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A STUDY OF WHITE ETCHING AREAS IN AN ANNEALED 52100 STEEL THROUGH HIGH PRESSURE TORSION PROCESSES

TRACK OR CATEGORY

Wind turbine tribology

AUTHORS AND INSTITUTIONS

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INTRODUCTION

White Structure Flaking (WSF) is a type of surface damage responsible for some early failures in wind turbine gearbox bearings. WSF has been associated with microstructural changes registered close to the damaged surface that appear to be white after etching, hence the name White Etching Areas (WEAs). Local hydrogen liberation from lubricants [2] and adiabatic shear bands [3] have been related to WEAs development. Moreover, it is believed that local plastic deformation promoted by shear stress occurs during WEA formation [4]. WEAs can be observed in other mechanical applications such as rail tracks [5], hard turning machining [6] or steel discs processed by High Pressure Torsion (HPT) [7]. HPT, as a Severe Plastic Deformation process (SPD), produces extremely refined grain sizes through a combination of shear and compressive stresses. HPT allows a detailed record of the microstructure evolution after different strains to be determined, although it is limited by the final hardness admissible in the samples compared to the dies used to deform the workpieces. This study shows the initial results on the use of HPT to create WEAs in an annealed AISI 52100 bearing steel and their microstructural characterization.

MATERIALS AND METHODS

Standard rollers of AISI 52100, 10 mm in diameter, 14 mm long and hardness 750 ±10 HV were annealed following BSI standards [8]. The rollers were softened to avoid damaging the anvils used to deform the steel disc specimens during HPT tests, as the hardness of the final HPT processed specimens cannot be greater than 600 HV. The HPT samples were cut from the annealed rollers to obtain 10 mm diameter discs 0.8-0.9 mm thick. The HPT tests were conducted under a range of load and various turns, where WEAs were found to be created under 3 GPa pressure after 2 turns at 1 rpm rotational speed. Metallographic preparation was conducted on all of the samples prior to examination by optical and scanning electron microscopy. Hardness measurements were also carried out using a Vickers micro-hardness tester. Samples were etched with 2% nital prior to the microscopic inspection.

RESULTS AND DISCUSSION

The annealing heat treatment reduced the hardness of the AISI 52100 rollers to 180 ±10 HV and produced a microstructure of small carbides distributed uniformly in a ferritic matrix. After applying HPT, WEAs appeared in regions located at greater than 3.5 mm from the centre of the disc sample. The WEAs morphology changed with radial position, from small structures that resemble swirling clouds located at 4 - 4.5 mm (Figure 1a.), to solid and well defined areas located close to the edge of the sample, at a radial distance of 4.5 and 5 mm (Figure 1b.). Solid WEAs usually contained crack networks, as shown in Figure 1c. An atypical carbide distribution appears surrounding the WEAs (Figure 1c). This carbide distribution seems to arise from a forced flow of the ferritic matrix that drags the carbides. The high plastic deformation associated with this flow could lead to carbon diffusional processes inside the WEAs.

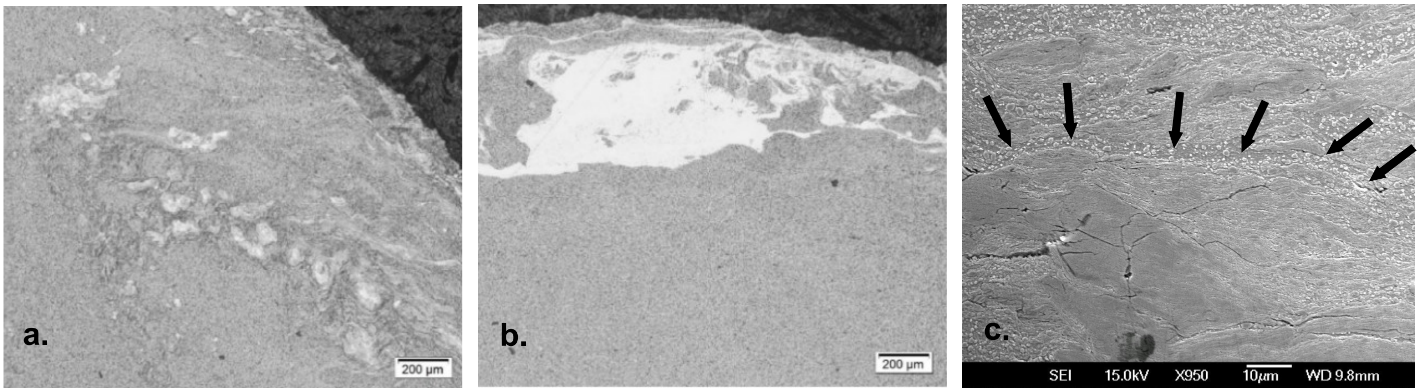

Figure 1. Light microscopy of swirling clouds and solid WEAs located at 4-4.5 mm (a.) and 4.5 - 5 mm (b.) SEM/SEI of solid WEA with network cracks located close to the sample edge Arrows show an atypical carbide pattern that seems to arise from a forced flow close to WEAs (c.). Samples etched with 2% nital.

