Continuation Proposal to the TAMU Turbomachinery Research Consortium

EXPERIMENTS ON THE PERFORMANCE OF LARGE DIAMETER METAL MESH FOIL BEARINGS: RADIAL AND THRUST (YEAR II)

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May 2015

SIGNIFICANCE

Gas foil bearings (GFBs) are compliant surface hydrodynamic bearings using ambient air or process gas as the working fluid. GFBs currently enable oil-free microturbomachinery (MTM<400 kW) to operate at high speed and high temperature with significant reduction in power loss and increases in system thermo-mechanical efficiency. Oil-free systems have a lesser part count, footprint and weight and are environmentally friendly with demonstrated savings in long-interval maintenance schedules. There is no bearing manufacturer company in the USA offering the technology of foil bearings at a low cost.

Metal mesh foil bearings (MMFBs) are simple geometry mechanical devices whose underspring structure is simpler and more cost effective to manufacture than typical bump foils. Research at TAMU [1-3] has paved the way for a growth of interest on MMFB technology [4-6]. Recall that low damping in bump-foil bearings (BFBs) is one of the limiting factors for their reliable use commercial applications [4]. Vance and Zarzour [1] demonstrate experimentally that a metal mesh has significant damping properties (mechanical energy dissipation), not affected by temperature nor the lack/presence of a lubricant. Recently, De Santiago and Solórzano [6] demonstrate that two MMFBs (ID = 90 mm) are able to support a five-stage, 550 N centrifugal compressor rotor at a relatively low surface speeds (43 m/s).

SUMMARY OF WORK 2015

TRC Project #32513/1519N1 was funded on December 2014 and Mr. Travis Cable, graduate research assistant, began work in the project on January 2015. During the spring semester, Mr. Cable, a seasoned student with knowledge of bearings and rotordynamics, completed the manufacturing and static load tests of two metal mesh foil bearings and a preliminary design for a thrust metal mesh foil bearing test rig.

Technical report TRC-B&C-03-15 [6] details a manufacturing procedure and tools developed for construction of metal mesh pads for assembly of a large diameter ($D$=90.1 mm, $L$=101 mm) metal mesh foil bearing. The pads, 6.5 mm and 7.0 mm thick, are woven from a Copper gauze ($\phi$=11 mil) with a very uniform mesh to reach a compactness ratio of ~ 33% and 30%, respectively. The report gives measured mechanical deflection vs. static load for individual metal mesh pads, so as to ensure their structural uniformity. In other tests, an assembled bearing is mounted on a journal supported on a lathe, see Figure 1, for further measurements of bearing deflection as an applied static load varies. A strain gauge load cell connects to the center of the bearing cartridge and two eddy current sensors, facing the axial ends of the bearing, record the relative displacement between the bearing cartridge and the static journal.
Figure 1. [a] Schematic representation [b] photograph of a setup for load versus displacement measurements for an assembled five pad metal mesh bearing.

Figure 2 displays the recorded static load (per unit area=\(L \times D\)) versus mechanical deflection for two metal mesh bearings, one assembled with five 6.5 mm thick pads, and the other with five 7 mm thick pads. All pads are 67° in arc length. The bearing with thinner pads has a radial clearance of \(\sim 200 \mu m\), while the other bearing, the one with thicker pads, has no clearance with its journal, i.e. an interference fit that creates a mechanical preload on all the pads. Note the significant difference in load vs. deflection paths for both bearings. The bearing with a clearance is much softer as the pads are not fully engaged (compressed) until a significant load is applied. On the other hand, the bearing with no clearance engages all the bearing pads as soon as a load is applied, hence appearing much stiffer due to its mechanical preload. The data show typical hysteresis loops during the load-unload processes. The area inside the loops is a measure of the mechanical (internal) energy dissipated \(E_{\text{dis}}\) and best characterized by a material loss factor \(\gamma = E_{\text{dis}} / \left( \frac{\pi K_e \delta^2}{2} \right)\) with \(K_e\) and \(\delta\) as an effective stiffness and characteristic deflection. Presently, the analysis of the results in Fig. 2 reveals \(\gamma = 0.14\) and \(0.22\) for the bearing configurations with a clearance and a mechanical preload, respectively.

Commercial foil bearings usually are mounted with an interference fit to ensure there is a sizable structural stiffness (before rotor lift-off) albeit the preload causes contact with the rotor that demands a large start-up (break away) torque.

Figure 2. Specific load \(W/(LD)\) versus displacement for a metal mesh bearing assembled with 6.5 mm and 7 mm pads.
PROPOSED WORK 2015-16 (YEAR II)

In year II of the research on thrust and radial metal mesh foil bearings, the tasks for completion are:
(a) Construct metal jigs to manufacture identical metal mesh pads.
(b) Determine a more accurate means of classifying metal mesh pad dimensions and verification of assembled bearing clearances.
(c) Design and construct a novel thrust metal mesh foil bearing.
(d) Overhaul an existing test rig to statically load the thrust metal mesh foil bearing.
(e) Measure rotor lift-off speed and break away torque, touchdown speed and stall torque, load versus minimum film thickness, and drag power losses, over a range of shaft speed to 25 krpm.

BUDGET FROM TRC FOR 2015-2016

<table>
<thead>
<tr>
<th>Item</th>
<th>Year II</th>
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<tbody>
<tr>
<td>Support for graduate student (20 h/week) x $2,300 x 9 months</td>
<td>$20,700</td>
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<td>Fringe benefits (2.7%) and medical insurance ($377/month)</td>
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<td>Tuition three semesters ($363 credit hour x 24 ch/year)</td>
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<td>Test rig components and instrumentation</td>
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<td>Manufacture metal jigs and purchase metal mesh</td>
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<td>Travel fees and expenses for a technical conference</td>
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<td>Total Cost</td>
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REFERENCES