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The effect of strain rate and stress/strain state on the mechanical behavior of 301 austenitic stainless steel characterized using in-situ high-speed imaging

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Abstract

The mechanical properties and performance of metastable austenitic stainless steels are enhanced by the transformation-induced plasticity (TRIP) phenomenon, which results from strain-induced austenite-to-martensite phase transformation. This phase transformation increases the strength during deformation without compromising ductility. This combination of high strength and high ductility is attractive for various engineering applications, especially in the automotive industry, where TRIP steels provide lighter parts, reduce carbon emissions, and increase passenger safety thanks to their high energy-absorption capabilities. However, the phase transformation is a very complicated phenomenon, and it depends on several factors such as strain rate, adiabatic heating and strain/stress states. For example, the strain rate influences the formation of nucleation sites, and the local heating affects both the nucleation and growth of martensite particles. In addition, stress/strain state influences the formation and intersection of shear bands and finally the phase transformation rate. In order to identify whether austenite grains mainly transform or deform plastically under different strain rates and loading paths, this work investigates how the initial and evolving dislocation density in austenite influences the onset and kinetics of the strain-induced martensitic transformation. Because of the complexity of the strain induced phase transformation, specific and similarly sophisticated measurement methods that enable simultaneous measurements of stress, strain, temperature, phase fractions, and dislocation density are needed to characterize the mechanical response and the phase transformations. In this work, we present a new multiphysical experiment that uses high energy synchrotron X-Rays combined with optical and infrared imaging of the deforming specimen. Mechanical tests were carried out at different strain rates ranging from 10-3 s-1 to 1 s-1 in uniaxial tension, simple shear, and plane strain loading to acquire the full thermomechanical response of the material while simultaneously using in-situ XRD to observe the microstructural evolution. The developed experimental approach and the key conclusions of the recent experimental-theoretical research are presented in this study.

Keywords:

TRIP phenomenon Dislocation Density Synchrotron XRD Phase volume fractions Optical and Infrared imaging