INVESTIGATION OF MAIN BEARING OPERATING CONDITIONS IN A THREE-POINT MOUNT WIND TURBINE DRIVETRAIN

Conference for Wind Power Drives, March 10, 2021, Version 1.4

Olle Bankeström,[1] Yi Guo,[2] Roger Bergua,[2] Jonathan Keller,[2] and Mark Dunn[3]

[1] AB SKF, 41550 Göteborg, Sweden

[2] National Renewable Energy Laboratory, Golden CO 80401, USA

[3] SKF USA, Lansdale PA 19446, USA

Do wind turbine main shafts make harmful axial motion?

NREL GE 1.5 MW.
Photo by NREL

SKF

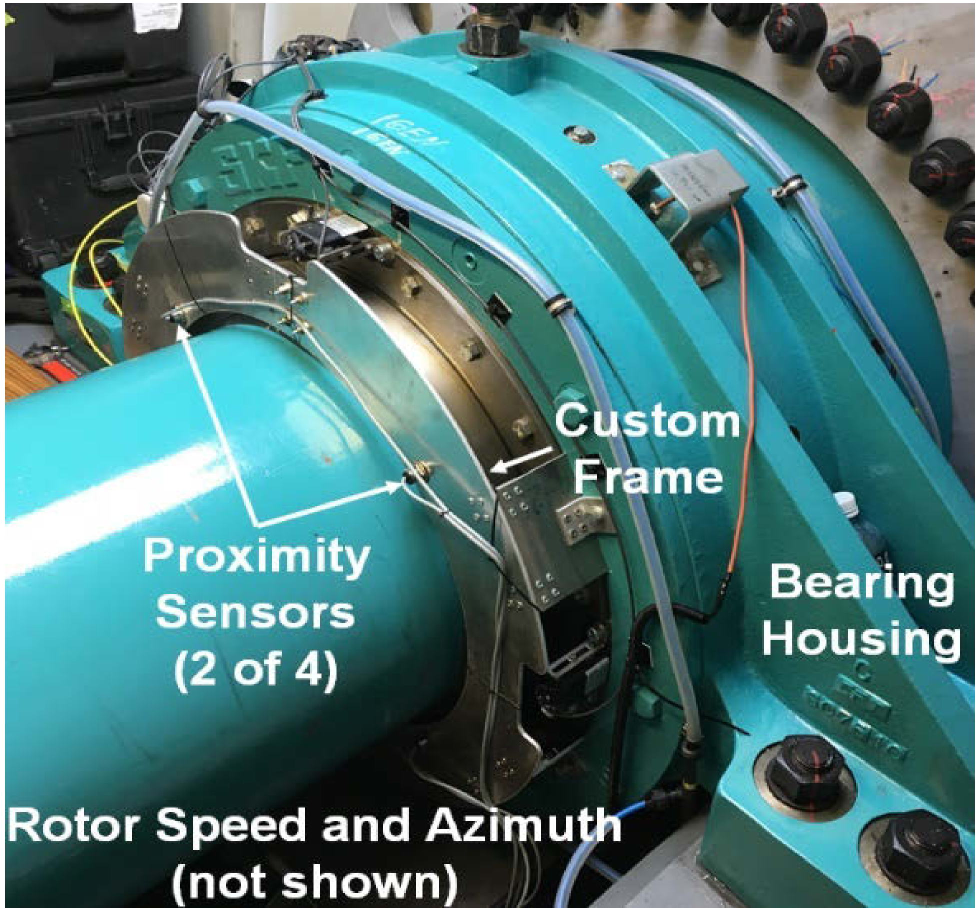
Overview

- Present study
  - Why?
    - Texts on the web and in litterature refer vaguely to axial movement as a risk both for the bearing and the drivetrain.
    - Often believed to relate to rapid dynamics
    - Quantification or fundamental criteria generally missing. Unspecific experiences.
    - Texts are not recognizing all the positive experience. Not all turbines are problematic!
    - Here is an obvious knowledge gap! We have turbine data that may help close the gap!
      - Clear hypotheses that can be tested are missing.
