TRC CONTINUATION PROPOSAL 2016-2017

Nonlinear Prediction and Experiment Verification of Thermally Induced Instability (Morton Effect)

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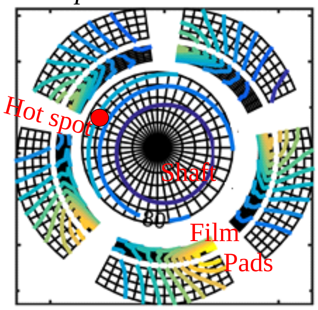
INTRODUCTION AND JUSTIFICATION

Temperature distribution



(a) **Morton Effect**: Synchronous rotor instability phenomenon, known as the Morton Effect (ME) is caused by the temperature differential across the journal in fluid film bearings (see right fig.). The temperature difference will bend the rotor and cause increased vibrations, which will continue to grow and drive the system unstable in certain conditions. ME is quite sensitive to operational parameters including oil temperature, bearing clearance, overhung mass, etc. Accurate prediction of ME instability onset speed requires precise modelling of the rotor dynamics, heat conduction and elastic deformation of the rotor and bearing.

(b) **Dynamic Coefficients**: Accurate prediction of dynamic coefficients for tilting/fixed pad includes effect of 3D lubricant temperature, nonlinear pivot stiffness, 3D flexible pad model, misalignment effect, bearing structure deformation and 3D deformation of the shaft and bearing.

(c) **Flexure Pivot Bearing/Tilting Pad Bearing:** Standard tilting pad bearings achieve low cross-coupling through rocking or sliding motion. Flexure pivot bearings have integral pad and pivot structure and thus have higher stability. Their dynamic model should be carefully handled to predict the correct dynamic response.

DELIVERABLES

Two user friendly software pkgs. (a) Precise Morton effect prediction with steady/transient analysis considering both initial bow and disk skew. (b) Dynamic coefficients determined with an ultra-high fidelity (detail) bearing model for fixed/tilting pad bearing, flexure pivot bearing, etc. Both codes will have EXCEL input, output interfaces and user's manual, and will be integrated into XLTRC2.

COSTS

- 1 PhD Student; 12 Months Salary $2200/mo.; $200/mo Insurance; 2.8% Fringe; 3 semesters*$3996 Tuition & fees
- Requested amount: $42,000

STATUS OF CURRENT WORK

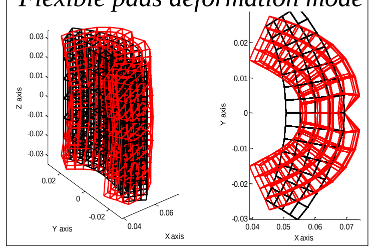
(a) All mechanical parts of the Morton effect testing rig have been finished including the bearing housing, eccentric rotor, motor brackets, etc.

(b) All software (including the vibration and temperature monitoring software) for the testing rig has be finished.

(c) Double/single overhung simulation software for the Morton effect with transient and steady analysis to show rotor dynamics and temperature distribution with respect to both time and rotor rotational speeds.

(d) Software packages using hybrid programing of MATLAB and C, which improves the execution speed by 20 times at most.

Flexible pads deformation mode



(e) Analysis of parameter study on the Morton effect including influences of lubricant supply temperature, bearing clearance, thermal expansion coefficient, thermal boundary condition and pad flexibility, etc.

(f) Investigation of Morton effect remedies including heat barrier sleeve, ceramic insulation, etc.

