Journal bearing performances with novel bionic surface topographies over the bore under mixed lubrication regime with cavitation and thermal effects

M. R. Pattnayak*, R. K. Pandey, J. K. Dutt

Department of Mechanical Engineering, IIT Delhi, New Delhi-110016, India
*Corresponding author: mpattnayak01@gmail.com
Co-authors: rajpandey@mech.iitd.ac.in, jkdutt@mech.iitd.ac.in

The static and dynamic performances of an oil-lubricated journal bearing have been explored in mixed lubrication regime employing novel bionic topographies over the bore surface. The novel surface topographies involve the synergistic presence of micro-depth rectangular/trapezoidal pockets and bio-inspired textures mimicked from the skin of freshwater fish. The effects of surface topographies, cavitation and thermal have been incorporated in the numerical investigations. The FVM, FBNS, and Broyden's algorithms have been employed to solve the governing equations. Significant improvements in the tribodynamic performances have been found in presence of novel bionic surface topographies over the bearing bore compared to plain bore.

Keywords: bionic surface, lubrication regimes, cavitation, thermal effects, static and dynamic performances

1. Introduction

Oil-lubricated journal bearings have widely been employed in plant machines and mechanical systems to support and guide the radially loaded rotors due to their low frictional and inherent high damping features. In pursuit of further improving the tribological and dynamical performance behaviors of journal bearings, researchers are doing explorations using the micro/macro pockets and textures over the bore surfaces [1, 2]. Taking inspiration from this, the authors thought to explore and improve the tribodynamics of an oil-lubricated journal bearing employing synergistic presence of micro-depth rectangular/trapezoidal pockets and bio-inspired textures mimicked from the skin of freshwater fish over bore surface under mixed lubrication regime.

2. Novel bionic surface topography

Figures 1(a)-1(e) provide the idea about the novel surface topographies adopted in the investigations and their effect on the pressure profiles.

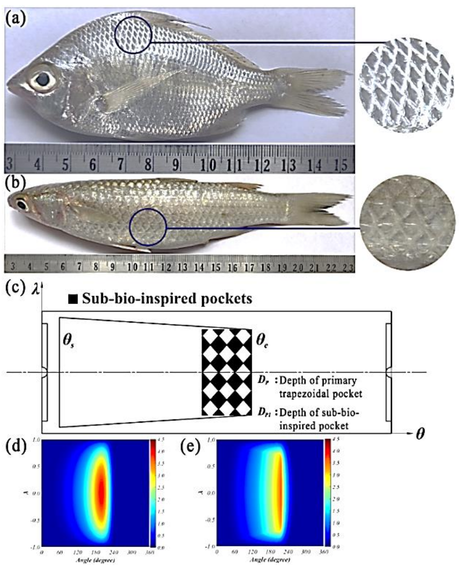

Fig.1 Novel bionic surface topography

3. Governing equations

In the numerical simulation, the following governing equations have been employed:

$$\frac{\partial}{\partial x}\left(\phi_x \frac{\rho}{\mu} h^3 \frac{\partial p}{\partial x}\right) + \frac{\partial}{\partial y}\left(\phi_y \frac{\rho}{\mu} h^3 \frac{\partial p}{\partial y}\right) = 6u\phi_c \frac{\partial\left[(1-\theta)\rho h\right]}{\partial x} + 6u\sigma \frac{\partial\left[(1-\theta)\rho \phi_s\right]}{\partial x} + 12\phi_c \frac{\partial\left[(1-\theta)\rho h\right]}{\partial t} \quad (1)$$

$$p + \theta - \sqrt{p^2 + \theta^2} = 0 \quad (2)$$

$$k_p \frac{\partial^2 T}{\partial z^2} = -\mu\left[\left(\frac{\partial u}{\partial z}\right)^2 + \left(\frac{\partial \upsilon}{\partial z}\right)^2\right] - \beta_T T\left(u\frac{\partial p}{\partial x} + \upsilon \frac{\partial p}{\partial y}\right) + \rho c_p\left(u\frac{\partial T}{\partial x} + \upsilon\frac{\partial T}{\partial y} + \frac{\partial T}{\partial t}\right) \quad (3)$$

The input data employed in the computations are: radial clearance=50 μm; bearing bore= 35.1 mm; L/D=1, applied load= 2500-4000N, speed=3000-5000 rpm; oil viscosity at 36.8^0C=0.03 Pa-s;

4. Results and discussion

Based on the numerical investigations presented herein with novel bionic surface topographies, 20 – 65% increase in minimum film thickness, 12 – 15% decrease in friction force, 13-30% reduction in temperature rise have been found in comparison to conventional bore bearing. The effective stiffness, damping and critical mass values have significantly improved with novel journal bearing bore.

5. References

[1] Bayada, G. et al., "An Average Flow Model of the Reynolds Roughness Including a Mass-Flow Preserving Cavitation Model," ASME J. Tribology, 127, 4, 2005, 793-802.

[2] Tala-Ighil, N. et al., "A numerical investigation of both thermal and texturing surface effects on the journal bearings static characteristics," Tribology International, 90, 2015, 228-239.