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Analysis of bearing stiffness variations, contact forces and vibrations in radially loaded double row rolling element bearings with raceway defects
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Abstract
A method is presented for calculating and analyzing the quasi-static load distribution and varying stiffness of a radially loaded double row bearing with a raceway defect of varying depth, length, and surface roughness. The method is applied to ball bearings on gearbox and fan test rigs seeded with line or extended outer raceway defects. When balls pass through the defect and lose all or part of their load carrying capacity, the load is redistributed between the loaded balls. This includes balls positioned outside the defect such that good raceway sections are subjected to increased loading when a defect is present. The defective bearing stiffness varies periodically at the ball spacing, and only differs from the good bearing case when balls are positioned in the defect. In this instance, the stiffness decreases in the loaded direction and increases in the unloaded direction. For an extended spall, which always has one or more balls positioned in the defect, this results in an average stiffness over the ball spacing period that is lower in the loaded direction in comparison to both the line spall and good bearing cases. The variation in bearing stiffness due to the defect produces parametric excitations of the bearing assembly. The qualitative character of the vibration response correlates to the character of the stiffness variations. Rapid stiffness changes at a defect exit produce impulses. Slower stiffness variations due to large wavelength waviness features in an extended spall produce low frequency excitation which results in defect components in the velocity spectra. The contact forces fluctuate around the quasi-static loads on the balls, with rapid stiffness changes producing high magnitude impulsive force fluctuations. Furthermore, it is shown that analyzing the properties of the dynamic model linearized at the quasi-static solutions provides greater insight into the time-frequency characteristics of the vibration response. This is demonstrated by relating the low frequency event that occurs when a ball enters a line spall to the dynamic properties of the bearing assembly.

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