      - Wear normally happens when lubrication is insufficient.
  - What?
    - Can the axial movements disturb the lubricant film formation?
  - How?
    - NREL test turbine (GE 1.5 MW) instrumented to measure main shaft motion.
    - Evaluated measurements
    - Compared to experimental data to models on turbine level
    - Compared to bearing lubricant film conditions
  - Who?
    - Olle Bankeström, SKF
    - Mark Dunn, SKF
    - Yi Guo, NREL
    - Roger Bergua, NREL
    - Jon Keller, NREL

Common damage. Wear extending over downwind row.

Photo by NREL

Specific Instrumentation



Four inductive sensors are fitted on the housing looking at the side face of the locknut.

Post processing involves, for example:

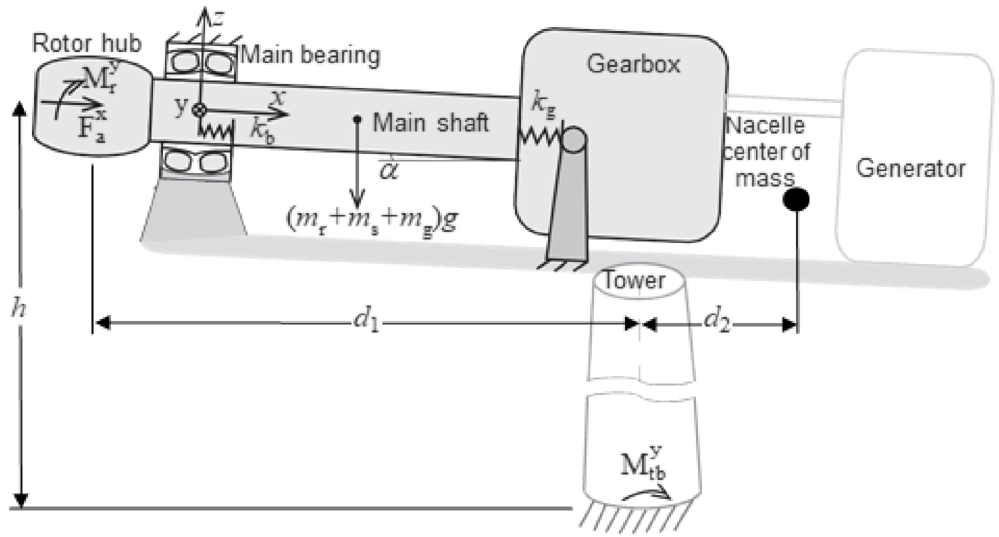
- Correction for the geometric run-out of the locknut
- Averaging the four channels to bring out the axial component.

Analytical Model—Quasi-Static and Dynamic

Rotor thrust is estimated from measured tower bending moments and rotor pitch moment in the quasi-static model applied for normal operation.

