Structural Evolution of Metals during Adiabatic Shear Banding

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Abstract

Within materials which plastically deform easily, under rather high rates of loading, adiabatic shear bands are commonly observed. These shear bands are localized regions of very large plastic deformation which can also experience a significant temperature increase. The thickness of these bands depend upon boundary conditions, but generally are 10s of μm and is impacted by the heat transfer rate away from the shear plane. Resolving adiabatic shear banding computationally has long been a challenge. With heating, the mobility of dislocations increase and mechanical softening is realized within the shear zone material. In recent years, there has been increasing evidence to suggest that a form of dynamic recrystallization occurs and contributes an additional softening mechanism. This process is believed to follow a path of rotational recrystallization which does not rely upon thermally activated mechanisms. This process however is challenging to observe experimentally due to the very rapid loading rates involved. Significant reductions in characteristic grain size are believed to occur. A new thermodynamically based model to describe the thermal softening and dynamic recrystallization process in 316L stainless steel is presented. This model is implemented computationally into a framework designed to alleviate systemic mesh sensitivity in simulations of adiabatic shear banding. Simulation results are presented which describe both development of adiabatic shear banding but also structural evolution during dynamic recrystallization during deformation. This is represented by the effective temperature model through first and second law imposed competition between dislocation accumulation/annihilation and formation of new grains. This model also affords the opportunity to naturally describe the Taylor-Quinney factor in a rigorous way which is also deformation history dependent. These results are compared against experimental results of a commonly used sample loaded dynamically in the Split-Hopkinson Pressure Bar system. Observations and remaining challenges will be discussed.