Abstract

In order to assess the fatigue life of drive train components, we seek to determine how the component damage index can be estimated, not only in terms of its expected value, but also its distribution due to a turbulent wind field introducing randomness. For assessing the fatigue life of main shaft bearings it was found that:

- A quasi-static drive train model may be sufficient for a direct drive concept in normal operation.
- The average and variability of the damage index rate varies substantially with the mean wind speed.
- The variability of the estimated total component damage index should be considered when estimating the total damage.

Simulation model

As a basis for this investigation, we consider a simulation model for a commercial multi-MW direct drive wind turbine which was implemented in the software ViDyn [1] developed by TeLEDAG AB. The simulation model is a structural model of the full turbine, including control system with individual pitch control, subjected to a 3-dimensional wind field, wind loads computed using Blade Element Momentum theory, implemented in code Aerohd [4]. The wind fields are random realizations based on the Kaimal spectra as described in the standard IEC 61400 [2] characterized by turbulence intensity for a specific mean wind speed. Each such wind field realization is used as input to the full turbine model from which the forces at the hub are extracted. These forces are used as input for a drive train model based of Euler-Bernoulli beam theory implemented in Matlab.

Hub load extracted from ViDyn simulation

\[
D_1 = \frac{1}{2} \sum_{i=1}^{4} I_i \left( \frac{F_i}{P_i} \right)^{1.5}, \quad I_i = \alpha F_i + \beta F_i^2 + \gamma F_i^3
\]

Thus, each wind field realization (10 minutes) is mapped to one value of damage rate index per bearing, with the aim of assessing the distribution of calculated DI-values. It should be noted that this damage rate is for classical subsurface fatigue and not, e.g., white etch cracking [5].

Model fidelity

Observations:

- Quasi-static assumption sufficient to predict damage index rate for main bearings.
- Inertia effects should be considered to predict the damage index rate of the stator bearings.

Mapping of damage index rate

Histogram of damage index rate for front main bearing (left), rear main bearing (middle) and stator bearing (right) at different mean wind speeds

Distribution of average total damage index rate for front main bearing (left), rear main bearing (middle) and stator bearing (right) at different mean wind speeds

Observation: For the main bearings, a "tail" extends to higher damage index rates, indicating that a substantial safety factor is needed if the variability is not properly considered.

Conclusion and outlook

- Model detail can for some cases affect the estimated damage rate.
- The main result of the present investigation was that the not only the mean, but also the variance of damage rate depend on mean wind speed, and that this carries over to the predicted accumulated damage index. An important future work is to investigate the generality of these conclusions with respect to other drive train designs.
- Future work will in more detail study the efficient sampling of wind turbine simulations to estimate mean and variability of predicted damage index in the turbine drive train components with sufficient accuracy.

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References