TRC CONTINUATION PROPOSAL 2017-2018

Software Development for Morton Effect Prediction (Thermally Induced Rotor Instability)

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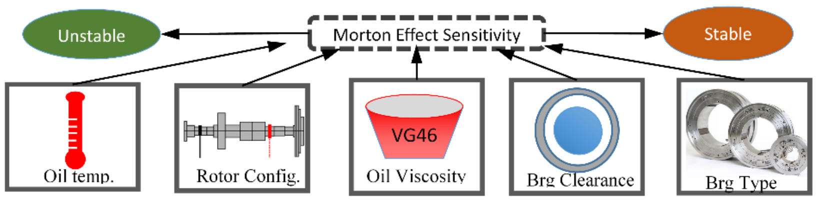
INTRODUCTION AND JUSTIFICATION

(a) ***Morton Effect****:* Synchronous rotor instability phenomenon, known as the Morton Effect (ME) is caused by the temperature differential (ΔT) across the journal circumference in fluid film bearings. The ΔT will bend the rotor, increasing the vibrations and driving the system unstable in certain conditions. The ME is quite sensitive to operational conditions below. Accurate prediction of ME instability requires precise modeling of the rotordynamics, 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

Three user friendly software pkgs. (a) High-fidelity Morton effect software with steady/transient analysis. (b) Simplified Morton effect software with steady analysis, i.e., results are shown with respect to rotor speed. (c) Dynamic coefficients software with an ultra-high fidelity (detail) bearing model for fixed/tilting pad bearing, flexure pivot bearing, etc. All codes will have EXCEL input, output interfaces and user's manual.

COSTS

1 PhD Student, Salary \$2200/mo×12 months; \$2500 for insurance and fringe benefits; \$11000 tuitions and fees; \$2400 for computer cost, \$700 for software cost, \$2000 for traveling to conference.
The total cost amount is ***\$45,000***.

STATUS OF CURRENT WORK

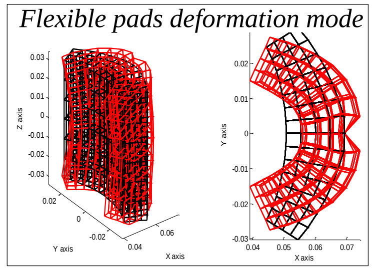
(a) Conduct experiments to measure the journal circumferential temperature with 20 sensors and operate under various journal eccentricity and supply oil temperature.

(b) Develop the high-fidelity 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.

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

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

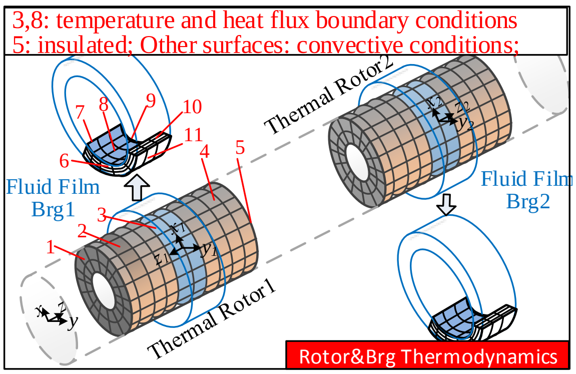
Flexible pads deformation mode

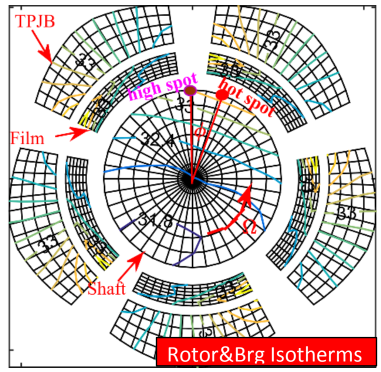


(e) Investigate Morton effect remedies including heat barrier sleeve, ceramic insulation, etc.
(f) Develop new dynamic coefficient software for tilting pad and flexure pivot bearing with 3D thermal expansion of journal and pads, 3D pad flexibility, nonlinear pivot stiffness and 3D lubricant temperature.
(g) Model the 3D tilting pad bearing dynamics with tilt-pitch-yaw motion and model the nonlinear stress conditions (including axial) on pivot, which provides more accurate predictions of pivot fatigue life.
(h) Provide TRC members with user friendly software to obtain benefits in (b) – (g).

PROPOSED WORK 2017-2018

(a) Continue to optimize the high-fidelity Morton effect (ME) software, especially focusing on how to increase the execution speed. This includes adoption of hybrid C++ or FORTRAN, optimized mesh size for 3D lubricant, bearing, and shaft finite element model.





(b) Develop the simplified Morton effect software for more efficient prediction. The high-fidelity software will be used to benchmark the simplified version to significantly increase efficiency without losing accuracy.

(c) Conduct parametric studies including bearing type, lubricant viscosity, supply oil temperature, rotor configuration, based on case studies to investigate solutions of Morton effect. Operating conditions will be optimized and criteria will be proposed to help eliminate ME.

(d) Mixing coefficient, i.e., hot oil carryover ratio, will be investigated with CFD software and its effect on rotor temperature distribution will be cautiously analyzed.

(e) Model the friction in the tiling pad spherical pivots and evaluate its influence on the rotor stability. Proper pivot geometries will be recommended to avoid Morton effect.

(f) Model the babbitt fatigue life using the current 3D finite element bearing model.

(g) Investigate other thermal bow induced rotor instability problems, such as Newkirk effect, etc., and propose solutions to cure instabilities based on case studies.

(h) Investigate ME in rolling element bearings, tilting pad gas bearings, foil bearings and ferrofluidic seals.

(i) Predict the rotor thermal bow caused by asymmetric heating, not cooling, in compressors and turbines.

In the past two years, we have assisted more than 6 TRC member companies to predict Morton effect in their equipment with our software. We will continue to provide technical support and refine our software in both accuracy and efficiency in the future based on your feedbacks.

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.