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Blade Testing at the National Wind Technology Center

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National Renewable Energy Laboratory

2012 Sandia Wind Turbine Blade Workshop

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May 30 – June 1, 2012

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.

AGENDA

David Snowberg

- NREL/NWTC test capabilities
- Static test with load controller
- NREL Ethercat DAQ
- Multi-station resonant fatigue
- Dual-axis resonant fatigue.

Michael Desmond

- Partnerships and collaborative testing
- Non-destructive blade property testing
- Advanced blade test method development
  - Base Excitation Test System (BETS)
  - Phase Locked EXcitation test system (PhLEX).

NREL'S NATIONAL WIND TECHNOLOGY CENTER

- 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 (online fall 2012)
  - Controllable grid interface
- Blade testing – Wind and Water
  - 3 test labs at NWTC, up to 50m blades
  - 90m blades at Massachusetts blade test facility.

NREL PIX 17398

NREL PIX 19008

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.

NWTC BLADE TESTING CAPABILITIES

- Testing facilities
  - STL – Blades to 50 m
  - Building A60 – Blades to 19 m
  - Building 251 – Blades to 19 m
- Typical test sequence
  - Property testing (modal, mass distribution)
  - Static testing
  - Fatigue testing
  - Post-fatigue static testing
- ISO/IEC 17025, A2LA accredited for full-scale blade testing
- Subcomponent Testing.

NREL PIX 20438—MHI Blade for MWT102

NREL PIX 12893

CERTIFICATION TESTING

NREL PIX 19513—MHI Blade for MWT102

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

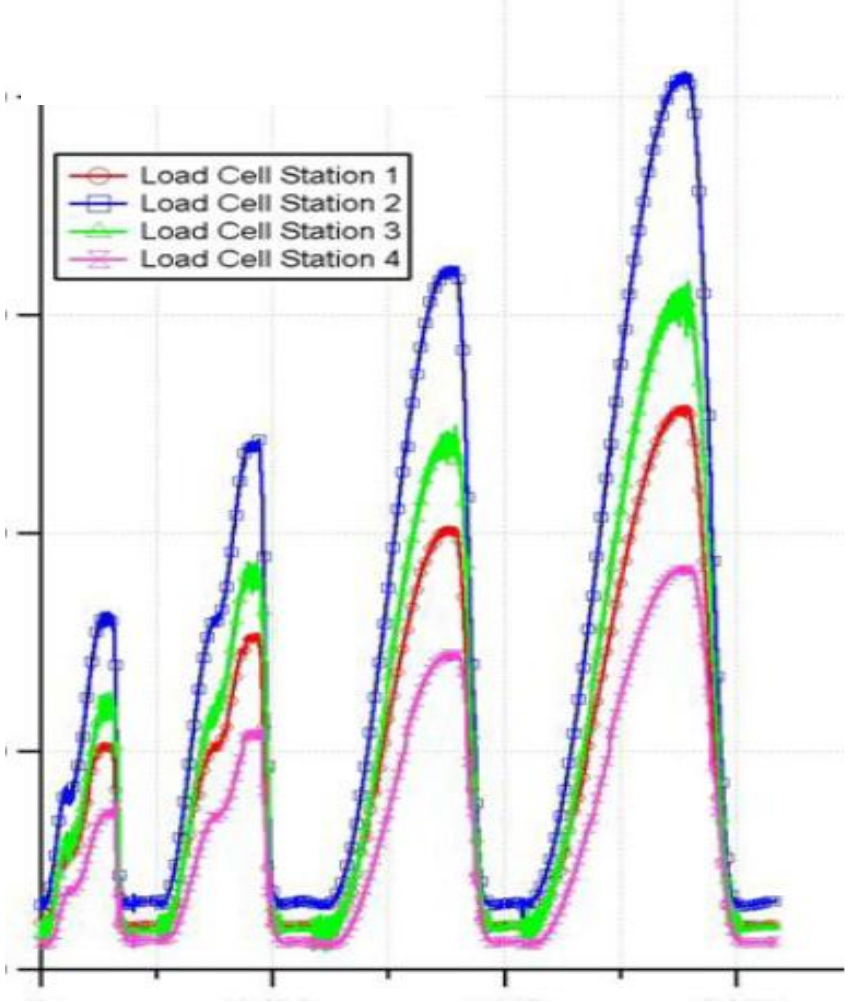
- Lifetime verifications
  - 20-year blade life on the order of $1x10^9$ in-field cycles
  - Laboratory testing accelerates loading through increasing load magnitude
- Methods
  - Single-axis
  - Dual-axis
  - Forced Displacement
  - Resonant.

