40th Leeds-Lyon Symposium on Tribology & Tribochemistry Forum 2013
September 4-6, 2013, Lyon, France

Understanding White Etching Cracks (WEC) in rolling element bearings: the effect of hydrogen charging

A. Ruellan[1,2,3,*], F. Ville[1], X. Kleber[2], A. Arnaudon[3], B. Liatard[3]

[1)] Laboratoire de Mécanique des Contacts et des Structures (LaMCoS), INSA de Lyon, F69621 Villeurbanne Cedex, France.
[2)] Laboratoire de Matériaux Ingénierie et Science (MATEIS), INSA de Lyon, F69621 Villeurbanne Cedex, France.
[3)] NTN-SNR, European R&D center, Annecy, France.

[*]Corresponding author for arnaud.ruellan-du-crehu@insa-lyon.fr

1. Introduction

Among tribological failures in Rolling Element Bearings (REB), an unusual rolling/sliding contact fatigue mode has been characterized as White Etching Cracks (WEC) being long subsurface 3D branching crack networks bordered by nano-ferritic white etching microstructure. To the author's knowledge, as only hydrogen precharged specimens have allowed WEC reproduction on test rigs in the literature [1;2], initiation and propagation mechanisms are not yet fully understood in application.

In this study, the analysis of a standard REB test rig contact conditions reproducing WEC on neutral and hydrogen precharged inner rings is proposed to identify influent parameters on the formation of WEC.

2. WEC reproduction on standard bearing test rig

A classical and minimalist endurance test bench in a neutral environment, have allowed WEC reproduction on two sets of standard ball bearings. The first set of inner rings was in standard 100Cr6 bearing steel and lasted more than 1000 hours before surface damage. The second set also in 100Cr6 was hydrogen charged cathodically in an aqueous solution of sulfuric acid and failed within 104 hours. On both sets, circumferential and axial Optical Micrographs (OM) (2% Nital etching) and fractographies revealed large WEC networks.

For the first time, up to the authors' knowledge, WEC have been reproduced with and without hydrogen charging repeatedly, for the same loadings and in a controlled manner.

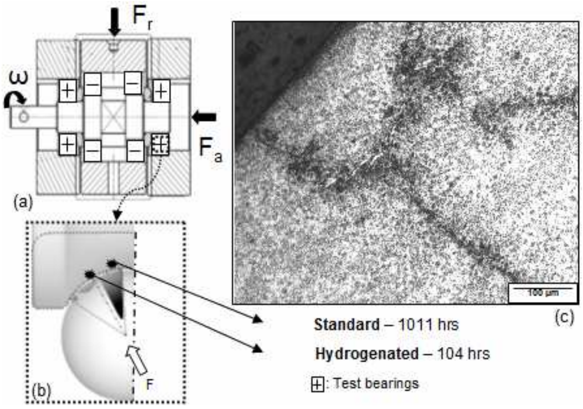

Fig. 1: (a) Standard contact ball bearing test rig; (b) Contact area in an axial cut: position of the WEC for neutral and hydrogenated rings; (c): circumferential Nital 2% etched OM of a WEC linked to the surface.

3. Hydrogen charging effect on WEC initiation

Comparing the WEC revealed by axial OM and fractographies to the contact theoretical positions, it is clear that the cracks do not form at the same location : WEC in hydrogenated rings appear under the computed angle of contact, at the maximum Hertz pressure while WEC in standard rings appear at the edge of the contact ellipsoid where slippage is maximum.

Moreover, surface axial hairline cracks have been observed on neutral rings at the contact edge but not on hydrogenated rings. SEM analysis of a fractographies of a neutral rings reveal smooth and ground axial cracks linked to the surface that pre-existed the artificial fracture with a rough and granular aspect.

Those results tend to show that excessive embrittlement by hydrogen artificial charging can modify WEC initiation mechanisms despite similar propagation aspects and can lead to false interpretations.

4. Discussion on the WEC formation in REB

According to the authors, WEC formation in application should be considered in two steps: initiation and propagation. The semi-circular top-down growth of WEC, confirmed by [2] indicate that, first, surface axial microcracks have to be formed by high tensile surface stress due to high slippage at the contact edge, especially at discontinuities such as inclusions or irregularities in the compressive surface residual stress. This allows degraded lubricant, hence hydrogen to penetrate in the steel due to high slippage at the contact boundary or within the rubbing crack itself as it has been proved in the literature. Second, the hairline cracks progressively propagates radially to form millimeter long WEC branching networks characteristic of local hydrogen embrittlement at crack tips. Moreover, most of the WEC observed in application present hydrogen sources: water contamination, presence of "hydrogen poisons" such as sulfurs in MnS inclusions or lubricant additives, electrical current.

5. References

[1] Evans, M-H., "White structure flaking (WSF) in wind turbine gearbox bearings: effects of ‘butterflies’ and white etching cracks (WECs)." Materials Science and Technology, 28(1):3–22, 2012.
[2] Vegter, R.H., and Slycke, J.T., "The role of hydrogen on rolling contact fatigue response of rolling element bearings." J. of ASTM Int., STP1524:201–217, 2009.