Modelling of Wind Turbine Main-Bearings

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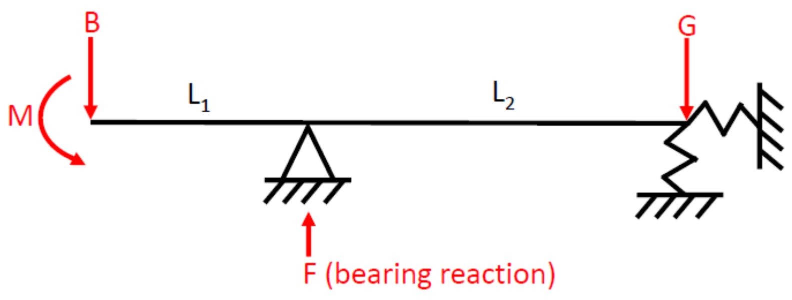
1. Abstract

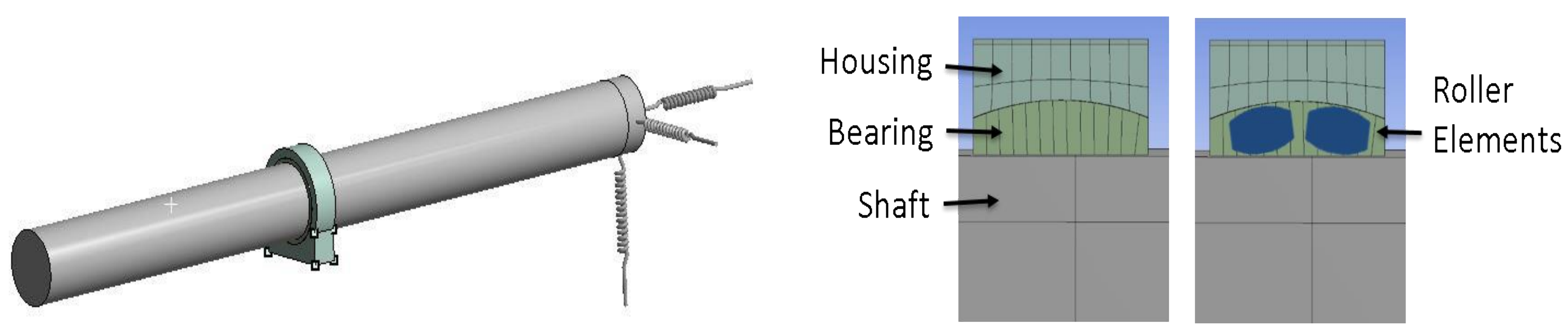
Wind turbine main bearing failures have been identified by industry experts as being a critical issue for increasing wind turbine reliability [1]. In response to this, simplified analytical models have been developed and used in [2] to explore the relationships between turbulent wind fields and corresponding main-bearing loads. The current work looks to validate these models and understand their accuracies and limitations when compared to higher fidelity 3D finite-element (FE) models. It is shown that previously developed models accurately reproduce loading for non-moment reacting main-bearing cases (such as for spherical rollers - SRBs), but in the case of moment reacting main-bearings (tapered rollers - TRBs) additional factors must be included. It is demonstrated that, in this latter case, a new analytical model can be defined and tuned such that close agreement is obtained for both types of main-bearing. This work therefore advances the possibilities of efficient main-bearing modelling to cover both spherical and tapered roller bearing cases.

2. Spherical Roller Bearing Analysis

The vertical plane of the analytical SRB model is displayed on the right. The model is limited in that the bearing is modelled as a single point fixed support. However, it is fast and computationally efficient, opening up the possibility for large numbers of load profiles to be run quickly, resulting in statistically significant output. The higher fidelity SRB model is displayed below and is still a simple representation of the single main-bearing (SMB) drivetrain. The bearing and housing were modelled as a spherical joint to prevent moment reactions.

