Shape Memory Alloy’s Post Constrained Recovery Residual Stress (PCRRS): A Potential to a Paradigm Shift in Smart Materials

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INTRODUCTION

MOTIVATION

- Shape memory alloys (SMAs) possess unique ability to remember and recover their original shapes after being subjected to constrained recovery and returned to its low temperature martensite state.
- New investigation at UWM has revealed that Nickel Titanium (NiTi) SMAs can produce residual stresses in an unactuated state to recover the inelastic strain or to gain full actuation capabilities.

BACKGROUNG

- Recent experimentation has revealed the ability to produce continuing residual stresses in NiTi SMAs without continuous application of heat.
- This PCRRS has potential in applications like self-healing materials where residual loads that keep cracks and damage closed providing mechanical strength to the cracked structure.

OBJECTIVE

- To explore mechanical properties beyond the generation of PCRRS state by multiple mechanical experimentations to uncover the nature of PCRRS.
- To propose conceptual and comparative analysis of both traditional SMA-assisted and PCRRS-self-healing mechanism.

EXPLORATION OF PROPERTIES OF PCRRS

MATERIAL AND METHOD

MATERIALS

- Samples of NiTi wires 0.1 mm in diameter were used for experimentation.
- Ni-20% Ti eutectic alloy of 165°C melting point has been fabricated by casting process as a base matrix alloy to demonstrate the healing mechanism; reinforced with etched NiTi wires.

EXPERIMENTAL STRESS-STRAIN-THEME RHEALING relationships for NiTi exposed to different thermomechanical loading for following cases:

(a) Initial cycles of PCRRS loading path for predetermined prestained (point A) of ε_r=3.4% and resulting in PCRRS of ε_p=51.28 MPa.
(b) Samples exposed to smaller strain cycles from the PCRRS state
(c) Samples exposed to residual load reduction cycle after initial cycle from the PCRRS state

CONCLUDING REMARKS

- NiTi SMAs can generate PCRRS and this ability to actuate without application of energy will lead to a paradigm shift in intelligent material design, specially in self-healing regime.
- For every small strain cycle, PCRRS developed showed a nearly linear decreasing trend: however, full recovery of PCRRS can be attain by providing thermal loading.
- The proof concept presented herein could not only close the cracks and heal the fracture but also could inhibit future cracks to formulative compressive loads created due to PCRRS.
- Research is ongoing to characterize and to develop the theoretical modeling of PCRRS to predict the behavior in order to implement it in engineering applications.

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Schematic overview of the self-healing process in metal/SMA composite with PCRRS.
(a) SnBi eutectic matrix reinforced with pre-strained NiTi wires exposed to tensile load,
(b) Crack formation due to tensile load resulting in deformation of the NiTi wires,
(c) Compressive stress due constrained recovery after exposing to heat resulted into crack closure,
(d) Adjacent crack base healing and bonding due partial melting,
(e) Removal of heat resulted into PCRRS which creates residual load to inhibit cracks,
(f) Small strain application due fatigue (or any service load) creates the blocking force due to PCRRS without heat application which obstruct further crack propagation of healed specimen.

LITERATURE CITED

2. Haider et al.: Smart Mat. and Struct, 2019, vols. 28, pp. 105044. DOI: 10.1088/1361-6633/ab3ad4