SELF-SEALING OF MICROCRACK DAMAGE IN STRUCTURAL FIBER REINFORCED COMPOSITES

Jericho L. Moll[1], Chris L. Mangun[2], Scott R. White[3] and Nancy R. Sottos[4]

[1]University of Illinois at Urbana-Champaign, Department of Materials Science and Engineering,
1304 W. Green St., Urbana IL, 61801, USA.
Email: jericho.moll@gmail.com

[2]CU Aerospace
2100 South Oak St., Suite 206, Champaign IL, 61820, USA.
Email: cmangun@cuaerospace.com

[3]University of Illinois at Urbana-Champaign, Department of Aerospace Engineering,
104 S Wright St., Urbana IL 61801, USA.
Email: swhite@illinois.edu

[4]University of Illinois at Urbana-Champaign, Department of Materials Science and Engineering,
1304 W. Green St., Urbana IL, 61801, USA.
Email: n-sottos@illinois.edu

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ABSTRACT

Fiber reinforced composite tanks provide a promising method of storage for liquid oxygen and hydrogen for aerospace applications. The inherent thermal fatigue of these vessels leads to the formation of microcracks, which allow gas phase leakage across the tank walls. Self-sealing functionality provides a potential solution to this problem. In this work, we adopt a dual microcapsule healing chemistry comprised of silanol terminated poly(dimethyl siloxane) plus a crosslinking agent and a tin catalyst, which are? stable to 150^{0}C. The microcapsules are incorporated into a woven glass fiber/epoxy composite, which is processed at a temperature of 120^{0}C to yield a glass transition temperature of T_g = 130^{0}C. The composites are damaged by cyclic loading of an indenter tip on opposing surfaces of the samples. As a crack propagates through the material, microcapsules rupture and release the monomer, crosslinker, and catalyst, triggering polymerization in the crack plane. Self-sealing ability is investigated for composites with two different microcapsule sizes and concentrations The success rates for sealing are summarized in Figure 1. Incorporation of a lower volume fraction (9%) of larger (41 µm) capsules or a higher volume fraction (11 %) of smaller (25 µm) capsules into the composite matrix leads to 100% of the samples sealing after 30 minutes at 275 kPa.

We have have successfully integrated microcapsules in a $[0/90]_s$ uniweave carbon fiber/epoxy composite. Figure 2 shows crack damage that was introduced by thermal cycling from liquid nitrogen (-196^{0}C) to elevated temperature (90^{0}C) multiple times. Cracks accumulate with increasing cycles. Over time, the ply damage connects, causing a percolating crack network from one side of the composite to the other, resulting in a gas permeable specimen. Crack damage accumulation and the corresponding changes in sample permeability are measured with increasing number of thermal cycles for both self-sealing and traditional non-self-sealing composites.

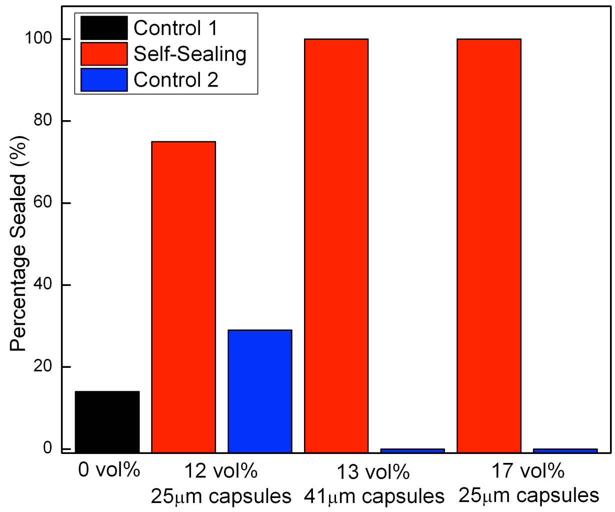

Figure 1. Success rate for sealing mechanical damage with a thermally stable sealing chemistry.

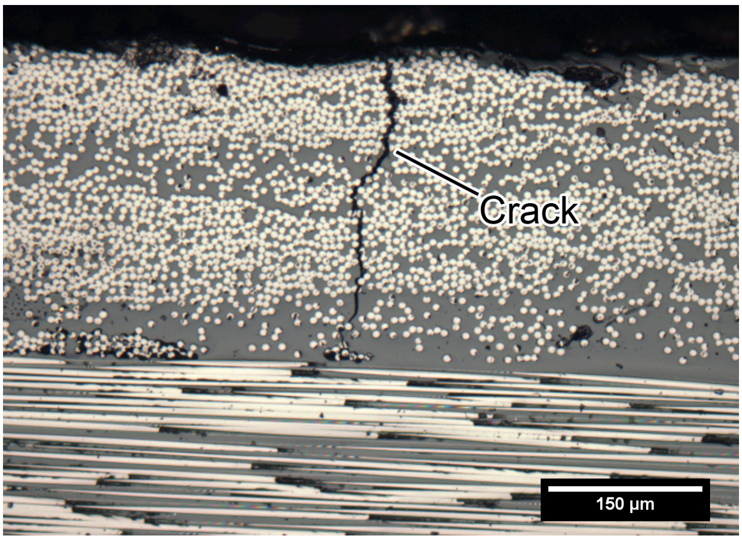

Figure 2. Crack in a carbon fiber/epoxy composite formed as a result of thermal cycling.