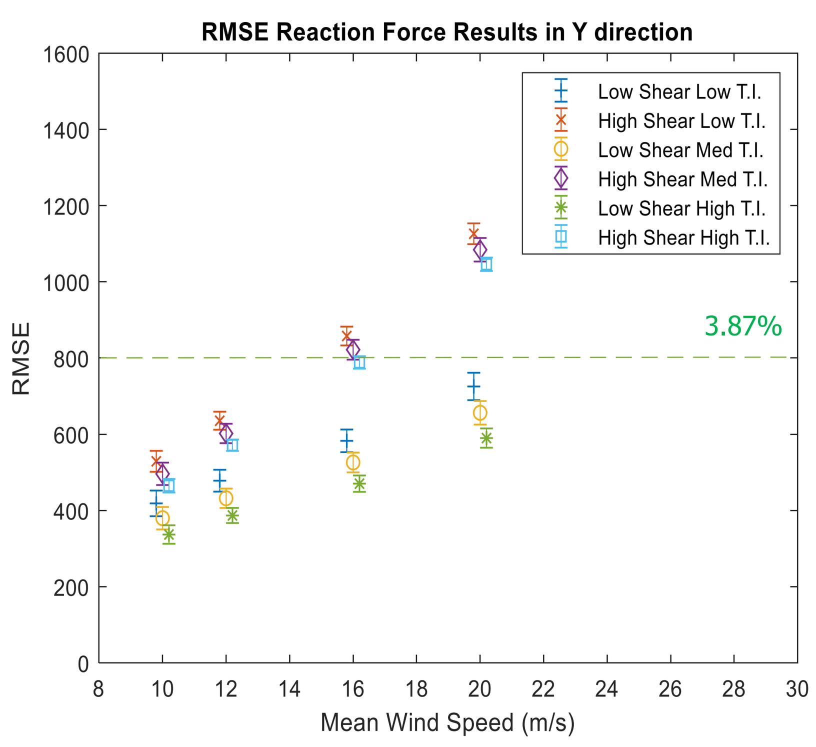


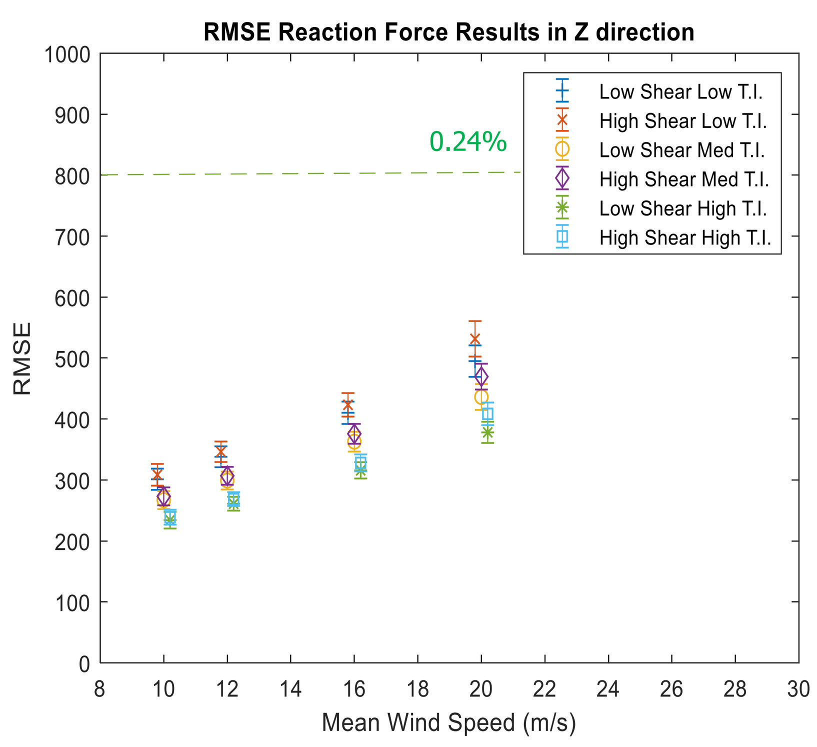
Note: *the analytical model consists of two of the models displayed above; one in the horizontal and one in the vertical planes.*

