TRC CONTINUATION PROPOSAL 2020-2021

Morton Effect and Bearing Software Development

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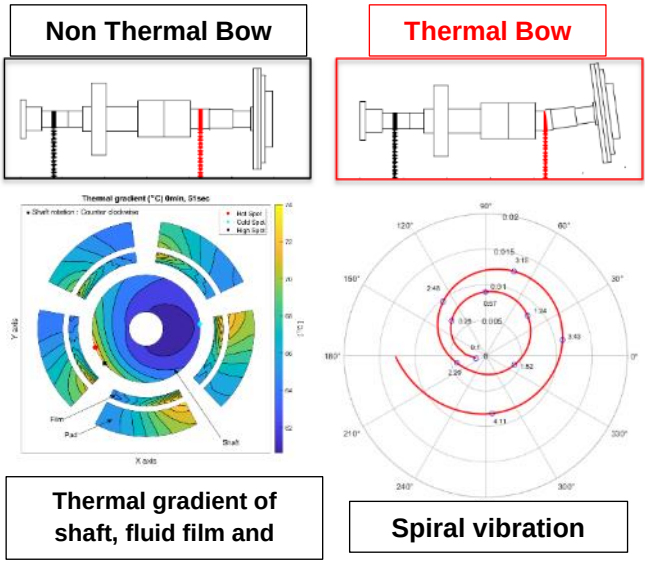
INTRODUCTION AND JUSTIFICATION

(a) **Morton Effect (ME)**: This synchronous rotor instability is caused by the temperature difference (ΔT) across the journal circumference in fluid film bearings. The ΔT will bend the rotor, increase vibrations and drive the system unstable in certain conditions. Accurate prediction of ME requires precise modeling of the rotor dynamics, thermodynamics and elastic deformation of rotor and bearing.

(b) **Simplified Morton Effect**: This is a newly developed Morton effect prediction software which is at most 6 times faster than the current high-fidelity one.

(c) **Tilting Pad / Flexure Pivot / Fixed Pad / Pressure Dam / Gas Bearings:** Various types of bearing design are provided for Morton effect prediction and dynamic coefficients software.

(d) **Dynamic Coefficients**: Accurate prediction of dynamic coefficients for tilting and fixed pad/pressure dam/flexure pivot/gas bearings includes the 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.



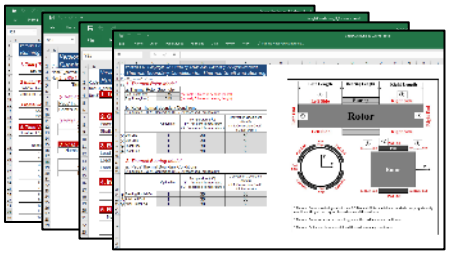
Thermal gradient of shaft, fluid film and

Spiral vibration

DELIVERABLES

Standalone user friendly software including

- High-fidelity Morton effect software with steady/transient analysis
- Simplified Morton effect software with steady analysis
- Dynamic coefficients software with an ultra-high fidelity(detail) bearing model for tilting/fixed pad, flexure pivot, pressure dam, gas bearings and etc.



ME Prediction and Dynamic coefficient

STATUS OF CURRENT WORK

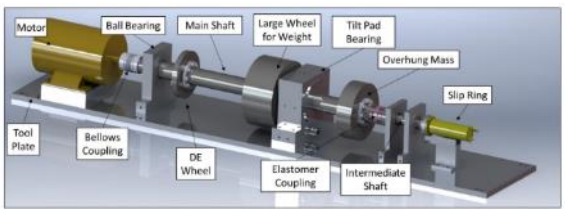
(a) Conducted experiments to measure journal circumferential temperature at various journal eccentricity and supply oil temperature.

(b) Developed the high-fidelity software for ME with transient and steady analysis to show rotor dynamics and temperature with respect to time and rotational speed.

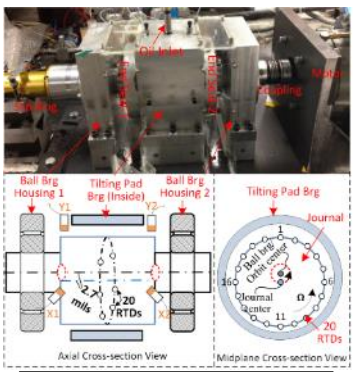
(c) Developed the simplified ME software which is up to 6 times faster than the high-fidelity one. The accuracy of the software has been validated by comparison with measurements and high-fidelity one.

