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A Methodology to Classify Acceptable Operating Conditions for Heavily Misaligned Marine Journal Bearings

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In this work, a methodology to predict the operational state of marine journal bearings is presented. The bearing is modeled with single or double slope and the shaft is elastically bent within the bearing length. The solution of an elasto-hydrodynamic coupled model is numerically solved for a range of operating conditions. The numerical results form the acceptable operational envelope of the bearing and highlight the operational margins in terms of maximum acceptable load and the respective lift off speed, where hydrodynamic lubrication is the dominant phenomenon. Finally a machine learning algorithm is trained to classify the acceptable journal bearing states.

Keywords (from 3 to 5 max): hydrodynamic lubrication, marine journal bearing, bearing operating condition, lift off speed, machine learning

1. Introduction

Marine journal bearings quite often operate under some degree of misalignment. Especially the stern tube bearing requires significant attention and a more sophisticated design, due to the large L/D ratio and the excessive load from the overhanged propeller [1]. According to investigations of misalignment of the journal bearings, it is shown that the static and dynamic characteristics are significantly influenced by misalignment, particularly when the load is heavy and misalignment is large [2]. The influence of the axial movement of journal on the bearing performance is greatly affected by the eccentricity and is also directly related to the rotational speed [3]. Excessive misalignment or axial movement is disadvantageous on the performance of the journal bearings, leading to the most common marine bearing failures. Therefore, classification societies have shown great interest regulating towards minimizing this effect. In the literature, the film thickness is modeled utilizing a mean misalignment value of the shaft, which is acceptable for bearings with a relatively low L/D ratio.

2. Methodology

In order to accurately model the journal bearing film thickness for traditional marine bearings operating under various conditions, the bearing bushing is modeled with a single or double slope [1], and the shaft is modeled as an elastically bent beam, utilizing a shaft alignment tool to calculate the hull deflections and thereof the transient vertical offset of the bearing. Shaft alignment calculations have been performed to determine the elastic line of the shaft at different operating conditions of the vessel. Following the current regulatory framework for acceptable journal bearing operation, a minimum film thickness of 3μm is required to ensure no metal to metal contact and a continuous hydrodynamic lubrication. An isoviscous and isothermal solution of the Reynolds equation is performed taking into account the elastic deformation of the shaft.

The numerical solution of the classical Reynolds equation, under the Reynolds boundary conditions, for a wide grid of bearing loading conditions points yields the envelope of acceptable operating conditions, providing the margins of hydrodynamic lubrication state, the maximum load and minimum lift off speed to ensure safe operation and minimum wear of the journal bearing.

A case study is performed for a typical marine journal bearing design under four distinct mean shaft misalignment values, namely zero misalignment, 0.1, 0.2 and 0.3 shaft misalignment. The bearing performance parameters for more than 3.500 acceptable and not-acceptable loading conditions are calculated and the loading envelope margins are determined in terms of maximum load and the respective lift off speed for each misalignment scenario.

Several machine learning algorithms as well as ANNs were used to classify the acceptable operating states for the bearing. The algorithms were trained utilizing the numerical results of the Reynolds solution and show very promising results for bearing operating condition identification.

3. Discussion

The numerical results of the Reynolds equation solution for the studied case show a relation between the increasing load and the respective lift off speed, in direct proportion to the mean shaft misalignment. Also, it is highlighted that problems, such as lubricant contamination, that reduce fluid viscosity are very critical for the safety and reliability of the system. The proposed methodology to estimate with relatively low computing resources the different operational conditions of the bearing is essential to avoid contact between the bearing and the shaft for the different operational states. Machine learning and AI algorithms are shown to be a very useful tool for state identification of the bearing performance, with potential to generalize given a sufficiently large training dataset.

4. References

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