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HYDRODYNAMIC ANALYSIS OF GAS LUBRICATED JOURNAL BEARINGS

Amith Hanumappa Reddy
M.S. Candidate

Faculty Advisor: Dr. Michael Khonsari

ABSTRACT

Compliant journal bearings popularly known as foil bearings have gained significant importance in recent years based on their unique mode of operation and applications. These types of bearings have various advantages compared to conventional oil based or gas lubricated rigid journal bearings in terms of higher load carrying capacity, lower power loss, stability and endurance. These bearings are self acting hydrodynamic bearings, and can operate with ambient air or any process gas as lubricating fluid. The need for complex lubrication systems is eliminated which result in significant weight reduction and lower maintenance. Since the lubricant type is normally ambient air which is available abundantly, these bearings can operate flawlessly without being affected by the contaminants present in air or even at elevated temperatures. Where as bearings operating with conventional oil based lubricants fail at elevated temperatures as viscosity drops exponentionally with rise in temperature.

Air foil bearings are now being used in industries ranging from computer hard drives, spindles in textile industry [1], cryogenic turbo compressors, and high-speed rotating machinery for use in aerospace applications. To this end, a successful test of a mesocopic scale turbojet engine simulator has already been carried out with miniature air foil journal bearings [2]. These bearings are of higher importance in the aerospace industry with regards to reduction in weight and extreme operating conditions.

Fig. 1 represents the configuration of a 1st generation foil journal bearing [3] which is comprised of an outer bearing sleeve or outer housing which houses the corrugated series of bumps on a thin foil strip and over the bump foil strip a thin smooth top foil sheet is laid. These foils are welded at one end (leading edge) and are free at the other (trailing edge). The series of bumps in the strip supports the top foil sheet and acts as a spring bed which makes the bearing compliant, Fig. 2. The journal has an interference fit in the bearing with clearance being almost nil [4]. The journal and the foils will be in contact when the journal is stationary and remain in contact until a critical lift off speed is achieved, at which point the journal rides on a thin gas film developed due to the hydrodynamic pressure between the journal and the bearing. Under the action of pressure, the top foil tends to deform, forcing it away from the shaft towards the bump strip. The hydrodynamic pressure developed varies with operating speed and has a significant influence on the deformation of the foils. Hence the film thickness is function of hydrodynamic pressure and the elastic properties of the foils [5, 6].

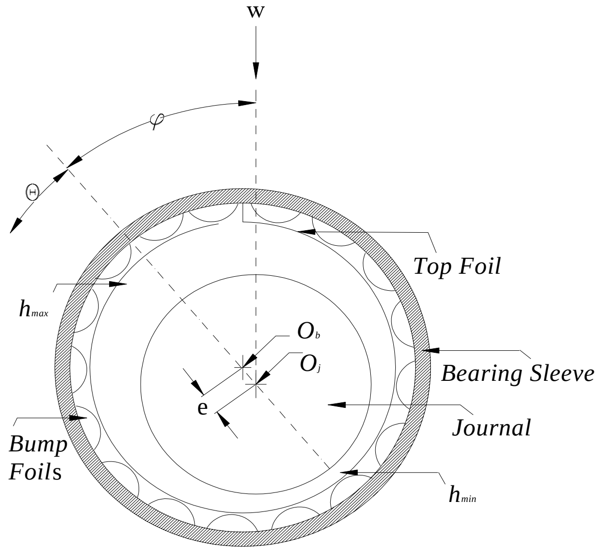

Figure 1: Compliant Foil Journal Bearing

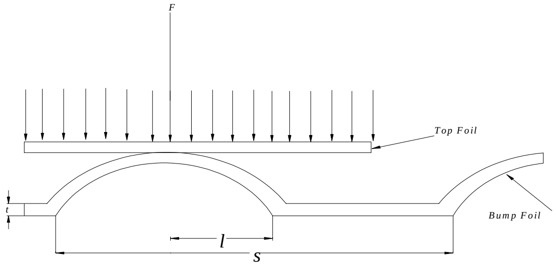

Figure 2: Configuration of top and bump foils.

A hydrodynamic analysis should account for the above parameters and also the compressibility of the lubricant. [7-10]. For this type of analysis a dimensionless Compressible Reynolds equation in polar co-ordinates is considered, different cases based on Infinitely Long Approximation - 1D,Fig's.1&2, Short bearing theory - 2D and a modified parabolic assumption which could pave way for the faster computation based on simplification of the model is currently under investigation. The objective of this analysis is to develop the necessary tool for predicting the foil bearing performance parameters such as the pressure profiles, film thickness profiles, load carrying capacity, minimum operating film thickness, and attitude. Figures 3 & 4 represent the pressure profile comparison and film thickness comparison between a rigid bearing and foil bearing running at 30,000 rpm. The pressure profile for the foil bearing is spread over a larger area compared to its rigid bearing counter part resulting in capacity for greater load carrying capacity. The film thickness profile spans over a greater area in the foil bearing due to the deformation of the foils. The program converged with a minimum film thickness equivalent to 10 µm.

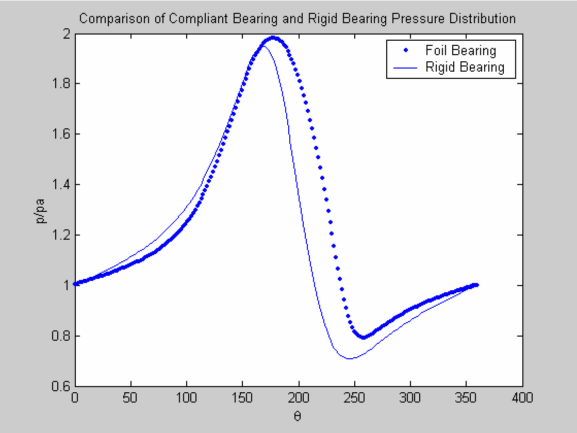

Figure 3: Pressure profiles for rigid and compliant bearing.

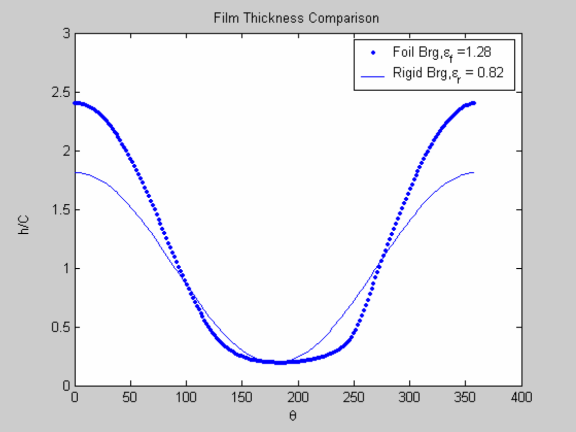

Figure 4: Film thickness profiles for rigid and compliant bearing

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