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Identification of clearances and stability analysis for a rotor-journal bearing system

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Abstract

Significant wear occurs on the surface of bearings, which support rotating shafts for long periods of time. Therefore, the need for a new clearance identification method is required. Furthermore, having identified these new clearances, the investigation of gauging reliable future operation with regards to stability is also an important task.

The rotor is modeled here using the finite element method with 4DOF's per node, including the gyroscopic effect. The dynamic coefficients of the bearing are calculated by solving the Reynolds equation, thus obtaining the pressure distribution of the oil film, and by finding the equilibrium position. The 4×4 stiffness and damping matrices, including the force-moment and displacement-rotation relations with all non-diagonal coupling terms, are taken into account for the analysis.

Here, an identification method for the bearing radial clearances is presented theoretically, using response measurements of the rotor at a particular point (usually the midpoint of the rotor). These "measurements" should be taken at two different speeds and from different wear effects. The present theoretical work on this particular problem needs to be verified experimentally as well.

The sum of the squares of the differences between the measured and the computed responses at the abovementioned particular point and for two different speeds is used as an objective function to be minimized.

The stability of the system as a function of the rotational speed and the wear is also examined.

Keywords: Rotordynamics; Lubrication; Journal bearings; Identification; Stability

1. Introduction

The long term operation of a rotating shaft in the bearing housing is the cause of wear. So, it is of high interest to have knowledge of the bearing condition, which affects the dynamic behaviour as well as the stability of such rotor-bearing systems.

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Nomenclature

A	area
a, b, c	interpolation coefficients
$C_{R_i\dot{X}_j^k} = C_{R_i\underbrace{\dot{X}_j\dot{X}_j\ldots\dot{X}_{j^k}}}$	damping coefficients
$\overline{C}_{R_i\dot{X}_j^k} = \overline{C}_{R_i\underbrace{\dot{X}_j\dot{X}_j\ldots\dot{X}_{j^k}}}$	dimensionless damping coefficients
c	radial clearance
D or d	journal diameter
e_0	eccentricity
$\varepsilon = e/c$	eccentricity ratio
$K_{R_iX_j^k} = K_{R_i\underbrace{X_jX_j\ldots X_{j^k}}}$	stiffness coefficients
$\overline{K}_{R_iX_j^k} = \overline{K}_{R_i\underbrace{X_jX_j\ldots X_{j^k}}}$	dimensionless stiffness coefficients
$\overline{K}_{F_iX_j} = K_{F_iX_j}\frac{c}{W}$	dimensionless stiffness coefficients due to force–displacement
$\overline{K}_{F_i\psi_j} = K_{F_i\psi_j}\frac{c}{WL}$	dimensionless stiffness coefficients due to force rotations
$\overline{K}_{M_iX_j} = K_{M_iX_j}\frac{c}{WL}$	dimensionless stiffness coefficients due to moment displacement
$\overline{K}_{M_i\psi_j} = K_{M_i\psi_j}\frac{c}{WL^2}$	dimensionless stiffness coefficients due to moment rotation
$\overline{C}_{F_i\dot{X}_j} = C_{F_i\dot{X}_j}\frac{c\omega}{W}$	dimensionless damping coefficients due to force–displacement
$\overline{C}_{F_i\psi_j} = C_{F_i\psi_j}\frac{c\omega}{WL}$	dimensionless damping coefficients due to force rotation
$\overline{C}_{M_i\dot{X}_j} = C_{M_i\dot{X}_j}\frac{c\omega}{WL}$	dimensionless damping coefficients due to moment displacement
$[K_p]$, $[K_V]$, $[K_U]$	fluidity matrices
N_i, N_j	shape functions
N	revolutions
F_x, F_y	hydrodynamic forces
F_{hydr}	hydrodynamic forces
F_{ext}	external loads
h	film thickness
l	bearing length
M_x, M_y	hydrodynamic moments
μ	lubricant viscosity
P	fluid film pressure
r	journal diameter
R_{b}	bearing diameter
ω	angular velocity
S	Sommerfeld number
U	velocity of journal surface parallel to the film
L_{rot}	rotor length
V	squeeze film velocity
ψ_x, ψ_y	misalignment angles
ϕ_{a}	attitude angle
I	power functional
x, y	spatial coordinates
$\cdot = \frac{\partial}{\partial t}$	time derivative
q_i	generalized coordinate
δ_0	dimensionless wear depth
λ	the system eigenvalues
$\overline{\psi_i} = \psi_i\frac{l}{c}$	dimensionless misalignment angle