XLTRC2: Prediction of Tilting Pad Bearing Dynamic Force Coefficients Including Manufacturing Tolerances

NEW PROPOSAL

Adolfo Delgado
Associate Professor

Diego Hidalgo
Prospective Student

June 2021

Introduction

Accurate prediction of critical speeds and stability performance are of paramount importance when pushing the design envelop of new turbomachinery and troubleshooting existing systems. High performance turbomachinery heavily relies on tilting pad bearings for achieving high speed operation while maintaining acceptable stability margins. These bearings comprise multiple components and their dynamic performance can vary significantly due to relatively small variations of key parameters such as pivot flexibility, pad preload and clearance. Furthermore, as shown by Romero et al. [1] and Libraschi et al. [2], variation of these parameters from pad to pad can yield large deviations of the force coefficient from their nominal values. The effect of these variations cannot simply be evaluated at each of the extreme tolerance values for each geometric parameter.

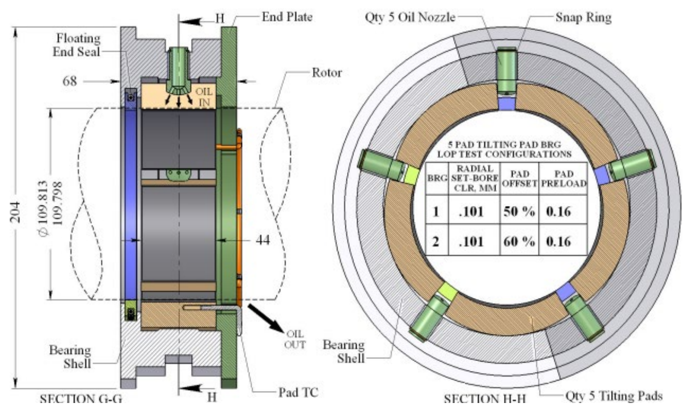

Figure 1 Cross-section of a 5-pad tilting pad bearing showing geometric parameters.

There are statistical approaches available [3,4] to assess the impact of bearing manufacturing tolerances on their performance, but these are either limited to a component-level assessment or are cumbersome to implement. Furthermore, these approaches are difficult to integrate into XLTRC2®. A novel approach is proposed using global and local adaptive Kringing models capable of running much faster than high-fidelity models. Table 1 shows an example of the difference between the training of a bearing metamodel compared to running a Reynolds equation solver to evaluate multiple points (tolerance variation).

Table 1. Computational time for running multiple points in a high-fidelity code compared to a Kringing based meta-model

Model	High Fidelity	Local Adaptive	Global Adaptive
First Tolerance	3.23 hrs	196.14 s 48 % Support Points 52 % Training/Prediction	407.19 s 23 % Support Points 75 % Training 2 % Prediction
Second Tolerance	3.23 hrs	64.99 s 100 % Training/Prediction	7.12 s 100 % Prediction
Third Tolerance	3.23 hrs	99.52 s 100 % Training/Prediction	6.67 s 100 % Prediction

Proposed work

An efficient algorithm to build a metamodel capable of processing multiple inputs and outputs is proposed to be integrated into XLTRC2. This model will initially be designed to output the variation of bearing force coefficients according to the manufacturing tolerance of critical geometric parameters such as: pad thickness, pad preload, set bore clearance, including pad-to-pad variations. The next step will be to directly associate these variations to the output of a system-level rotordynamic analysis. This will allow to directly relate manufacturing tolerances to variations in critical speeds and stability margins.

Budget	
Graduate Student Payroll, 12 months @ $2200/month	$ 26,400
Fringe Benefits	$ 5,755
Tuition and fees	$ 13,275
Computer and Software	$ 4,570
Total	$ 50,000

References

[1] Romero Quintini, JC, Pineda, S, Matute, JA, Medina, LU, Gómez, JL, & Diaz, SE. "Determining the Effect of Bearing Clearance and Preload Uncertainties on Tilting Pad Bearings Rotordynamic Coefficients." Proceedings of the ASME Turbo Expo 2014: Turbine Technical Conference and Exposition. Volume 7B: Structures and Dynamics. Düsseldorf, Germany. June 16–20, 2014. V07BT32A021. ASME.

[2] Libraschi, Mirko; Crosato, Oscar; Catanzaro, Michael; Evangelisti, Silvia (2013). Review of Experimental Sub-Synchronous Vibrations on Large Size Tilting Pad Journal Bearings and Comparison with Analytical Predictions. Texas A&M University. Turbomachinery Laboratories.

[3] Cavalini, A. A., , Jr., Dourado, A. G. S., Lara-Molina, F. A., and Steffen, V., , Jr. (September 30, 2016). "Uncertainty Analysis of a Tilting-Pad Journal Bearing Using Fuzzy Logic Techniques." ASME. J. Vib. Acoust. December 2016; 138(6): 061016.

[4] Barsanti, M., E. Ciulli, and P. Forte. 2019. "Random Error Propagation and Uncertainty Analysis in the Dynamic Characterization of Tilting Pad Journal Bearings." In Journal of Physics: Conference Series. Vol. 1264. Institute of Physics Publishing. doi:10.1088/1742-6596/1264/1/012035.

[5] Da Silva, Heitor Antonio Pereira, and Rodrigo Nicoletti. 2019. "Design of Tilting-Pad Journal Bearings Considering Bearing Clearance Uncertainty and Reliability Analysis." Journal of Tribology 141(1).