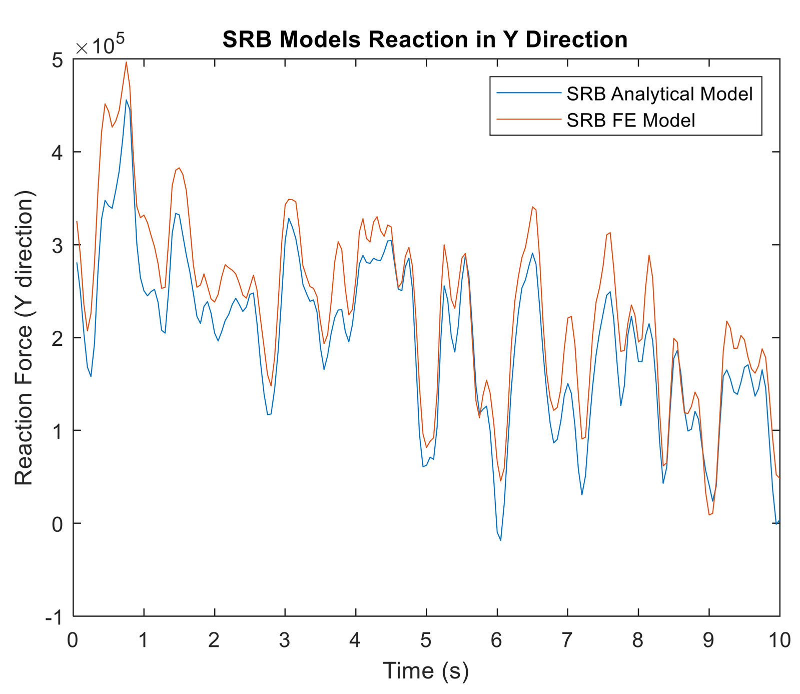


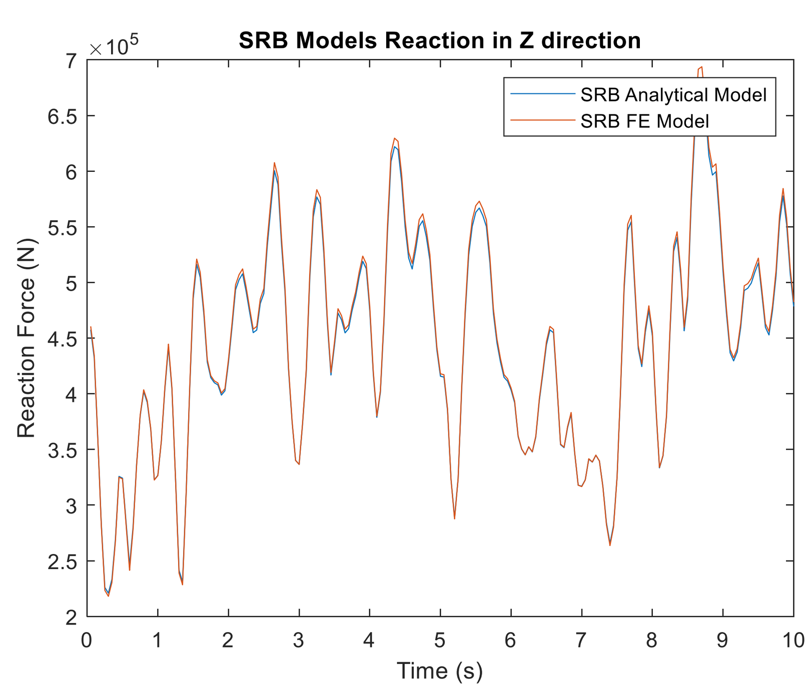
Note: *the roller elements are visual representation aids and were not modelled.*

144 wind fields were generated using a Kaimal spectrum in accordance to IEC standards [2] and utilised in the DNV-GL Bladed software to run fully aero-elastic multi-body simulations of a 2MW wind turbine. The range of wind fields consisted of 6 seeds for every combination of 4 mean wind speeds (10, 12, 16, 20 m/s), 3 turbulence intensities (low, medium, high) and 2 power law shear exponents (0.2, 0.6). The force and moment loads on the hub were extracted from Bladed for every wind field and applied to the models presented in this study. The root mean squared error (RMSE) results between the analytical and SRB FE models are presented below.



