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SELF HEALING OF IMPACT DAMAGE IN TWO AND THREE-DIMENSIONAL WOVEN GLASS FIBER COMPOSITES

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ABSTRACT

Fiber-reinforced composites exhibit excellent in-plane mechanical properties and high specific strength, but are particularly prone to damage from out-of-plane impact events. Embedded microcracks and delaminations that occur from impact are often difficult to assess and expensive to remedy. An alternative method of self-repair based on a two part microcapsule system utilizing a dicyclopentadiene (DCPD) monomer in conjunction with first generation Grubbs' catalyst has been previously reported [1]. Autonomic recovery of two-dimensional (2D) fiber-reinforced composites using this microcapsule based system has also been demonstrated by Patel and co-workers [2]. We discuss, herein, methods for fabrication, introduction of low-velocity impact damage, assessment of impact damage, and mechanical self-recovery of three-dimensional (3D) woven glass fiber reinforced composites containing a microcapsule based healing system.

Fabrication methods for self-healing 3D woven glass fiber composites containing urea-formeldehyde (UF) encapsulated wax microspheres with 10 wt% first generation Grubbs' catalysts and UF encapsulated endo-dicyclopentadiene (DCPD) microcapsules are reported. Fabrication methods employ the use of an aqueous impregnation suspension and nip rollers for insertion of the capsules into the three-dimensional glass woven preform followed by infusion of resin with a vacuum assisted resin transfer moulding (VARTM) process. Optical imaging of the composite cross section indicates a heterogeneous distribution of microcapsules, with a high concentration of capsules focused in resin rich regions of the composite (figure 1).

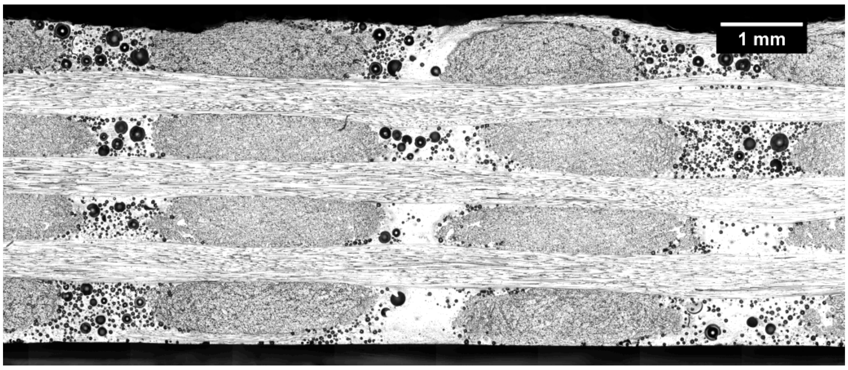

Figure 1. Tiled optical image of 3D woven glass fiber reinforced composite containing UF encapsulated first generation Grubbs'-in-wax microspheres and UF encapsulated DCPD microcapsules

Qualitative and quantitative damage characterization of 3D woven glass fiber composites subjected to low-velocity impact events is also investigated and contrasted with previous work using 2D woven systems [2]. Qualitative imaging techniques demonstrate that composites containing a 3D architecture exhibit inherent toughening mechanisms in the form of delamination bridging and deflection. Quantitative analysis reveals that at higher impact energies 3D panels show less total delamination length, less delamination cross-sectional area, and less delamination separation when compared to 2D woven panels.

Additionally, a new testing protocol for evaluation of mechanical properties of woven composites subjected to impact events is presented. This new flexure after impact (FAI) protocol employs the use of a Charpy impact tower in conjunction with a double cantilever clamped composite beam specimen to introduce damage. Mechanical self-healing of 3D woven composites is reported using the FAI protocol. In general, four point FAI testing of the 3D composite with microcapsules containing healing components shows minimal recovery of stiffness and strength when compared to control samples.

Minimal recovery of mechanical properties in 3D composites is attributed, in part, to the heterogeneous distribution of microcapsules. This heterogeneous distribution leads to fiber tow overlap regions which are devoid of healing agents and catalyst. Since delamination is the primary damage mode and these delaminations tend to occupy space in tow overlap regions where no capsules exist, mechanical recovery is severely hindered.

More recently, 3D composites containing a network of microchannels have been developed as a method of introducing healing agent to all areas of the composite architecture and overcome the shortcomings of the microcapsule based system. Fabrication methods are briefly discussed.

REFERENCES

[1] S.R. White, N. R. Sottos, J.S. Moore, P. Geubelle, M.R. Kessler, E.N. Brown, S. Suresh, and S. Viswanathan. Autonomic healing of polymer composites. *Nature*, 409:794-797, 2001.

[2] Patel, AJ. Sottos, NR. Wetzel, ED. White, SR. Autonomic healing of low-velocity impact damage in fiber-reinforced composites, *Composites: Part A,* **41**, 2010, p. 260-368.