(d) Developed new dynamic coefficient software for tilting/fixed pad, pressure dam, flexure pivot and gas bearings with 3D thermal expansion of journal and pads, 3D pad flexibility, nonlinear pivot stiffness and 3D lubricant temperature. Developed software packages using hybrid programing of MATLAB and C, which improved the execution speed by 20 times at most.

(e) Conducted Parametric study on ME including the influence of supply oil temperature, bearing clearance, thermal boundary condition and pad flexibility and etc.



New ME Testing Rig (In progress)



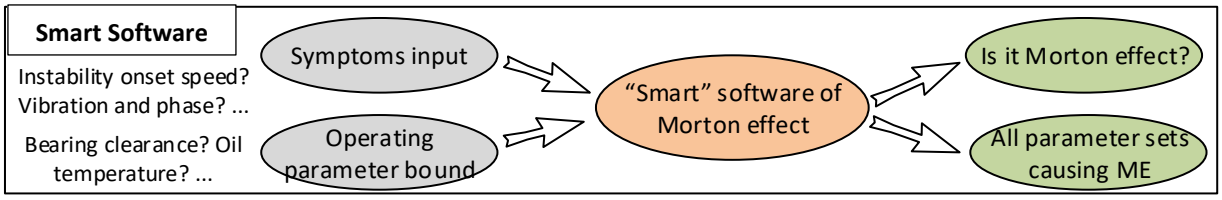
Past ME Testing Rig

(f) Modeled the 3D tilting pad bearing dynamics with tilt-pitch-yaw motion and the nonlinear stress (including axial) on pivot, which provides more accurate predictions of pivot fatigue life.
(g) Developed gas bearing (Flexure pivot tilting pad) model and investigated the ME induced by gas bearings.
(h) Modeled the friction in the tiling pad spherical pivot and evaluate its influence on ME.
(i) Employed squeeze film damper to suppress ME vibration
(j) Implemented CFD Machine learning-based mixing coefficient model to improve the prediction accuracy

Implementing Flow Starvation (Reduced flow rate) and its effect on the ME

PROPOSED WORK 2020-2021

(a) Model the bump foil, floating ring, rolling element bearings, and ferrofluidic seals and investigate ME in those systems.
(b) Add more cooling approaches (supply oil) to ME simulation and analyze its effect on ME.
(c) Update the simplified ME software (currently up to 6 times faster calculation) based on Kirk and Murphy's simplified models for more accurate and efficient predictions.
(d) Develop the simulation options with the exclusion of the thermal expansion effects of shaft and bearing pad.
(e) Verify the suppression effect of the squeeze film dampers on Morton effect with test rig.
(f) Implement the flow starvation effect (reduced flow rate effect) in various bearing models and analyze its effect on ME
(g) Combine the simplified and transient high-fidelity analysis to develop a "smart software", which is able to search for all possible sets of operating conditions that could cause ME using optimization techniques.



(h) Increase the execution speed of ME software using C++ and optimized mesh for 3D lubricant, bearing, and shaft finite element model.
(i) Investigate other thermal bow induced rotor instability problems, such as rotor-stator rubbing (Newkirk effect) and etc., and propose solutions to cure instabilities based on case studies.
(j) Predict the rotor thermal bow caused by asymmetric cooling, not heating, in compressors and turbines.
(k) Combine the stochastics modeling technique, which considers the tolerance of bearing design parameters such as bearing clearance, preload, pad thickness etc.
(l) Combine the surface roughness effect into Reynold's equation and investigate its effect on ME.
(m) Model the jacking grooves, scratches, wear and damaged parts in current bearing models
(n) Model the babbitt fatigue life using the current 3D finite element bearing model.
(o) Work with TRC members to model their machines with ME problems

Implementing Foil and Floating ring bearings and its effect on ME

In the past five years, we have assisted more than **10 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.

Budget for 2020-2021

1 PhD Student, Salary $2200/mo×12 months; $2500 for insurance and fringe benefits; $17000 tuitions and fees; $2000 for computer cost, $700 for software cost, $1400 for traveling to conference.
The total cost amount is $50,000.