APPLICABILITY OF WINKLER AND FEM MODELS FOR ELASTOHYDRODYNAMIC ANALYSIS OF DEFORMABLE OIL AND WATER-LUBRICATED JOURNAL BEARINGS

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ABSTRACT
Journal bearings are widely employed in various industries to support rotating shafts and reduce friction and wear. Precise assessment of the performance of journal bearings with deformable surfaces is essential, particularly for water-lubricated bearings. This is because of the relatively elastic bush materials (such as polymers and rubber) commonly utilized in water-lubricated applications. In particular, their low modulus of elasticity results in significant deformations, thereby affecting the pressure development and vice versa. In the present study, an elastohydrodynamic lubrication analysis of journal bearings is conducted, taking into consideration the elastic deformations of the bearing. While numerous studies exist in the literature, most utilize numerical techniques such as the elastic/Winkler foundation model to handle and couple the displacement and pressure fields due to its ease of use and low demand for computational resources. However, this model has limitations associated with the assumptions [2] used in its derivation, primarily being applied in stiff oil-lubricated bearings with thin liners. In this work, these assumptions are highlighted, and its applicability and validity are investigated and compared against the more detailed and computationally expensive Finite Element Method (FEM) model.

An iterative solver is developed, coupling the Reynolds equation for hydrodynamic lubrication with the open-source FEM software, CalculiX. The steady-state Reynolds equation is solved using the Finite Difference Method with Reynolds boundary conditions, while the displacement field of the bearing bush is obtained via the Finite Element Method and compared to the Winkler model. Both oil and water-lubricated bearings are examined, and the validity of the Winkler model is investigated, pointing out the circumstances under which it provides satisfactory results. While fluid-solid interaction and EHD analysis of journal bearings are well-documented in the literature [1,3], few studies offer a cross-domain comparison between FEM and Winkler models. This study is assessing the bearing performance over a range of operational conditions, including different loads, rotational speed, values of the elastic modulus, and shaft misalignment conditions. The model results are compared and validated against existing literature results. Further, an intriguing phenomenon observed mainly in water-lubricated bearing bush materials, strongly linked to Poisson ratio and material incompressibility, is illustrated and discussed. In particular, this phenomenon manifests as negative values of radial displacements (opposite to the applied pressure) in the divergent region of the fluid film.

The primary outcomes of this work include:

- Development of a fully coupled EHD model of journal bearings under various operational conditions.
- Applicability study, comparing the Winkler model with the respective FEM model, identifying conditions for which the Winkler model accuracy in not satisfactory.
- Identification of the effect caused in relatively high Poisson ratio, affecting the shape of the radial displacements on the bearing bush.

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