NREL PIX 20440—MHI Blade for MWT102

144 Full-scale blade tests have been conducted at the NWTC

STATIC TESTING WITH LOAD CONTROLLER

- **Load control**
- **PID controller**
- **Four station static test (see plot to right)**
  - Load cell feedback from each station
  - Independent load control
  - Each station with different wire rope line parts (i.e. different load/displacement ratios)
  - Overshoot tuned out of system
  - Stable.

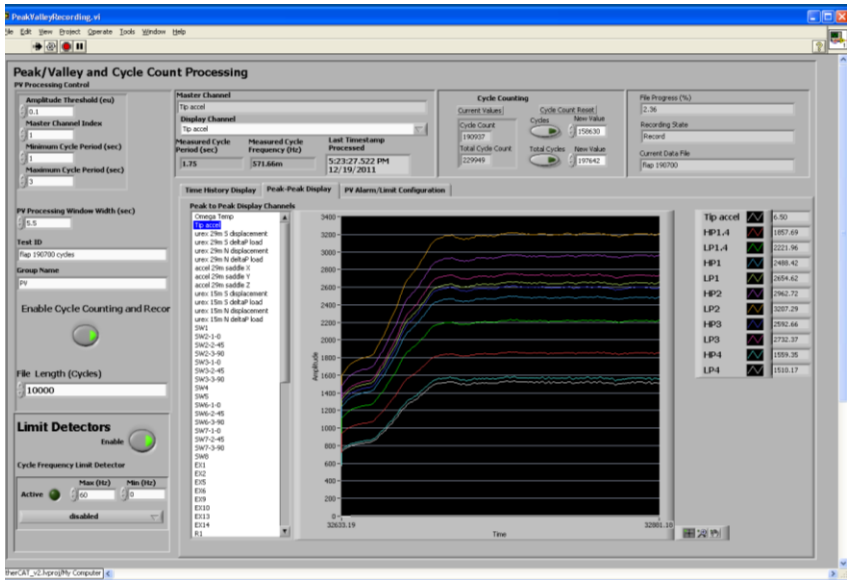


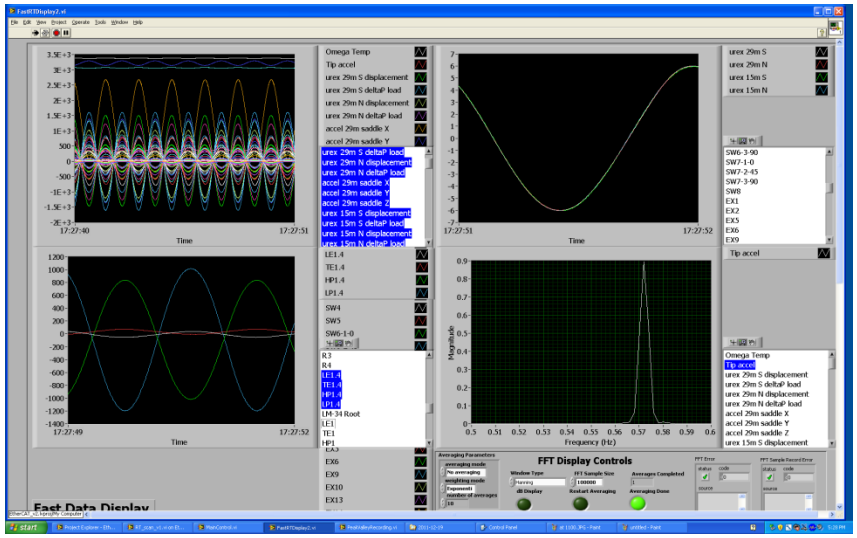
STATIC TESTING WITH LOAD CONTROLLER

NREL PIX 19514—MHI Blade for MWT102

NREL ETHERCAT DATA ACQUISITION SYSTEM

- **NREL developed and validated—used for accredited testing to IEC 61400-23**
- **Real-time:**
  - Calculated channels for control
  - Peak-valley channel processing during fatigue test
  - Channel alarms and test interlocks
  - Programmable over and under-peak limits will stop test
  - Watchdog stops test if communication issues are detected
- **Commercially cost competitive**
- **Tested to 250Ch at 2kHz—more possible.**
- **24-bit acquisition**
- **Distributed and synchronized**
- **Compatible with all C-series NI modules**
- **Capability for 3rd party equipment integration.**