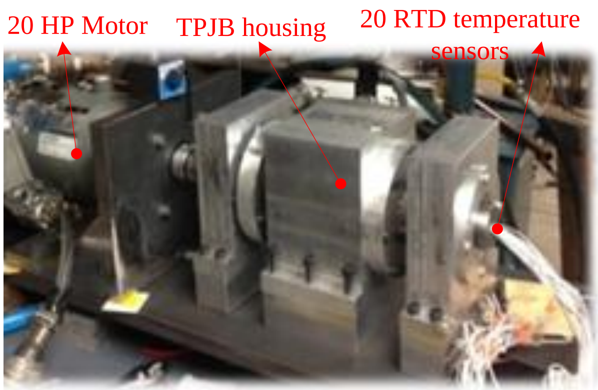
(g) New dynamic coefficient software for tilting pad and flexure pivot bearing where 3D thermal expansion of journal and pads, 3D pad flexibility (see right fig.), nonlinear pivot stiffness and 3D lubricant temperature are considered.

(h) 3D tilting pad bearing model with tilt-pitch-yaw of pad and nonlinear stress conditions (including axial) on pivot will provide more accurate predictions of pivot fatigue life.

(i) Assist in shutdown decision in cases of high amplitude synchronous journal whirl by providing estimates of dynamic stress, babbitt fatigue life and bearing hot spot temperature.
(j) Provides TRC members with user friendly software to obtain benefits in (c) – (i).

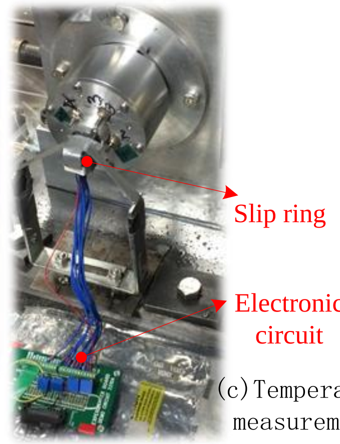
PROPOSED WORK 2016-2017

(a) Design necessary mechanical or electronic features to reduce the current motor electromagnetic radiation and switch resistance change. Thus, more accurate temperature signals can be acquired from temperature sensors.



(a) Morton effect testing rig

(b) 5-pad tilting pad journal bearing



(c) Temperature measurement

(b) Investigation of remedies for the Morton effect, such as heat barrier sleeve design including geometry optimization and material selection.
(c) Experimental investigation about the influence of the supply oil temperature, bearing clearance, pivot offset on the Morton effect based on the current testing rig.
(d) Bimaterial bearing pad modeling with babbitt layer characterized with different stiffness, heat conduction and thermal expansion coefficient.
(e) Based on the current high-fidelity software, develop the simplified double overhung Morton effect simulation software with higher speed and good accuracy.
(f) Partial arc bearing and flexure pivot bearing model for both the dynamic coefficients and Morton effect prediction.
(g) Pressure dam bearing and offset bearing model with large motions and transient force prediction.
(h) Numerical model for babbitt fatigue life prediction using current 3D finite element bearing model.
(i) Reducing computation time with hybrid C++ or FORTRAN, utilization of optimized mesh size for 3D lubricant, bearing, and shaft finite element model.
(j) Unloaded tilting-pad self-excited fluttering in rotordynamic system.
(k) Newkirk rotor- stator dry rub excitation in rotordynamic system simulation model.

Current experiment and software with high fidelity provide the benchmark for precise Morton effect prediction. Moreover, simplified methods by using approximate pressure and temperature profile types, etc. will be tested to get a rough and fast prediction.

Related Publications of Dr. Palazzolo's Lab:

- Tong, Xiaomeng, Palazzolo, Alan and Suh, Junho, "Rotordynamic Morton Effect Simulation with Transient, Thermal Shaft Bow." *Journal of Tribology*,138.3 (2016): 031705.
- Tong, Xiaomeng, and Palazzolo, Alan, "Double Overhung Disk and Parameter Effect on Rotordynamic Synchronous Instability-Morton Effect Part I: Theory and Modeling Approach", *Journal of Tribology*, 2016 (Accepted).
- Tong, Xiaomeng, and Palazzolo, Alan, "Double Overhung Disk and Parameter Effect on Rotordynamic Synchronous Instability-Morton Effect Part II: Occurrence and Prevention", *Journal of Tribology*, 2016 (Accepted).