Dynamic Behaviour Analysis of a Dual-Rotor System Using the Transfer Matrix Method

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This paper presents a general formulation for the problem of the steady-state unbalance response of a dual rotor system with a flexible intershaft bearing using an 'extended' transfer matrix method, where the transfer matrix assumes a dimension of (33×33). The validity of the formulation is established by comparing the results obtained through a computer program with closed form solutions available for some simple cases. Some interesting phenomena of steady-state whirl orbits of the dual rotor system are described.

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Nomenclature

$\left.\begin{array}{l}[A],[B]\\ [C],[D]\end{array}\right\}$ – Represent transfer matrices, each of dimension (33×33)
$[\bar{B}]$ – Bearing matrix
C_{yy}, C_{zz} – Direct damping coefficients
C_{yz}, C_{zy} – Cross coupled damping coefficients
C_H, C_L – High and low rotor damping, respectively
E – Modulus of elasticity
e – Eccentricity
$[F]$ – Field matrix
$[\bar{F}]$ – Overall field matrix
h – Thickness of the disk
$[I]$ – Unit matrix
I_T – Transverse mass moment of inertia of the disk
I_P – Polar mass moment of inertia of the disk
K_{yy}, K_{zz} – Direct stiffnesses
K_{yz}, K_{zy} – Cross coupled stiffnesses
K_H, K_L – High and low rotor stiffness, respectively
l – Sectional length
M_y, M_z – Moments about y- and z-axes, respectively
M_H, M_L – High and low rotor mass, respectively
m – Mass of the element per unit length
m_b – Mass of the shaft at bearing station
m_e – Unbalance mass
$[P]$ – Point matrix
$[\bar{P}]$ – Overall point matrix
U_y, U_z – Unbalance components
V_y, V_z – Shear force in y- and z-directions, respectively
v, w – Deflection along y- and z-axes, respectively
X, Y, Z – Fixed co-ordinate system
$\bar{X}, \bar{Y}, \bar{Z}$ – Rotating co-ordinate system
$\{\bar{S}\}$ – Modified State vector at any station
$\left.\begin{array}{l}\{S\}_{OA},\{S\}_{OB}\\ \{S\}_{OC},\{Z\}_{OD}\end{array}\right\}$ – Represent end conditions of the dual rotor system
ω_m, ω_n – Inner and outer rotor speeds, respectively
θ, ϕ – Slope in x-z and y-z planes, respectively
β – Angular position of unbalance
λ – Eigenvalue

Subscripts

m, n – Pertaining to the effect of inner and outer rotor speeds, respectively
c – Cosine component
cm, cn – Cosine components of inner and outer rotor, respectively
s – Sine component
sm, sn – Sine components of inner and outer rotor, respectively
y – Along y-axis
z – Along z-axis
j – Pertaining to a junction

Superscripts

R – Right to a section
L – Left to a section
t – Transpose of a matrix

1. INTRODUCTION

With the ever increasing demand of large power and smaller gas turbine engines for aircraft propulsion, a two spool system with intershaft bearings is becoming a standard layout to accommodate the compressor and turbine rotors.