Effect of Heat Treatment on the Ultrasonic and Mechanical Response of NiTi Shape Memory Alloys

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Abstract: Shape memory alloys (SMAs) such as NiTi can recover deformation outside the elastic regime due to the reversible, thermoelastic martensitic transformation. Many parameters, such as transformation temperatures, critical stresses, and reversible strain, characterize the performance of NiTi. Heat treatments generate variation in the non-transforming host structure, such as the precipitate phases, size, and coherency, which tailor the transformation properties. Thus, these nanoscale phases contribute to bulk mechanical behavior, but linking these length scales can be difficult due to the lack of inspection protocols sensitive to both domains. This work explores UT as a complementary characterization step to spatially map ultrasonic parameters such as wave speed and attenuation in differently processed specimens. A set of hot-rolled Ni50.8Ti (at.%) parallelepipeds were prepared for inspection by solution treatment and aging. An ultrasonic immersion setup facilitated thickness-independent measurements of longitudinal wave speed and attenuation at normal incidence in a pulse-echo configuration. Using traditional characterization methods to probe the underlying structure of specimens, possible influences on the ultrasonic response are studied. Electron backscatter diffraction is used to assess grain size and morphology, allowing comparison of wave propagation to analytical estimates. X-ray diffraction, differential scanning calorimetry, and scanning electron microscopy enable conclusions about precipitate phases. The mechanical performance under compressional loading is then measured, and digital image correlation produces full-field strain contour measurements. The thermal processing resulted in changes in critical stresses, residual strains, strain localization, and transformation front spreading. Comparisons between the ultrasonic maps and strain contours suggest property-determining signatures in wave speed and attenuation. Repeating ultrasonic testing after one loading cycle yields the conclusion that residual strain, possibly attributed to plastic strain or residual martensite, is detectable through the ultrasonic response. These connections may enable researchers to better understand structure-property interactions.