Tribology International 69 (2014) 1–9

Contents lists available at ScienceDirect

Tribology International

journal homepage: www.elsevier.com/locate/triboint

Analysis of couple stress fluid lubricated partially textured slip slider and journal bearing using narrow groove theory

T.V.V.L.N. Rao*, A.M.A. Rani, T. Nagarajan, F.M. Hashim

Department of Mechanical Engineering, Universiti Teknologi PETRONAS, 31750 Tronoh, Perak Darul Ridzuan, Malaysia

ARTICLE INFO

Article history:
Received 18 March 2013
Received in revised form
28 July 2013
Accepted 12 August 2013
Available online 22 August 2013

Keywords:
Partially textured slip
Couple stress
Load capacity
Coefficient of friction

ABSTRACT

A theoretical model of partially textured slip slider and journal bearing lubricated with couple stress fluids is developed using narrow groove theory (NGT). The partially textured slip bearing configuration is analyzed using couple stress effects. The nondimensional pressure and shear stress expressions are derived based on one-dimensional analysis using modified Reynolds equation. The partially textured slip parameters used in the analysis are: nondimensional texture length; nondimensional depth of recess; land with slip to recess region ratio; and nondimensional slip coefficient. Partially textured slip is effective in the case of parallel slider and concentric journal bearing lubricated with couple stress fluids to yield an improvement in load capacity and reduction in coefficient of friction.
© 2013 Elsevier Ltd. All rights reserved.

1. Introduction

There has been widespread interest in surface texturing and surface slip patterning to improve the performance of hydrodynamic bearings. The theoretical studies by Tønder [1] were focused on introducing series of dimples or roughness at the inlet of sliding surface. The beneficial effects of partial texturing on the enhancement of load capacity in parallel thrust bearings (Brizmer et al. [2]) and hydrodynamic journal bearings (Brizmer and Kligerman [3]) were examined by numerical studies. Fowell et al. [4,5] developed analytical and numerical models using comprehensive parametric studies of textured surfaces in one dimensional hydrodynamic bearing. Cupillard et al. [6] investigated the mechanism of pressure buildup in a textured slider bearing. Pascovici et al. [7] and Rahmani et al. [8] presented analysis of the textured slider bearings and derived analytical relations. Tala-Ighil et al. [9] studied the influence of texture location on the performance of hydrodynamic journal bearing. Using numerical simulations, Aurelian et al. [10] presented the comparison of surface texturing and wall slip conditions in hydrodynamic bearings.

However, investigation of the texture parameters have revealed that number of cells in the texture region has little impact on the bearing performance characteristics. Vohr and Chow [11] analyzed herringbone grooved gas-lubricated journal bearing based on narrow groove theory (NGT). The overall pressure distribution in an idealized bearing with an infinite number of grooves provides a good approximation to the actual pressure distribution around bearing with a large but finite number of grooves [11].

The partial texturing as well as partial slip pattern on bearing surfaces at inlet is an effective approach to reduce friction and increase load support. Experimental studies using smooth surfaces reported in Refs. [12–14] have revealed the occurrence of slip. Spikes [15,16] and Wu et al. [17] analyzed the potential application of slip phenomenon to improve the performance of slider bearing. The effect of heterogeneous slip/no-slip surface in slider bearings (Salant and Fortier [18]) and journal bearings (Fortier and Salant [19]) were examined by numerical studies using modified slip length model. Wang et al. [20] derived an extended Reynolds equation based on modified slip length model considering limiting shear stress for a journal bearing. Huang et al. [21] derived the lubrication governing equations of the second-order fluid for a plane inclined slider and journal bearing. Rao et al. [22] analyzed the improvement in load capacity and reduction in friction coefficient for partially textured slip slider and journal bearing. Rao [23] presented stability characteristics of partial slip journal bearing. Tauviqirrahman et al. [24] explored the possibility of slip and texture in order to improve the performance characteristics. Results indicate that the combined texture/slip pattern increase load capacity and decrease friction.

The couple stress theory of fluids derived by Stokes [25] based on microcontinuum theory is applied to consider the effect of additives in lubricants. Stokes couple stress theory has been widely used to study effect of lubricant additives on the performance of journal bearings. Based on couple stress theory of fluids, Lin [26] investigated the lubrication performance of finite journal bearing. Lin et al. [27] presented steady-state and dynamic

* Corresponding author. Tel.: +605 368 7005; fax: +605 365 6461.
E-mail address: tvvlnrao@gmail.com (T.V.V.L.N. Rao).

0301-679X/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.triboint.2013.08.006

