

Characterization and modeling of ductile damage accumulation in martensitic stainless steels

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The automotive industry is constantly looking for new high strength materials to improve the safety and efficiency of new vehicles. Martensitic stainless steels (MSS) are valid candidates for automotive applications as they present a good combination of tensile strength, fracture toughness and corrosion resistance. However, these steels show limited fracture strain in some cases, for instance under three point bending conditions. The fracture strain is controlled by the evolution of ductile damage as the material is plastically deformed, the initiation and propagation of ductile damage being strongly influenced by microstructural features involving the ferrite and martensite phases and the presence of carbides. For this reason a better understanding of the ductile failure mechanisms in MSS is needed. In this work, two different MSS grades exhibiting similar microstructures are studied. Samples of both grades were first heat treated at high temperature ($> 900^{\circ}\text{C}$) to get a microstructure consisting of approximately 83% of martensite, 17% of ferrite and a volume fraction of chromium carbides that depends on the MSS grade. The non-deformed microstructures were observed in optical and scanning electron microscopy, and image analysis was used to precisely quantify the volume fraction of the different phases. Uniaxial tension specimens were tested up to fracture at a constant strain rate and samples were extracted within the necking area for damage characterization. In particular, the void are fraction, void density, void size range and void orientation were measured as a function of local strain within the necking area. The interaction of damage with microstructure is assessed by metallographic observations and the effects of martensite/ferrite phase boundaries and chromium carbides on ductile damage are emphasized. Finally, a first attempt to link the microstructure to damage evolution through the development of a finite element model is presented.