Manuscript Title: Investigating Grease Behaviour in Tilted Double-Row Tapered Roller Bearing Installed in Wind Turbine by Developing a Full Scale Multi-Phase CFD Model

Journal: Wind Energy Science

Responses to Comments from Reviewer 3

Referee Comment:

Please discuss geometric differences between the simplified test rig and the wind turbine bearing test rig.

Author Response:

We thank the reviewer for this valuable suggestion. The revised manuscript now includes Table 6, which summarizes the principal geometric characteristics of the experimental test bearing (32224-XL), including the bearing dimensions, roller dimensions, pitch diameter, contact angle, and the number of rolling elements. This table allows the reader to clearly identify the geometric differences between the validation bearing and the wind turbine main bearing.

To clarify the scope of the validation, the manuscript now explicitly states that the objective is not to establish complete geometric similarity, but rather to validate the capability of the proposed CFD framework to reproduce the dominant grease redistribution mechanisms. Although the overall bearing dimensions differ substantially, both bearings are tapered roller bearings and therefore exhibit similar rolling kinematics and lubricant transport mechanisms. Furthermore, the CFD formulation, grease rheology, and boundary-condition treatment were kept identical to ensure methodological consistency.

Referee Comment:

Provide an overview about non-dimensional numbers (Reynolds, Froude,...) that characterize the flow between the test rig and wind turbine bearing to get an understanding how relatable the results are

Author Response:

We thank the reviewer for this important comment. In the revised manuscript, we have expanded the validation section by introducing both local geometric similarity parameters and dynamic similarity parameters, including Reynolds and Froude numbers, to better relate the experimental test bearing to the wind turbine main bearing

Since the validation bearing differs substantially in its overall dimensions from the wind turbine bearing, the objective was not to demonstrate complete geometric similarity, but rather to compare the local geometric features that govern grease transport. For this purpose, the circumferential packing density of the rolling elements and the normalized radial position of the roller row were introduced. The circumferential packing density differs by only 1.2%, indicating that the periodic arrangement of the rolling elements and the passages available for grease transport are nearly identical in both bearings. Similarly, the normalized radial position differs by only 5.3%, indicating that the rolling elements occupy a comparable radial location within the bearing envelope.

In addition, the Reynolds number was calculated using the cage translational velocity as the characteristic velocity and the mean roller diameter as the characteristic length. The resulting Reynolds numbers are approximately 29.5 for the wind turbine main bearing and 28.4 for the validation bearing, corresponding to a difference of approximately 4%. This indicates that both configurations operate within a comparable Reynolds-number regime and therefore exhibit a similar balance between inertial and viscous effects.

Collectively, these local geometric and dynamic similarity measures demonstrate that the dominant mechanisms governing grease transport are well represented by the validation bearing, thereby supporting the applicability of the experimental observations to the proposed CFD model.

Referee Comment:

please clarify what is validated and what is not validated with this experimental results.

Author Response:

We thank the reviewer for highlighting the need to clarify the scope of the validation. The revised manuscript has been updated to explicitly distinguish between the aspects of the model that are validated experimentally and those that remain numerical predictions.

The experimental comparison provides a qualitative validation of the grease-distribution behaviour by demonstrating that the CFD model reproduces the principal grease redistribution mechanisms observed in the experiments, including grease spreading, accumulation, redistribution, and the evolution of the overall grease-film coverage.

Referee Comment:

Oil distribution is clearly different. Discuss where this differences come from (different time?) and why the results might still."

Author Response:

We thank the reviewer for this valuable observation. Following this comment, the qualitative comparison has been revised by selecting experimental images that exhibit a better agreement with the numerical predictions. In the previous version of the manuscript, the experimental and CFD images were extracted at the same physical time. However, this approach did not account for the initial acceleration phase of the experimental test rig, during which the rotational speed increased from rest to the target operating condition. This transient acceleration is inherently present in the experiments but was intentionally neglected in the CFD simulations, which were initialized directly at the prescribed operating speed in order to reduce the computational cost. Consequently, a slight temporal offset between the experimental and numerical datasets is expected and should be considered when comparing instantaneous grease distributions.

After accounting for this effect, the revised Figs. 11 and 12 show an improved qualitative agreement between the experimentally observed and numerically predicted grease distributions. At this stage of operation, the grease distribution has approached a quasi-steady state, resulting in similar grease-film coverage, dominant accumulation regions, and overall flow patterns in both the experiments and the simulations. The remaining local discrepancies are mainly attributed to the inherently transient nature of grease transport and to experimental factors such as surface imperfections, manufacturing tolerances, and small variations in the initial grease distribution, which cannot be reproduced exactly in the numerical model. Overall, the revised comparison further supports the capability of the proposed CFD methodology to capture the dominant mechanisms governing grease redistribution within the bearing.