A FLOW STARVATION MODEL FOR RADIAL AND THRUST BEARINGS – TOWARDS BETTER COMPUTATIONAL ANALYSIS TOOLS

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SIGNIFICANCE

Hydrodynamic thrust bearings (TBs) support axial loads and control rotor position in rotating machinery, with tilting pad thrust bearings (TPTBs) producing less drag power and showing a lesser fluid temperature rise than those in rigid surface bearings. In an experimental investigation [1], while operating with a reduced oil flow of 50% of the nominal flow recommended by the manufacturer, a mid-size TPTB still maintains its load carrying ability while showing a low drag power loss without alarming pad temperatures. Hence, a reduction supply flow is a viable strategy to effectively lessen the energy consumption and the operational costs of fluid film bearings. The major query, however, is to predict how low can the flow be to maintain a low enough pad temperature rise.

XLTHRUSTBEARING[R] [2-3] software is a multiple-pad analysis tool for the static and dynamic force performance of laminar/turbulent flow TPTBs. The analysis tool also delivers load performance predictions for self-equalizing TPTBs accounting for the contact forces (normal and friction) acting between the leveling plates, a unique feature to date. The engineering goal is to reach greater levels of confidence (accuracy) on the prediction of bearing performance without resorting to costly, time consuming tests. To continue serving TRC members' need for a modern predictive tool, efforts in 2019/20 will incorporate an analysis to model flow starvation applicable to both tilting pad thrust bearings and tilting pad journal bearings.

SUMMARY OF WORK 2018-2019

In 2018-2019, graduate research assistant Rasool Koosha developed a computational analysis tool for self-equalizing tilting pad thrust bearings (TPTB). This bearing type consists of a series of leveling plates that automatically adjust the position (tilt) of the bearing pads to evenly distribute the applied load across the pads. The model, including contact friction forces, offers an option to include a commercial 3D model of the leveling plates and hence performs analysis not constrained by geometrical assumptions.

An example of analysis takes a six-pad self-equalizing TPTB with OD = 127 mm and ID = 63 mm. The bearing carries a 2.0 MPa specific load per pad and operates at 4 krpm (maximum surface speed $Ro\ \Omega$ =27 m/s). The assumed thrust collar static misalignment equals φ =0.01°, equivalent to a tilt displacement $R_o\varphi$= 11.3 µm, ~75% of the minimum film thickness obtained with a conventional TPTB. The analysis considers three cases: (a) without including the pad leveling system, i.e. a regular TPTB, (b) with an active pad leveling system but disregarding friction forces, and (c) with an active pad leveling system and accounting for friction forces at the contact points, i.e. a realistic performance. Figure 1 shows the predicted fluid film thickness field (top graphs) and the pressure field (bottom graphs) for the three cases studied. Compared to the regular TPTB, the self-equalizing TPTB with no friction shows a significantly larger minimum fluid film thickness and a lesser peak pressure. Accounting for the friction forces, however, produces a smaller minimum film thickness and a larger peak pressure than those in the bearing leveling plates with no friction.

