MICROSTRUCTURE EVOLUTION OF ADIABATIC SHEAR BAND IN ULTRA-FINE-GRAINED IRON UNDER DYNAMIC SHEAR LOADING

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Summary In the present study, evolution of adiabatic shear band (ASB) in Ultra-fine-grained (UFG) Fe under dynamic shear loading was investigated. With increasing shear deformation, the evolution of ASB was found to be a two-stage process, namely a nucleation stage followed by a thickening stage. In the thickening stage, ASB evolution is accompanied by increasing in both thickness and micro-hardness of ASB, and by crack propagation within ASB.

INTRODUCTION

UFG/NC materials have unique mechanical properties, such as increased strength/hardness, improved toughness and enhanced diffusivity compared to their coarse grained counterparts [1]. However, UFG/NC materials usually show reduced strain hardening and limited ductility, especially under high strain rate deformation [2-3]. One of the reasons is the shear band formation during dynamic loading [3]. The mechanical behavior of ultrafine-grained (UFG) Fe processed by SPD has been the subject of recent work due to their increased strength/hardness [2-5]. However, most of reported research work on UFG Fe was carried out under quasi-static loading, and few under dynamic loading. Although the propensity and the properties of ASB in UFG Fe produce by ECAP have been investigated in [3], the origin and evolution of ASB in UFG Fe is still poorly understood. In the present study, hat-shaped specimen set-ups in Hopkinson bar experiments are used to study the evolution of ASB in UFG Fe by controlling dynamic shear displacement.

EXPERIMENTAL PROCEDURES

The hat-shaped specimen set-up for Hopkinson-bar testing is shown in Fig. 1a. The hat shape is designed to concentrate shear deformation in a narrow zone facilitating the formation of a shear band. The shear displacement is controlled by the stopper ring for each experiment. Following impact, the hat-shaped specimens were sectioned in half along the impact axis. The half sections were then polished to 2000 grit and final polished with 0.5 μm diamond paste. This was followed by etching with 5% Nital. The etched half sections were then examined by optical micrograph and SEM. Micro-hardness measurements were also made on these polished half sections using a Vickers diamond indenter at a load of 10g for 15s dwell time. The EBSD map of ECAP-6 Fe is shown in Fig. 1b. After pressing for 6 passes, the grains are experienced severe shear deformation and the grain size is approximately 500 nm in the transverse direction.

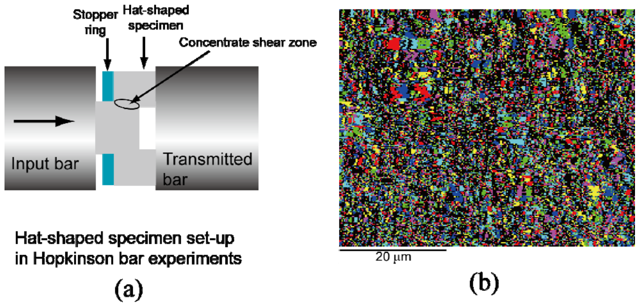

Fig. 1: (a) Hat-shaped specimen set-up in Hokinson bar experiments; (b) EBSD map of ECAP-6 Fe.

RESULTS AND DISCUSSIONS

Fig. 2a shows optical micrographs of evolution of ASB with the increasing shear displacement, while Fig. 2b shows the corresponding SEM pictures. Fig. 3 shows Vickers micro-hardness traversing an ASB for experiments H2 and H3. When the shear displacement is small (0.3 mm for H1), the shear deformation is not enough to form a shear band, but only distort the origin texture produced by ECAP. As the shear displacement is increased, the evolution of the shear band is found to be a two-stage process, namely an initiation stage followed by a thickening stage. In the initiation stage, the shear band occurs within a thickness 35 μm. The initial shear band consists of two regions: a core region, which shows a more or less equi-axed morphology; on the two sides of the core region, two transition layers exist where the

