control
    • Build and test subscale structures
    • Build and test a SMART rotor
Sandia Blade Research Projects
Blade Geometry and Major Laminate Regions

Source: Josh Paquette
Challenges - Defects ... cosmetic or not?
“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.

Challenges - The Monitoring

Monitor What?
loads, wind dynamics, turbine dynamics, strains, temperature gradients, ...

Monitor Where? (location, location, location)
manufacturing defects, joints, bond lines, cracks, dry-spots, voids, discovered defects, impacts, design stress concentrations, ...

Monitor with What? (sensing technology)
piezo-based sensor/actuators, metal-foil strain gages, optical strain gages (FBGs), acoustic emission sensors, accelerometry, IR thermography, ...

Monitor When? (and how often)
condition-based versus schedule-based

Monitor How? (technique)
integration method, redundancy, interrogation, NDT, CM, SHM, PHM, ...
Blade and Substructure Testing

- Fatigue Test
- Ultrasonic NDT
- Static Test
- IR Thermography
- Radiography
- Flash Thermography
Metal-Foil Strain Gaging Setup and Response during a Fatigue Test of Sandia CX-100 Blade
Fatigue Test Setup for TX-100 Blade

UREX=Universal Resonant Exciter
Lab Test Setup of TX-100 Blade

List of devices shown in the photos:
- Macro Fiber Composite (MFC) piezoelectric sensors/actuators
- Acoustic emission NDI sensors
- Metal foil strain gages
- Photoelastic panel
- Single axis accelerometer
- Two multi-axis accelerometers
- Force actuator
- Force transducer
Response from Acoustic Emission NDT during a Fatigue Test of Sandia TX-100 Blade

*Note: Energy defined as area under V-t curve.

Source: Paquette, "Structural Testing of 9 m Carbon Fiber Wind Turbine Research Blades"
Active in-plane Virtual Forces sensitive to damage.

SHM performed by Jon White and Doug Adams

Lead-lag Virtual Force

Root-tip Virtual Force

Fatigue Cycles $10^6$
Photoelastic and Infrared Thermography

Shot at maximum load: maximum compression load on lower surface, maximum tensile load on upper surface.

Shot at minimum load: minimum compression load on lower surface, minimum tensile load on upper surface.
**Goal:** Increase the viability of wind energy by implementing sensing technologies in blades to enable advance wind turbine control and monitoring strategies.

**Challenges:**
- Implementing applicable sensing technologies in blades
- Maintaining or improving system reliability

**Opportunities:**
- New markets for sensing systems suppliers
- Increased wind turbine capability, reliability and availability
- Decrease the cost of energy from the wind
Sensor Integration Issues

Fiberglass and resin matrix in a wind turbine blade

Unsuccessful Bonding

Fiber Optic Sensor
“Structural Damage Identification in Wind Turbine Blades using Piezoelectric Active-Sensing”
Abraham Light-Marquez, Alexandra Sobin

Gyuhae Park ● Kevin Farinholt

Lamb Wave Testing

Time Series Analysis

Frequency Response Method
Thank You!

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