Shape Memory Adaptive Materials: Leveraging Digital Image Correlation to Investigate the Underlying Phase Transformation at the Macro- and Meso-Scale

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Abstract: Shape memory alloy systems (SMAs) are a class of adaptive, multifunctional, stimulus-responsive material system which can recover deformation (nearly 8x conventional ductile metals) via a solid-state phase transformation. This work explores an advanced manufacturing technique: Laser Directed Energy Deposition (LDED) additive manufacturing (AM) technology for fabricating binary NiTi SMAs. Novel NiTi SMAs referred to as Ti-rich are fabricated via LDED using elementally blended Ni and Ti metallic powder feedstock. The phase transformation occurs in a parent phase matrix crystal structure within a non-transforming host structure, comprised of composition, grains, precipitates, pores, secondary phases, etc. produced by the employed manufacturing technique. Thermomechanical experimentation is carried out to characterize the stress-induced shape memory transformation using ASTM standards reporting requirements and procedures. This work employs a technical approach that defines key descriptors that go beyond standard characterization and augments characterizing the stress-strain with full-field deformation/strain analysis using digital image correlation (DIC). The results presented here report on the strength properties and shape memory responses of the as-deposited (i.e. without post fabrication heat treatments) materials. Ultimately, the aim is to demonstrate the multiscale deformation analysis approach for understanding the nature of the underlying phase transformation mechanism interacting with the host structure that produces the measured properties and characteristic stress-strain response.