Multi-Station Flap Fatigue with MTS UREX

<u>Video</u>:

flap_ fatigue_1.wmv

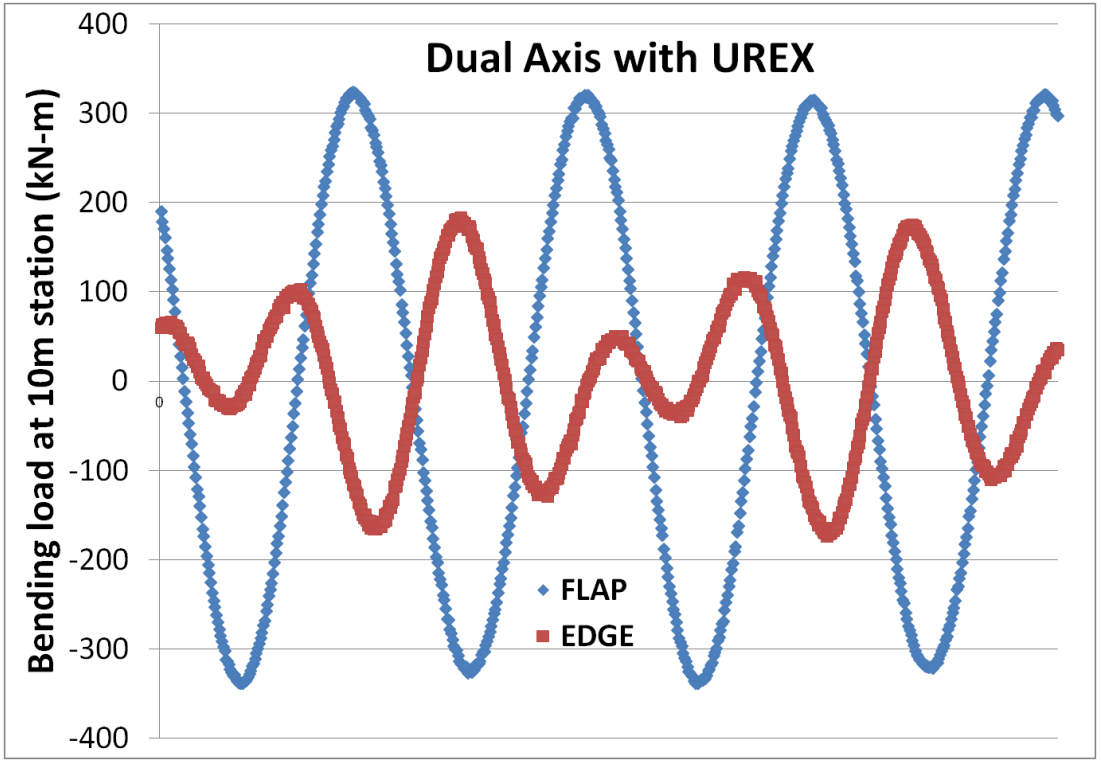
Dual Axis Testing with MTS UREX

<u>Video:</u>

urex dual axis.wmv

DUAL AXIS TESTING WITH MTS UREX

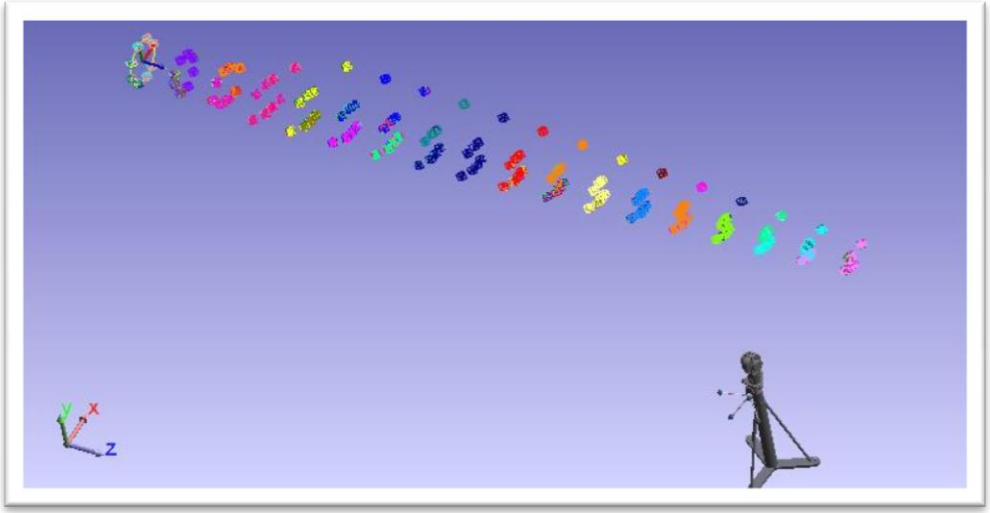
- LE actuator at 1st edge frequency
- TE actuator at 1st flap frequency
- Rain flow count edge cycles.



