

MULTISCALE ANALYSIS OF HYDRODYNAMIC JOURNAL BEARING CONSIDERING THE EFFECT OF THE PHYSICALLY ADSORBED BOUNDARY LAYER

Kaicheng Gu, Shaojin Shao and Yongbin Zhang*

College of Mechanical Engineering, Changzhou University, Changzhou 213164, China

(Received 16 June 2022; Revised 5 September 2022; Accepted 6 September 2022)

ABSTRACT—In itself, there is a very thin boundary layer physically adsorbed to the bearing surface. When the bearing clearance is far larger than the thickness of this layer, the boundary layer effect in the bearing is negligible, and conventional hydrodynamic lubrication theory just addresses on this topic. However, with the worsening of the operating condition, the bearing clearance can be largely reduced and comparable to the thickness of the adsorbed boundary layer. For this case, the effect of the adsorbed boundary layer must be considered. The present paper presents the multiscale analysis for the performance of the hydrodynamic journal bearing in a wide range of bearing clearance considering the effect of the physically adsorbed boundary layer. The calculation results indicate for how low bearing clearances the adsorbed boundary layer effect should be incorporated. When the minimum bearing clearance is on the same scale with the thickness of the adsorbed boundary layer, the hydrodynamic pressure in the bearing is locally largely increased by the effect of the adsorbed boundary layer, and the load-carrying capacity of the bearing is correspondingly largely increased. This is particularly significant for a strong fluid-bearing surface interaction. The study shows the great contribution of the physically adsorbed boundary layer to the performance of the hydrodynamic journal bearing in the condition of low surface clearances, and indicates the necessity of the multiscale analysis for this bearing.

KEY WORDS : Adsorbed layer, Hydrodynamics, Journal bearing, Load, Multiscale, Pressure

NOMENCLATURE

a_0, a_1, a_2 : constants
 c : bearing clearance, $R-r$
 C_q : ρ_{bf}^{eff} / ρ
 C_v : η_{bf}^{eff} / η
 D : fluid molecule diameter
 e : eccentricity of the bearing
 h : continuum fluid film thickness
 h_{bf} : thicknesses of the adsorbed boundary layer
 $h_{cr,bf}$: critical thickness
 H_{bf} : $h_{bf}/h_{cr,bf}$
 K : h_{bf}/c
 m_0, m_1, m_2, m_3 : constants
 N : numbers of the discretized points
 p : hydrodynamic pressure
 P : dimensionless hydrodynamic pressure
 P_{conv} : hydrodynamic pressure calculated from the conventional hydrodynamic theory
 q_0 : Δ_{j+1}/Δ_j
 q_m : mass flow rate per unit contact length through

the bearing
 Q_m : dimensionless mass flow rate per unit contact length through the bearing
 r : radius of the shaft
 R : radius of the sleeve
 u : shaft circumferential speed
 w : load per unit contact length carried by the bearing
 W : dimensionless load per unit contact length carried by the bearing
 x, y : coordinates
 β : angel, Equation (20)
 γ : exponent
 ε : eccentricity ratio, e/c
 ε_0 : parameter, Equation (28)
 λ_{bf} : h_{bf}/h
 ϕ : angular coordinate
 ϕ_0 : angular coordinate of the location where the maximum pressure occurs in the bearing
 ϕ_e : angular coordinate of the exit of the bearing
 $\Delta\phi$: envelope angles of the two neighboring discretized points
 Δ_x : separation between the neighboring fluid molecules in the circumferential direction in the adsorbed layer
 Δ_j : separation between the $(j+1)^{th}$ and j^{th} fluid molecules across the layer thickness

*Corresponding author. e-mail: engmech1@sina.com