Continuation Proposal to the TAMU Turbomachinery Research Consortium

LARGE SIZE METAL MESH FOIL BEARINGS AND TEST RIGS FOR LOAD CAPACITY

METAL MESH FOIL BEARINGS: RADIAL AND THRUST

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SIGNIFICANCE

Gas foil bearings (GFBs) are compliant sub-structure hydrodynamic bearings. GFBs enable oil-free microturbomachinery (MTM<400 kW) to operate at high speed and high temperature with significant reduction in drag 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 long-interval maintenance schedules. There is no US bearing manufacturer offering GFBs at low cost.

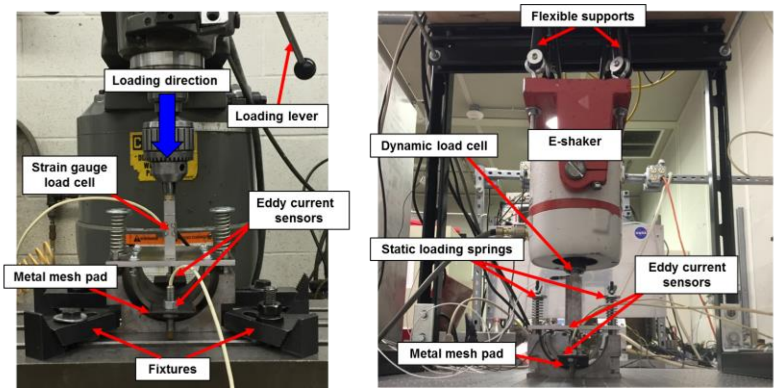
Near the turn of the 21st century, Dr. John Vance and students provided extensive empirical evidence on metal mesh dampers (MMDs), an alternative to squeeze film dampers [1,2]. MMDs have damping as large (even greater) than a similar size oil film element; their stiffness and damping being insensitive to temperature and impervious to oil entrainment. Ertas [3,4] later found that nickel-titanium MMDs give more damping than other metals (steel 304, Inconel 600, and copper) and incorporated it into a hybrid gas bearing. San Andrés and Chirathadam [5,6] first used metal mesh as a *true* uniform underspring structure in a gas foil bearing – low cost and simple in manufacturing- that demonstrated comparable performance to a bump-strip layer GFB. De Santiago and Solórzano [7] and Delgado [8] show, separately, that metal mesh pads (MMPs) can be used in large diameter bearings; 90 mm and 110 mm, respectively, carrying loads up to 1.3 kN (1.40 bar unit load). Metal mesh foil bearings (MMFBs) could easily replace oil lubricated bearings in mid-size rotating machinery (rotors weighing less than 300 kg, $W/(LD)$ ~ 150 kPa).

SUMMARY OF WORK 2015-2016

Work over the past year included the construction of a jig for manufacturing metal mesh pads (MMPs) and a rig for characterizing their structural properties (static and dynamic). Report TRC-B&C-02-16 [9] details a consistent manufacturing process and the characterization of five individual copper MMPs. These pads make the underspring structure of a large diameter (90 mm ID) FB. In addition, the design phase for a test rig to measure the performance of thrust foil bearings nears completion. Fig. 1 displays two photographs of the rig to characterize an individual MMP. Static load measurements show that the copper mesh pads, although rolled and compressed in the same way, have significantly different thickness (varying as much as ~0.35 mm) albeit with similar structural stiffness.

