Dynamic Characterization of a Low-Power Loss Tilting Pad Bearing

NEW PROPOSAL

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June 2022

Introduction

High performance turbomachinery relies on tilting pad journal bearings (TPJB) for high speed operation while maintaining acceptable stability margins. However, TPJB's can develop large power losses that increase with machine size and speed, reaching as high as 1–2 MW loss per bearing in a large turbine generator [1]. A significant amount of work has been dedicated to evaluate different designs (i.e. textured surfaces, flooded and evacuated configurations) and operating conditions (i.e. reduced oil flow rates) toward reducing the power losses of the bearing associated to both oil shearing and oil churning [2-8]. In 2018 and 2019, TRC funded a program to quantify the effects of reduced (or higher than nominal) flow rate on the performance of a TPJB (load in between pads [LBP] and with a flooded configuration (2019) and with evacuated ends (2020), see Refs. [7-8]. Fig. 1 shows the test four-pad bearing, OD=101 mm (4"), L/OD=0.6, and spherical pivots. The pads are 72^o with a 0.30 preload and 50% pivot offset. The nominal cold clearance = 4.5 mi (0.115 mm). ISO VG46 oil at a constant temperature of 60 ^{o}C (140 ^{o}F) flows into the bearing at a (user) set flow condition. A 60 kW air motor spinning to a maximum 16 krpm drives the shaft supported on two precision ball bearings. The experimental results indicate that reducing the oil supply flow by 50% has a minimal impact on the bearing dynamic performance while the drag power loss is reduced 10-20% depending on the unit load and shaft surface speed.

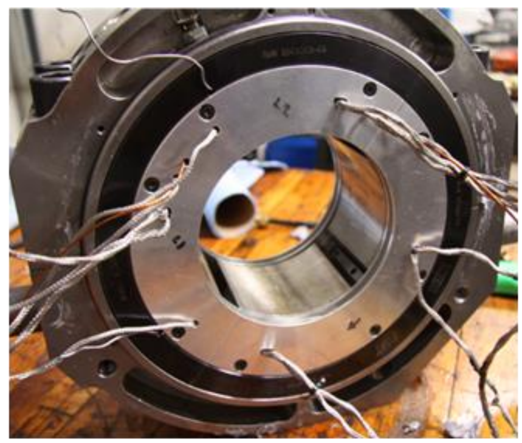

Figure 1 4-Pad tilting pad bearing with spherical pivot and single orifice feed.

The power savings from reduced flow rate operation could be potentially increased by modifying the bearing assembly. In tilting pad bearings, although only two to three pads are actively engaged (reacting static and dynamic loads) during operation, all of the pads contribute to the bearing shear drag power losses. Except when using flexible pivots, the top pads can travel radially and rest on the rotor, thus leading to unnecessary shear losses that could potentially be avoided without a penalty on load capacity or dynamic load performance.

Sano et al. [9] and Kawashita et al. [10] evaluate the static and dynamic performance of a 2-pad tilting pad bearing, respectively. The power loss measurements in [9] show that the direct lubrication 2-pad bearing yields the lowest loss factor out of four bearing configurations tested. The dynamic performance evaluation presented in [10] indicates that the bearing damping ratio decreases as the oil supply decreased. However, the experimental results do not include explicit stiffness and damping coefficients. Yang and Palazzolo [1] partially leverage the pad removal approach by adding a large undercut to the unloaded pads such as to create a lubricant cavitation region and also to reduce the pad surface area and the associated shear losses. In Ref. [1], the authors evaluated this concept using CFD and demonstrated a 27% power loss reduction on a 5-pad single orifice supply TPJB, but with a measurable impact on the logarithmic decrement along the bearing pads' unloaded direction.

Proposed work

The proposed work will aim at experimentally evaluating the impact of removing the top pad on the dynamic performance and power losses of LOP TPJB. The experiments will include a combination of three unit loads (to 200 psi) and supply flow (50% to 150% nominal of 4 pad bearing) rates while operating at 6 and 12 krpm for the evacuated configuration. The experimental results will include pad temperatures, oil inlet and exit temperatures, drive torque and power loss, and the full set of bearing force coefficients ranging from 20 Hz to 200 Hz. The experimental conditions will be such as to allow a direct comparison with previous tests at the Turbo Lab for the 4-TPJB. Alternatively, according to preliminary results, the top cavity resulting from removing the top pad, may be partially field with a spacer in order to reduce churning losses [11].

Funding of this work would be critical to enable knowledge transfer between students and ensure smooth operation of the bearing test rig at the Turbomachinery Laboratory.

Budget

Graduate Student Payroll, 12 months @ $2250/month	$ 27,000
Fringe Benefits	$ 3,093
Tuition and fees	$ 17,349
Test rig supplies	$ 2,558
Total TRC	$ 50,000
Additional supplies	$ 1,000
Alignment (torque meter installation)	$ 1,200
Undergraduate research assistant	$ 8,640
Total	**$60,840**

References

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