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PII: S0142-1123(17)30417-6
DOI: https://doi.org/10.1016/j.ijfatigue.2017.10.018
Reference: JIJF 4492

To appear in: *International Journal of Fatigue*

Received Date: 24 July 2017
Accepted Date: 30 October 2017

Please cite this article as: Jelina Rydel, J., Toda-Caraballo, I., Guetard, G., Rivera-Díaz-del-Castillo, P.E.J., Understanding the factors controlling rolling contact fatigue damage in VIM-VAR M50 steel, *International Journal of Fatigue* (2017), doi: https://doi.org/10.1016/j.ijfatigue.2017.10.018

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November 18, 2017

Abstract

Sub-surface initiated spalling remains a key factor in determining the ultimate life of properly maintained bearings. In its early stages, spalling is manifested by the development of cracks and accompanying microstructure alterations, so-called butterflies, around the microstructure inhomogeneities. Base upon a unique three-dimensional microscopic characterisation of a large population of butterflies in VIM-VAR M50 samples that underwent rolling contact fatigue under different experimental conditions, the key factors determining butterfly nucleation and growth has been identified. The work identifies the conditions for crack nucleation and growth, and quantitatively relates them to microstucture. The model encompasses the sub-surface stress field and the microstructural parameters of the material leading to crack growth. Outputs of numerical evaluation of the model show good agreement with experimental data concerning number density, depth distribution and size distribution of butterflies across the wide range of fatigue test conditions.

Keywords: Modelling; Fatigue; Martensite; Carbides; Serial-sectioning

1 Background and introduction

Bearings are used in virtually any piece of machinery involving relative rotation of elements to support the axial and/or longitudinal loads of a shaft while transmitting the torque to adjacent elements. This is achieved by introducing balls or cylindrical rollers between the inner and outer bearings raceways in order to transform a sliding contact into a rolling contact, which minimises the energy loss due to friction. Such geometry results in extreme contact pressures, in the order of a few GPa [1], as well as significant sub-surface shear stresses, which typically exhibit a maximum at tens to hundreds of µm below the contact surface, depending on the load, size and bearing design. The sub-surface stresses inevitably lead to fatigue damage, commonly known as spalling, unless the bearing fails earlier by one of the surface-related damage modes. Surface initiated failures in bearings are nowadays perceived as avoidable by ensuring proper lubrication [2], hence the sub-surface initiated rolling contact fatigue (RCF) remains a factor determining the ultimate life of a properly mounted and lubricated bearing [3].