Assessment of Interface Strength Between Shape Memory Alloy and Metal Matrix in Self-Healing Composites

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INTRODUCTION

• Self-healing materials have the potential to revolutionize engineered structures by altering the definition of mechanical failure.
• Metallic self-healing composites are of great practical interest because their mechanical properties and healing capabilities can be superior compared to polymeric or ceramic self-healing materials.
• To date, investigation into metallic self-healing material systems has been limited due to the complexity of synthesis.

MOTIVATION

• Integration of nickel titanium (NiTi) shape memory fibers into self-healing composites enables bulk geometry restoration after a fracture, a capability not present with other forms of self-healing.
• The strength of the interface between fibers and matrix is critical to optimization and the creation of strong fiber reinforced composite structures.
• A major concern for SMA reinforced self-healing materials is the non-wettability of the NiTi SMA due to the formation of very stable titanium oxide (TiO₂) on the NiTi surface.
• While many theoretical, numerical and experimental studies have been conducted to analyze NiTi fibers, very few studies have addressed NiTi-matrix interface strength.

BACKGROUND

OBJECTIVE

• Investigate the interface strength between NiTi and Metal Matrix Composite (MMC) in states with native oxide present vs. removed to quantify the change in strength resulting from removing the TiO₂ layer.

MAJOR TASKS

SAMPLE SYNTHESIS

• Two sets of specimens were created consisting of a single NiTi wire embedded in a block of Sn-20%-Bi (a self healing matrix).
• A control set with the native TiO₂ layer present.
• A test set that had the TiO₂ layer etched off.

SINGLE FIBER PULL TEST

• The matrix was held in place with a fitting while one end of the wire was pulled out using a universal test machine in displacement control mode.
• The magnitude of the force applied was recorded.
• The test was recorded via video camera for better observation and to understand failure mechanisms.

RESULTS

• Initially it was observed that several mm of displacement occurred straightening and aligning the wire.
• There is a clear difference in the load line produced by the control and test specimens.
• The test specimens, that had the TiO₂ etched off showed a stronger interface failure strength.

CONCLUSIONS & VISION

• Knowledge of the interface strength and failure modes between NiTi and Sn-20%Bi will enable design and optimization of the internal microstructure of composite materials MMCs, specifically wire/fiber diameter, to ensure proper load transfer between composite fibers and matrix to maximize strength and support self-healing capabilities.

REFERENCES

1. Haider et al.: Smart Mat. and Struct, 2019, vols. 28, pp. 105044. DOI: 10.1088/1361-665X/ab3ad4