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Texture-induced cavitation bubbles and friction reduction in the Elrod–Adams model

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Abstract

A thrust bearing consisting of an infinitely wide pad, subject to a constant load and sliding at constant speed on a runner with transverse sinusoidal textures is considered. The analysis method consists of time- and mesh-resolved simulations with a finite volume approximation of the Elrod–Adams model. Friction and clearance contours as functions of the texture depth and wavelength are built by performing more than 10,000 simulations. Conclusions are drawn for bearings of low, moderate and high conformity, unveiling basic mechanisms of friction reduction and global quantitative trends that are useful for texture selection.

Keywords

Textured bearings, Elrod–Adams model, friction reduction, cavitation, numerical simulation

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Introduction

Textured tribological surfaces have attracted much attention of the research community lately. After a significant number of experimental and theoretical studies, the possibility of reducing friction by means of microtextures has been established, together with a basic understanding of why this happens (at least in the hydrodynamic regime).[1–4]

That certain textures reduce friction in some hydrodynamic bearings is by no means an obvious phenomenon. Buscaglia et al.[5,6] performed asymptotic analyses of general smooth (i.e., untextured) surfaces by introducing short-wavelength periodic perturbations of arbitrary shape and obtained that the untextured shape *always* (in the hydrodynamic regime) maximizes the load carrying capacity and minimizes the friction coefficient. This implies that, for friction reduction to take place, there exist two possibilities: It can be a consequence of a *finite* perturbation (outside the validity of asymptotic theory), *or* involve physical mechanisms which were not considered in the aforementioned mathematical studies, such as *cavitation*.

In a recent study, Checo et al.[4] discussed several hundred numerical simulations and concluded that in fact *both* of the previous possibilities hold true in textured bearings that exhibit less friction than their untextured counterparts. As had already been advanced by Etsion,[3] friction reduction only occurs in high-conformity bearings, in which the surfaces are so parallel that a texture of some suitable size and depth manages to produce local cavitation.

High-conformity bearings are not infrequent in technology. Assuming a bearing of length L with a nominally planar surface opposing a surface with curvature radius R, the degree of conformity can be measured by the quotient R/L. For the compression ring of an internal combustion engine R/L is already quite high (up to 52 in diesel engines, as discussed by Gadeschi et al.[2]), and it is much higher for other piston rings (oil rings in particular) and for other contacts such as seals.

It was numerically shown by Gadeschi et al.[2] with a non-mass-conserving model, and later by Checo et al.[4] with a mass-conserving model, that for a

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