

Unbalance Response Prediction for Rotors on Ball Bearings Using Speed and Load Dependent Nonlinear Bearing Stiffness

David P. Fleming

NASA Glenn Research Center, Cleveland, Ohio, USA

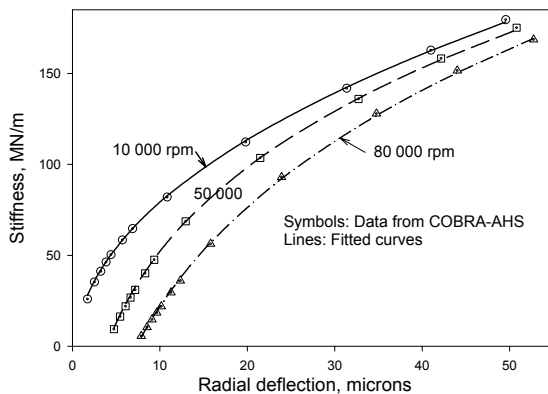
J. V. Poplawski

J. V. Poplawski and Associates, Bethlehem, Pennsylvania, USA

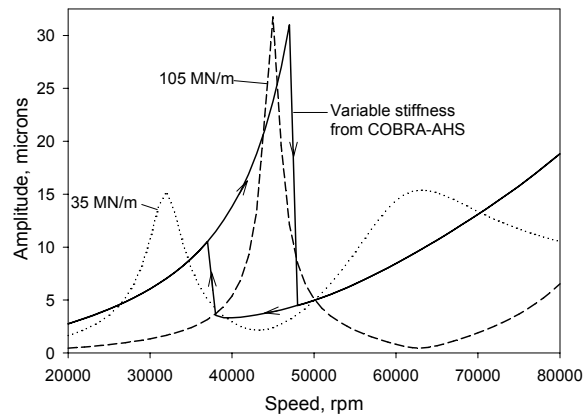
ABSTRACT

Rolling-element bearing forces vary nonlinearly with bearing deflection. Thus an accurate rotordynamic analysis requires that bearing forces corresponding to the actual bearing deflection be utilized. In this work, bearing forces were calculated by COBRA-AHS (Computer Optimized Ball and Roller Bearing Analysis - Advanced High Speed), a recently developed rolling-element bearing analysis code. Bearing stiffness was found to be a strong function of bearing deflection, with higher deflection producing markedly higher stiffness (see left figure below). Curves fitted to the bearing data for a range of speeds and loads were supplied to a flexible rotor unbalance response analysis. The rotordynamic analysis showed that vibration response varied nonlinearly with the amount of rotor imbalance. Moreover, the increase in stiffness as critical speeds were approached caused a large increase in rotor and bearing vibration amplitude over part of the speed range compared to the case of constant bearing stiffness (see right figure below). Regions of bistable operation were possible, in which the amplitude at a given speed was much larger during rotor acceleration than during deceleration. A moderate amount of damping will eliminate the bistable region, but this damping is not inherent in ball bearings.

Keywords: Rotordynamics, rolling-element bearing stiffness, dynamic analysis, rolling-element bearings, bistable operation.



Ball bearing stiffness for various speeds and displacements



Rotor amplitude at bearing location for fixed and variable bearing stiffness; imbalance = 12 g cm