Fluid Mechanics, Contact Angles, Bearings

Faculty Collaborators

S. H. Davis (Engineering Sciences and Applied Mathematics, Northwestern Univ)
M. J. Braun (Mechanical Engineering, Univ of Akron)

Graduate Students – Doctoral In Progress

Joshua Johnston

Overview of Current Investigations

Bearings or seals that work at high temperatures are both a critical necessity and a bottleneck for raising the temperature of the thermodynamic cycle of internal combustion engines. The objective of this project is to evaluate the feasibility of a new tribological self-lubricating bearing system that can work at temperatures in excess of 1300 C, and at high speeds (20-100K rpm). Such bearings can be used in the hot sections of a jet engine, in power gas turbines and rocket turbopumps, or the in- and out-cylinder components of automobiles. The proposed concept is cost-effective, mitigates environmental concerns and presents extraordinary possibilities for further and rapid technology transfer to the aeronautics and automotive industries, as well as the general population of rotating machinery. Success in this endeavor will yield revolutionary, rather than evolutionary, design and product outcomes.

The proposed zero-leakage, self-lubricating, tribological system consists of a hydrodynamic porous bearing system lubricated with a liquid Gallium/Indium mixture. This fluid is stored in the porous medium of the bearing race as well as the doughnut shaped reservoir that wraps around it. As hydrodynamic pressure rises in the convergent regions of the bearing due to rotation of the shaft, the fluid tends to run out either axially, or radially through the porous medium. At the axial ends of the bearing the fluid encounters a system of inward pumping spiral groove seals and a labyrinth seal. These seals prevent axial leakage. The radially outgoing fluid leaves the bearing through the porous medium in the high-pressure region, returning to the reservoir. By continuity, momentum, natural and forced convection laws, the fluid will circulate in the reservoir and re-enter the bearing in the low-pressure region through the porous medium. The result is a potentially zero-leakage device that lacks an external, pump-driven lubricating system.

To design this self-lubricating, zero-leakage bearing we are: (i) developing mathematical models of flow in the bearing system; (ii) developing a model for the thermal management of the liquid metal lubricant, that ensures appropriate cooling in the absence of an external pump driven circulating system; (iii) developing an integrated computer code for calculations of the bearing and adjacent axial seals performance; (iv) providing a fundamental scientific framework for parametrically designing this novel bearing system; and (v) designing and constructing a bench-top prototype bearing that proves feasibility at the operational parameters of the aeronautics and automotive industries.

Publications

1. "The Flow Induced by a Plate Oscillating Across a Fluid Interface," G. W. Young and S. H. Davis, *Journal of Fluid Mechanics,* Vol. 174 (1987), pp. 327-356.

2. "Rivulet Instabilities," G. W. Young and S. H. Davis, *Journal of Fluid Mechanics*, Vol. 176 (1987) pp. 1-31.

3. "Mathematical Description of Viscous Free Surface Flows", G. W. Young, Free *Boundaries in Viscous Flows - IMA Volumes in Mathematics and its Applications* - Vol. 61, edited by Robert A. Brown and Stephen H. Davis

4. "Modeling a Porous Slider Bearing with an External Reservoir", J. Johnson, M.J. Braun and G. W. Young, *Proceedings of the STLE/ASME International Joint Tribology Conference,* San Diego, California, October (2007), pp. 1-2.

5. "An Asymptotic Expansion Approach to Modeling the Heat Transfer in a Reservoir-Extended Porous Slider Bearing", J. Johnson, M.J. Braun and G. W. Young, *Proceedings of the STLE/ASME International Joint Tribology Conference,* Miami, Florida, October (2008), pp. 1-2.

Patents

1. International Application No. PCT/US2008/003499, International Publication No. WO 2008/115473, "Self-Acting, Self-Circulating Fluid System without External Pressure Source and Use in Bearing System", M. J. Braun, A. M. Balasoiu, S. I. Moldovan, G. W. Young and J. D. Johnston, September 25, 2008.