In situ characterization and evolution of shear band microstructures at different shear strain rates

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Abstract

The formation of adiabatic shear bands (ASBs) is a phenomenon of highly localized shear deformation in metallic materials that occurs especially at high shear strain rates. The conventional thermo-mechanical understanding focuses on the effect of thermal softening associated with energy dissipation during strongly localized plastic deformation; recent work however strongly indicates that microstructural softening, related to dynamic recrystallization, is the main mechanism that promotes ASB formation in most metals (1). Further experimental work is needed to substantiate these observations, and to clearly separate the contributions of microstructural and thermo-mechanical effects.
Several well-established shear test samples with different geometries (e.g. SCS0 (2), CFSS (3)) allow to experimentally trigger the formation of well-defined ASBs. However, an in-situ observation by digital image correlation (DIC), thermography and in-situ microstructural observations of the shear zone remains experimentally challenging due to the limited accessibility of the deformed area. In this contribution, we introduce a plane S-shaped sample made from a sheet material for the experimental investigation of ASB formation. The samples can be subjected to uniaxial compression, which leads to local simple shear deformation in a geometrically well-defined shear zone. The plane surface of this sample geometry considerably simplifies an in-situ observation of deformations by DIC as well as temperature variations by infra-red thermography during ASB formation.

We present in detail the potential of the sample geometry by considering quasi-static and dynamic experiments using both Ti-10V-2Fe-3Al and AA5754 alloys. Nominal quasi-static and dynamic strain rates up to 1000 1/s are used to produce different types of shear bands at local shear rates in the range of 0.02 1/s to 70000 1/s. Furthermore, our special experimental set-up allows to limit the deformation of the samples with low increments and high accuracy to investigate the evolution of shear band microstructures, even at high rates. We are therefore able to study the different deformation stages from initiation and propagation of shear banding to crack formation with in-situ techniques including DIC and thermography or post-mortem analyses like electron backscatter diffraction (EBSD) and micro-hardness mappings. Our experimental approach contributes to a deeper understanding of the rate-dependent mechanisms of shear bands in different metallic materials.

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