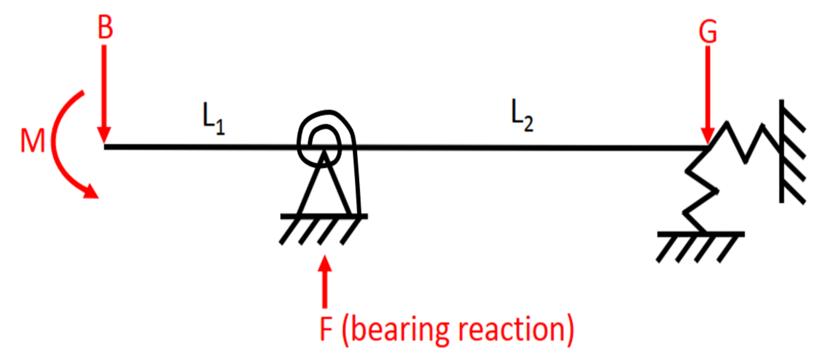




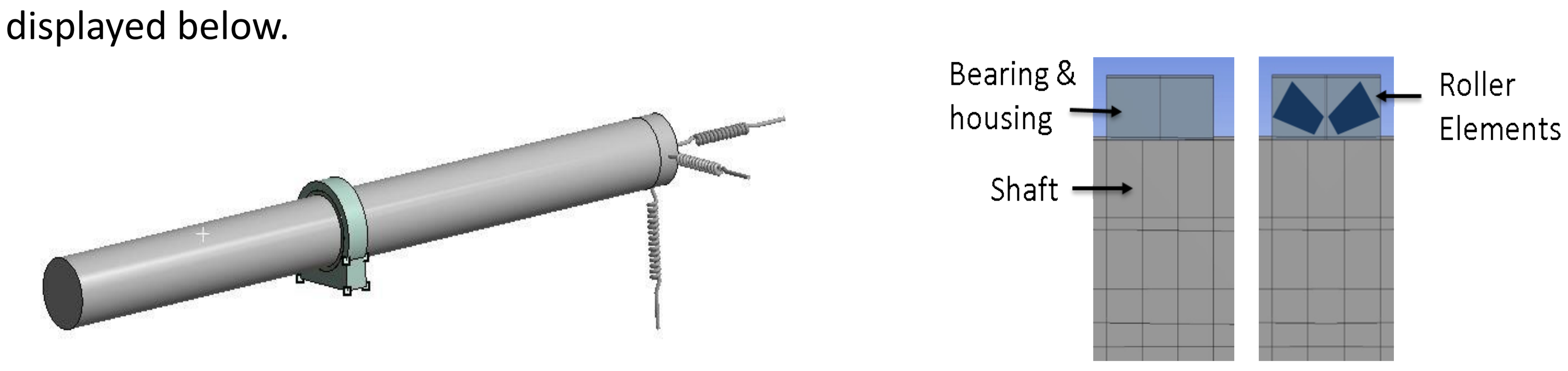


3. Tapered Roller Bearing Analysis

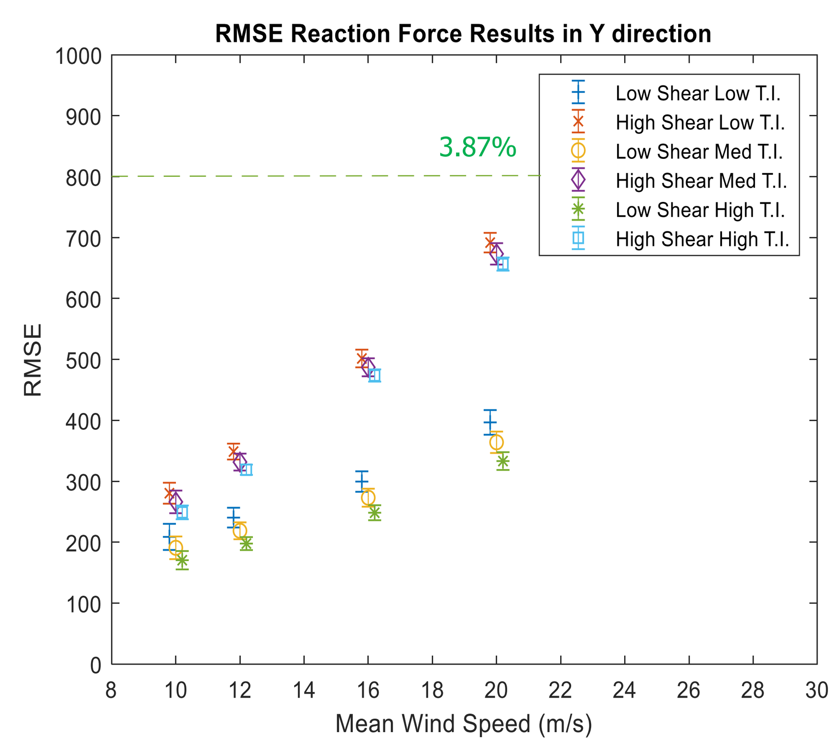
Torsional springs were added in the horizontal and vertical planes of the analytical model to represent a moment reaction and create a new analytical TRB model. This was compared with the higher fidelity TRB FE model displayed below. The bearing and housing are modelled as one piece of material to represent the preloading of TRBs and the main shaft is bonded to the inner race to emulate moment reactions. The FE model was used to estimate the spring stiffness values in both planes and the RMSE results are displayed below.

