ARTICLE IN PRESS

Alexandria Engineering Journal (2016) xxx, xxx–xxx

HOSTED BY

ELSEVIER

Alexandria University

Alexandria Engineering Journal

www.elsevier.com/locate/aej
www.sciencedirect.com

REVIEW

Thermohydrodynamic analysis of airfoil bearing based on bump foil structure

S.Y. Maraiy *, W.A. Crosby, H.A. EL-Gamal

Department of Mechanical Engineering, Faculty of Engineering, Alexandria University, Alexandria, Egypt

Received 27 April 2016; revised 23 May 2016; accepted 4 June 2016

KEYWORDS

Foil bearings;
Thermohydrodynamic analysis;
Bump foil structure

Abstract The load carrying capacity of the gas foil bearing depends on the material properties and the configuration of the underlying bump strip's structure. This paper presents three different cases for selecting the dimensions of the foil bearing to guarantee the highest possible load carrying capacity. It focuses on three main parameters that affect the compliance number; these parameters are the length of bump in θ direction, the pitch of bump foil, and the thickness of bump foil. It also studies the effect of changing these parameters on load carrying capacity according to both isothermal and thermohydrodynamic approaches.

Contents

* Corresponding author.
E-mail address: sabrien_maraiy@yahoo.com (S.Y. Maraiy).

Peer review under responsibility of Faculty of Engineering, Alexandria University.

http://dx.doi.org/10.1016/j.aej.2016.06.015
1110-0168

Nomenclature

a	viscosity constant of air, Pa s/°C
b	bearing width, m
C	radial clearance, m
C_p	specific heat at constant pressure, J/kg K
d	distance between bumps, m
D	bearing diameter, m
D_h	housing diameter, m
e	eccentricity, m
E	modulus of elasticity, Pa
h	fluid film thickness, m
$\bar{h}$	dimensionless air film thickness, $\frac{h}{C}$
h_b	bump height, m
$h_{\min}$	minimum film thickness, m
$\bar{h}_{cr}$	dimensionless film thickness at $\theta = \theta_{cr}$
J	number of iterations of the matlab program
K	constant reflecting the structure rigidity of the bumps, m^3/N
K_a	conductivity of air, W/K m
l	half length of bump in θ direction, m
L	bearing length, m
n	number of bumps
p	fluid film pressure, Pa
$\bar{P}$	dimensionless hydrodynamic pressure, $\bar{P} = \frac{p}{p_a}$
p_a	ambient pressure, Pa
Q_{rec}	recirculating flow rate, kg/s
Q_{suc}	suction flow rate, kg/s
r	radius of bump, m
r_o	radius of spindle, m
R	radius of shaft, m
S	pitch of bump foil, m
t_b	thickness of bump foil, m
T	temperature of gas, °C
T_a	ambient temperature of the air, °C
T_{in}	inlet temperature of the gas film, °C
T_{ref}	reference temperature, °C
u	linear velocity of shaft speed, m/s
v	linear velocity of gas flow in axial, y, direction, m/s
w	linear velocity of gas flow in z direction, m/s
W	bearing load carrying capacity, W_x, W_z, components, N
W_t	radial deformation of the bump foil due to the steady-state aerodynamic pressure, m
$\bar{W}_x$	non dimensionless load component in the direction of foil movement, $\bar{W}_x = \frac{W_x}{P_a RL}$
$\bar{W}_z$	non dimensionless load component in axial length direction, $\bar{W}_z = \frac{W_z}{P_a RL}$
x	Cartesian coordinate in the direction of motion
y	Cartesian coordinate across the film thickness
z	coordinate in axial length direction, m
$\bar{z}$	dimensionless coordinate in axial length direction, $\bar{Z} = \frac{Z}{L/2}$

Greek symbols

α	bump foil compliance number
α_v	coefficient of cubic expansion
β	wrap angle, °
δ	bearing liner deformation, m
ε	eccentricity ratio, $\varepsilon = \frac{e}{C}$
θ	angular coordinate in the direction of motion
θ_{cr}	critical value of θ at subambient hydrodynamic pressure
Λ	bearing number, $\Lambda = \frac{6\mu_a\omega}{P_a}\left(\frac{R}{C}\right)^2$
μ	absolute viscosity of the fluid, N s/m^2
μ_a	viscosity of air, N s/m^2
υ	Poisson ratio
ρ	density, kg/m^3
φ	attitude angle, °
ψ	bump arc angle, °
ω	angular velocity of the shaft, rad/s

Subscripts

a	ambient, bearing entrance conditions
x, y, z	quantities in the x, y, or z directions
r, θ	quantities in the r or θ directions
v	volume
t	time

Overbar

$\overline{(\text{symbol})}$ non-dimensionalized parameters

1. Introduction

In recent years, foil bearings have gained more attention than any other types of bearings because of their unique mode of operation and diversity of applications. They also have various advantages compared to the conventional rigid journal bearings in terms of higher load carrying capacity, lower power loss, better stability, and greater endurance. These bearings are self-acting, and can operate with ambient air or any processing gas as the lubricating fluid.

Their assembly includes a first thin smooth compliant sheet facing the shaft, one or more corrugated foil, a second sheet between the foils and a compliant sheet for preventing sagging of the first sheet between ridges of foil. Under the action of the hydrodynamic pressure, the foil structure deforms. Therefore, the fluid film pressure must be coupled to the deformation of the foil structure in order to know the characteristics of the foil bearing performance. From this point of view, many analytical studies have been conducted based on a range of structural models.

The concept of a foil bearing was first described in a report over 50 years ago by Blok and Van Rossum [1]. In 1957, Patel and Cameron [2] followed this work with another experimental investigation using steel tape and oil by introducing a more elaborate differential equation for finite width and derived a less restrictive differential equation for the gap thickness than Blok and Van Rossum [1].

Please cite this article in press as: S.Y. Maraiy et al., Thermohydrodynamic analysis of airfoil bearing based on bump foil structure, Alexandria Eng. J. (2016), http://dx.doi.org/10.1016/j.aej.2016.06.015