Figure 2a. presents a montage of several images from the sample periphery after HPT, where WEAs can be seen in regions close to the edge of the sample. Figure 2b, a black/white mask of Figure 2a. generated by *Image J*, was utilized to calculate the % WEAs in 0.5 mm wide rings defined by their mid-radius position. One example of these rings is shown as a hatched region in Figure 2b (radius from 3.5 to 4 mm). The % WEAs within each ring are plotted against the corresponding average strain in figure 1c. True strain at these locations were calculated using the equation given in the same figure, where N is 2 turns, h is 0.8 mm and r is the mid-radius of each ring (2.75, 3.25, 3.75, 4.25 and 4.75 mm). The percentage of WEAs in the rings is found to increase notably with radial distance or strain with a sharp increase when the strain was over 65. Micrographs from the centre of the sample were omitted from the analysis as WEAs were not present at these locations. Figure 3 shows hardness measurements taken between 3.775 and 4.175 mm from the sample centre. Points A and E correspond to measurements taken in the matrix, whilst points B, C, D and F correspond to the hardness registered in WEAs. The WEAs were found to be approximately 12% harder than the matrix at similar radius.

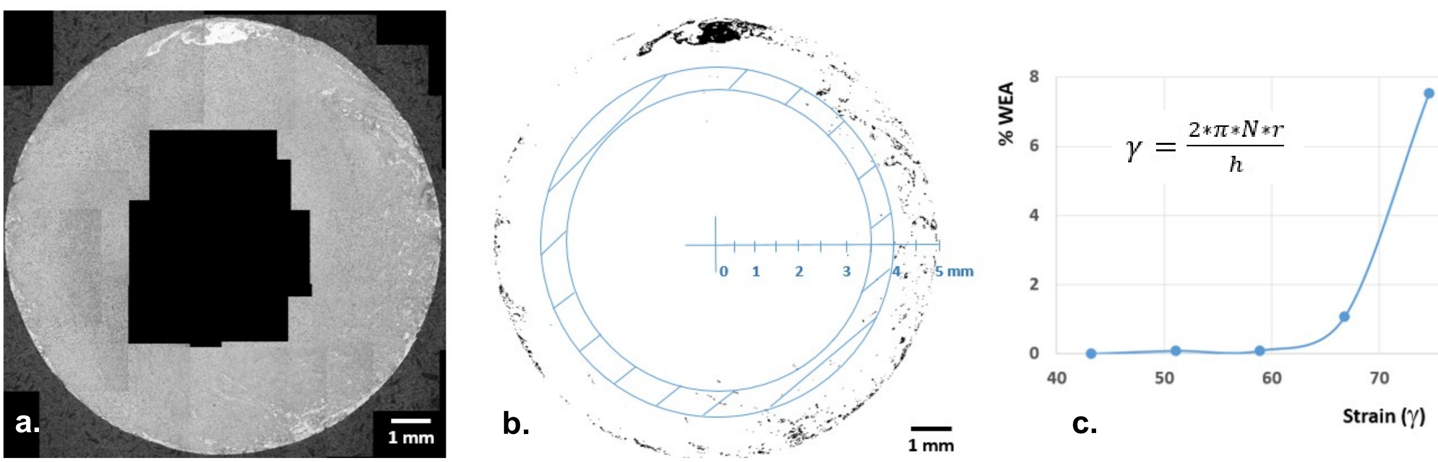

Figure 2. Montage of micrographs from AISI 52100 sample processed using HPT under 2 GPa and 2 turns (a.). Black/white mask taken from Figure 2a. generated by *Image J*, and as an example a 0.5 mm wide ring at a mid-radius of 3.75 mm used to calculate the % WEAs (hatched region) (b.). % WEAs as a function of strain in the mid-radius rings after the HPT tests. Light Microscopy 2% nital.

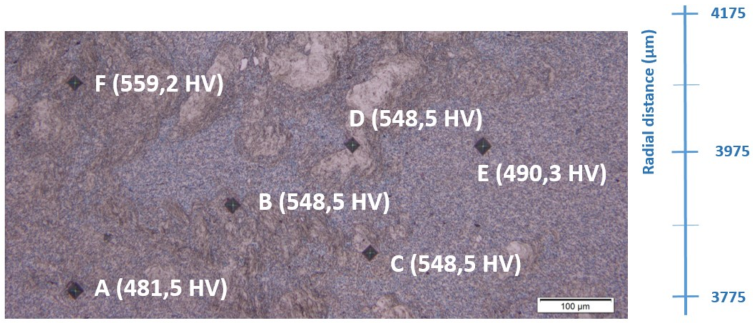

Figure 4. Hardness measurement taken between 3.775 and 4.175 mm from the sample centre. Points A and E correspond to the matrix and registered lower hardness values, whilst points B, C, D and F (WEAs) were approximately 12% harder. Etched in 2% nital.

CONCLUSSIONS

After processing the annealed AISI 52100 by HPT using 2 turns and 3 GPa, at least two different WEAs configuration were generated: swirling clouds and solid regions. The carbide patterns that surround these WEAs show strong similarities to the WEAs found in failed rolling bearings. The amount of WEAs increased with radial position or strain imposed during HPT. No WEAs were found at a radial distance of 3.75 mm or less which suggests a critical value of strain is necessary for their formation. Finally, WEAs registered higher hardness values than the matrix close to them. This feature has been reported in WEAs in WSF.

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KEYWORDS

Applied Tribology: Power Generation, Rolling Bearings: Rolling Element Bearings, General, Wear: Rolling-Contact Fatigue