Continuation Proposal to the TAMU Turbomachinery Research Consortium

A TEST RIG FOR EVALUATION OF THRUST BEARINGS AND FACE SEALS

MEASUREMENT OF STATIC LOAD PERFORMANCE IN A HYDRODYNAMIC THRUST BEARING (YEAR IV)

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SIGNIFICANCE

Thrust hydrodynamic bearings (TBs), oil or process fluid lubricated, are vital components in rotating machinery. Axial loads in a turbomachine arise from pressure fields on the shroud and back surfaces of an impeller, hence are shaft speed (and load) dependent. To date, prediction of aerodynamic induced thrust loads is still empirical. Hence, the need to design and manufacture proven thrust bearings into any turbomachinery. This proposal addresses to the shortcomings in TB technology by delivering reliable experimental results to validate predictive tools that will better the design of TBs.

DESCRIPTION OF THRUST BEARING TEST RIG

Figure 1 depicts a cross sectional view of the test rig with water lubricated hydrostatic bearings, thrust and radial. USAF funded the construction of the test rig in 2007 [1]. Through a diaphragm coupling and quill shaft, a motor drives a rotor made of a 197 mm long 316 stainless steel shaft with two 316 stainless steel thrust collars. The shaft diameter at the location of the radial bearings is 38.1 mm, while the thrust collars have a diameter of 108 mm. Two radial hybrid bearings (4-pad flexure-pivot with diameter=38.1 mm and radial clearance=0.089 mm) support the test rotor. Presently, the test rig hosts two eight-pocket hydrostatic thrust bearings with inner diameter D_i 40.6 mm and outer diameter D_o=76.2 mm. One is a test bearing and the other is a slave bearing, both facing the outer side of the thrust collars on the rotor. The slave TB is affixed rigidly to a bearing support, as shown on the right of the figure. Through a non-rotating floating shaft, a load system delivers an axial load (static and/or dynamic) to the test TB. Two aerostatic bearings support the axial load shaft with minute friction. The test TB displaces to impose a load on the rotor and the slave TB reacts to this axial load.

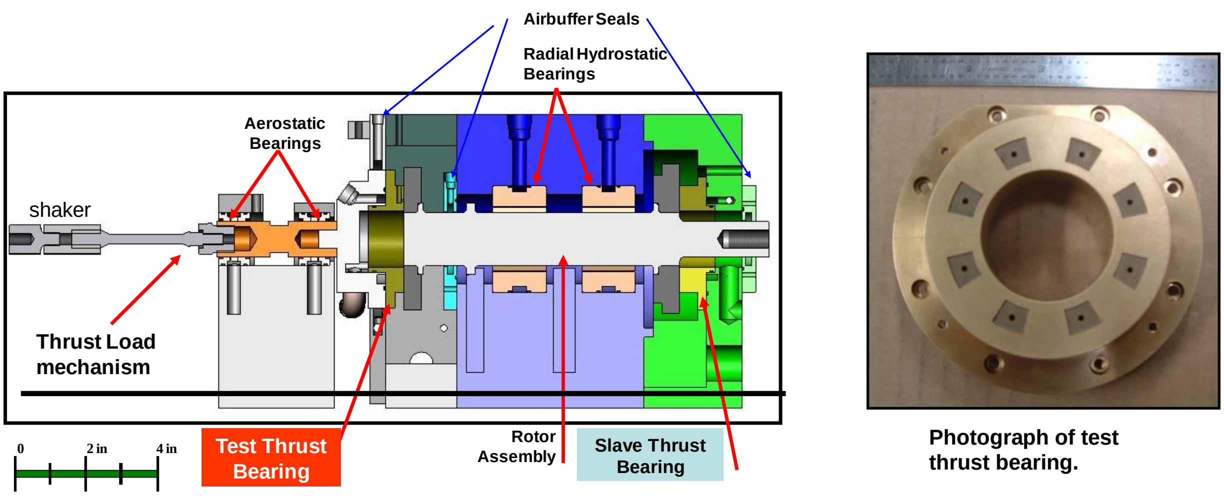

Figure 1. Schematic view of thrust bearing test rig [2].

SUMMARY OF WORK IN 2016-17

Technical report **TRC-B&C-03-16** [2] describes modifications made in 2015, including the construction of a closed loop water delivery system and a mechanism to apply external axial loads, and details measurement of the TB operating clearance vs. static load for tests with a rotor speed of 3 krpm ($\frac{1}{2}\Omega D_o$ ~ 12 m/s) and with water supplied at max. 4.14 bar(g). The load mechanism combines a lever and spring for application of a static load and an end connection for delivery of impacts during dynamic load tests. In the tests, water at room temperature (24 °C and 31 °C) feeds the journal bearings at 3.45 bar(g) and the thrust bearings at an increasing supply pressure, max. 4.14 bar(g).