Nomenclature

a_h slope parameter for slider bearing
A non-dimensional slip coefficient
B width of slider bearing, m
C radial clearance, m
C_f nondimensional friction coefficient; $C_f = F/W$
f friction force, N; $F = fh_1/\mu ULB$ for slider bearing; $F = fC/\mu URL$ for journal bearing
h, H film thickness, m; $h = h_1 - (h_1 - h_2)x/L, H = h/h_1$ for slider bearing; $h = C(1+\varepsilon \cos \theta), H = h/C$ for journal bearing
h_1, h_2, H_2 inlet and outlet film thickness of slider bearing, respectively, m; $H_2 = h_2/h_1$
H_{pr} nondimensional film thickness at recess for parallel slider bearing and concentric journal bearing
h_r, H_r depth of recess, m; $H_r = h_r/h_1$ for slider bearing; $H_r = h_r/C$ for journal bearing
l characteristic length of additives; $l = \sqrt{\eta/\mu}$
L length of the slider bearing; length of the journal bearing, m
n number of cells (lands with slip and recesses with no slip surface)
p, P pressure distribution, N/m^2; $P = ph_1^2/\mu UL$ for slider bearing; $P = pC^2/\mu UR$ for journal bearing
p_r, p_d pressure distribution over the recess and land regions, respectively, N/m^2
q, Q volume flow rate per unit length along film thickness, m^2/s; $Q = q/Uh_1$ for slider bearing; $Q = q/UC$ for journal bearing
R journal radius, m
S, S_s Sommerfeld number; $S = \mu UR^2L/\pi wC^2, S_s = \mu UR^2L/wC^2$ for journal bearing
u velocity component along x or θ direction for slider or journal bearing, respectively, m/s
U slider velocity along x direction; Journal velocity along θ direction, m/s
w, W static load, N; $W = wh_1^2/\mu UL^2B$ for slider bearing; $W = wC^2/\mu UR^2L$ for journal bearing
W_ε, W_ϕ nondimensional radial and tangential static load for journal bearing
x, X coordinate along x direction, m; $X = x/L$ for slider bearing; $\theta = x/R$ for journal bearing
X_t nondimensional texture length for slider bearing
X_{ts}, X_{tn} nondimensional length of land and recess region for textured slider bearing
y, Y coordinate along y direction, m; $Y = y/h_1$ for slider bearing; $Y = y/C$ for journal bearing
α, A slip coefficient; $A = \alpha\mu/h_1$ for slider bearing; $A = \alpha\mu/C$ for journal bearing
γ land to recess region ratio; $\gamma = X_{ts}/(X_{ts}+X_{tn})$ for slider bearing; $\gamma = \theta_{ts}/(\theta_{ts}+\theta_{tn})$ for journal bearing
ε journal bearing eccentricity ratio
η material constant for couple stress property, kg m/s
λ, l couple stress parameter; $\lambda = l/h_1$ for slider bearing; $\lambda = l/C$ for journal bearing
μ fluid viscosity, Ns/m^2
θ angular coordinate measured from the position of maximum film thickness in journal bearing
θ_r angular extent of film rupture for journal bearing
θ_t angular coordinate measured from the position of maximum film thickness for journal bearing for textured bearing surface with slip on land region
θ_{tn} angular extent of successive regions of recess for journal bearing
θ_{ts} angular extent of successive regions of slip on land for journal bearing
τ_{xy}, Π shear stress component, N/m^2; $\Pi = \tau_{xy}h_1/\mu U$ for slider bearing; $\Pi = \tau_{xy}C/\mu U$ for journal bearing
ω angular velocity of journal bearing, rad/s

stiffness and damping characteristics of plane inclined slider bearing using couple stress fluids. Liao et al. [28] analyzed stability threshold for long journal bearings lubricated with couple stress fluids. Mokhiamer et al. [29] presented couple stress fluid lubricated journal bearing performance characteristics considering elastic deformation of liner. Wang et al. [30] investigated thermal and cavitation effects on the performance of journal bearing lubricated with couple stress fluids. Li and Chu [31] developed thin film lubrication model using couple stress fluid effects. Elsharkawy [32] investigated the effects of lubricant additives on the hydrodynamic lubrication of journal bearing using couple stress fluids.

The boundary slip configuration in journal bearing using couple stress fluids improves load capacity and reduces coefficient of friction. In the present work, the nondimensional pressure and shear stress expressions are derived using NGT. The partially textured slip configuration is assessed for load generation and coefficient of friction reduction considering couple stress fluids.

2. Partially textured slip couple stress fluid lubricated slider bearing analysis using NGT

The schematic of partially textured slip slider bearing is shown in Fig. 1. The partially textured slip surface (X_t) is composed of a number of successive regions of land with slip (X_{ts}) and recess (X_{tn}), respectively. γ is expressed as the ratio of land with slip to recess region. Reynolds boundary conditions are incorporated in the analysis based on NGT. The derivation of overall pressure gradient and shear stress for the partially textured slip couple stress fluid lubricated bearing using NGT are provided in Appendix.

2.1. Convergent slider bearing

The nondimensional film thickness for plain slider bearing is expressed in Eq. (1) and the nondimensional film thickness in the recess region of slider bearing is expressed as $H + H_r$.

$$H = 1 - a_h X \text{ where } a_h = 1 - H_2 \tag{1}$$

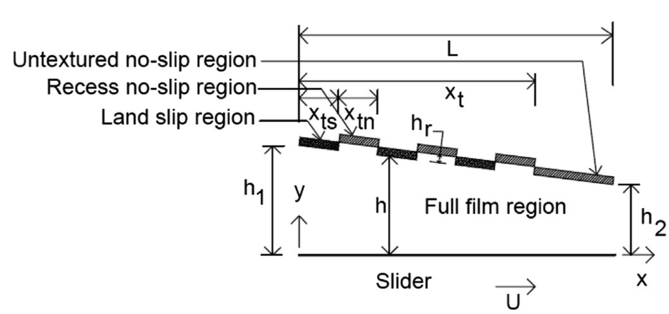

Fig. 1. Geometry of partially textured slip slider bearing.

Download English Version:

https://daneshyari.com/en/article/614860

Download Persian Version:

https://daneshyari.com/article/614860

Daneshyari.com