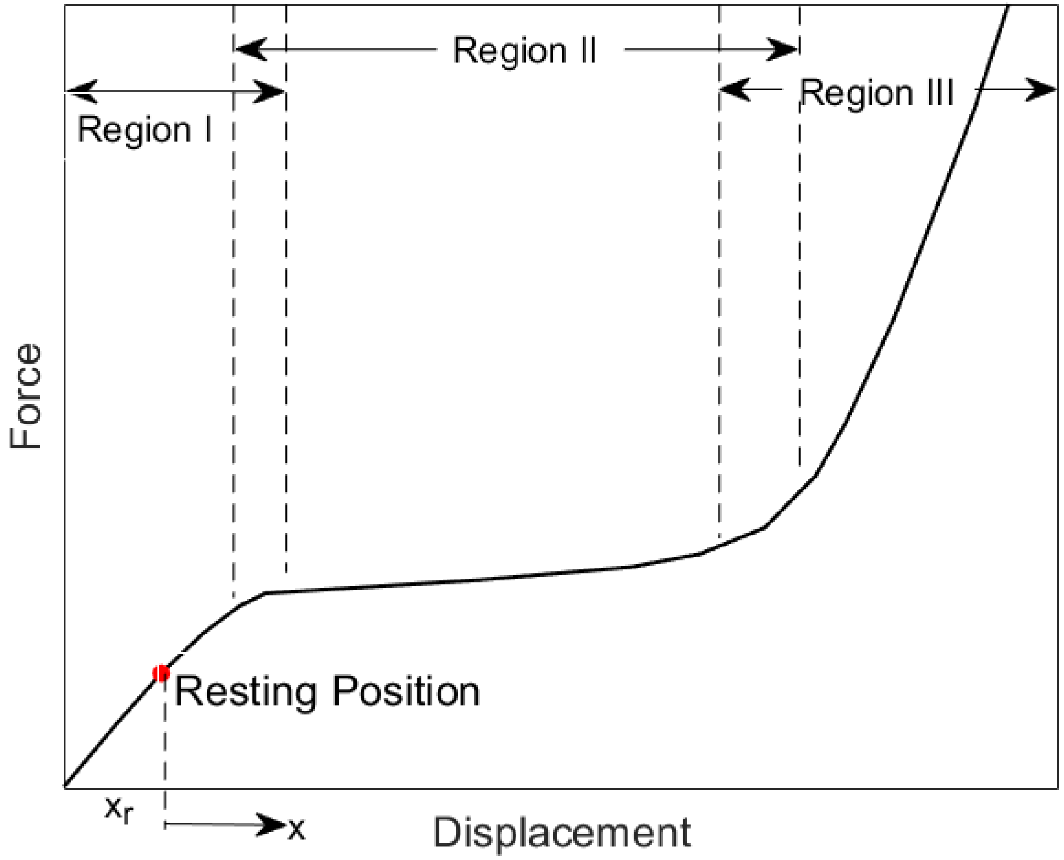
At e-stop, aerodynamic thrust is no longer dominant, but also inertia needs to be considered. A compensation term based on nacelle acceleration is applied.

This rotor thrust is applied to the model shown at right, and an expected axial displacement can be derived to compare with the measured axial displacement.

