AN EFFICIENT CFD MODEL FOR QUANTIFICATION OF HEAT OIL CARRY-OVER COEFFICIENTS IN GROOVES AND READY INTEGRATION INTO XLTRC² PREDICTIVE TOOLS

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SIGNIFICANCE

Fluid film bearings, radial or thrust, enable high performance rotating machinery to operate at high surface speeds and carrying significantly loads. Prediction of bearing performance continues to be a crafted engineering task as these mechanical elements are vital to the life and efficient operation of rotating machinery.

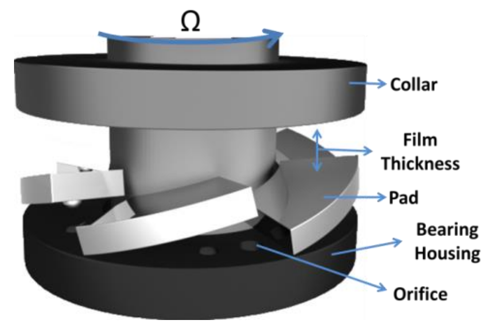


Fig. 1: A schematic view of a 6-pad TPTB (exaggerated clearance**)**

During a three-year effort funded by TL and TRC, San Andrés and Koosha [1, 2] built a predictive tool for the static and dynamic load performance of hydrodynamic thrust bearing; tilting pad type, as shown in Fig. 1. The tool XLTHRUSTBEARING® is integrated into the XLTRC® software suite. The analysis employs a 3D thermal energy transport equation in the fluid film, coupled with a 3D heat conduction equations in the pads, and a generalized Reynolds equation with cross-film viscosity variation. The pressure and temperature fields fed into a finite element structural model to produce 3D elastic deformation fields in the bearing pads. Prior work in 2014-1017 developed a similar tool, XLJBEARING®, for radial bearings, tilting pads or rigid pads.

Despite the complex and advanced models built for the flow in the fluid film region along with mechanical and thermal deformations of the bounding solids, the analysis uses a simplified (yet universal) model for the flow and thermal energy mixing at the oil feed groove. The model relies solely on a *hot oil* carry-over coefficient (λ) to set the lubricant inlet temperature at the pad leading edge. λ is an empirical parameter that depends on the orifice configuration, flow regime, and whether the bearing ends are sealed (flooded) or evacuated.

In 1980, Ettles [3] working with thrust bearings reports λ varies from 0.4 to 0.95, a function of the feed groove geometry, bearing load, and shaft speed. A year later, Vohr [4] proposes an empirical formulation based on test data in Ref. [3]. In 2002, Glavatskih et al. [5] develop a model for predicting the oil inlet temperature by using an energy balance that also accounts for the total flow of hot lubricant carried out from the pad sides and the trailing edge. Predictions for a TPTB operating with 3 krpm and under a 2.0 MPa load deviate from test data [3], with up to a 16% difference in power loss, pad temperature, and fluid film thickness. The model does not produce more accurate predictions in comparison to existing conventional models.

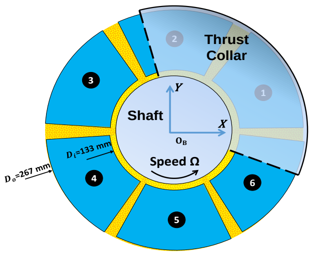
To show the significance of the thermal mixing coefficient (λ), Fig. 2 depicts load performance predictions obtained with XLTHRUSTBEARING® for a six-pad, 267 mm outer diameter, TPTB operating at 7 krpm rotor speed and under 3 MPa specific load per pad. As λ increases, 0.4 → 0.95, the minimum film thickness, power loss and lubricant supply flow rate reduce substantially by 23%, 25%, and 50% respectively.

