Vibration Characteristics of a Ball Bearing Considering Point Lubrication and Nonuniform Surface Waviness

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Surface waviness is one of the main geometrical errors in ball bearings. Time-varying contact stiffness excitations (TCSEs) produced by the uniform and nonuniform waviness on races of a lubricated ball bearing cannot be accurately described by the previous uniform waviness models considering the time-varying displacement excitation (TDE) in the literature. To overcome this problem, a new dynamic modelling method coupling both the TDE and TCSE produced by the uniform and nonuniform waviness on the races of a lubricated ball bearing is proposed. Effects of the amplitude and nonuniform distribution of waviness on the contact stiffness between one ball and races of the lubricated and unlubricated bearings are investigated, as well as vibrations of the bearings produced by the uniform and nonuniform waviness. Numerical results show that the proposed model can describe the TDE and TCSE produced by the uniform and nonuniform waviness on the races of the lubricated bearing, which cannot be described by the previous uniform waviness models. The results also show that the peak frequencies of spectra of accelerations of the bearing with the waviness will be changed by the lubricating film oil. It seems that the proposed model can provide a new dynamic modelling method for formulating the vibrations of a lubricated bearing with the uniform and nonuniform waviness on its races.

NOMENCLATURE

- $c$: Damping coefficient, N m/s
- $D_i$: Diameter of the normal inner race, mm
- $D_o$: Diameter of the normal outer race, mm
- $d$: Diameter of the ball, mm
- $E_1$ and $E_2$: Elastic modulus of the two contact components, Pa
- $E^*$: Equivalent elastic modulus of the contact components, Pa
- $F_x$ and $F_y$: Components of the external force applying on the shaft, N
- $G$: Dimensionless material parameter
- $H_{cc}$: Dimensionless central film thickness
- $h_{ij}$: Central film thickness between the ball and inner race, mm
- $h_{oj}$: Central film thickness between the ball and outer race, mm
- $j$: $j$th ball
- $K_d$: Total contact stiffness between one ball and two races, N/mm
- $K_{id}$: Contact stiffness between the ball and normal unlubricated inner race, N/mm
- $K_{od}$: Contact stiffness between the ball and normal unlubricated outer race, N/mm
- $K_{w1}$: Contact stiffness between the ball and abnormal unlubricated inner race, N/mm
- $K_{w2}$: Contact stiffness between the ball and abnormal unlubricated outer race, N/mm
- $K_{w1}$: Contact stiffness between the ball and abnormal unlubricated inner race, N/mm
- $K_{w2}$: Contact stiffness between the ball and abnormal unlubricated outer race, N/mm
- $K_{d1}$: Contact stiffness between the ball and lubricated inner race, N/mm
- $K_{d2}$: Contact stiffness between the ball and lubricated outer race, N/mm
- $K_{do}$: Total contact stiffness between the ball and the race, N/mm
- $K_e$: Total contact stiffness between the ball and lubricated race, N/mm
- $k$: Elliptical eccentricity parameter
- $L_{us}$: Arbitrary position of $s$th wave, mm
- $m$: Total mass of the shaft and inner race, kg
- $N_w$: Number of the waves
- $n$: Load-deflection exponent
- $Q$: Contact load, N
- $Q^*$: Dimensionless load parameter
- $R_i$ and $R_o$: Radius of the inner race and outer race, respectively, mm
- $R_{us}$: Curve radius of $s$th waviness, mm
- $R_b$: Radius of the ball, mm
- $R_m$: Pitch radius, mm
- $R$: Equivalent radius for the two contact components, mm
- $r_i$: Curvature radius of the normal inner race, mm
- $r_o$: Curvature radius of the normal outer race, mm
- $s$: $s$th wave
- $U$: Dimensionless speed parameter
- $x$ and $y$: Displacements along $X$- and $Y$- direction, respectively, mm
- $Z$: Number of balls
- $\alpha$: Contact angle, degree
- $\lambda_{ws}$: Mean wavelength of $s$th wave, mm
- $\lambda_i$: Loading zone parameter
- $\Pi_{us}$: Maximum amplitude of the waviness, mm
- $\Pi_{0s}$: Initial amplitude of $s$th wave, mm