Dynamics and Fatigue Damage of Wind Turbine Rotors during Steady Operation - DTU Orbit (02/02/2019)

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A number of sub-models for use in the evaluation of the load-carrying capacity of a wind turbine rotor with respect to short-term strength and material fatigue are presented. The models constitute the theoretical basis of a computer code ROTORDYN which, in conjunction with an initial finite-element analysis and eigenvalue extraction, performs a dynamic analysis of a wind turbine rotor for lifetime prediction.

The models comprise a structural model which is essentially linear and solves for periodic and stochastic loading in the frequency domain. The model includes the centrifugal stiffening of the blades and a linearization of the aero-elastic effects as well as power regulation by pitch control. The aerodynamic model is based on blade element theory.

The stationary deterministic loads arising from a spatially non uniform wind field and gravity as well as loads caused by the rotation are treated as periodic deterministic loads; turbulence loading, on the other hand, is formulated in terms of a stochastic model. The turbulence is introduced in terms of power spectra as seen from a point in a rotating frame of reference.

Statistics of the combined deterministic periodic and stochastic response are represented, and an asymptotic theory is derived for the extremes of the responses during typical operation of the wind turbines.

A fatigue model is presented which takes into account the special structure of the stress response. The model avoids computer simulation and succeeding rainflow counting and yields an analytical solution for the expected damage rate at a certain mean wind speed.

The resulting computer program can be used to analyze most Danish types of wind turbines with respect to dynamic response, fatigue damage and extreme loads during steady operation as well as stand-still. The comparisons made up to now between measured and calculated data for wind turbine responses show satisfactory agreement.