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Whirl Frequencies and Critical Speeds of a Rotor-Bearing System with a Cracked Functionally Graded Shaft – Finite Element Analysis

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Abstract

Finite element (FE) formulations have been developed for dynamic analysis of a functionally graded (FG) shaft having a transverse crack. Two nodded Timoshenko beam element with four degrees of freedom (DOFs) per node has been used where effects of translational and rotary inertia, transverse shear deformations, and gyroscopic moments are considered. Local flexibility coefficients (LFCs) of the cracked FG shaft are determined analytically as a function of crack size, power-law gradient index (*k*), and temperature using the Castigliano's theorem and Paris's equations which are used to compute the stiffness matrix in the FE analysis. Temperature dependent thermo-elastic material properties of the FG shaft are considered graded in the radial direction following power-law gradation. Using the present formulations, an FG shaft composed of zirconia (ZrO_2) and stainless steel (SS) is considered and the forward and backward whirl frequencies and critical speeds are determined. Influences of crack size, power-law gradient index, slenderness ratio, and temperature gradient on the dynamic characteristics of the rotor-bearing system with an FG shaft have been studied. Results show that the power-law gradient index has significant influence on the whirl frequencies and critical speed both for cracked and un-cracked FG shaft and could be judiciously chosen in designing FG shafts.

Keywords: Functionally graded cracked shaft; Finite element; Whirl frequency;

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