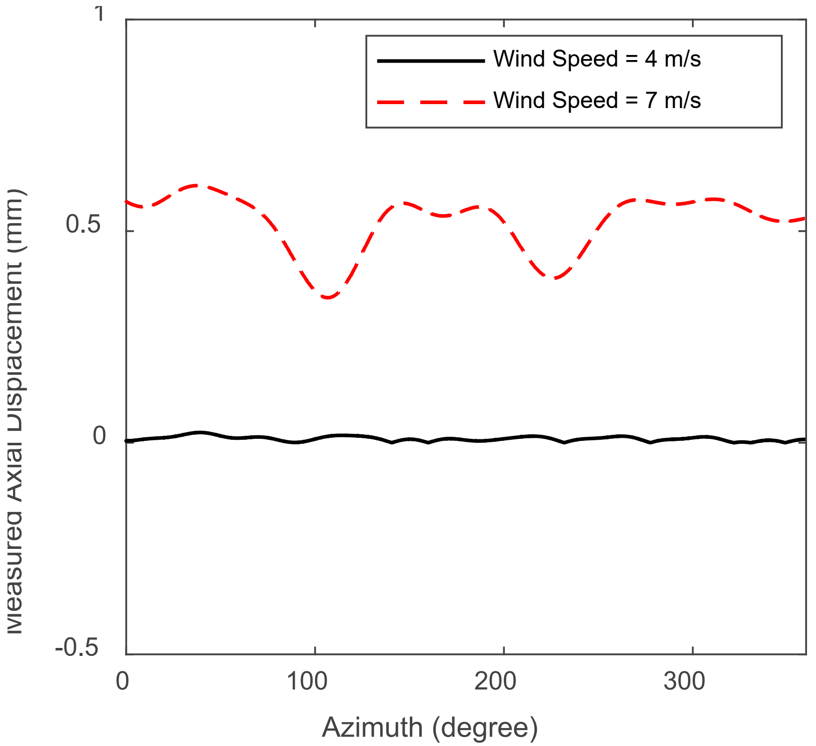


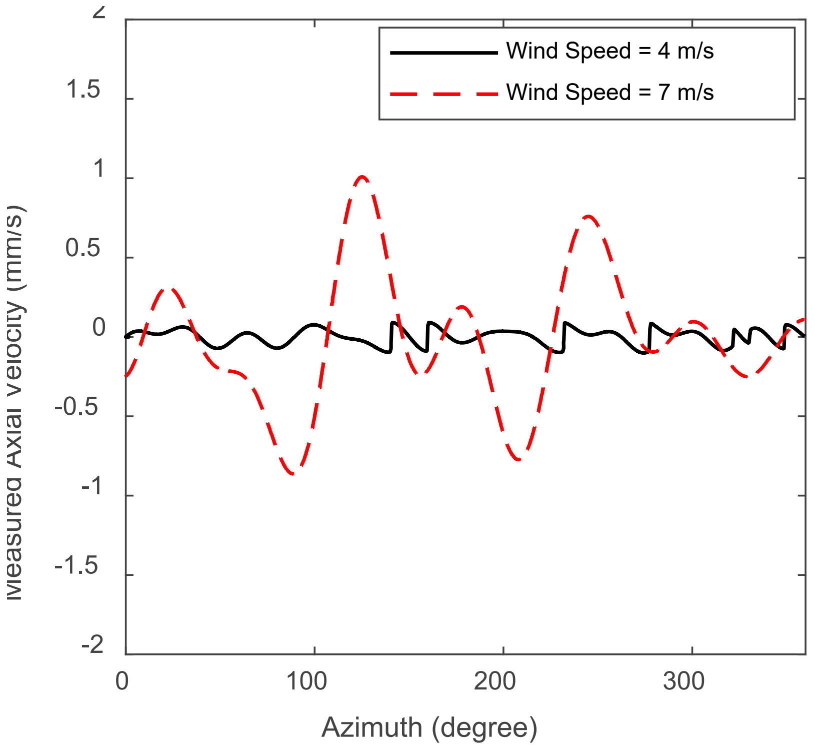
Main Bearing Under Constant Radial Load

Axial force vs. axial displacement



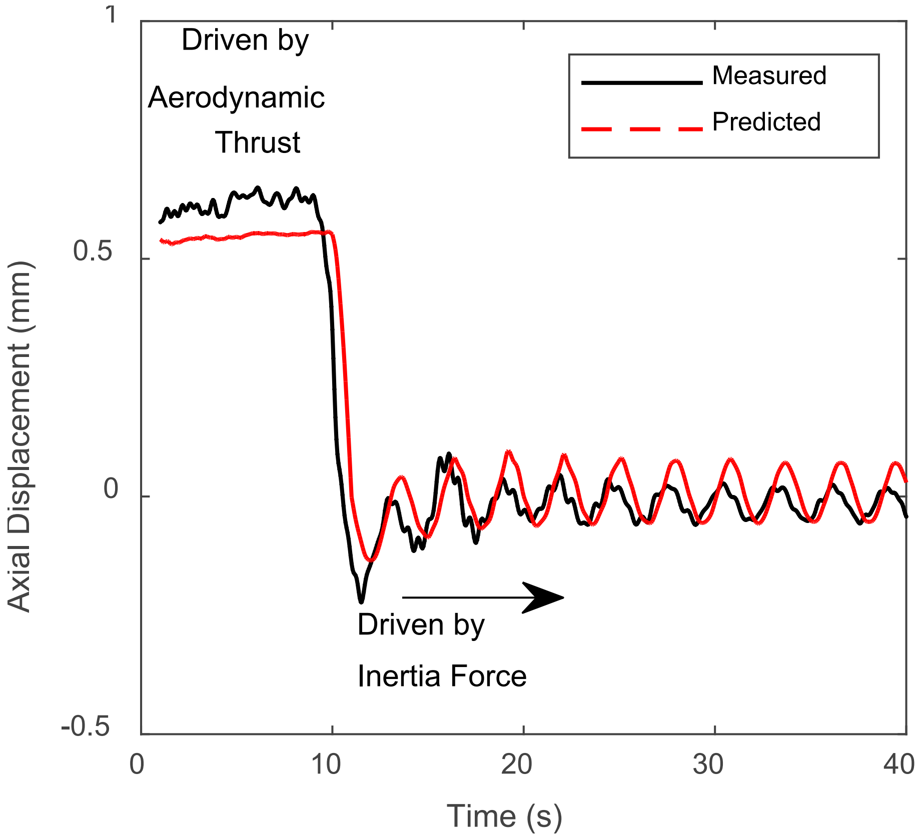
