TRC CONTINUATION PROPOSAL 2019-2020

Experimental Investigation of Morton Effect ME (Thermally Induced Rotor Instability)

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INTRODUCTION AND JUSTIFICATION

(a) ***Morton Effect****:* Synchronous rotor instability phenomenon, known as the Morton Effect (ME) is caused by the temperature circumferential differential (ΔT) across the journal in fluid film bearings. The temperature difference will bend the rotor and cause increased vibrations, which will continue to grow and drive the system unstable in certain conditions.

(b) ***Experimental Morton Effect***: The ME experiment involves measuring vibrations and the detailed journal circumferential temperature distribution with embedded RTD's and a slip ring at high speed. The ME experiment utilizes dozens of RTD sensors slightly beneath the journal surface to accurately measure the high spot – hot spot angle and ΔT across the journal. Our prior Morton rig (version 1.0) was designed only to measure the asymmetric temperature distribution around the journal due to an imposed synchronous orbit resulting from an eccentrically machined shaft. It could not produce the Morton synchronous instability (MSI). The current proposal is for continuing work on rig version 2.0 which will produce MSI, and will be utilized for benchmarking the companion prediction software and for providing possible remedies for the ME.

DELIVERABLES

Morton effect test rig (version 2.0) with measurement capability of (a) both journal circumferential and axial temperature (b) operating with various journal orbits, supply oil temperatures, supply oil flowrates, bearing lubrication methods, bearing clearance, rotor overhung configuration, etc. The rig is designed to produce the Morton effect, and allow for variations of rotor/bearing/support configuration or other operating conditions to investigate their influence on Morton effect.

Experiment report including (a) transient journal temperature in both circumferential and axial direction at various operating conditions (b) steady state analysis of journal vibration and temperature difference (c) summary of parametric recommendations related to suppressing the ME.

Budget ($50,000)

1 Graduate Student, 12 months $2,200/mo. Salary, $200/mo. Insurance, 2.5% fringe on salary, approximately $13,000 tuition and fees, $9,000 for pressure dam bearing, enhanced instrumentation for bearing and shaft temperature measurement, and for anticipated shaft/rotor mod for controlling ME.

STATUS OF CURRENT WORK

(a) ME test rig ver.1.0 measured 20 temperatures of a dynamically eccentric journal in a five-pad tilting pad journal bearing (TPJB).

(b) Operated test rig ver.1.0 up to 5500 rpm with different supply oil temperature for the TPJB and collected the rotor transient vibration and temperature data. (Hot oil: 41 ℃; Cool oil: 28℃).

(c) Operated test rig ver.1.0 up to 5500 rpm with different journal static eccentricities and collected the rotor transient vibration and temperature data. (eccentricity: 0 and 0.32 C_b)

(d) The TRC high-fidelity Morton effect software predicted very close rotor temperature distribution with the measurements from rig ver.1.0 at different supply oil temperature and journal eccentricity.

(e) Used Morton Effect Prediction software to design the shaft and system parameters for test rig version 2.0 to exhibit Morton Effect.

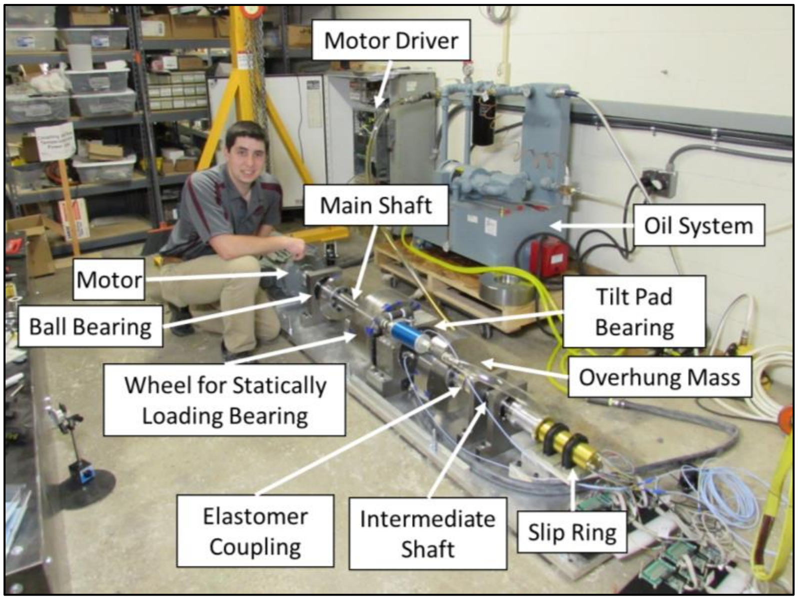
(f) Designed ME test rig version 2.0, including both shafts and all bearing housings.

(g) Purchased and machined all parts and components for version 2.0 of the test rig. (Total cost $60,000).

(h) Installed test rig baseplate, including stiffness and frequency testing.

(i) Assembled main shaft and intermediate shaft subassemblies.

(j) Conducted free-free mode testing on the shaft with and without the wheels mounted to validate the model. Measured frequencies and mode shapes agreed with predictions.
(k) Cemented and tested all RTDs. Determined correction values for each RTD for improved accuracy.
(l) Installed electronics cabinet for safe and reliable control of the motor and pumps.
(m) Test rig assembled with oil and electrical lines connected.



PROPOSED WORK 2019-2020

(1) Balance and commission version 2.0 of the test rig to design speed of 7000 rpm.
(2) Operate test rig with parameters at design values. If ME is evident, compare to predictions for validation. If not, vary the parameters to find configuration that produces ME then compare.
(3) Vary operating conditions including supply oil temperature, oil viscosity, bearing clearance, etc., for parametric study. Develop optimum operating parameters recommendation for ME suppression.
(4) Test various fluid film bearings including tilting pad bearings with different pads, nozzle type lubrication & loading direction, pressure dam bearings, partial arc bearings, etc.
(5) Test misaligned bearings by angling the TPB housing.
(6) Add additional thermocouples to map temperatures of the pads and between pads, for comparing with our tilt pad software model results, and to measure inlet and outlet oil temperatures at TPB housing.
(7) Add additional proximity sensors to measure pivot deflection and pad angles to compare with tilt pad software model results. Add proximity sensors along shaft to measure shaft bow.

The test rig version 2.0 is designed to produce the Morton effect, i.e., display large rotor vibration due to rotor thermal bow. The rig configuration (rotor, bearing, support) and operating conditions can be changed, aiming to seek for the most effective measures to mitigate the Morton effect. The Tilt Pad Bearings for version 2.0 were generously donated by Hunan SUND and Dr. Wenbiao Sun completely free of charge.

Our Related Publications

[1] Tong, Xiaomeng, Palazzolo, Alan and Suh, Junho, 2016, "Rotordynamic Morton Effect Simulation with Transient, Thermal Shaft Bow." *ASME Journal of Tribology*, 138(3), 031705. 2016 Best Paper Award, Journal of Tribology.

[2] Tong, Xiaomeng, Palazzolo, Alan and Suh, Junho, 2017, "A Review of the Rotordynamic Thermally Induced Synchronous Instability (Morton) Effect," *ASME Applied Mechanics Reviews*. Review Paper Invited by Editor.

[3] Tong, Xiaomeng, and Palazzolo, Alan, 2017, "Double Overhung Disk and Parameter Effect on Rotordynamic Synchronous Instability-Morton Effect Part I: Theory and Modeling Approach", *ASME Journal of Tribology*, 139(1), 011705.