Subsurface Deformation and Structural Changes during Scuffing of Steel

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1. Introduction

The term scuffing is used to describe a catastrophic surface failure accompanied by sudden increases in friction, wear rate and temperature during sliding contact. Observations on subsurface changes induced by scuffing have provided important findings for understanding scuffing mechanism. Ajayi et. al. [1] suggested that scuffing is initiated by adiabatic shear instability based on observations of subsurface structural and compositional changes accompanying scuffing failure. Sheiretov et. al. [2] proposed that scuffing is caused by gradual subsurface changes including accumulation of plastic deformation, formation and propagation of cracks.

This study presents some experimental analysis on subsurface changes of steel induced by scuffing. The tribometer for scuffing tests in this study employs a ball-on-disc concentrated contact between a stationary SUJ2 steel ball and a rotating sapphire disc. The contact area was continuously monitored by an optical microscope and a CCD digital camera during the tests. Experiments were conducted under a lubricated condition using n-hexadecane at a bath temperature of 50 ℃. The rotation speed of the disc was 1 m/s. A step-loading protocol was used with each load step lasting for 5 minutes. The initial load was 110 N, the second step load was 220 N and the third step load 440 N. Scuffing occurred at the third load step. After the scuffing test, subsurface deformation and structural changes of the steel ball at different stages of scuffing were observed by optical microscope, SEM, micro indentation and XRD.

2. Results and discussion

Assisted by the in situ monitoring, the scuffing test could be terminated during the expansion of scuffing to the whole contact area. An overview of the subsurface material of the steel ball during the expansion of scuffing was shown in Fig. 1. From Fig. 1 it can be seen that a light yellow etching region exists at the subsurface. The light yellow etching region corresponds to the scuffed area, the latter can be recognized by the in situ observation. Figure 1 also shows a dark etching region in the subsurface, which gradually lightens with depth. As for the spatial distribution, the dark etching region is symmetric while the light yellow etching region is eccentric to the right, both should reflect the subsurface temperature distribution during the sliding. An enlarged SEM view of the transitional region, indicated with a rectangle in Fig. 1, was shown in Fig. 2. From Fig. 2 it can be seen that for the area where the light yellow etching region does not exist, marks of plastic flow are clearly visible. Figure 2 also indicates that the light yellow etching region is composed of very fine grains, and marks of plastic flow become less distinct and even invisible within this region. It seems that scuffing of the steel involves a rapid temperature rise within the light yellow etching region shown in Fig.1.

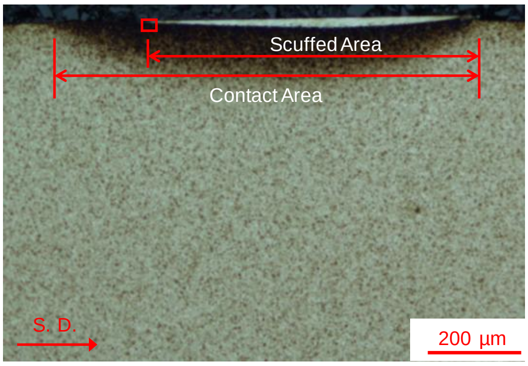

Fig. 1 Optical micrograph showing the overview of the subsurface material during scuffing. Etching condition: 2 vol.% nital, 25 seconds.

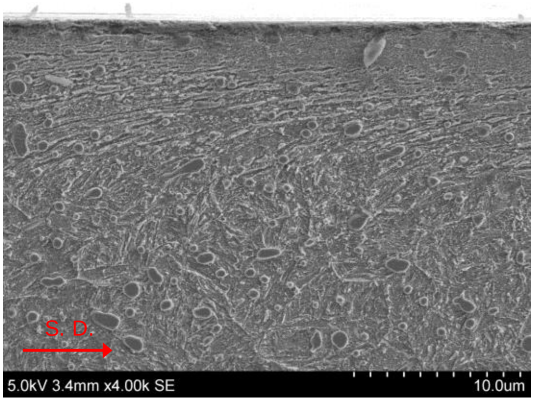

Fig. 2 SEM micrograph of the rectangled area in Fig. 1.

3. References

[1] Ajayi O.O., Lorenzo-Martin C., R.A. et. al., “Scuffing mechanism of near-surface material during lubricated severe sliding contact,” Wear, 271, 2011, 1750-1753.

[2] Sheiretov T., Yoon H., et. al., “Scuffing under dry sliding conditions—Part I: experimental studies,” Tribology Transactions, 41, 1998, 435-446.