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A STUDY OF MICROSTRUCTURE CHANGES PRESENT IN WHITE STRUCTURE FLAKING FAILURES OF WIND TURBINE BEARINGS THROUGH HIGH PRESSURE TORSION TESTS

TRACK OR CATEGORY

Wind Turbine Tribology

AUTHORS AND INSTITUTIONS

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INTRODUCTION

Over recent years, White Etching Areas (WEAs) in bearing steels have received considerable attention due to their relationship with premature failures of rolling bearings, especially those assembled in wind turbine gearboxes. The formation of WEAs has been related to the Hertzian stresses present in the subsurface of the contact areas that generate localized and severe plastic deformation (SPD) conditions. SPD could promote grain refinement and dissolution of carbides in well-defined regions. Both phenomena seem to be closely related to WEAs initiation and evolution [1]. Similar mechanisms have been suggested as an explanation of the origin of White Structures (WES) encountered in pearlitic steels processed by High Pressure Torsion tests (HPT) [2]. HPT is conducted on a thin disc sample placed between two anvils that transmit compression and high torsional stresses. Compression and shear stresses combined can produce homogeneous microstructures with grain sizes of less than 1 µm [3]. Although HPT differs from Rolling Contact Fatigue, RCF, it can be a viable alternative to study the effects of compression and shear in very limited volumes. To study the WEAs evolution in bearings affected by SPD conditions, HPT was used to produce WES in an AISI 52100 bearing steel. A detailed characterization of these WES was conducted by SEM / BSI / EBSD / EDS. These results were used to shed some light on the evolution of WEAs in AISI 52100.

MATERIALS AND METHODS

The material selected was from standard through hardened AISI 52100 bearing rollers 10 mm in diameter, 14 mm long and 750 ± 10 HV hardness. To overcome the limitation in sample hardness of the HPT test machine (it cannot process materials with a final hardness of over 800 HV after HPT), the rollers were annealed to reduce their hardness to 180 ±10 HV. The annealed bearing rollers were cut into discs samples 9.8 mm diameter and 0.8-0.9 mm thick and processed using a HPT test machine. HPT tests were conducted using 0.5, 1, 3, 6, GPa pressure and 1, 2, 3 turns. All tests were conducted without any lubrication, at ambient temperature and 1 rpm rotational speed. Each HPT test parameter combination was repeated three times. After conducting the HPT tests, axial sections were cut along the diameter of the disc samples and polished with 6 µm, 3 µm and 1 µm diamond suspensions and 50 nm colloidal silica Oxide Polishing Suspensions (OP-S) prior to being imaged by r SEM /BSI / EBSD / EDS.

RESULTS AND DISCUSION

Figure 1 a0 presents a schematic of the HPT process. A collage made from SEM images of an axial section taken from a disc sample processed under 3 GPa 2 turns is presented in figure 1 b). Some WES were observed at the top surface (called Top – WES or TWES) and in the subsurface (called Subsurface – WES or SWES). TWES and SWES are referred to as Regions 1 and 2 in the white rectangles in figure 1 b), which were characterized using SEM / EBSD /EDS analysis.

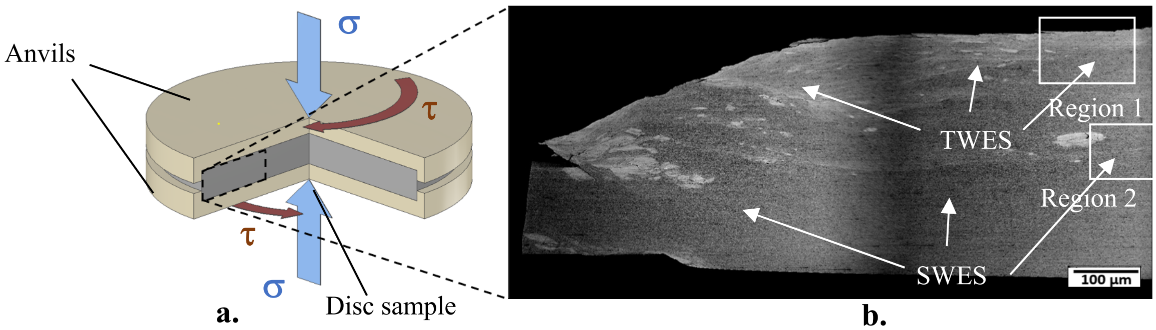

Figure 1. a) Schematic of a HPT test. The pressure and torsion are applied on the disc sample through the anvils. b) Axial section of a HPT disc sample processed using 3 GPa 2 Turns. WES are visible at the top surface (TWES) and in the subsurface (SWES). The white rectangles show the regions analyzed in figure 2.