Normal Operation

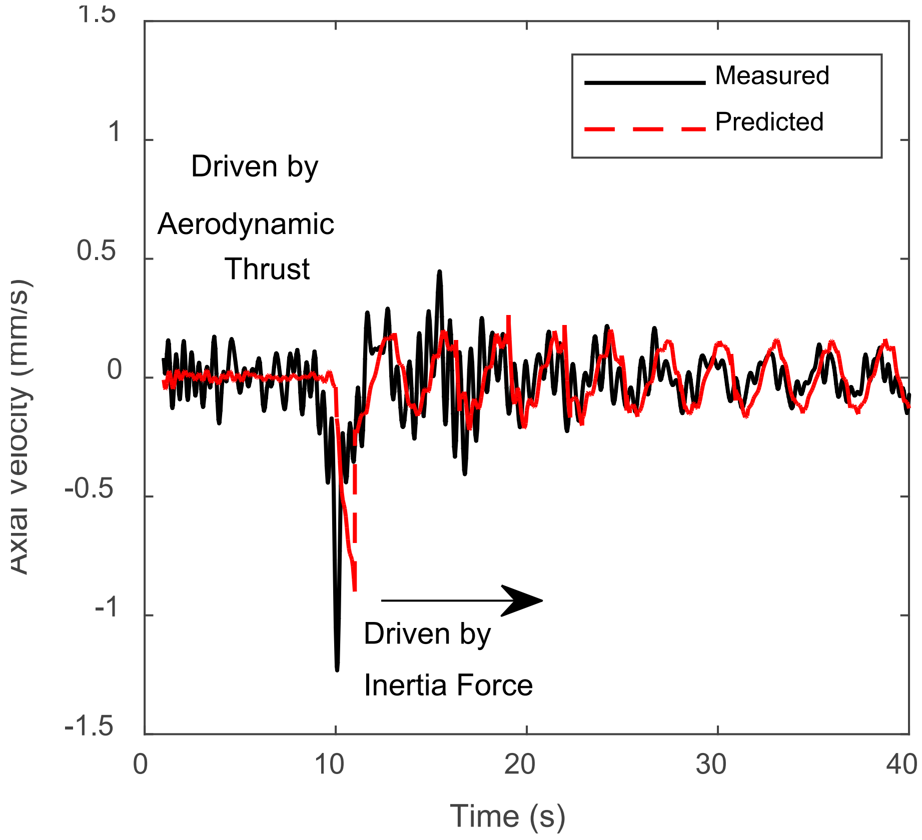




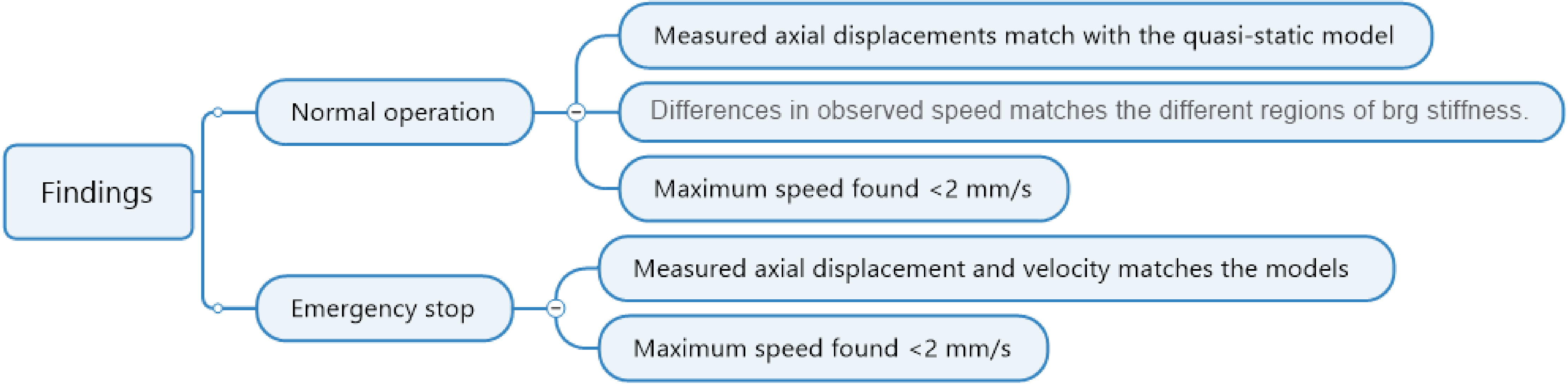
Main shaft axial position and axial velocity. Black: Region I operation. Red: Region II

Emergency Stop





