Steady-State Analysis of the Long Plain Journal Bearing in the Nanotechnology Environment

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ABSTRACT

Effects of gas film rarefaction with fully diffused molecular accommodation at both containing walls are treated for the analysis of the steady-state operation of a long plain self-acting gas lubricated journal bearing. These effects are important for bearings of sub-millimeter and smaller diameter.

The gas film flux law is presented in a modified Burgdorfer form with the first order term multiplied by a high rarefaction flow factor. The latter is emulated by an empirical analytical formula that is obtained by curve-fitting of recently published databases compiled from kinetic theory computations. The formula incorporates enforces the asymptotic trend for the molecular flow and thus can be extended beyond the published databases. It is smooth and continuously differentiable for the full range of rarefaction so that it can be readily adapted in Newton-Raphson iterative computation schemes.

The Mass Content Rule (MCR) is formally derived and is shown to comprise a simple algebraic function of the bearing eccentricity and the ambient Knudsen number and an additional dependence on the variation of the high rarefaction flow factor in the end-leakage region. The latter is neglected in the results presented here.

Computations were performed to examined rarefaction-compressibility interactions for a long bearing operating at $\varepsilon = 0.6$ for $0.05 \leq \Lambda \leq 1500$ with $0.1411 \leq Kn_a \leq 0.5644$, corresponding to radial bearing clearance from 125 nm to 500 nm for operation in air at 50 °C.

The influence of rarefaction is considerable. In general, rarefaction degrades he hydrodynamic wedge action and tends to suppress compressibility effect. At a small Λ, the load capacity at $Kn_a = 0.5644$ is only one-fifth of that of a continuum gas film. Potential risk of higher vulnerability to whirl instability is an additional concern.