Developments in Wind Turbine Blade Fatigue Testing

Sandia Blade Workshops

July 20, 2010

Tim Westphal

Knowledge Centre WMC
The Netherlands

t.westphal@wmc.eu
Outline

- Introduction
- Fatigue test methods
  - Single axial
  - Bi-axial
- Fatigue damage single axial vs bi-axial
- Variable amplitude fatigue testing
- Conclusions
Wind turbine Materials & Constructions

- Full-scale structural testing
- Material research
- Software development
WMC History
Blade design and testing (1984)

WMC did a re-design of the all steel WPS30 blade and developed the full scale testing procedure for rotor blades.

In 1994 WMC was the convenor making the international IEC guideline on full scale testing of rotor blades. In 2004 WMC was again appointed as the convenor for the update of the guideline/code.
Full Scale Test Lab

- High flexibility
- Strong floor 66 x 28 m
- Three blade test stands
- Blades up to 60 m (75 m planned)
- In house workshop
Blade Testing
Multiple-point Single-axis Static Test
Testing Hub/Bearing Assembly

Measurements during pitch operation while blade root is loaded in three directions
Fatigue Testing
**Fatigue Test Methods**

**Single axial resonance**
Blade is tested twice, one test for flapwise loading and one for edgewise loading
- Exciter with mass on blade
- Actuator to floor

**Biaxial fatigue test**
Flapwise and edgewise loading in one single test, more representative for operational loading
- Forced displacement
- Resonance for one or both axes
  - same or different frequency for either axis
Single Axial Testing
Bi-axial Testing
Fatigue Loading of a rotor blade (in a perfect world)

In operation a rotor blade is loaded bi-axial due to out of phase wind and gravity loading.
Single Axial Fatigue

Advantages
- Simple hardware
- Simple tuning of bending moment distribution
- High frequency
- Low energy consumption
- Distributed loading

Disadvantages
- Separate flap and edge test
- Not testing total circumference
- Mass on blade for $R 
eq -1$
Bi-axial Fatigue Testing

Advantages
- Accurate coordination of flat & edge loading combinations
- Torsion loading
- Short test time
- All R-values, weight compensation possible
- Automated stiffness measurements
- Moderate energy consumption

Disadvantages
- More complicated hardware and controlling
- Tuning of moment curve requires additional hardware
Damage Comparison
Single vs Bi-axial Fatigue Test
Single Axial vs Bi-axial

- 62.5 meter generic blade
- FSF = Fatigue Strain Factor (Reserve factor for fatigue damage)
- Design loads fatigue damage
Single Axial test

- Sequential flapwise and edgewise test (no resonance)
- FSF for both tests combined

Test focuses on spar and leading and trailing edge
Biaxial test

- Combined flapwise and edgewise testing
- More realistic loading for off-axis sections
- Better distribution of fatigue damage over circumference
Single Axial vs Bi-axial Test

2 x Single axial

Bi-axial
Torsion at root section of blade

Single axial

multi axial

\[ F \]

\[ d \]
Concluding Remarks

- The type of blade fatigue test should be based upon the critical areas of the blade.
- Single axial tests focus on spar and leading and trailing edge. Easy to test a large blade span.
- Bi-axial tests give a better distribution of fatigue damage over the circumference of the blade.
- Variable amplitude tests are more representative for low cycle fatigue and less sensitive to the fatigue formulation.

More information: www.wmc.eu