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Microstructural strain memory and associated plasticity in superelastic niti under low cycle fatigue

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ABSTRACT

When cyclically loaded in tension, superelastic Nickel Titanium (NiTi) undergoes a characteristic shakedown behavior which dramatically changes its hysteretic stress–strain response. As many uses of superelastic NiTi involve cyclic loading, a detailed understanding of the interaction between phase transformation and associated plasticity is necessary to predict the lifetime behavior of NiTi devices. Earlier macroscopic studies have dealt with this phenomenon on a bulk material level, but its microstructural origin and small scale analogues remain largely uninvestigated. To that end, low cycle, low strain-rate fatigue tests were performed on superelastic NiTi sheet to examine the local damage and accumulation of plastic deformation that contribute to the evolution of its stress strain response. Local strain measured in situ with Scanning Electron Microscopy Digital Image Correlation was matched with individual microstructural features – such as individual parent grains and grain neighborhoods – measured with Electron Backscatter Diffraction. Martensitic transformation associated with superelasticity was inferred from the full-field strain maps captured each load cycle. Special attention was paid to the particular martensite variants and twinning modes that nucleate in the first cycle and their similitude to subsequent martensite transformation. In addition, cyclic behavior such as martensite retention and ratcheting, strain memory of both martensite and austenite configurations, and damage accumulation are also considered.