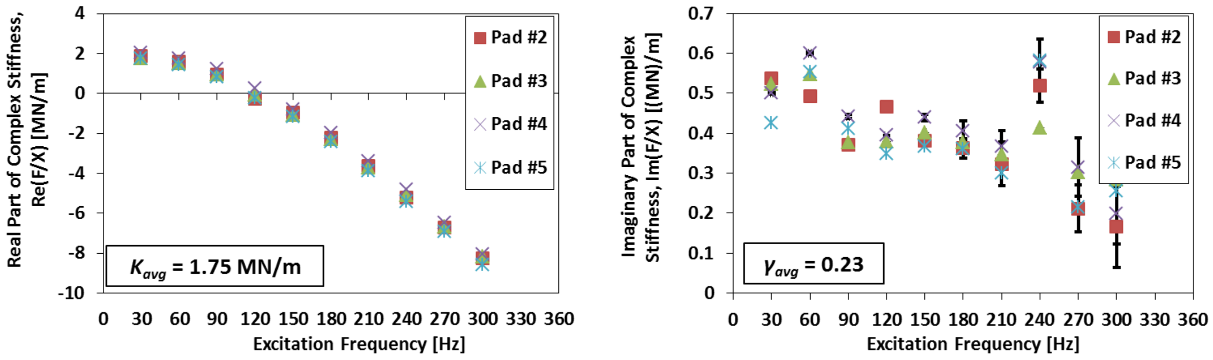
Next, tests with a single-frequency periodic load (F) and measurements of pad deformation (X~10 μm) serve to extract the pad structure stiffness and damping coefficients (K, C). Fig. 2 displays the real and imaginary parts of the complex stiffness (F/X) vs. frequency (ω) for the four MMPs. The applied preload is ~ 60 N (W/A_{pad}=14 kPa). The real part of the complex stiffness Re(F/X) → $K-\omega^2 M$ gives K and the system equivalent mass M. The quadrature part Im(F/X) ~ γK where γ is a material loss factor, typical of hysteretic damping.

Fig. 2 includes the average K and γ for each MMP which operates distinctly different from a viscous element that shows Im(F/X) = C_{eq} x ω. Test data show that K increases linearly with both preload and motion amplitude. Within the 30 Hz - 300 Hz range, the MMPs show a material loss factor that drops by ~50%.



(a) (b)

Fig. 1 A metal mesh test rig: (a) on vertical mill for static load tests, and (b) on a bedplate for dynamic load tests.



(a) (b)

	Pad #2	Pad #3	Pad #4	Pad #5
Stiffness, *K* [MN/m]	1.72	1.66	1.97	1.61
Average loss factor, γ [-]	0.22	0.24	0.20	0.24

Fig. 2 (a) Real & (b) imaginary parts of complex stiffness (*F*/*X*) vs. excitation frequency for four metal mesh pads.

PROPOSED WORK 2016-2017

In the 3rd year of work with thrust and radial MMFBs, the continuation tasks are to:

(a) Refine test rig for the dynamic load characterization of metal mesh pads.

(b) Assemble a radial MMFB (5 pads), mount it atop a rotor, and measure its lift-off speed and break away torque, touchdown speed and stall torque, and drag power for tests with shaft speed to 40 krpm and an increasing static load (specific load up to ~180 kPa).

(c) Complete design and construct a novel metal mesh foil thrust bearing.

(d) Complete the construction and troubleshoot a test rig for evaluation of foil thrust bearings and perform static load tests with a metal mesh foil bearing.

BUDGET FROM TRC FOR 2016-2017

	Year III
Support for graduate student (20 h/week) x $ 2,400 x 12 months	$ 28,800
Fringe benefits (2.7%) and medical insurance ($377/month)	$ 5,300
Tuition three semesters ($ 363 credit hour x 24 *ch*/year)	$ 9,090
Travel fees and expenses for a technical conference	$ 1,200
Total Cost:	**$44,390**

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[5] San Andrés, L., Chirathadam, T. A. and Kim, T.H., 2010, “Measurement of Structural Stiffness and Damping Coefficients in a Metal Mesh Foil Bearing,” ASME J. Eng. Gas Turbines Power, **132**, pp 1-7.

[6] Chirathadam, T. A., and San Andrés, L., 2012, “A Metal Mesh Foil Bearing and a Bump Type Foil Bearing: Comparison of Performance for Two Similar Size Gas Bearings,” ASME J. Eng. Gas Turbines Power, **134**, pp. 10250.

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