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Rolling Contact Fatigue Induced Transformations of Dark Etching Region and White Etching Bands in Bearing Steels

Mostafa El Laithy[1)*], Ling Wang[1)], Terry Harvey[1)], Alexander Schwedt [2)], Bernd Vierneusel[3)] Joachim Mayer[2)]

[1)] National Centre for Advanced Tribology at Southampton (nCATS), University of Southampton University Road, Southampton SO17 1BJ, UK
[2)] Central Facility for Electron Microscopy (GFE), RWTH Aachen University, Ahornstraβe 55, 52074 Aachen, Germany
[3)] Schaeffler Technologies AG & Co. KG, Georg-Schäfer-Straße 30, 97421 Schweinfurt, Germany.
*Corresponding author: mel2g13@soton.ac.uk

DER, LABs and HABs in bearing steels have been analyzed in RCF-tested ball bearings. All features consist of three constituents: equiaxed ferrite grains; elongated ferrite grains and lenticular carbides (LCs) evidenced through SEM analysis. Similar transformations are associated with each feature, suggesting a recurring cycle of ferrite/carbide formation and breakdown in the microstructure. FIB/TEM analysis of the ferrite bands have investigated the equiaxed/elongated ferrite grain transformations while EBSD analysis is used at different DER/WEBs stages to examine the grain structure/texture evolution to determine the formation mechanism.

Keywords: dark etching region, white etching bands, rolling contact fatigue, rolling bearing

1. Introduction

Cyclic stresses arising within rolling element bearings due to rolling contact fatigue (RCF) can result in the manifestation of subsurface microstructural alterations known as dark etching regions (DER) and white etching bands (WEBs), the latter consists of low (LAB) and high-angle bands (HAB). While these features have been previously reported in literature [1], their formation mechanism remains debated. The aim of this study is to investigate the formation mechanism of DER/WEBs and their associated transitions in the microstructure.

2. Experimental Details

RCF tested angular contact ball bearings of three steel microstructures (100Cr6 Martensite, Bainite and 50CRMo4 Martensite) under 2.9 GPa contact pressure over a range of stress cycles (between 591 and 7886 million) have been examined to study the influence of materials and stress cycles on the formation of DER and WEBs. The bearings have been cross-sectioned and metallographically analysed using SEM, EBSD and TEM to elucidate mechanisms of the microstructural alteration processes at micro- and nano-scale.

3. Results & Discussion

Fig.1 and Fig. 2 present SEM images DER and WEBs in the 50CrMo4M and 100Cr6 samples respectively, showing the progression of the features from low to high stress cycles. Similar to a previous study [2], this study has confirmed that all features consist of equiaxed and elongated ferrite grains. This study has also found that the DER in the parent matrix as ‘inhomogeneous dark patches’ (Fig. 1a) consisting of parallel thin elongated (needle-like) ferrite grains (Fig. 1b). As the ferrite grains grow, the ‘DER patches’ become homogenously distributed at later stages. The dense needle-like structures eventually contribute to equiaxed ferrite grain formation and are believed to initiate LAB formation. A similar process is found to occur in LAB (Fig. 2a), where equiaxed ferrite bands orientated at 30° to the surface develop followed by the formation of needle-like elongated ferrite grains (similar to that in the DER but longer and oriented at 30˚). It was also found that LCs form adjacent to the elongated ferrite grains due to carbon migration from the ferrite band. Similar progression cycle is observed in HAB (Fig. 2b), extending across pre-existing LABs but with larger dimensions.

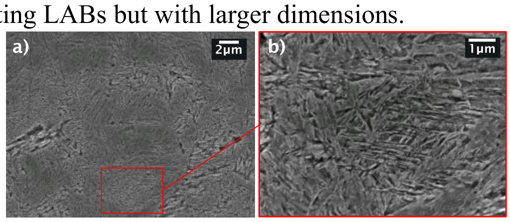

Figure 1: a) inhomogeneous DER patches (elongated and equiaxed ferrite) in early-stage sample (846 million cycles). b) region showing parallel elongated ferrite grains marking DER initiation.

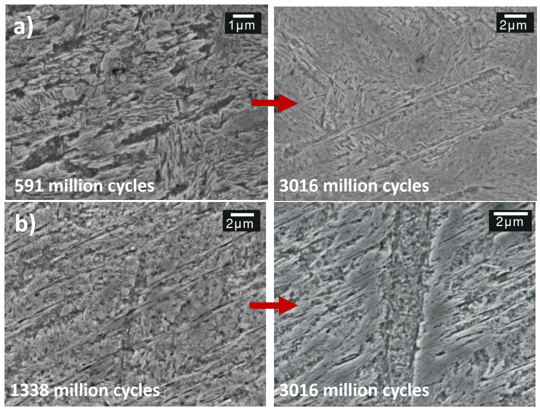

Figure 2: progression from equiaxed ferrite band to the formation and growth of elongated ferrite grain and LC in a) LABs and b) HABs

TEM has been conducted on the cell structure of equiaxed/elongated ferrite to examine the transformation and EBSD to identify the grain structure/texture development at different progression stages. Findings from the analysis will be presented and discussed at the conference to conclude the formation mechanisms of DER, LAB and HAB in high and low carbon steels.

4. References

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