Long-Term Probability Distribution of Wind Turbine Planetary Bearing Loads

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Abstract

Among the various causes of bearing damage and failure, metal fatigue of the rolling contact surface is the dominant failure mechanism. The fatigue life is associated with the load conditions under which wind turbines operate in the field [1]. Therefore, it is important to understand the long-term distribution of the bearing loads under various environmental conditions. The National Renewable Energy Laboratory's 750 kilowatt (kW) Gearbox Reliability Collaborative wind turbine was studied in this work. A decoupled analysis using several computer codes was carried out. The global aero-elastic simulations were performed using HAWC2. The time series of the drivetrain loads and motions from the global dynamic analysis were fed to a drivetrain model in SIMPACK. The time-varying internal pressure distribution along the raceway was obtained analytically [2]. A series of probability distribution functions were then used to fit the long-term statistical distribution at different locations along raceways. The long-term distribution of the bearing raceway loads were estimated under different environmental conditions. Finally, the bearing fatigue lives of the bearings were calculated.

Objectives

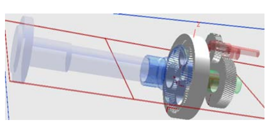
During the study, research objectives included:

- Characterizing the bearing contact load zone distribution of the inner and outer raceways
- Investigating the validity of different probability distribution functions in fitting the long-term radial contact force and in estimating the basic rating life
- Comparing the effect of wind conditions on fatigue life estimation
- Understanding the effects of misalignment/tilting on fatigue life

Methods

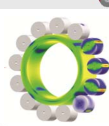
HAWC 2 — Aero-elastic simulation

↓ Main shaft loading



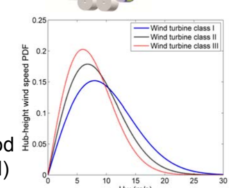
SIMPACK — Multibody simulation

↓ Bearing integrated force



Hertzian theory — Bearing internal forces

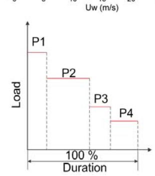
↓ Load histogram



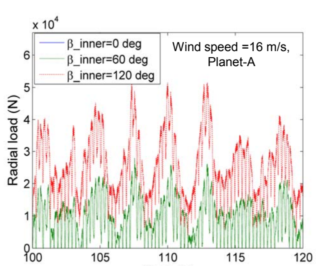
Probabilistic model — Long-term load distribution

↓ Simplified method (roller equivalent load) / Refined method (raceway load)

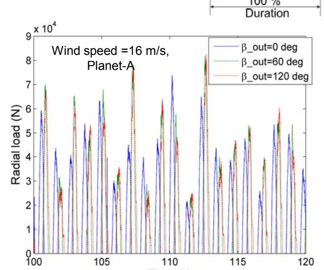
Load duration distribution method — Bearing basic rating life



Results

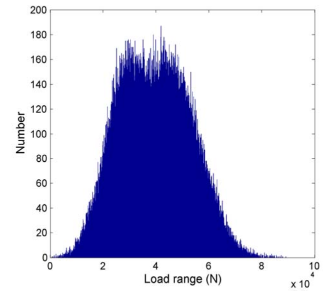


Inner raceway

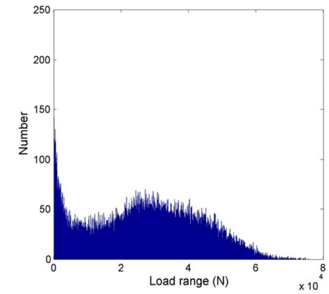


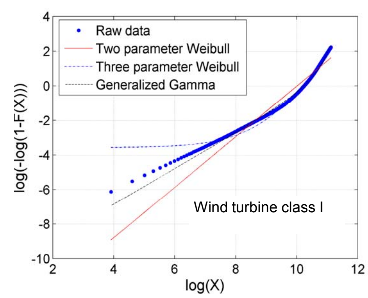
Outer raceway

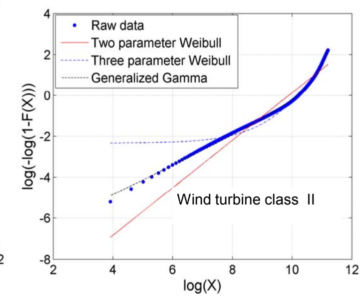
Uw = 25 meters per second (m/s), β_inner = 200 degrees (deg)

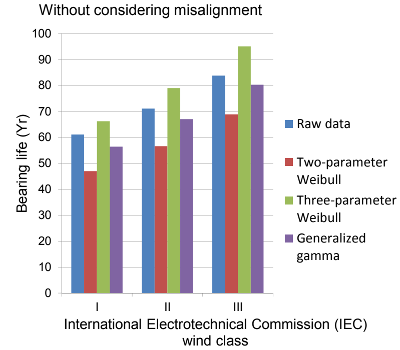


Uw = 25 m/s, β_outer = 200 deg

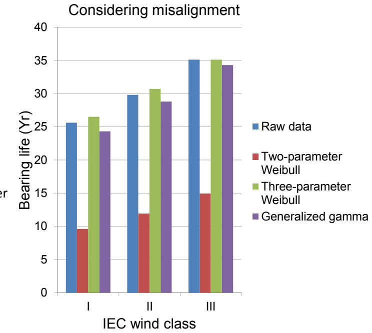








Inner raceway



Outer raceway

Conclusions

- The inner raceway has a more concentrated load zone than the outer raceway
- Raw data distribution displays curvature on the Weibull probability paper
- The generalized gamma model fits better than the Weibull models
- Bearing fatigue life is sensitive to wind speed: when the wind turbine class was changed to II and III, the fatigue life of the planet-A bearing calculated by the refined method increased by 16.4% and 37.1%, respectively, without considering misalignment
- The tilt angle of the bearing lies in the ranges of 10^{-1} degree during dynamic simulations
- Consideration of misalignment leads to a 50%-60% reduction of bearing life

Future Work

- Compare the results of theoretical formulas on bearing load zone with Calyx results based on the approach by Guo and Parker (2012) [3]
- Use a crack-propagation model to calculate fatigue life

Acknowledgment

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References

1. Musial, W., Butterfield, S., McNiff, B. (2007). "Improving Wind Turbine Gearbox Reliability," *European Wind Energy Conference*, Milan, Italy.
2. Harris, T. A., Kotzalas, M. N. (2007). *Rolling Bearing Analysis: Essential Concepts of Bearing Technology*, 5th ed., Taylor and Francis Group, U.S.
3. Guo, Y., Parker, R. G. (2012). "Stiffness matrix calculation of rolling element bearings using a finite element/contact mechanics model", *Mechanism and Machine Theory*, Vol. 51, p. 32-45.