Self-Healing Materials for Mitigation of Blast Damage

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Abstract

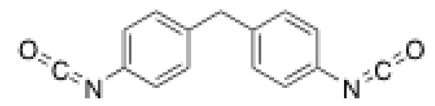
A microvascular-based approach is adopted to autonomously repair blast damage in structural sandwich panels. Self-healing materials are inspired by living systems, in which minor damage (e.g., a bump or bruise) triggers an autonomic healing response. We successfully introduce vasculature into both the foam core and the woven fiber reinforced composite face sheets. Preliminary experiments demonstrate the potential for full recovery (100%) of fracture properties in the foam core. Work is in progress to achieve healing in the composite face sheets.

Relevance

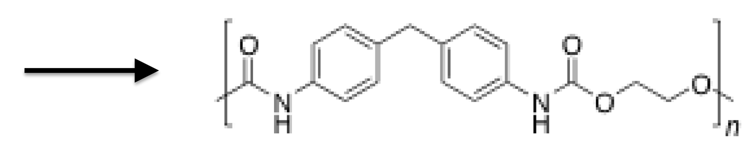
While external armor is designed to absorb the primary energy from a blast, significant damage also occurs deep within a structure. This secondary damage can impair function and lead to failure even if the structure survives the initial explosion. Autonomic healing of this secondary damage can significantly improve reliability and safety by providing recovery of structural integrity. We are pursuing a bioinspired microvascular strategy[4] that offers the advantages of a virtually unlimited supply of healing agents in addition to the capability of recovery from multiple injury events. Our approach is transferable and consists of modifying components of a commercial composite sandwich panel shown to exhibit superior performance in recent shock tube experiments.[2] Energy is absorbed through anticipated failure mechanisms and recovered for subsequent loading cycles.

Technical Approach

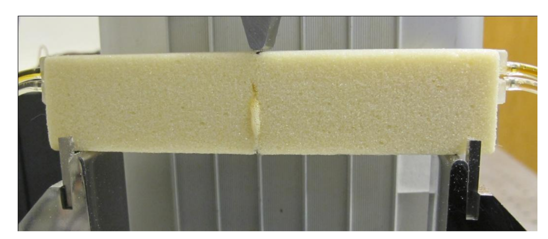
Self-Healing Polymer Foam

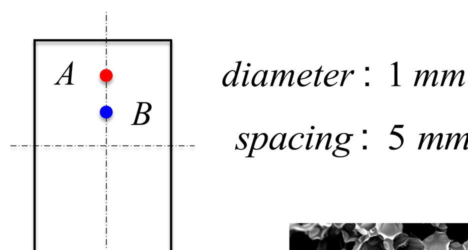


Part A - (MDI) + Part B - (Polyol) + catalysts, surfactants, blowing agents

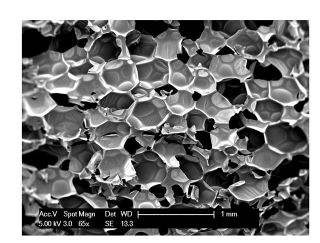


Polyurethane (PUR) foam

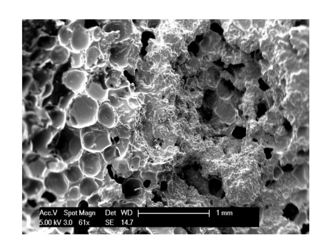




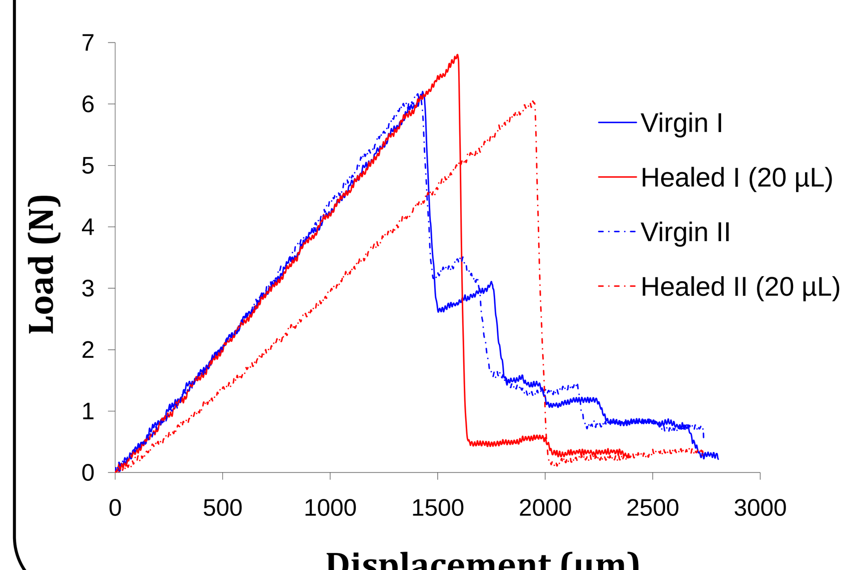
Dual-Channel 3pt. Single Edge Notched Bend (SENB) Specimen



Virgin Material



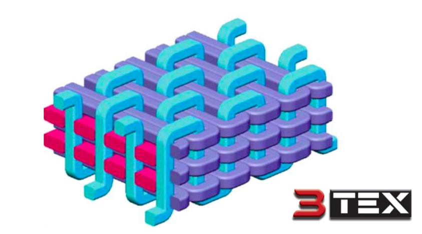
Healed Fracture Plane



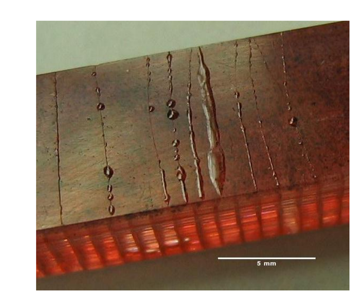
Can achieve 100% recovery in fracture properties!