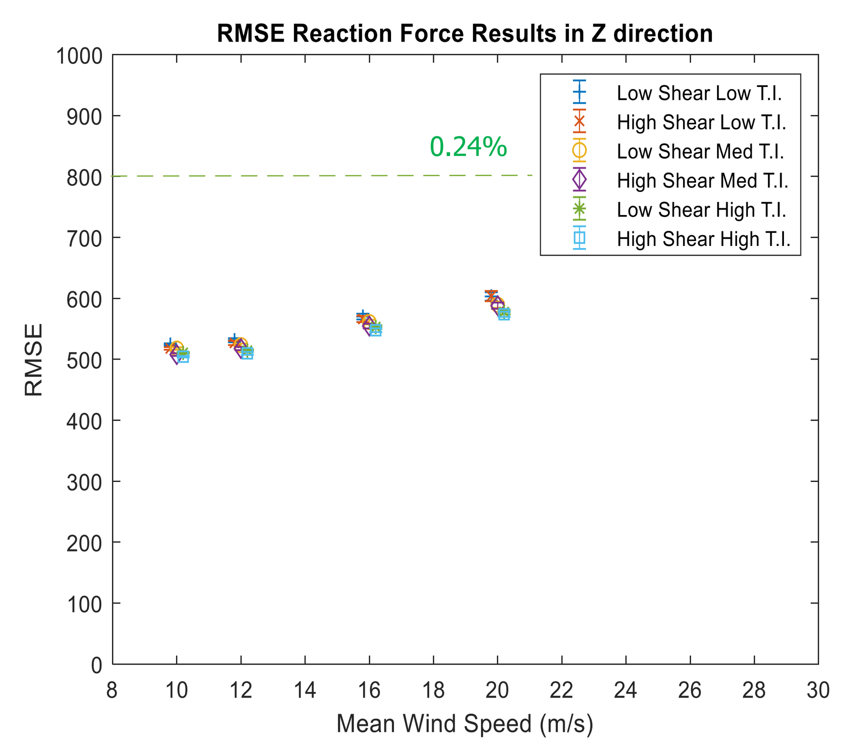


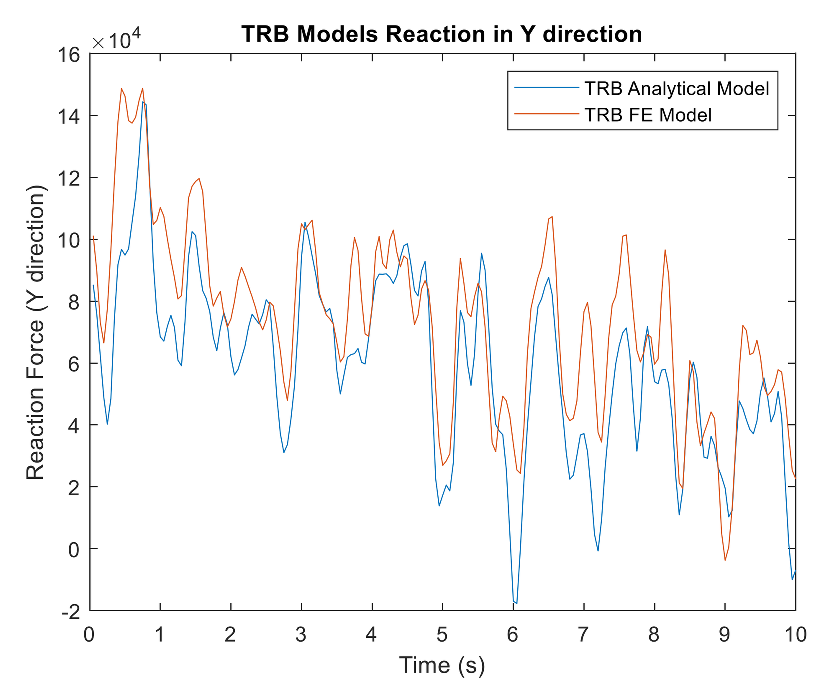
Note: *the analytical model consists of two of the models displayed above; one in the horizontal and one in the vertical planes.*

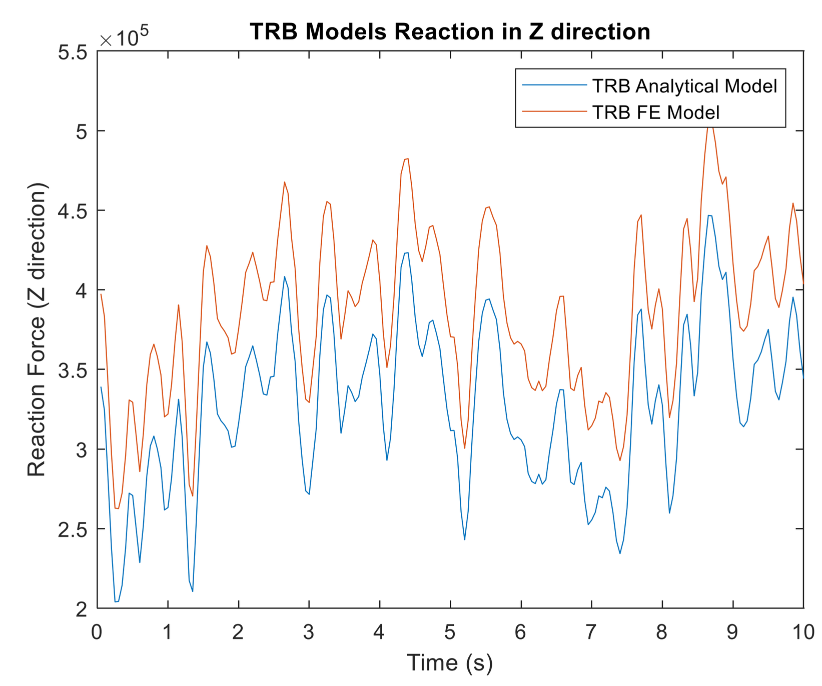


Note: *the roller elements are visual representation aids and were not modelled.*









4. Conclusions

This study concludes that carefully defined 2D analytical models can provide results which closely match that of higher fidelity 3D FE models with respect to reaction loads on wind turbine main bearings. These results held true across all 144 tested load cases. The presented analytical models can be simulated much faster than FE models, opening the door to embedding such accurate but efficient main-bearing models in windfarm simulation software, or allowing very large numbers of simulations to be run quickly. This will also allow for phenomena such as wake impacts on main-bearings across a wind farm to be studied in the immediate future.

References

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3. B. EN, "61400-1: 2005,," Wind turbines: Design requirements(London: British Standards Institution 2005)