PROPOSED WORK 2018-2019

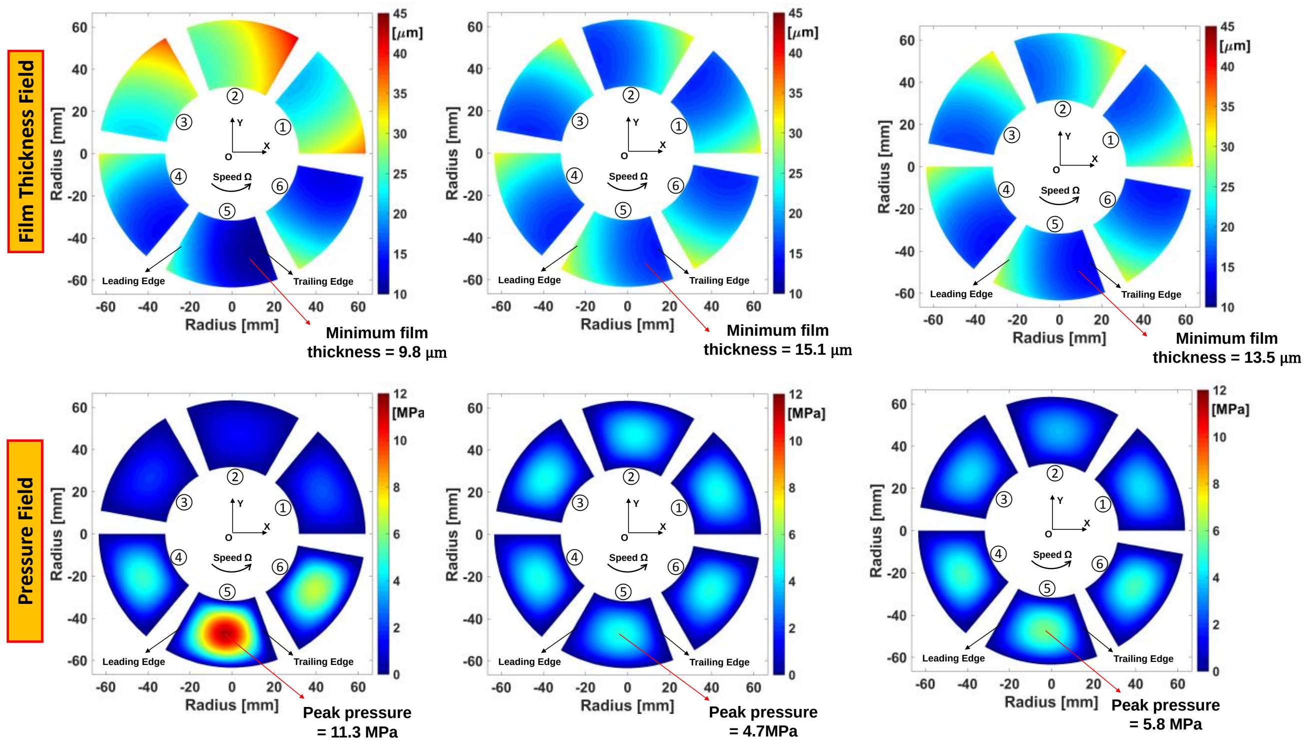
The main objectives are to further the analysis toward building a realistic physical model for flow starvation in journal and thrust bearings and to integrate the model into the current predictive tools. In addition, the work will upgrade the analysis for the journal bearing [4] tool to include a 3D energy transport equation accounting for oil viscosity variation across the fluid film. The itemized tasks are:

(a) Upgrade the analysis for journal bearing to include a 3D energy transport equation and cross-film viscosity variation in the Reynolds equation for pressure generation.

(b) Build a flow starvation model for tilting pad bearings based on the analysis described in Ref. [5].

(c) Implement the flow starvation model into both the thrust bearing and the journal bearing analysis tools.

(d) Update the Excel GUIs for the predictive tools to allow input of parameters related to flow starvation and to output predictions.



(a) Regular TPTB

(b) Self-Equalizing TPTB: Friction forces disregarded.

(c) Self-Equalizing TPTB: Friction forces included (μ = 0.2).

Fig. 1. Predicted fluid film thickness field (top) and pressure field (bottom) for a TPTB of (a) regular type, (b) self-equalizing type without including contact friction forces, and (c) self-equaling type with contact friction forces included. Bearing operates with 0.01° thrust collar (static) misalignment. Bearing OD= 126 mm, Rotor speed = 4krpm, specific load per pad = 2 MPa.

BUDGET FROM TRC 2019-2020 (YEAR III)

Support for graduate student (20 h/week) × \$2,400 ×12 months	\$ 28,800
Fringe benefits (2.4%) and medical insurance (\$422/month)	\$ 5,064
Tuition & allowable fees for three semesters	\$ 13,275
Travel and registration to (US) technical conference	\$ 2,861
Total Cost:	**\$ 50,000**

REFERENCES

[1] Gregory, R., 1974, "Performance of Thrust Bearings at High Operating Speeds," J. Lub. Tech., **96**(1), pp. 7–13.

[2] San Andrés, L., and Koosha, R., 2018, "Thermo- Elasto-Hydrodynamic (TEHD) Computational Analysis of Tilting Pad Thrust Bearings: Analytical and FE Pad Structure Models," **TRC-B&C-05-17**, Annual Progress Report to Texas A&M University Turbomachinery Research Consortium, College Station, USA, May 16-19.

[3] Koosha, R., and San Andrés, L., 2019, "A Computational Model for The Forced Performance Analysis of Self-Equalizing Tilting Pad Thrust Bearings," **TRC-B&C-01-18**, Annual Progress Report to Texas A&M University Turbomachinery Research Consortium, College Station, USA, May 15-18.

[4] Abdollahi, B. and San Andrés, L., 2019, "Improved Estimation of Bearing Pads' Inlet Temperature: A Model for Lubricant Mixing at Oil Feed Ports and Validation against Test Data," J. Tribol., **141**(3), p. 031703.

[5] San Andrés, L., Koo, B. and Hemmi, M., 2017, "A Flow Starvation Model for Tilting Pad Journal Bearings and Evaluation of Frequency Response Functions: A Contribution Towards Understanding the Onset of low Frequency Shaft Motions," J. Engineering for Gas Turbines and Power. **140**(5), p. 052506.