Formation of White Etching Areas during Rolling Contact Fatigue of SAE 52100 Bearing Steel - the Influence of Diffusible Hydrogen

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White etching cracks (WECs) have been studied over the last decades as a common cause for premature failure of roller bearings made of the bearing steel SAE 52100 in various applications. As a consequence of a non-directional and branched crack network formation associated with an altered microstructure named white etching area (WEA, after the light-optical appearance of Nital-etched cross-sections) the bearing components fail by cracking or flaking.

In earlier works ([1], [2]), it has been shown based mostly on a correlative application of SEM-based techniques like orientation contrast imaging, EDX, EBSD and finally SE-imaging of the subsequently Nital-etched sections that the variety of microstructual alterations largely exceeds the mere formation of the nanocrystalline microstructure components finally leading to the white appearance in the LOM. In this work, a series of hydrogen-precharged tempered-martensitic samples has been systematically tested in a four-wheel test rig using different hydrogen concentration, Hertzian pressure and number of load cycles. Subsequently, the microstructure alterations were analysed in order to understand the accelerating influence of diffusible hydrogen on the formation of WEAs/WECs.

The results of the microstructure analyses (cf. Fig. 1) show a considerable recrystallization and growth of ferritic components in the course of the microstructure alterations. Cracks are mostly found laterally at the boundaries between altered microstructure and unaltered matrix. In order to better understand the spatial relation between cracks and microstructure alterations, the analytical approach has been extended by a 3D PFIB analysis of a $(100\ \text{micron})^3$ cube containing both, cracks and microstructurally altered regions. Also in 3D (cf. Fig. 2), the cracks are preferably found at the sides of the altered areas. Altered regions without any connection to a crack could also be found.

These findings support the idea that the microstructural alteration occurs prior to crack formation. The role of hydrogen, therefore, has to be thought as accelerating the microstructure alteration rather than initiating the crack formation.

[1] Diederichs A. M., Schwedt A., Mayer J., and Dreifert T., 2016,"Electron microscopy analysis of structural changes within white etching areas," Materials Science and Technology, 32(11), pp. 1683 - 1693.

[2] ŠmeÄova V., Schwedt A., Wang L., Holweger W., and Mayer J., 2017,"Microstructural changes in White Etching Cracks (WECs) and their relationship with those in Dark Etching Region (DER) and White Etching Bands (WEBs) due to Rolling Contact Fatigue (RCF)," International Journal of Fatigue, 100, pp. 148 - 158.

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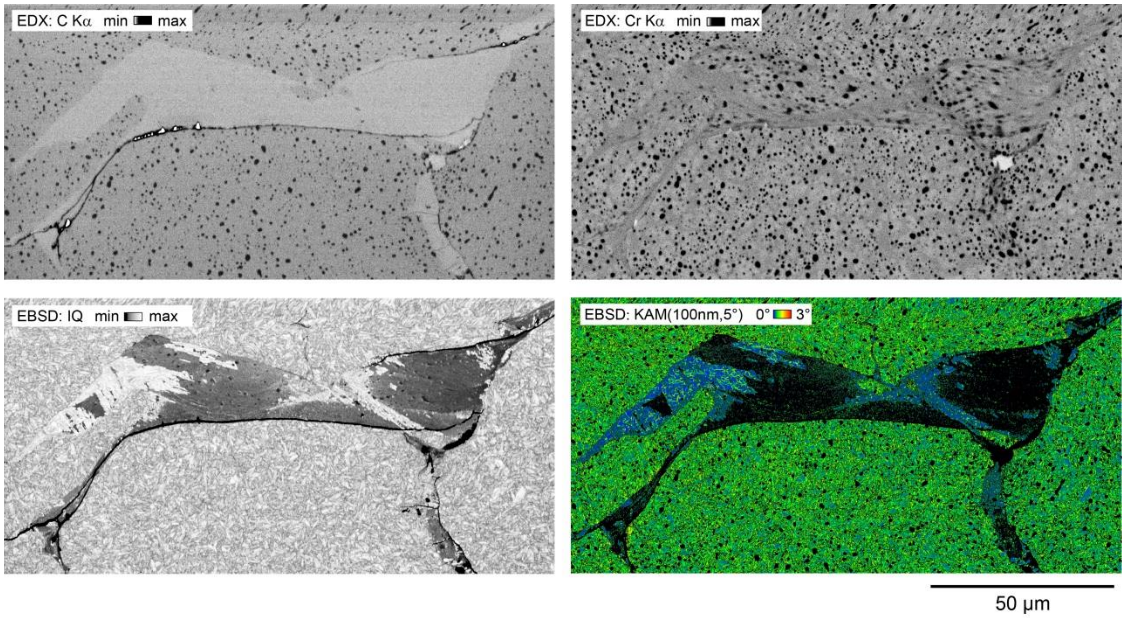

