

OPERATIONAL RESIDUAL STRESS FORMATION IN VIBRATION-LOADED ROLLING CONTACT

Jürgen Gegner and Wolfgang Nierlich

SKF GmbH, Dept. of Material Physics, Ernst-Sachs-Strasse 5, 97424 Schweinfurt, Germany

In many engineering applications like paper making and printing press equipment, wind turbines, fans or tractors, rolling bearings are operated under external vibrations, e.g., from adjacent machines. This additional loading is usually discounted in failure analyses. However, mechanical vibrations may cause critical mixed friction running conditions that lead to near-surface fatigue eventually. Secondary electron microscopy (SEM) and failure metallography respectively show partial to complete smoothing of the machining marks and dark etching regions in the outermost edge zone, which are formed by microstructural changes due to material aging. The resulting depth profiles of residual stress and {211} martensite XRD line width are also illustrated by typical concrete examples from the field. The applied evaluation of X-ray diffraction material response analysis (XRD-MRA) is outlined. Despite indentation-free raceway, compressive residual stresses are formed up to a certain distance from the surface but far above the depth of maximum v. Mises equivalent stress of the Hertzian macro contact. These findings suggest the initially postulated failure mechanism of vibration-induced mixed friction. Two distinct types of residual stress depth profiles are observed. The analysis of the influence of friction in rolling-sliding contact provides an interpretation. Superposition of the additional tangential forces to the radial loads raises the equivalent stress and shifts its peak towards the raceway surface. The occurrence of residual stress depth profiles revealing either a secondary minimum or monotonous increase in the edge zone thus points to friction coefficients of 0.2 to 0.3. Even for non-ideal lubrication conditions, however, overall values of about 0.05 are typical of rolling bearings. The proposed model of localized friction coefficients explains the discrepancy. This assumption is supported by the thixotropy effect on the lubricant that loses viscosity due to shear loading caused by the vibrations. By satisfying the occurring average according to a mixing rule, high friction coefficients act temporarily in small regions of the contact.

Tests are carried out to experimentally simulate the effect of external mechanical vibrations on bearing performance. A specifically designed and suitably equipped rig is used. The lipless outer ring of a type N cylindrical roller bearing is axially displaced with a typical frequency of 100 Hz. Its raceway suffers maximum vibrational loading via the roller contact. This component thus becomes the test specimen although the Hertzian pressure is higher on the rotating inner ring. XRD-MRA shows that controlled sliding friction introduced by axial vibrations changes the residual stress state in the edge zone without raceway indentations and leads to material fatigue, there. Imaging and analytical SEM reveals smoothed honing marks, surface cracking along tribochemically dissolved MnS inclusion lines and gray staining, i.e. flatly expanded micropitting. Infrared spectroscopy on used aliphatic oil from the test provides evidence of oxidation and incipient resinification by polycondensation. The vibration-induced tribochemical processes thus lead to an acidification of the aging lubricant. The use of contaminated aged grease strongly increases the effect culminating in abrasive wear, plastic deformation and corrosion. The temperature in the lubricating gap depends on the type of lubricant and rises linearly with contact area-related friction power loss.