Morton Effect and Bearing Software Development - 00014

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INTRODUCTION AND JUSTIFICATION

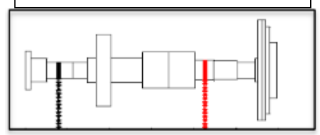
(a) **Morton Effect (ME)**: This synchronous rotor instability is caused by the temperature difference (ΔT) across the journal circumference in fluid film bearings. The ΔT will bend the rotor, increase vibrations, and drive the system unstable in certain conditions. In similar machines from the same OEM why do some develop ME? 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.

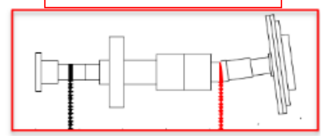
(c) **Tilting Pad / Flexure Pivot / Fixed Pad / Pressure Dam / Gas Bearings:** Various types of bearing design are provided for Morton effect prediction and dynamic coefficients software.

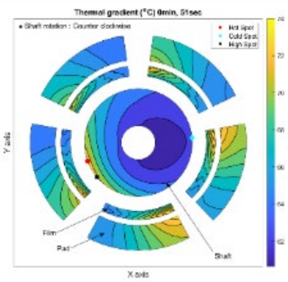
(d) **Dynamic Coefficients**: Accurate prediction of dynamic coefficients for tilting and fixed pad/pressure dam/flexure pivot/gas bearings includes the effect of 3D lubricant temperature, nonlinear pivot stiffness, 3D flexible pad model, misalignment effect, pad wear, bearing structure deformation and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

Non-Thermal Bow

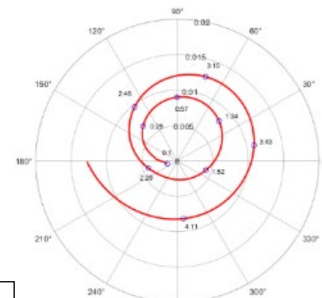


Thermal Bow





Thermal gradient of shaft, fluid film and

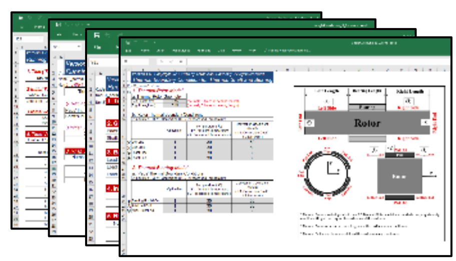


Spiral vibration

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.

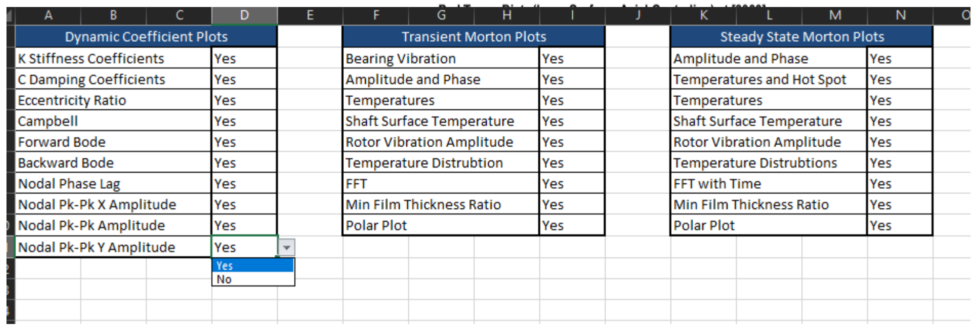


ME Prediction and Dynamic coefficient

STATUS OF CURRENT WORK

(a) Improved user's manual and included examples on SharePoint
(b) Developed more accurate hot spot prediction by increasing the number of nodes used in the calculation
(c) Incorporated user-friendly drop-down lists to simplify user input interactions
(d) Decreased computation time with optional figure toggling
(e) Further decreased computation time by upgrading to MATLAB R2021b and recompiling the source code for Runtime R2021b
(f) Included user defined complex shapes of pad surfaces to model the jacking grooves, scratches, wear and damaged parts in bearing models
(g) Matched the wear grove simulations to publications for code validation

(h) Incorporated the wear grooves for Morton Effect simulations
(i) Conducted wear groove parametric studies for Morton Effect
(j) Developed C++ code to quickly execute the wear groove simulations
(k) Increased the maximum mesh size the C++ compiled code can evaluate for increased deformation resolution



