Blade Testing at NREL’s National Wind Technology Center

2010 Sandia National Laboratory
Blade Workshop
Scott Hughes
July 20, 2010

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.
NREL Turbine Test Capabilities

- **Field testing**
  - Demonstrates advances in control systems, load alleviation, innovative technology
    - MW-scale turbines
    - Small and mid-size turbines
- **Drive train testing**
  - 225 kW dynamometer
  - 2.5 MW dynamometer
  - 5 MW dynamometer by 9/2012
  - Grid integration upgrade
- **Blade testing – Wind and Water**
  - 3 test labs at NWTC, up to 50m blades
  - 90-m blades at Massachusetts blade test facility
Why Test Blades?

- Blade reliability identified as significant O&M cost

- Minimize risk of field failures

- Testing is a certification requirement
  - Withstand the design/test loads
  - Identify manufacturing weaknesses

- Validate model data with empirical values
  - Proof of concept and prototype testing
  - Stress and strain
  - Stiffness / deflection
  - Ultimate static strength
  - Design life verification
Advancing Blade Test Methodology

• Goal
  – Attain high levels of blade and rotor system reliability through advanced test methods
  – Reduce the cost and time of testing

• Approach basis
  – 30 years of blade testing experience at the NWTC
    • Design innovative test system hardware
    • Advanced test methods with fast, low-cost deployment
    • Collaborations with federal labs, industry, and academia
NWTC Blade Test Capabilities

• **Testing facilities**
  – IUF – Blades to 50 m
  – Building A60 – Blades to 19 m
  – Building 251 – Blades to 19 m

• **Typical test sequence**
  – Static testing
  – Fatigue testing
  – Property testing (modal, mass distribution)

• **ISO/IEC 17025, A2LA accredited for full-scale blade testing**

• **Subcomponent Testing**
Certification Testing

Static Testing
- Tests the ability of the blade to withstand design load cases
- Typically applied in 4-6 load vectors
- Load application through quasi-static methods
  - Cranes
  - Ballast Weights
  - Winches
  - Hydraulic actuators

Fatigue Testing
- Lifetime verifications
  - 20-year blade life on the order of $1 \times 10^9$ in-field cycles
  - Laboratory testing accelerates loading through increasing load magnitude
- Methods
  - Single-axis
  - Dual-axis
  - Forced Displacement
  - Resonant

135 Full-scale blade tests have been conducted at the NWTC
Test Method Development

• Limitations of current test methods
  – Blade failures continue despite current testing practices
  – Complete testing time increases as blades get longer
  – Current test practices not representative of in-field loading

• Research and Development to improve test efficiency
  – Dual-Axis Resonant Testing (UREX)
  – Phased-Locked Dual-Axis Testing (PhLEX)
  – Base Excitation Testing (BETS)

• Assessment of test methods with field experience
Test Method Development

Continual improvement in test characteristics

Test cost and test time

Courtesy: MTS
Universal Resonant Excitation (UREX)

- Applies dual-axis fatigue loads at multiple resonant frequencies
- Prototype demonstrated on a 9-meter blade at NREL
- Commercialized version has been developed with MTS
  - Modular, scalable
  - Up to 2000-kg of oscillating mass at 0.15-meters of stroke
  - Multi-station capability
- Developed for use at the WTTC facility
- Demonstration on MW-scale blades Fall 2010
- Technology deployed to testing facilities worldwide
Phase-Locked Excitation (PhLEX)

- Control actuator stiffens system in the flapwise direction until the natural frequencies in both flapwise and edgewise directions are approximately equal
- Minimize point-load forces introduced by actuators
- Faster, more efficient resonant testing with ideal cycle-to-cycle load and phase control
- Prototype demonstration on a 9-meter blade fall of 2010
Base Excitation Test System (BETS)

• Design for applying dual-axis fatigue loads at multiple resonant frequencies
• Design for scaling to large blades
• Incorporate a flexible link at the root of the blade, which can be adaptable to existing test stand designs
• Prototype demonstration on a 9-meter blade at NREL in the Fall of 2010
Static Testing Development

- Specification and development of WTTC equipment
  - MTS UREX specifications
  - MTS static loading equipment specifications

- $2M of MTS test equipment supplied to WTTC by January 2011

- NREL contact Dave Snowberg, david.snowberg@nrel.gov

Winch module
Courtesy: MTS

Static test setup
Courtesy: MTS

Winch module
Courtesy: MTS
Innovation for Our Energy Future

Blade Test Data Acquisition Development

• Advanced NI distributed hardware
  – Short analog wires for reduced noise
  – Simplified test setup

• Records hundreds of channels at high sample rates (up to 5 kHz each)
  – Eigenfrequency analysis
  – Capture transient events

• NWTC customized software
  – Real-time monitoring of equivalent fatigue damage
  – Automated event detection
  – Virtual channels for quality control and display
Test Design Code: BladeFS

Developed to analyze and optimize blade test setup

- Modules for both static and fatigue tests
  - Test load calculation
  - Deflection prediction (discrete beam analysis)
  - Layout optimization for load introduction

- Graphical user interface

- Excel input file

- Word and Excel output files

http://wind.nrel.gov/designcodes/simulators/BladeFS/

Contact Michael Desmond: michael.desmond@nrel.gov
Sandia Sensor Blade Testing

- Collaborative test with SNL to demonstrate internal accelerometers and CM systems

- Blade tested in fatigue to failure, test collaborators to provide summary of results

- CM/NDE test collaborators
  - Los Alamos National Labs - Macro Fiber Composite actuator/sensor waveform
  - UMASS – Lowell – Digital Image Correlation
  - Luna Innovations – Fiber Optic Strain
  - Micron Optics – FBG fiber optic strain
  - Intelligent Fiber Optic Systems- fiber optic strain
  - NASA – Piezoelectric actuator/sensor waveform measurement
  - Laser Technology Inc - Shearography
WTTC Commissioning

• Objective
  – Demonstrate new facility capabilities with a MW-scale blade test
  – Optimize and validate test methods

• NREL solicits feedback from blade manufacturers and suppliers on effective means to conduct initial test to commission facility

• Approaches under consideration
  – Competitive CRADA solicitation
  – WTTC/NREL cost-shared demonstration blade test
  – Purchase of test blade

Technical contact is Derek Berry: derek.berry@nrel.gov
Business contact is Rahul Yarala: ryarala@masscec.com