Findings from Field Data

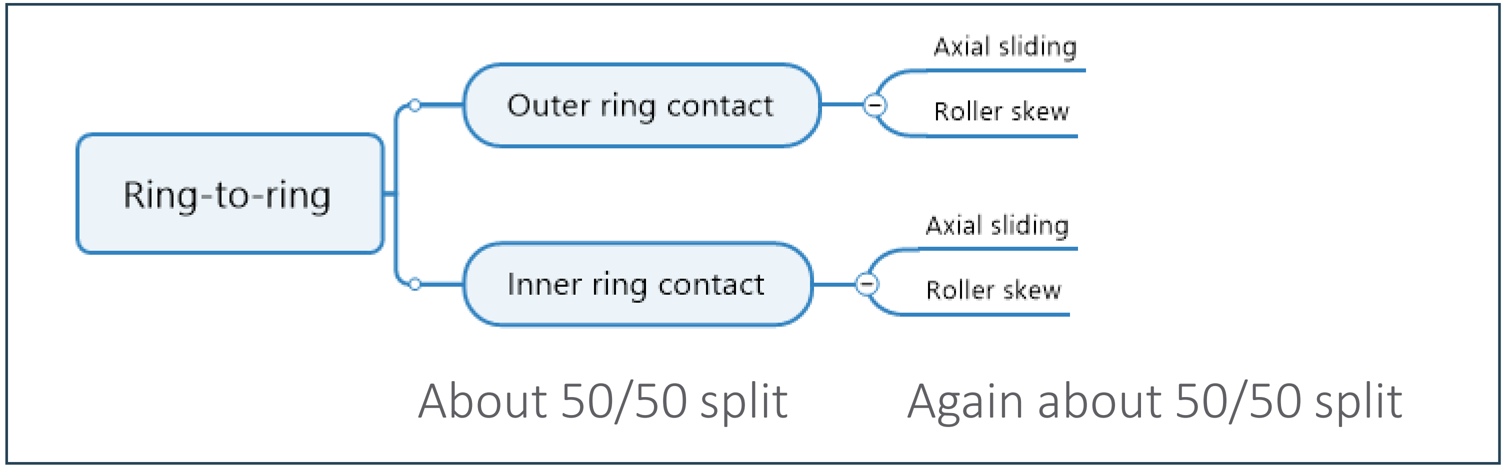


Data show that the relative axial motion of the main shaft to housing happens at a speed that is quite low in an everyday context—snail speed.