Fig. 1: Microstructure alterations in the cross section of a sample tested for 8.2h (raceway horizontally above the images)

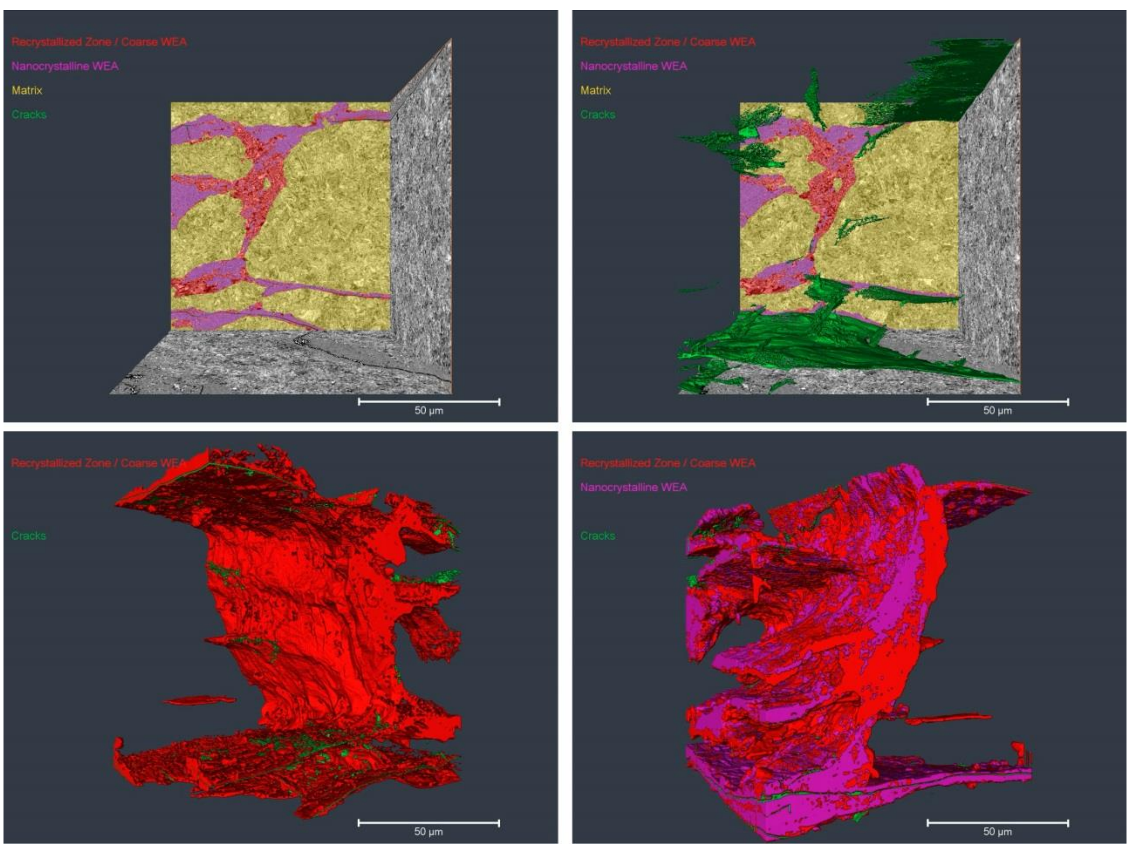

Fig. 2: 3D PFIB reconstruction and segmentation of another altered area from the same specimen (raceway approx. horizontally below the images).