2019 Tribology Frontiers Conference, Chicago Illinois

A Computational Fluid Dynamics (CFD) Investigation of Inertia Effects in the Hydrodynamic Lubrication of Journal Bearings; Static and Dynamic Performance

Troy A. Snyder and Minel J. Braun
Department of Mechanical Engineering, University of Akron, Akron, OH, USA

INTRODUCTION: The classical Reynolds equation in hydrodynamic lubrication assumes both laminar and inertialess flow. However, in high Reynolds number applications, inertia and turbulence can significantly alter the development of static and dynamic bearing pressures and forces. In marine bearings lubricated with water, the lubricant viscosity is two orders of magnitude lower than within oil-lubricated journal bearings, thus driving the higher Reynolds numbers. In the present work, the CFD software OpenFOAM [1] is used to predict the static and dynamic performance of journal bearings. The CFD-predicted results are compared directly with those obtained through the Reynolds equation inclusive of ad-hoc averaged-inertia [2] and if necessary, turbulence, modifications. Threshold values for sliding and squeeze Reynolds numbers for which advective and temporal inertia effects can respectively be neglected, are elucidated and compared with previous investigations.

RESULTS: Figure 1 shows the dependency of the Sommerfeld number $S = \frac{\mu N}{P}\left(\frac{R}{C}\right)^2$ on the eccentricity ratio $\epsilon = \frac{e}{C}$ given the presence of advective inertia (CFD), where P is the projected bearing pressure, μ is the dynamic viscosity of the lubricant, N is the rotational speed in rot/s, R is the rotor radius, C is the radial clearance, and e is the displacement of the rotor center from the journal center. CFD results are plotted at different reduced Reynolds numbers where $Re^* = \frac{\omega RC}{\nu}(\frac{C}{R})$ where ν is the kinematic viscosity and ω is the angular velocity in rad/s.

Figure 1 shows that the presence and effect of advective inertia as the Sommerfeld number (S) decreases with the increase of the reduced Re, causes an increase in the static load carrying capacity, for a fixed static eccentricity ratio. This result is at-odds with Armentrout et al. [3] who found that advective inertia had a slightly parasitic effect (6% reduction) in the static load carrying capacity of a water-lubricated tilting pad journal bearing. The results in Figure 1 indicate that presence of advective inertia enhances load-carrying capacity [2,4]. Neglecting advective inertia results in less than 10% error in S for Re* up to 10.47 when $0.1 < \epsilon < 0.9$, a conclusion consistent with the findings of [2] that advective inertia in journal bearings may be neglected for Re*<10.

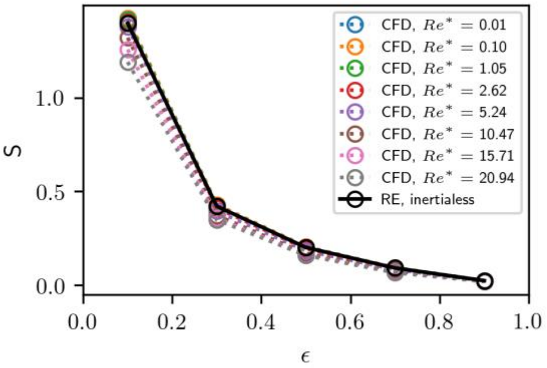

***Figure 1**: Effect of **advective inertia** (CFD) on Sommerfeld number. Inertialess Reynolds equation (RE) results for different Re* collapse onto a single line. Laminar flow. L/D = 1.0*

Figure 2 shows the dependency of the friction torque on the eccentricity ratio. At low Re*, CFD, Reynolds equation, and Petroff's Law compare well for $\epsilon \leq 0.5$. At higher eccentricities and low Re*, pressure shear effects become significant and Petroff's Law, which assumes pure sliding (Couette) shear, begins to provide inaccurate estimates of bearing torque. At higher Re*, CFD, Reynolds equation, and Petroff's Law estimates for bearing torque coincide only for very light loading. For $0.1 < \epsilon < 0.8$, CFD and Reynolds equation deviate from each other due to the presence of advective inertia. For $\epsilon > 0.8$, advective inertia effects are dominated by viscous effects, resulting in close agreement of the CFD- and Reynolds equation-predicted torques.

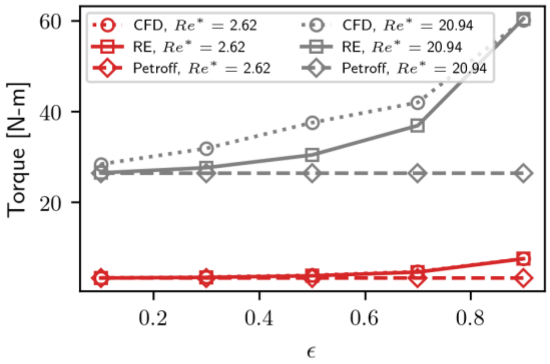

***Figure 2**: Effect of **advective inertia** on friction torque. Laminar flow. L/D = 1.0*

At high Re*, turbulence effects must be considered in concert with advective inertia. Comparison of Figure 3 with Figure 1 shows that turbulence has a more significant impact on the Sommerfeld number than advective inertia alone. At Re*=1.05, S predicted with laminar Reynolds equation is 14% or 58% in error (maximum over all ϵ) compared with results obtained with CFD (inertia + $k-\omega$ turbulence) or Reynolds equation (Constantinescu's turbulence model), respectively.

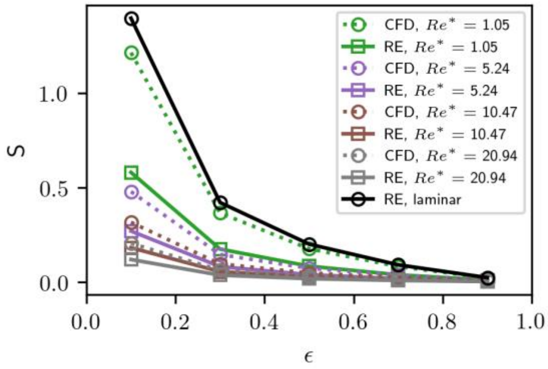

***Figure 3**: Combined effects of **advective inertia** and **turbulence** on Sommerfeld number. CFD and Reynolds equation (RE) results obtained with $k-\omega$ and Constantinescu turbulence models, respectively. L/D = 1.0*

REFERENCES: [1] Weller, H.G. et al., Computers in Physics, 12(6), p.620-631, 1998. [2] Constantinescu, V. et al., J. Lubr. Tech., ASME, 104, p.173-179, 1982. [3] Armentrout, R.W. et al., Trib. Trans., 60, p. 1129-1147, 2017. [4] Dousti, S. et al., Trib. Int., 102, p. 182-197, 2016.