Wind turbine main-bearing lubrication - Part 2: Simulation based results for a double-row spherical roller main-bearing in a 1.5 MW wind turbine

Dear Amir,

Thank you again for handling the review process for this submission. Please see below the comments provided and a summary of how we have incorporated them into the updated manuscript.

Comment (reviewer): Spherical roller bearings, unlike tapered roller bearings, are not preloaded. Often times, the roller elements within these bearings experience skidding when passing through the unloaded zone. It would be beneficial to inform the reader about the implications of this possible skidding in the film thickness.

Response: We agree that this is a point worth making in the paper. We have therefore added a discussion on the likely presence of some amount of individual roller slip outside of the loaded zone. This addition reads as follows. "The lubricant entrainment velocity is calculated assuming pure rolling, see Appendix B. Recent work by Bergua et al. (2021), in which up-tower measurements from an operational wind turbine were found to show no appreciable levels of main-bearing gross-slip, provides some justification for this assumption. In reality, some amount of individual roller slip would be expected to occur outside of the loaded zone, even in cases of no gross-slip. Such effects are not accounted for in this analysis. However, the lack of gross-slip observed for an operational main-bearing (Bergua et al., 2021) indicates that the pure rolling assumption is likely valid throughout most of the loaded zone and, importantly, at the point of maximum load". In the discussion section we then elaborate further on the possible implications of slip for lubrication and film thickness values "It will also be necessary to determine the impact of effects not accounted for here, including housing and bedplate flexibility and dynamic roller behaviour (sliding, skewing etc.). The presence of individual roller sliding/slip, through the unloaded zone, could result in high levels of friction as the roller re-enters the loaded zone and is accelerated back to pure rolling. While slip isn't expected to strongly influence film thickness values directly (Crook, 1961), increases in frictional energy may influence the temperature of the bulk lubricant in the main-bearing. Where a roller is sliding, non-Newtonian lubricant properties, such as shear thinning, may also become more important (Bair, 2005)."

Comment (editor): Thank you for addressing the comments. It would be nice to discuss a bit about the uncertainties associated with the results and elaborate more on the main bearing lubrication trend in larger turbines in the discussion

Response: Thank you for this suggestion. We would like to highlight that some of this is already covered in the discussion section, for example, we emphasise the main areas of uncertainties "As has been emphasised, uncertainties are present which mean that care must be taken when interpreting these findings. In particular, further work is needed to better understand properties related to key sensitivities, these being temperature, starvation and α^* values, for wind turbine main-bearings and their lubricating greases". This, combined with the sensitivity analysis presented in Table 2, we feel provides the reader with a good understanding of where the main uncertainties are, and the effect on film thickness results of these parameters having different values from those used. However, we do agree that it is useful to discuss whether these results might be extrapolated to larger wind turbines. Therefore, the following paragraph has been added to the discussion "At this stage, it is not clear how the results of this analysis might change for larger wind turbines. Indeed, it is difficult even to speculate. While larger wind turbines will experience increased load magnitudes

and generally rotate more slowly, the main-bearing will likely be of greater diameter and contain more rollers. The former will increase roller loads and decrease entrainment velocities, while the latter tend to have opposite effects. The overall drivetrain design, including the main-bearing(s), may also be quite different for larger wind turbines. Lubrication conditions in larger turbines will therefore ultimately be determined by the interplay of these various factors.”