Measuring Oil Films in Dynamically Loaded Journal Bearings

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A bespoke hydraulic loading system with programmable valves allows the application of dynamic loads with set loading patterns, including the simulation of loading patterns found in real components. Bearing mounted ultrasonic transducers offer a non-invasive direct measurement of the shaft-bearing interface. Tests under a range of rotation speeds and temperatures has allowed the detailed analysis of film thickness response to rapid changing loads. Results have been compared against eddy current sensors, a theoretical model and numerical techniques. This work focuses on the rig design, refining the technique, validation and how the system is being applied to current industrial problems.

Keywords: Journal Bearing, Dynamic Loading, Experimental, Film Thickness

1. Introduction

In many applications, such as connecting rods and reciprocating compressors, journal bearings are expected to withstand repeated dynamic loads [1]. Maintaining a sufficiently thick oil film, which decreases with load, is critical to prevent bearing contact which may increase risk of failure. Overcompensating for these effects with, for example, a more viscous lubricant can lead to decreased efficiency.

Those looking to understand dynamic loading behavior when designing bearing systems have primarily relied on analytical techniques. This is acceptable in well-understood systems with simple geometries, however behavior in cases with more complex geometries and significant deformation is more challenging to predict.

Conventional experimental methods have critical limitations which affect their accuracy [1]. The difficulty lies in that the measurement technique must not interfere with the shaft-bearing interface whilst still obtaining a direct measurement. The ultrasonic method solves this problem as transducers are mounted away from the interface, thus providing a non-invasive measurement. Also, the inherent nature of piezoceramic sensors allows rapid measurement response times.

2. Methods

A bespoke journal bearing test rig, shown in Figure 1, applies load via a hydraulic powerpack. Valves allow this load to be rapidly varied, for example 5kN to 22kN in under 10 ms, and may be programmed to follow even complex loading patterns.

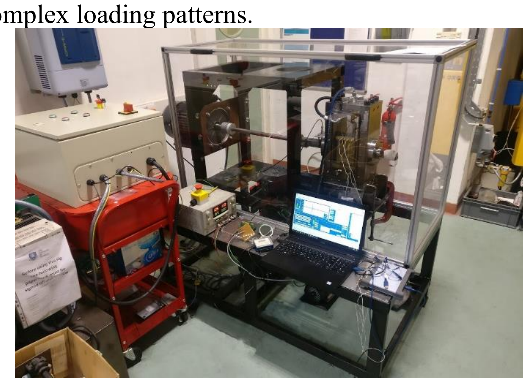

Figure 1: Photograph of dynamic loading bearing test rig.

2.1. Ultrasonic Film Measurement

Longitudinal ultrasonic transducers mounted on the outside face of the bearing allow direct measurement of the lubricant film thickness. This may be determined by comparing the phase of an ultrasonic signal response against a reference signal via Equation 1:

$$h = \frac{\rho c^2 (\tan \Phi_R)(z_1^2 - z_2^2)}{\omega z_1 z_2^2 \pm \sqrt{(\omega z_1 z_2^2)^2 - (\tan \Phi_R)^2 (z_1^2 - z_2^2)(\omega z_1 z_2)^2}} \quad (1)$$

2.2. Results

Testing under a range of rotation speeds and loading patterns have been performed. Figure 2 displays an example test case in which a square-wave dynamic loading pattern is applied.

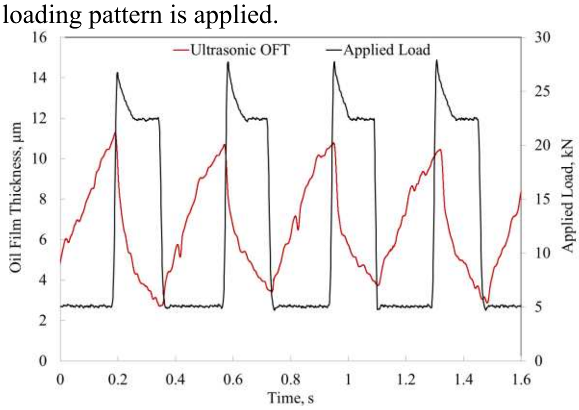

Figure 2: Minimum film thickness during a square-wave loading cycle at a 2.5 Hz loading frequency.

3. Discussion

These results highlight that film thickness does not develop or collapse to its final state instantly with variable load, known as the squeeze-film effect. A comparison between experimental results and a finite full-bearing numerical prediction show good agreement during film collapse, however predicting film recovery when load is reduced appears far more complex and depends on rotation speed and lubricant viscosity.

4. References

[1] Flores, P. (2006). Journal Bearings Subjected To Dynamic Loads: the Analytical Mobility Method. Mechanica Experimental, 13, 115–127.