At each supply pressure and shaft speed, the spring and lever mechanism applies a load that pushes the floating load shaft-test TB towards the thrust collar. Eddy current sensors measure the axial clearance, gap between bearing and collar, at three circumferential locations. A strain gauge sensor records the pressure (P_R) in one of the bearing pockets. For a fixed axial load, the TB axial clearance and the supplied flow rate both increase as the supply pressure into the TB increases.

For operation at 3 krpm, Fig. 2(a) shows that the axial clearance decreases as the applied load (*W*) increases, smaller water supply pressures giving lesser clearances. As the operating clearance increases (*W* decreases), the water supplied flow rate increases whereas the pocket pressure decreases, as seen in Figs 2(b) and 2(c). The error bands denote the variability on recording the axial clearance due to tilts of both the load shaft and the rotor thrust collar.

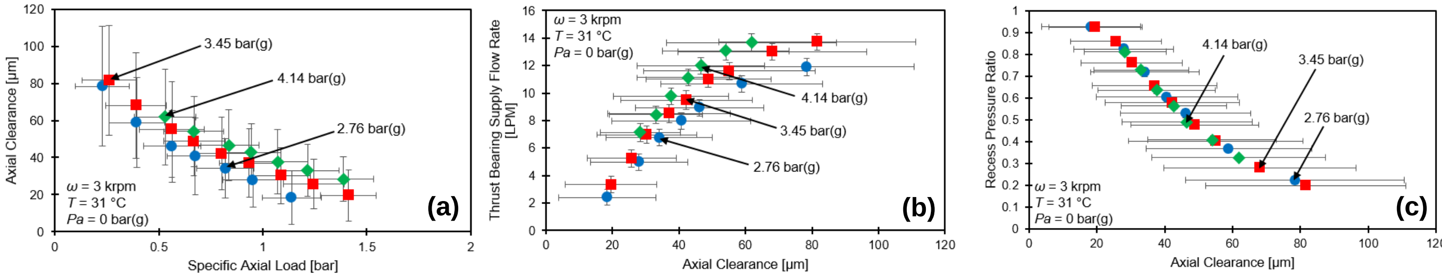

Fig. 2. <u>Water lubricated hydrostatic thrust bearing</u> (a) axial clearance vs. specific load (*W/A*), (b) supply flow rate vs. axial clearance, and (c) pocket pressure ratio vs. axial clearance. Operation at 3 krpm and bearing supplied with pressure P_S= 2.76, 3.45, and 4.14 bar(g). Water at 3.45 bar(g) feeds the journal bearings. Error bars indicate minimum and maximum clearances recorded on the face of the thrust bearing. Tests conducted at room temperature, 31 ºC.

PROPOSED WORK 2016-2017

On year IV, the main objectives are to automate the procedure for identification of dynamic force coefficients and to measure the performance of a water lubricated hydrodynamic thrust bearing. The tasks to be performed are:

- Troubleshooting of load mechanism for sound identification of axial force coefficients.
- Design and fabrication of a hydrodynamic thrust bearing (eight pads).
- Measurement of axial clearance vs. static thrust load (max. *W*=670 N [2.0 bar specific load] with rotor speed to a max. 9 krpm. The water will be supplied at just above ambient pressure for pure hydrodynamic operation.
- Measurement of TB axial response from impacts and identification of axial stiffness, damping and inertia force coefficients.

The proposed work will benchmark a predictive tool for hydrodynamic thrust bearings [3] thus leading to improvements in design, manufacturing and operation of thrust bearings in rotating machinery. The products of the research are important for compressors –barrel and integrally geared, turbochargers and turbo expanders, blowers, etc.

BUDGET FROM TRC FOR 2015-2016	Year IV
Support for graduate student (20 h/week) x $ 2,200 x 12 months	$ 26,400
Fringe benefits (2.7%) and medical insurance ($360/month)	$ 4,995
Tuition three semesters ($ 363 credit hour x 24 ch/year)	$ 9,090
Manufacture of thrust bearing	$ 4,300
Supplies: filters, hoses	$ 215
Total Cost:	**$ 45,000**

REFERENCES

[1] San Andrés, L., Childs, D., and Phillips, S., 2016, "A Water Lubricated Hybrid Thrust Bearings: Measurements of Static Load Performance," ASME Paper No. GT2016-56349, ASME Turbo-Expo, Seoul, South Korea, June 13-17.

[2] San Andrés, L., Rohmer, M., Wilkinson, S., Jani, H. 2016, "Measurement of Static Load Performance of a Water Lubricated Thrust Bearing," **TRC-B&C-03-16**, Progress Report to the Turbomachinery Research Consortium, May.

[3] San Andrés, L., 2000, "Bulk-Flow Analysis of Hybrid Thrust Bearings for Process Fluid Applications," ASME J. Tribol., **122,** pp. 170-180.