Fluid Film Bearing Code Development

The next generation of rocket engine turbopumps is being developed by industry through Government-directed contracts. These turbopumps will use fluid film bearings because they eliminate the life and shaft-speed limitations of rolling-element bearings, increase turbopump design flexibility, and reduce the need for turbopump overhauls and maintenance. The design of the fluid film bearings for these turbopumps, however, requires sophisticated analysis tools to model the complex physical behavior characteristic of fluid film bearings operating at high speeds with low viscosity fluids. State-of-the-art analysis and design tools are being developed at the Texas A&M University under a grant guided by the NASA Lewis Research Center. Originally, Texas A&M was funded by the Rocketdyne Division of Rockwell International and then by Pratt & Whitney to develop the tools; but in 1993, Lewis assumed responsibility for the effort.

The latest version of the code, HYDROFLEXT, is a thermohydrodynamic bulk flow analysis with fluid compressibility, full inertia, and fully developed turbulence models. It can predict the static and dynamic force response of rigid and flexible pad hydrodynamic bearings and of rigid and tilting pad hydrostatic bearings. The Texas A&M code is a comprehensive analysis tool, incorporating key fluid phenomenon pertinent to bearings that operate at high speeds with low-viscosity fluids typical of those used in rocket engine turbopumps. Specifically, the energy equation was implemented into the code to enable fluid properties to vary with temperature and pressure. This is particularly important for cryogenic fluids because their properties are sensitive to temperature as well as pressure. As shown in the figure, predicted bearing mass flow rates vary significantly depending on the fluid model used. In addition, the Texas A&M code accounts for inertia in the thin-film region as well as at the edge of hydrostatic bearing pockets. Because cryogens are semicompressible fluids and the bearing dynamic characteristics are highly sensitive to fluid compressibility, fluid compressibility effects are also modeled. In addition, a turbulence model must be included because of the high operating speeds and low-viscosity fluids encountered in cryogenic turbopumps. The code contains fluid properties for liquid hydrogen, liquid oxygen, and liquid nitrogen as well as for water and air. Other fluids can be handled by the code provided that the user inputs information that relates the fluid transport properties to the temperature.

The Texas A&M bearing code has become the standard analysis and design tool used by the rocket engine community. This code is well accepted for use in designing fluid film bearings because of confidence in its predictions. The code has been validated extensively by Texas A&M and Rocketdyne. In addition, Lewis has joined with the Air Force Phillips Laboratory to validate a key aspect of the analysis through a contracted effort with Texas A&M. Under the direction of the Air Force, Texas A&M is conducting bearing tests using a mixture of water and gaseous nitrogen to verify the code for fluid compressibility effects.

The Phillips Laboratory is interested in the code to support and guide their in-house hydrostatic bearing test program, which will, in turn, provide data to further refine the code. Rocketdyne is presently using a version of the code to design bearings for a low-cost liquid oxygen turbopump being developed under a NASA Marshall Space Flight

Center contract. Pratt & Whitney is also using a version of the code to support turbopump development programs including the advanced liquid hydrogen turbopump being developed for the Air Force. In addition, Marshall acquired a copy of HYDROFLEXT to incorporate it into a shaft and bearing kinematic and thermal analysis code, SHABERTH. Previously, SHABERTH was limited to rolling-element bearings.

The collaboration between NASA, the Air Force, and industry resulted in the successful development of a state-of-the-art fluid-film-bearing analysis and design tool. The effort is expected to continue to complete enhancements and validation. Analysis for an angular-injected hydrostatic bearing model and a two-phase flow model are presently being developed.
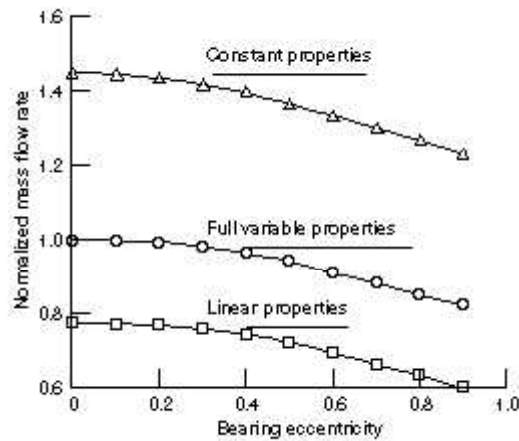
Predicted mass flow rate versus bearing eccentricity of a liquid hydrogen hydrostatic journal bearing for varying complexity fluid modes.

Bibliography

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