NON-DESTRUCTIVE BLADE PROPERTY TESTING

- Advanced non-destructive testing to quantify as-built blade properties
- Single-point quasi-static pulls conducted in both flap and lead-lag directions to measure bending stiffness
- Modal testing

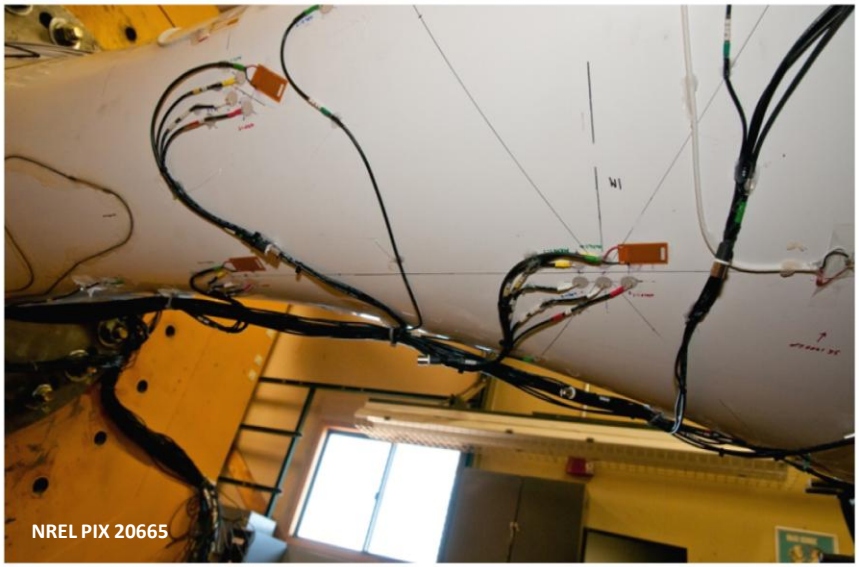
- Torque couple applied to measure torsional rigidity
- Precision 3D displacement measurements recorded with laser tracker capability
- Ability to measure airfoil profile deformations under load.



PARTNERSHIPS AND COLLABORATIVE TESTING

- Demonstrate advanced health monitoring techniques and innovative sensing technologies
- Test partners include:
  - Los Alamos National Labs (LANL)
    - Active and Passive ceramic PZT and MFC sensing
  - University of Massachusetts Lowell (UML)
    - Digital Image Correlation (DIC)
  - Sandia National Labs (SNL)
    - Micron FBG Fiber Optics and Accelerometers
  - Luna Technologies
    - Optical Backscattering Fiber Optics
  - Laser Technology Inc.
    - Shearography and Thermal Imaging
  - NASA
    - Active PZT sensing
  - NREL
    - Foil Strain Gages
    - Accelerometers
    - Acoustic Emission (collaboration with SNL)
    - Thermography.

NREL PIX 20664


NREL PIX 20665

ADVANCED BLADE TEST METHOD DEVELOPMENT

- **Goal**
  - Attain high levels of blade and rotor system reliability through advanced test methods
  - Reduce the cost and time of testing
- **Current Fatigue Test Method Limitations**
  - Blade failures continue despite current testing practices
  - Testing time and energy requirements increase with blade length
  - Current methods not representative of in-field loading
- **Approach**
  - 30 years of blade testing experience at the NWTC
  - Design innovative test system hardware
  - Advanced test methods with fast, low-cost deployment
  - Innovative technologies transferred to WTTC
- **Current Test Method R&D Activities**
  - Better, cheaper, faster test methods for large blades
  - Base Excitation Test System (BETS)
  - Phase-Locked Resonant Excitation Test System (PhLEX).

