VASCULAR SELF-HEALING COMPOSITE SANDWICH STRUCTURES

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Sandwich structures offer very high specific flexural stiffness by using high performing skin materials, such as glass or carbon fibre composite, separated by a lightweight core. This makes them an attractive design option in aerospace and marine applications. Resistance to sub-critical damage events such as impact continues to be a concern in composite laminates and sandwich structures. Impact damage can severely degrade mechanical properties [1]. For instance, in a sandwich structure residual flexural and compressive strength can be reduced by between 25% and 75%. Impact damage to sandwich structures typically consists of a region of skin-core disbonding with core crushing and a void under the impacted face [2, 3].

In general, a structure can be made damage tolerant by using higher factors of safety. Another philosophy would be to take a biologically inspired approach and make the material multifunctional by incorporating a self-healing ability. Several self-healing methodologies have been applied to composite materials to date. Both a microencapsulated monomer and dispersed catalyst approach [e.g. 4,5] and hollow glass fibres that break under impact damage [e.g. 6,7] are limited by the available volume of healing agent which cannot be easily replenished. Alternatively, polymers with the ability to break and e-bond at elevated temperatures [8,9] require external feedback to sense damage and stimulate the healing.

The approach taken in this study has been to create a simple vascular network, consisting of channels approximately 1.5mm in diameter, within a polymethacrylimide (Rohacell) core capped with glass fibre reinforced epoxy skins to give a component which appears as a conventional sandwich structure. Simulated impact damage has been introduced into beam specimens of this material, producing face-core debonding and core crushing. A pre-mixed two-part epoxy resin system was injected into the vascular network and the strength of undamaged, damaged and healed specimens assessed via four-point bend testing according to ASTM C393. The specimen geometry was modified to promote two different failure modes, core shear and compressive face failure. The requirements and drivers for healing network layout, the healing medium and recovery of mechanical properties are discussed. The intention is to demonstrate the potential for a self-healing system consisting of a recirculating healing agent within a vascular network. The work to-date provides the basis for ongoing studies to develop a circulating network using a healing agent which takes advantage of alternative mechanisms of polymerisation and offers improved operational life.

References

[1] Abrate S. 1997. *Applied Mechanics Reviews*. **50**. 69-82.
[2] Shipsha A, Hallstrom S, Zenkert D. 2003. *Journal of Sandwich Structures*. **5**. 7-31.
[3] Shipsha A, Zenkert D. 2005. *Applied Composite Materials*. **12**. 149-164.
[4] White SR, Sottos NR, Geubelle PH, Moore JS, Kessler MR, Sriram SR, Brown EN, Viswanathan S. 2001. *Nature*. **409**. 794-797.
[5] Brown EN, White SR, Sottos NR. 2005. *Composites Science and Technology*. **65**. 2474-2480.
[6] Bleay SM, Loader CB, Hawyes VJ, Humberstone L, Curtis PT. 2001. *Composites A*. **32.** 1767-1776.
[7] Pang JWC, Bond IP. 2005. *Composites Science and Technology*. **65**.1791-1799.
[8] Chen XX, Dam MA, Ono K, Mal A, Shen H, Nutt SR, Sheran K, Wudl F. 2002. *Science.* **295**. 1698-1702.
[9] Hayes SA, Jones FR, Marhiya K, Zhang W. 2005. *Proc 15th International Conference on Composite Materials,* Durban, South Africa, 27 June-01 July 2005.

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