XLTRC2: Prediction of System-Level Rotordynamic Response Including Manufacturing Tolerances

CONTINUATION PROPOSAL

Adolfo Delgado
Associate Professor

Dafu Gu
Graduate Research Assistant

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. 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.

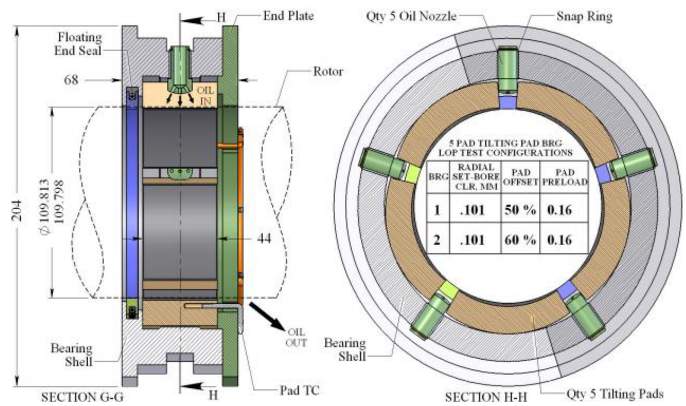

Figure 1 Cross-section of a 5-pad tilting pad bearing showing geometric parameters.

There are statistical approaches available [3-5] 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 [6] was proposed using global and local adaptive Kringing models capable of running much faster than high-fidelity models.

The first year of this project focused on implementing an efficient algorithm capable of processing multiple inputs and outputs to evaluate the 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 computational tool is currently a stand-alone executable Matlab file that calls XL_TPJB in a batch mode to calculate the bearing force coefficients and estimate the range of force coefficient values based on manufacturing tolerances.

Proposed work

The proposed tasks for year-2 are listed below:

1. Validate Probability-Density Functions (PDFs)

Currently, the probability-density functions are obtained by the Kriging Model. However, the results of this model haven't been validated with the high-fidelity model yet because of time constrains. Typically, it takes 15 seconds to compute one supporting point's exact value and one probability-density function contains at least 10000 sample points which means it needs one day and a half to validate one single output. For each validation, there are 8 outputs (K_{xx},K_{xy}, K_{yx}, K_{yy}, C_{xx}, C_{xy}, C_{yx}, C_{yy}) to be tested. In order to prove the effectiveness of the Adaptive Kriging Model, 10 different configurations will be given to examine the reliability and accuracy of this method.

2. Integrate the MATLAB Code into XLTRC2

For the simplicity of development, this model is initially created on the MATLAB. But it still needs XLTRC2 to generate input file which is not convenient for the users. Therefore, the code will be integrated into XLTRC2 once the model is fully-validated.

3. Compute PDFs for Natural Frequency and Frequency Response

The natural frequency and frequency response are related to the stiffness and damping. Once the PDFs for force coefficients are achieved, the PDFs for natural frequency and frequency response can also be computed. If admissible thresholds are given for each PDF, this can directly relate the manufacturing tolerances to the system-level rotordynamic performance of the machine.

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).

[6] D. Hidalgo, R.O. Ruiz, A. Delgado, 2022, "A novel framework for relationship of manufacturing tolerance and component-level performance of journal bearings," Applied Mathematical Modelling, 105, pp. 566-583.