Is this also a low speed from the perspective of a bearing lubricant film formation?

Axial Sliding in Contacts

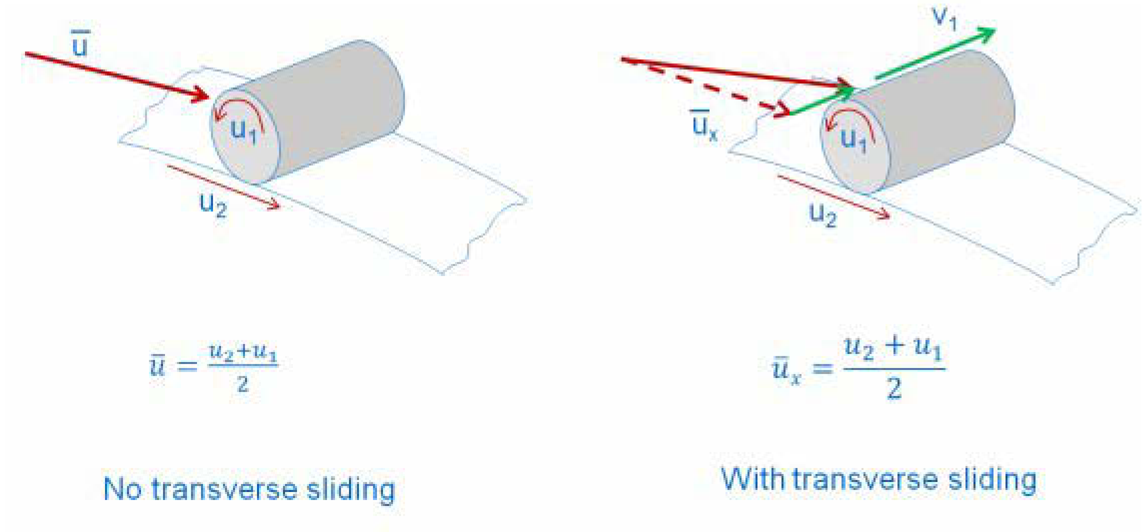
The measured quantity is the relative axial motion between the shaft and the housing, and this is taken to be the same as the ring-to-ring motion. This needs to be related to contact conditions.



Axial sliding in individual contacts will thus be on the order of 25% of the ring-to-ring sliding speed.

Measured maximum axial ring-to-ring speed is on the order of 2 mm/s.
Axial sliding speed in individual contacts is on the order of 0.5 mm/s .

Bearing Lubricant Film Formation—General



1. No noticeable effect on film thickness for transverse speed <10% of the speed of rolling.
2. It begins to make an impact only for values near 50% of the speed of rolling.
3. The most important phenomenon leading to this reduction is shear thinning of lubricant.

For the NREL test turbine main bearing at nominal speed, the speed of rolling is 352 mm/s.

The maximum speed of the axial sliding from the measurements is 0.5 mm/s, which is only 0.14% of the speed of rolling. Thus, we can safely say that the level of axial motion found has no noticeable effect on lubricant film formation.

SKF

Summary

1. The NREL test turbine (GE 1.5 MW) has been used as a test resource.

2. Axial motion has been studied in depth for several operating situations.

3. The behavior has been compared to analytic models, and there is good agreement.

4. The axial motion is slow compared to the speed of rolling, and it will not influence film formation.

NREL/PR-5000-79442

This work was authored in part by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Wind Energy Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.