Composite Sandwich Panel[2] for Blast Protection

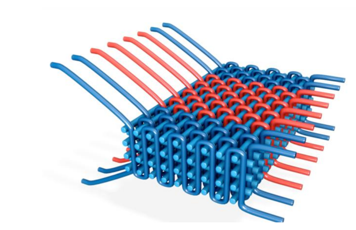
Polyisocyanurate (PIR) Foam Core

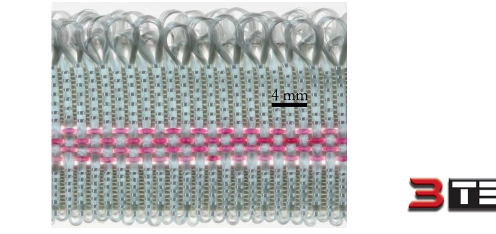


3D Woven Composite Face Sheets

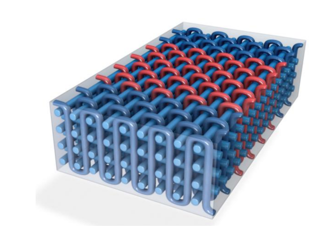


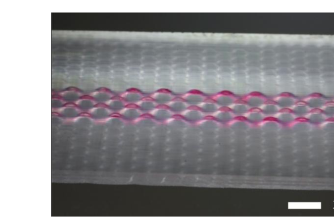
Bioinspired Microvascular Healing[3,4]



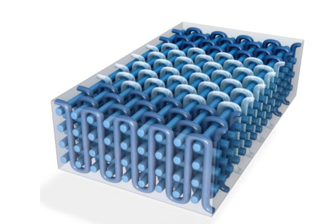


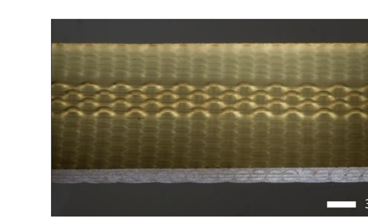
1. Catalyst treated polylactide (PLA) monofilament woven into 3D glass fiber preform



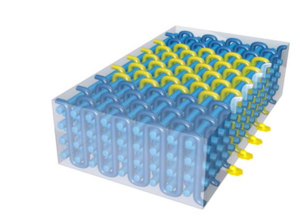


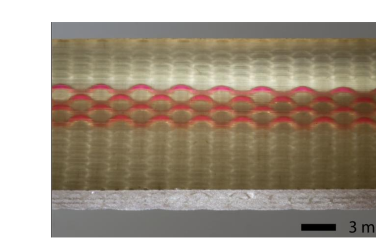
2. Composite fabrication using Vacuum Assisted Resin Transfer Molding (VARTM)





3. PLA evacuation by heating high T_g composite at 210 C for 48 hrs under vacuum





4. First 3D microvascular fiber-reinforced composite capable of fluid transport for self-healing

Accomplishments Through Current Year

We have developed materials and techniques[1] for the fabrication of 3D microvascular fiber-reinforced composites, providing a conduit for self-healing applications. Microvascular healing was successfully demonstrated in a rigid, structural foam using an expansive polyurethane (PUR) chemistry, ideally suited for large damage volumes.

Future Work

We intend to demonstrate the self-healing functionality of 3D microvascular fiber-reinforced composites. Once the distinct, self-healing capabilities of the foam core and composite face sheet components are established, a fully integrated structural sandwich panel will be fabricated and evaluated through shock tube testing at the University of Rhode Island.

Opportunities for Transition to Customer

Our self-healing systems have been designed around pre-existing sandwich technology and thus, are easily amendable to commercialization. An industrial partner, 3TEX, Inc., was responsible for weaving the 3D fiber preforms in both the existing[2] and newly developed microvascular[1] composite face sheets. The PIR foam core material is the same product found in the existing sandwich panel. The PUR healing agents are a commercially available 2-part system.

Patent Submissions

"Micro-Vascular Network Materials and Composites for Forming the Materials,"

University of Illinois Invention Disclosure (2011)

Publications Acknowledging DHS Support

[1] Esser-Kahn, et al. Three-Dimensional Microvascular Fiber-Reinforced Composites , *Submitted,* (2011).

Other References

[2] Tekalur, et al. Shock loading response of sandwich panels with 3-D woven E-glass composite skins and stitched foam core , *Composites Science and Technology*, **69**, 736-753, (2009).

[3] White, et al. Autonomic healing of polymer composites, *Nature*, **409**, 794-797, (2001).

[4] Toohey, et al. Self-healing materials with microvascular networks, *Nature Materials*, **6**, 581-585, (2007).