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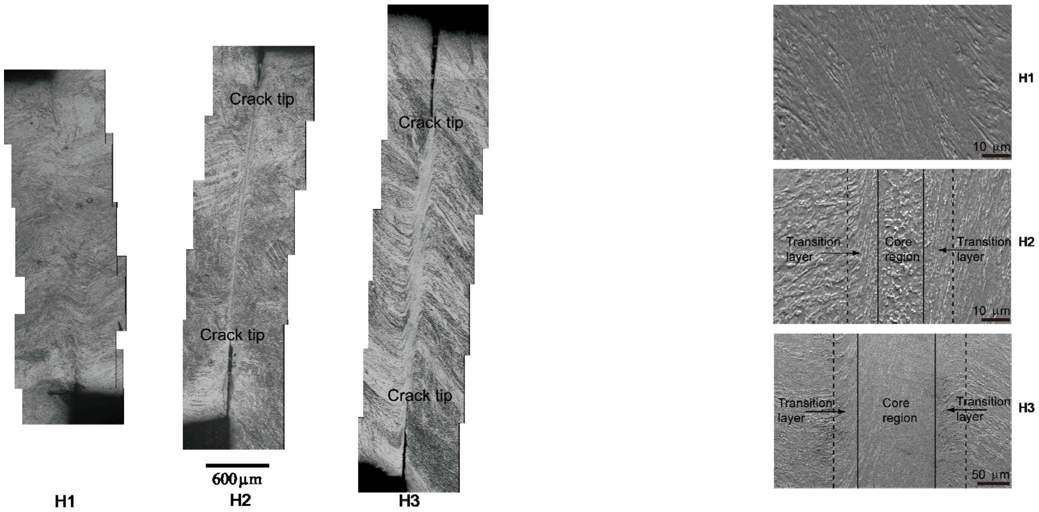
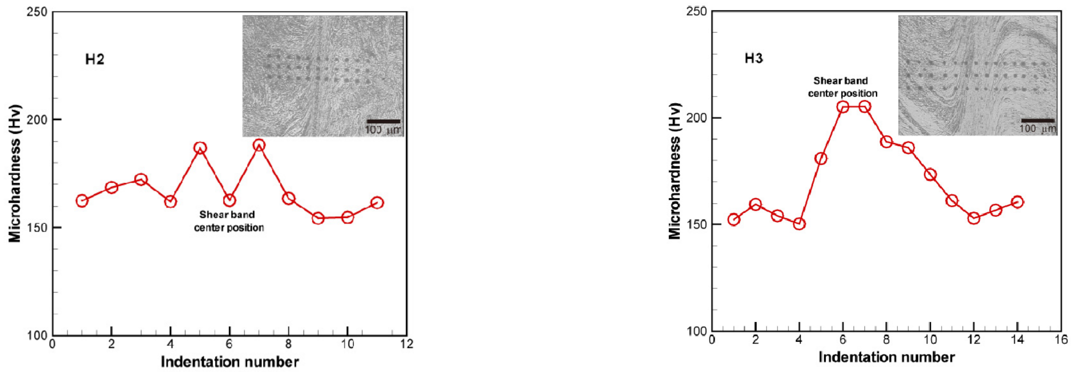
origin texture produced by ECAP is severely distorted. Increasing shear deformation leads to thickening of shear bands, which is composed of thickening of the core region by transforming the transition layers into the core region, and outward movement of the transition layers by deforming the adjoining matrix. In the thickening stage, ASB evolution is accompanied by increasing in both thickness and micro-hardness of ASB. This increasing micro-hardness in ASB indicates that grains in the shear band are further refined by severe shear deformation and temperature rise (dynamic recrystallization, DRX). Microvoids and microcracks in the shear band also coalesce into observable cracks which propagate along the shear bands with increasing shear displacement.



(a) (b)

Fig. 2: (a) Optical micrographs of half cross-section observed with increasing shear displacement (H1:0.3 mm; H2:0.8 mm; H3: 1.2 mm); (b) SEM micrographs of the shear band as observed with increasing shear displacement.



(a) (b)

Fig. 3: Vickers micro-hardness traversing an ASB (shown in inserts) for (a) H2; (b) H3.

CONCLUSIONS

In the present study, microstructure evolution of ASB in UFG Fe under dynamic shear loading was documented in detail. The results of the present paper will help us to not only understand the evolution of ASB in UFG Fe, but provide insights for improving ductility in such materials.

References

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