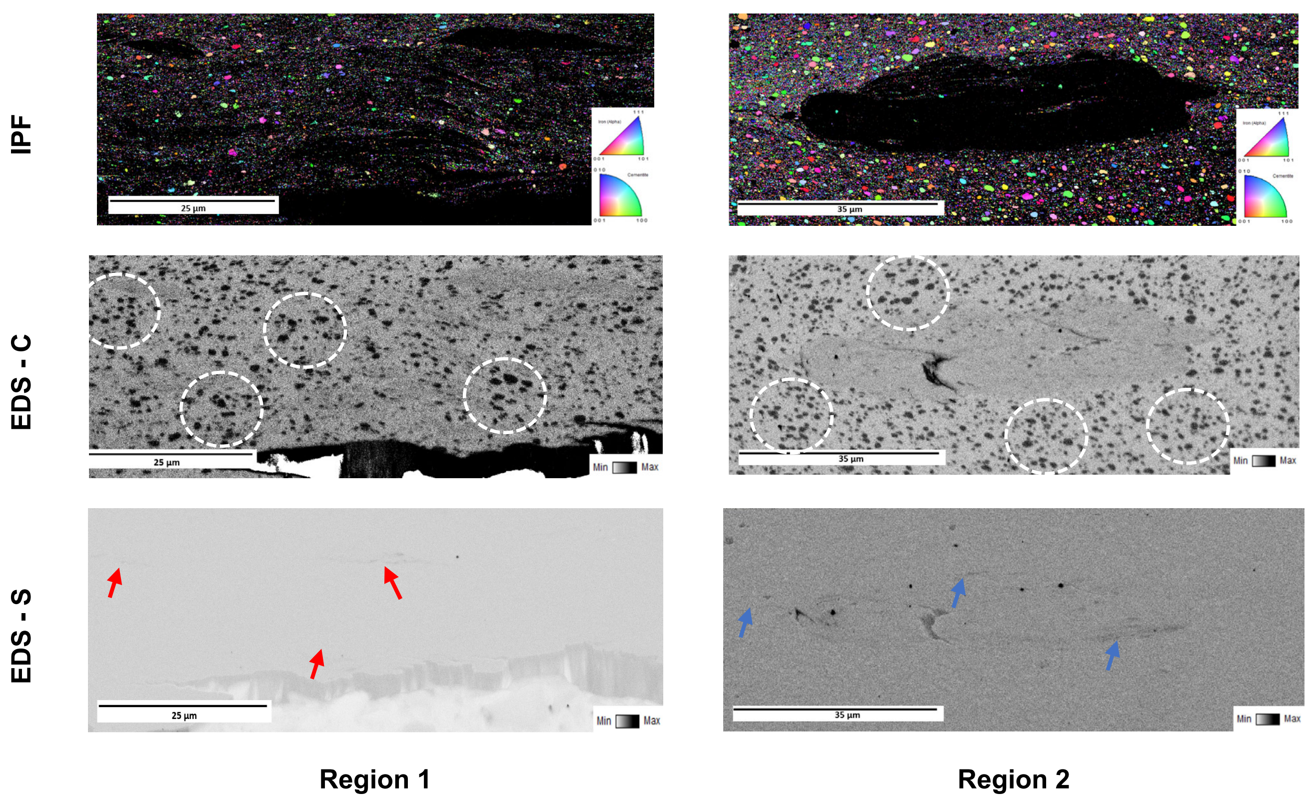

Figure 2. EBSD and EDS maps taken from Regions 1 and 2 presented in Figure 1 b). a), b) IPF maps revealed a very refined structure in the matrix whilst WES appeared as black areas. c), d) EDS – C maps revealed carbon redistribution inside the f WES. e), f). EDS – S maps revealed inclusions inside the f WES. IPF taken with Z axis as ND, CI greater than 0.1, WD between 5-7 mm.

Figure 2 a) and b) present the IPF maps of regions 1 and 2. The matrix surrounding the WES consisted of a very refined ferritic grain structure containing spheroidal carbides. Both phases, ferrite and cementite reported heterogeneous crystallographic orientations. Figures 2 c) and d) summarizes the results of EDS analysis for carbon in Regions 1 and 2. WES were visible because of their different contrast compared to the ferritic matrix, indicating they had a slightly higher C content than the matrix surrounding them. A significant reduction in the number of the spheroidal carbides was observed inside the WES. Although spherical carbides appeared dispersed in all directions, some clusters were visible in different areas (white dotted circles). The carbides that remained in these WES were smaller compared to those located in the surrounding matrix while others seemed to flow, leaving behind an ill-defined trail similar to a *comet tail*. These comet tails extended for significant distances and linked other small carbides. A similar phenomenon was visible in figures 2 e), f) where ill-defined sulphur *comet tails* were observed. Sulphur results from the presence of non-metallic inclusions inside WES. EBSD maps from the WES registered a significant reduction in the cementite patterns compared to the surrounding matrix, whereas the EDS signals taken from the same areas indicated a redistribution of carbon. The changes observed in the carbides remaining such as size reduction and their elongated shapes, suggest a progressive dissolution visible as *comet tails*. The plastic flow in the subsurface of the sample discs could be altered by the presence non-metallic particles and carbide clusters that block the shear deformation. This might lead to the formation of turbulent patterns at a sufficiently large shear strain similar to vortices.

CONCLUSIONS

HPT has successfully created WESs similar to those found in rolling bearings but under much simpler conditions. This has enabled the investigation of WEA formation under pure strain conditions. The formation mechanism of WESs appears to result from very localized plastic deformation caused by non-metallic inclusions or carbide clusters interrupting plastic flow. The carbides progressively dissolve leading to the WES exhibiting a higher carbon content, as revealed by EDS, than the surrounding matrix. This dissolution was influenced by the severe plastic flow as revealed by the comet tails. EBSD suggests that the WES has a nano-grained structure.

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KEYWORDS

Wear: Wear/Failure Testing Devices, Materials: Ferrous Alloys, Steel, Materials: Carbides