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Dual-Axis Fatigue Testing of Large Wind Turbine Blades

Wind turbine design standards require blades to be tested statically for extreme loads, and fatigue tested to prove that they can survive the design lifetime. The movement towards longer blades for increased power output (5MW and greater), higher capacity factor and/or sites with lower wind speeds presents unique challenges when performing fatigue tests. These tests are usually performed by vibrating the blade at its first resonant frequency, and for large blades this can be very low, resulting in long tests. This work will describe a novel test method that allows the test to be performed in an acceptable timeframe.

In service, flapwise loading is mainly due to aerodynamic loads and edgewise loading is mainly due to gravity loads. These two sources of loading occur at the same time during the service life, but for blade fatigue tests the flapwise direction is tested separately to the edgewise direction. This approach is less representative of what occurs in service and is also more time consuming than testing both axes simultaneously. However, testing both axes at the same time is not trivial.

The dual axis tests were optimised to match the damage caused by the service life, and comparisons were then made between dual axis testing and single axis testing.
There are several factors which can be controlled both before and during a resonant fatigue test. These include:
- The position and mass of the test equipment (which alters the mode shape and therefore the strain amplitude distribution along the blade length, and also the mean strain distribution along the blade length)
- The amplitude of the excitation in the flapwise and edgewise directions (which alters the strain amplitude)

The target bending moment distribution in the flapwise and edgewise directions along the length of the blade is calculated from the service life damage, the number of test cycles and the material fatigue properties. This bending moment distribution is then used as a target in an optimisation routine to choose the best position and mass for the test equipment.

The results show that an optimised dual axis test offers very significant time benefits when compared to single axis testing as well as improving how representative the test is of the loading seen in service. The over-testing which is associated with non-optimised dual axis tests is greatly reduced.