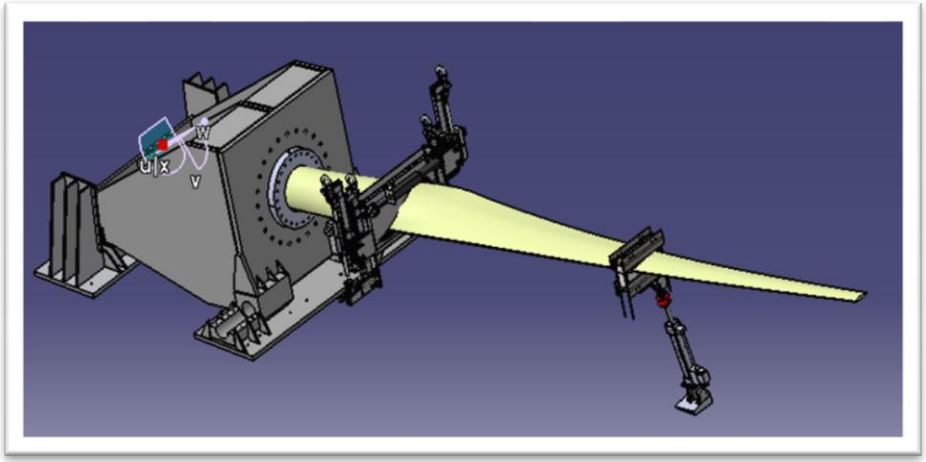
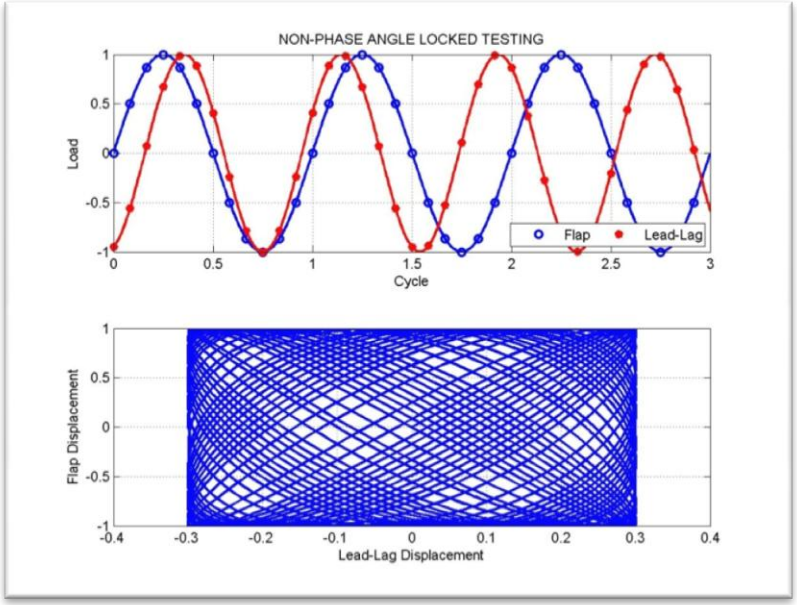
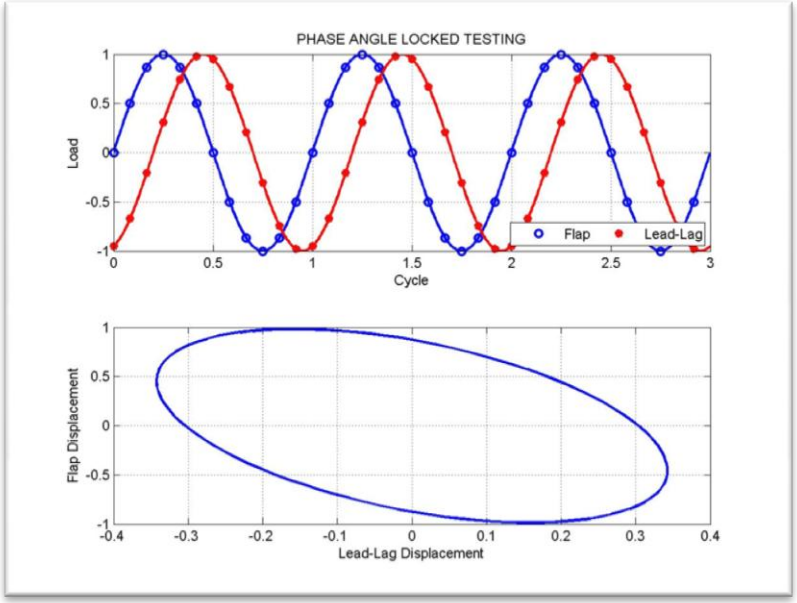
BASE EXCITATION TEST SYSTEM (BETS)

- Designed for applying dual-axis fatigue loads at distinct resonant frequencies
- Incorporates flexible link at the root of the blade with actuators to apply loads in both flap and lead-lag directions
- A successful prototype demonstration was conducted at NREL in the spring of 2011 on a Sandia 9-meter blade
- Current activities include model validation and scaling studies for large blades.

BETS DEMONSTRATION AT NREL - 2011

<u>Video:</u>

BETS.wmv

PHASE-LOCKED EXCITATION (PhLEX)

- Dual-axis resonant fatigue testing at the first lead-lag natural frequency
- Faster testing (~2x) with ideal cycle-to-cycle load and phase control
- Prototype demonstration on a 9-meter blade at NREL 2012
- Large scale system development.