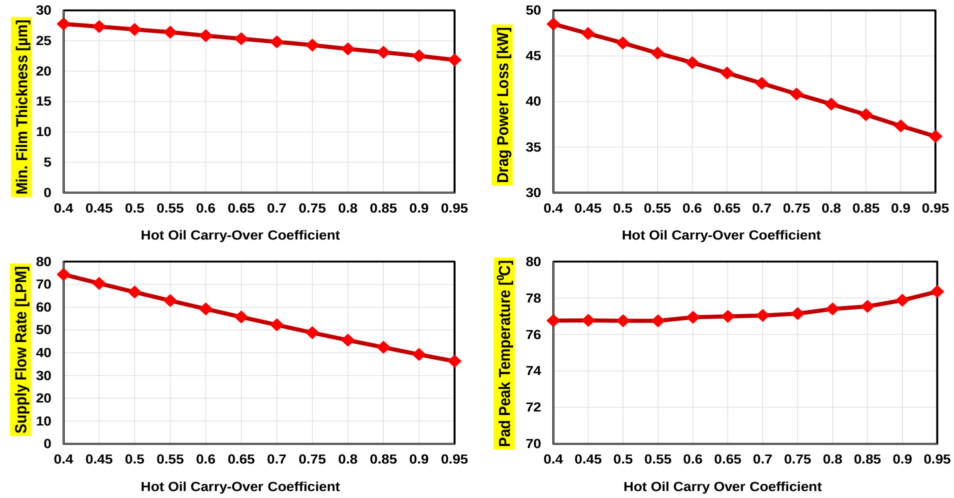
Funded by TRC, San Andrés et al. [6] built a simple flow thermal mixing model for the feed groove region in journal bearings. The model, rectifying known limitations associated with the conventional *hot oil* carry over model, makes an explicit distinction between flooded or evacuated configurations, as the physics of the thermal (flow and energy) mixing processes are different for each case. The model produces a feed groove efficiency (flow) parameter (C_g) that is independent of operating conditions, such as load and shaft seed. Predictions for performance of two bearings tested in laboratories, show a significant improvement compared to those using the conventional hot oil carry-over model. Importantly enough, the model in Ref. [8] can be used for bearing performance predictions where the flow rate is specified or known and not the inlet pressure.

Recent literature reports on computational fluid dynamics (CFD) analyses to model the flow in both the fluid film regions as well as the bearing feed groove [7,8]. Although CFD delivers accurate predictions for the whole flow field, its computational time is still orders of magnitude larger than that for a conventional lubrication type analysis.

CFD is not yet a tool for practical engineering requiring of quick multiple parameter simulations to be accomplished in a manner of minutes.

Fig. 2. Effect of hot oil carry-over coefficient on minimum film thickness, drag power, flow rate, and pad peak temperature. Example tilting pad thrust bearing. Load per pad = 3 MPa and rotor speed = 7 krpm.





PROPOSED WORK (2019-2020)

The main objective is to continue further development of the model in Ref. [6] to characterize via CFD analysis the fluid flow in distinct feed groove geometries and coupled to the upstream and downstream thin film flow regions. A scrutiny over a wide range of operating shaft speeds & applied loads determines the itemized tasks as:

(a) Build CFD models for feed grooves with distinct depth and width, and set the model boundary conditions with fluid velocities and temperature obtained from the thrust bearing analysis tool.

(b) Obtain CFD solutions of the ensuing flow & thermal fields and process data to quantify both a mixing flow hot carry over coefficient (λ) and/or a feed groove efficiency parameter (C_g) for the cases studied.

(c) Update the radial and thrust bearing predictive tools with the parameters found to improve the prediction of the oil inlet temperature into a pad.

TRC BUDGET (2019-2020)

Support for graduate student (10 h/week) × \$2,400 ×12 months	\$ 14,400
Support research associate (10 h/week) × \$5,000 ×12 months	\$ 15,000
Fringe benefits (2.4%, 16.8%) and medical insurance (\$210 & 743/month)	\$ 7,612
Travel and registration to (US) technical conference	\$ 2,500
Tuition & allowable fees for three semesters (50%)	\$ 8,598
High Performance Computing Center fees + data storage	\$ 1,890
Total Cost:	**\$ 50,000**

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