INVESTIGATION OF SUBSURFACE MICROSTRUCTURAL ALTERATIONS IN STEEL BEARINGS DUE TO ROLLING CONTACT FATIGUE

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ABSTRACT

Rolling Contact Fatigue (RCF) in steel bearings can manifest through subsurface microstructural alterations known as dark etching regions (DER) and white etching bands (WEB) under medium-high stress cycles. These features have been researched intensively for decades yet the formation mechanism and how these features contribute to bearing failure remains unknown. DER was reported to be randomly scattered deformed patches of ferrite [1] while WEBs form later in the bearing life and are parallel three-dimensional ferrite discs, which are found to be parallel to the contact surface in the axial direction and inclined to the surface in the circumferential section towards the rolling direction at 20-35° (known as low angle bands or LAB) or 65-85° (known as high angle bands or HAB). The aim of this study is to investigate the formation mechanisms of DER, LABs and HABs by analysing these features formed at different stages of bearing life. A number of angular contact ball bearings (ACBB) subjected to RCF testing under two maximum contact pressures of 2.9 GPa and 3.5 GPa at stress cycles ranging from 151 million to 4141 million are examined. The bearings have been cross-sectioned and metallographically analysed performed using light optical microscopy (LOM), Scanning Electron Microscopy (SEM), Energy Dispersive X-ray Spectroscopy; while nano-indentation tests and Electron Backscatter Diffraction were used to obtain the mechanical properties of different regions within the WEBs.

For the first time, a 3D-model of multiple HABs is established based on multiple LOMs obtained at 5 μm intervals through serial sectioning procedure that has confirmed the structure of the parallel bands in three dimensions (Figure 1). Similar to a previous study [2], analysing LABs and HABs at the very early stages of their formation has revealed that they consist of three main constituents 1) globular equiaxed ferrite grains, 2) elongated ferrite grains and 3) carbon-rich areas as shown in Figure 2.

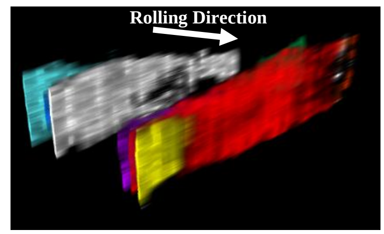

Fig.1 3D-model of HABs in ACBB inner ring

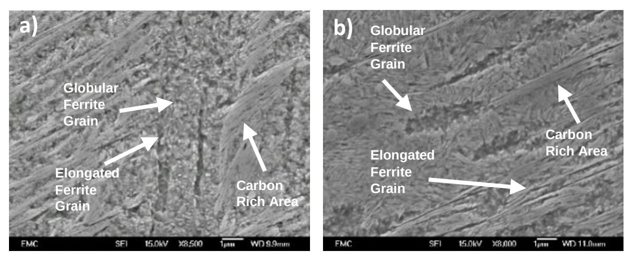

Fig.2 SEM images of a) HAB b) LAB

Based on the observations over multiple experimental results, it is proposed that the formation of WEBs initiates with the growth of globular equiaxed ferrite grains due to martensitic decay. The accumulation of plastic deformation during operation causes the globular grains to deform and elongate across the band which leads to the development of carbon-rich areas surrounding the elongated grains of the LABs. For the early stages of HABs it appears that, the globular regions of LABs transform into grains for the HABs where the direction of grain growth changes from about 30° to about 80°.

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