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THERMALLY REMENDABLE COMPOSITE STRUCTURES WITH RESISTIVE HEATING NETWORK OF CARBON FIBERS

Joseph S. Riendeau[1], Timothy H. Perram[2], Steven J. Oldenburg[3], Anthony F Starr[2], H. Thomas Hahn[1], Thomas K. Darlington[3]

[1]University of California, Los Angeles, 420 Westwood Blvd, 90095, Los Angeles, CA, USA
Email: hahn@seas.ucla.edu

[2]SensorMetrix, 10211 Pacific Mesa Blvd, San Diego, CA, USA
Email: astarr@sensormetrix.com

[3]nanoComposix, 4878 Ronson Court, Suite K, 92111, San Diego, CA, USA
Email: tom.darlington@nanocomposix.com

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ABSTRACT

Carbon fiber-reinforced composites undergo subcritical damage well before final failure. A self-healing composite material is being developed to autonomously sense and repair localized damage in composite structures. Healing is accomplished via two main components. The first component is a thermally remendable polymer matrix that is integrated into the structural carbon fiber composite and has the ability to be healed with the application of heat. The second component is an addressable conducting network (ACN) that can both sense resistance changes due to damage in carbon fiber composites as well as deliver current for resistive heating to addressable locations within the composite.

Previous work on 2MEP4F composites [1] has shown that damage smaller than 1 mm can be healed spontaneously with resistive heating. The ability of carbon fiber reinforced 2MEP4F composites to heal from damage with characteristic lengths of 5 mm to 30 mm was investigated. Damage of this scale requires compressive pressure and heat to reform the reversible cross-links between the 2MEP and 4F molecules. Damage of varying severity was caused by double cantilevered beam and short beam shear testing of these mendable composites. Recovery of damage from double cantilevered beam testing was limited, but good recovery of properties after short beam shear testing was demonstrated for the composite (Figure 1). Successive healings of the composites illustrate that properties can be recovered multiple times with only a small decrease in healing efficiency.

The ability of the electrical resistance change method (ERCM) to detect damage and healing for a self-healing composite was investigated. Short beam shear testing was used to induce delaminations on 2MEP4F mendable carbon fiber composites. Oblique resistance, resistance through the thickness, was measured during the loading of samples. The occurrence of a delamination was detected in each sample by a sharp increase in resistance. After damage occurred inside the sample, the relationship between resistance and strain is altered due to the change in contact of fibers across the delamination surface. An average resistance change of ~8.9% at zero strain after damage allows the facile detection of a delamination, even after multiple rounds of damage and healing (Figure 2). This work suggests that ERCM is able to detect a change in the damage mechanism or microstructure of the composite. Further investigation is necessary to understand the relative effect of each change in microstructure on the resistance of 2MEP4F laminates. This work has shown that ERCM serves as an effective health monitoring tool for self-healing composites and allows for the detection of damage, damage mechanism, and healing over multiple repair events.

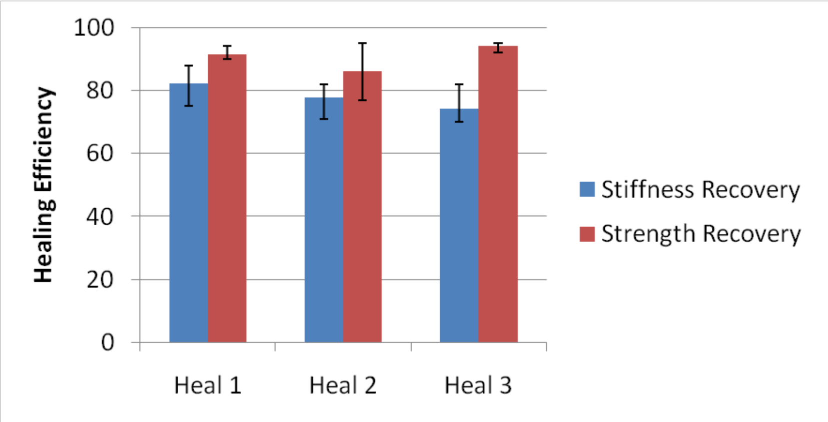

Figure 1: Stiffness recovery and strength recovery for 2MEP4F composites damaged in short beam shear testing and healed multiple times. Data shown are the average +/- standard deviation for three samples.

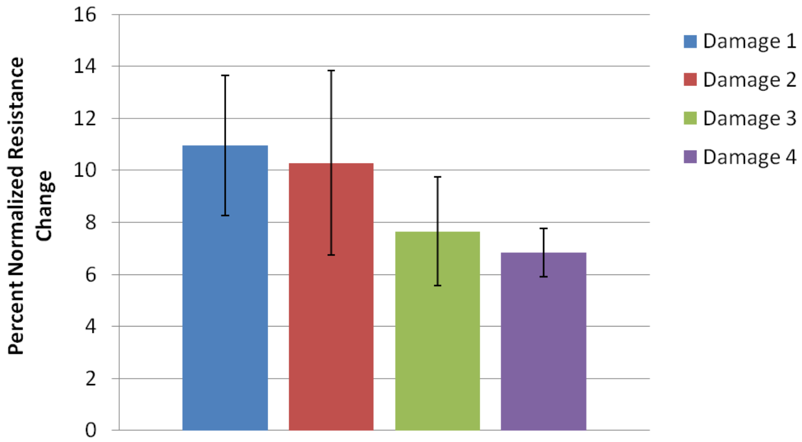

Figure 2: Percent increase of resistance at zero strain after each round of damage. Data shown are the average +/- standard deviation for three samples.

This technology provides a solution to the serious problem of detecting and repairing impact, delamination and microcracking damage in aircraft and vehicles. The ability to monitor the health as well as address structural issues remotely will provide an unprecedented ability to maintain inaccessible composite structures such as satellite and space vehicles.

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REFERENCES

[1] J. S. Park, T. Darlington, A. F. Starr, K. Takahashi, J. Riendeau, and H. Thomas Hahn, "Multiple healing effect of thermally activated self-healing composites based on Diels-Alder reaction," *Composites Science and Technology*, **70**, 2010, pp. 2154-2159.