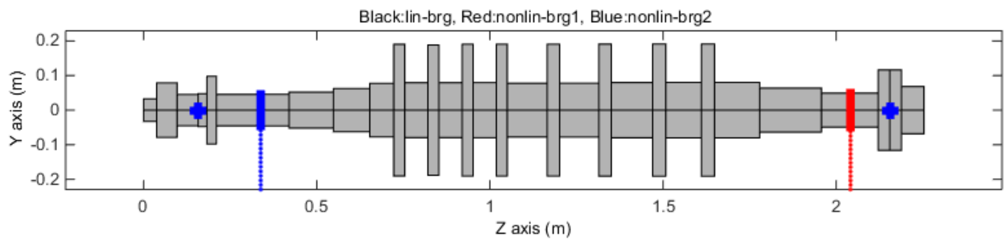
Dynamic Coefficient Plots	
K Stiffness Coefficients	Yes
C Damping Coefficients	Yes
Eccentricity Ratio	Yes
Campbell	Yes
Forward Bode	Yes
Backward Bode	Yes
Nodal Phase Lag	Yes
Nodal Pk-Pk X Amplitude	Yes
Nodal Pk-Pk Amplitude	Yes
Nodal Pk-Pk Y Amplitude	Yes

Transient Morton Plots	
Bearing Vibration	Yes
Amplitude and Phase	Yes
Temperatures	Yes
Shaft Surface Temperature	Yes
Rotor Vibration Amplitude	Yes
Temperature Distrubtion	Yes
FFT	Yes
Min Film Thickness Ratio	Yes
Polar Plot	Yes

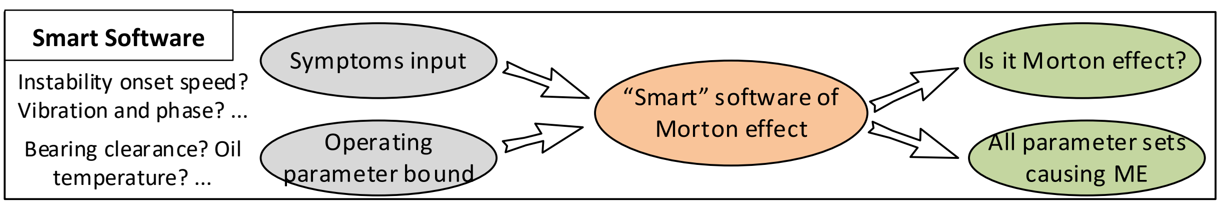
Steady State Morton Plots	
Amplitude and Phase	Yes
Temperatures and Hot Spot	Yes
Temperatures	Yes
Shaft Surface Temperature	Yes
Rotor Vibration Amplitude	Yes
Temperature Distrubtions	Yes
FFT with Time	Yes
Min Film Thickness Ratio	Yes
Polar Plot	Yes

PROPOSED WORK 2022-2023

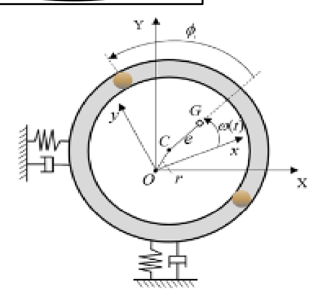
(a) Upgrade the functionality of the double overhung simulation software with features comparable to the single overhung



(b) Model the bump foil, floating ring, rolling element bearings, and ferrofluidic seals and investigate ME in those systems.
(c) Add more cooling approaches (supply oil) to ME simulation and analyze its effect on ME.
(d) 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.
(e) Implement the flow starvation effect (reduced flow rate effect) in various bearing models and analyze its effect on ME
(f) Create a Design of Experiment (DOE), for ME, which considers the tolerance of bearing design parameters such as bearing clearance, preload, pad thickness, wear etc.
(g) Develop "smart software", which can search for all possible DOE 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) Model the babbitt fatigue life using the current 3D finite element bearing model.
(k) Rewrite the source code to optimize parallel computing. Leveraging additional CPU cores and offloading large computations to the GPU should increase simulation times.
(l) Incorporate and validate Automatic Ball Balancer suppression system
(m) Include a user selectable fluid inertial effects option in the advanced settings.



Schematic of Automatic Ball Balancer

(l) In the past six years, we have assisted more than **11 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 2022-2023

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.