SIGNIFICANCE

A thermal instability refers to the phenomenon of rotor instability induced by an asymmetric temperature field at specific location(s) around a spinning rotor in a turbomachinery, a machine where either power is extracted or delivered to a fluid. The coupling of the asymmetrical thermal field and the synchronous rotor whirl usually results in an excessive rotor amplitude of motion, hence preventing machines to operate, even speed up to, the designed speed and load. When operating at a constant shaft speed, the typical symptom of such phenomenon is spiral rotor motions, with a growing amplitude and increasing phase as observed in a polar plot. A localized fluid shear drag and thermal energy transport induced by a spinning and whirling journal in a lubricant fluid film bearing lead to the Morton effect [1]. The time scale for the transfer and accumulation of mechanical energy is orders of magnitude greater than that of the system time constant for the rotating structure, hence the temperature field evolves slowly, on occasion lasting hours, and the subsequent rotor instability—as seen by an amplitude of motion growth—difficult to diagnose until the rotor displacements reach vibration limits [2]. The end result is an unexpected outage of the rotating mechanical system with immediate loss in production and revenue in the power turbomachinery, and risk to human lives when it comes to medical applications such as in blood pumps.

Research on thermally induced instabilities has seen renewed interest in the last few years. Current efforts build high-fidelity models for the entire rotor-bearing system with conjugate heat transfer on the stationary components [3-5]. Model validation against well-known egregious cases of instability relate only to the final outcome, stable or unstable, as experimental evidence remains scant. Despite the appearance of ever increasing complexity models, there are still remaining critical problems remaining to be addressed.

The phase lag between the hot spot, where the highest temperature locates around the spinning journal, and the high spot, where the amplitude of motion is largest, is a key element that drives the (appearance or not) of a thermally induced vibration. However, the phase lag is rarely considered in the archival literature due to the difficulty in solving, under unsteady conditions but over extended periods of time, the TEHD equations for the fluid film bearings (thermo-elasto-hydrodynamic) coupled to the rotordynamics of the rotating structure and the transport (conduction and diffusion) of thermal energy for the entire rotor system, including the support casing. In addition, the temperature field in a thin film or a constrained small space is difficult to be measured due to limitations of conventional measurement techniques. Besides, though solutions are proposed in the elimination of Morton effect, the rotordynamics influenced by the modifications of the system are not cursory evaluated. Moreover, it is apparent that the slow evolution towards a thermal equilibrium reduces the popularity of a numerical simulation of the Morton effect, except in cases where one has access to a large and fast super computer.
PROPOSED WORK 2015-2016

Therefore, a ready to use engineering method is needed for both the evaluation (prognosis) and practical solution (diagnostic or troubleshooting) of the Morton effect for engineering applications. To this end, a two year project will seek practical yet reliable predictions of Morton effect by tackling the issues listed above. The following chart details how the work will be accomplished.

During the first year, Dr. Gu [4,5] will extend her theoretical model and computational program into the XLTRC^® suite and devise a test rig to procure the measurements. In the second year, Dr. Gu and a student will build, assemble and operate a simple test rig, fully instrumented, for verification of the appearance of Morton effect and validation of the physical predictive model.

DELIVERABLES. At the end of Year I, a report will detail the analysis of the Morton effect for typical rotor-bearing systems in turbomachinery. Its major contributions will include:

- A ready-implemented approach for the evaluation of thermal instability induced by differential heating around the journal in a fluid film bearing.
- List practical methods for the solution of the Morton effect, along with an evaluation of their impact (implementation) on system rotordynamics.
- Provide an improved theory of coupled dynamics of multi-physical fields in turbomachinery.
- Design of the test rig for experimental verification in year II (External funds will be sought for the test rig construction).
- Improved experimental technique for temperature field of a rotating shaft in a closed small space.

BUDGET FROM TRC FOR 2015-2016

<table>
<thead>
<tr>
<th>Component</th>
<th>Year I</th>
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<tbody>
<tr>
<td>Support for researcher $ 4,200 x 60% x 12 months</td>
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<tr>
<td>Fringe benefits (18%) and medical insurance ($500 /month)</td>
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<td>PC and support software</td>
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<td><strong>Total Cost</strong></td>
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REFERENCES