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THERMALLY ACTIVATED HEALING IN A MENDABLE RESIN USING A NON WOVEN EMAA FABRIC

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ABSTRACT

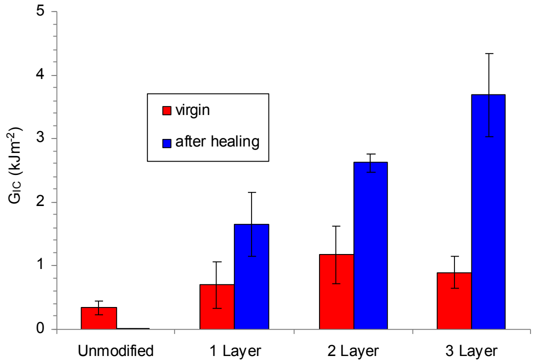
Thermoplastic modifiers as healing agents for composite materials are an alternative strategy that with some advantages over the more common micro-encapsulation approach of composite healing. They are simple to implement, repeatable over a number of damage events and can be indefinitely dormant until required. However, the fundamental challenge to this intrinsic healing approach is that the thermoplastic must be stable during fabrication yet still able to be activated externally afterwards, differentiating themselves from other autonomous methods. Meure et al (2010) first introduced the use of poly(ethylene-*co*-methacrylic acid) (EMAA) as a novel thermoplastic healing agent to [1,2,3] develop a novel mendable composite system when combined with an epoxy matrix. The mechanism originates from chemical reactions between the carboxylic acid groups in the thermoplastic and the epoxy resin during cure to produce a pressure delivery healing mechanism when thermally activated. Healing efficiencies of over 100% could be achieved according to mode I fracture toughness. The work presented here, continues to explore the robustness of this mechanism with respect to different modes of deformation and form of the healing agent. Instead of using a woven fabric as per previous work [3], a non-woven mesh of varying areal densities has been used, imitating successful interlayer toughening strategies [4,5,6] and its potential application to a manufacturing environment. The healing mechanism has been evaluated using mode I (crack opening) and mode II failure (shear) as well as repeated impact damage using a high speed falling weight.

The impact of varying concentrations (number of layers) of EMAA mesh on the mode I recovery is illustrated in Figure 1 showing the high levels of G_{IC} recovery which increases with increasing EMAA. These results compare well with the woven form of EMAA [3] reported previously and suggest that healing is unaffected by the form of EMAA used, whether woven or non-woven. SEM investigation of the fracture surfaces indicates that the pressure delivery mechanism is the primary mode of healing. This is evidenced by the thin film of EMAA on the surface of the fibres, extensive ductile tearing of the EMAA and the appearance of bubbles within the EMAA.

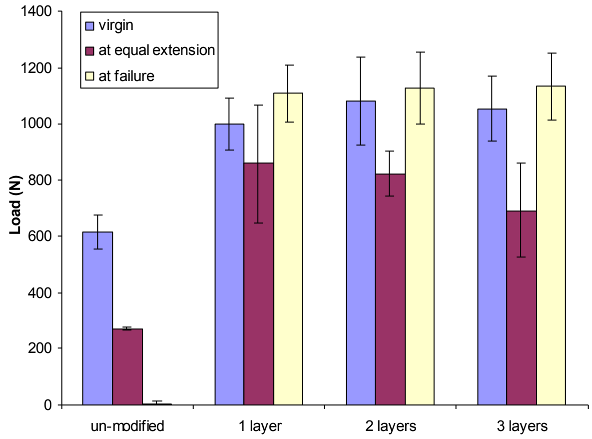
Figure 1 b) show the level of recovery in load and modulus when failed in shear of Mode II. As can be seen, recovery is very high, varying from 80% to over 100% depending on how recovery is measured. Also illustrated is the dual advantage of using thermoplastic healing agents, in that strength and toughness of the laminate is increased, while imparting adaptive behaviour. Though not as high as the load, the recovery in modulus also shows that it can be recovered significantly.

Restoration of impact strength after repeated impact is complex given likely fibre damage and the inability to ensure intimate contact during healing. The plot of the peak load versus number of impacts for the singly healed laminates after 5 and 20 repeated impacts is shown in Figure 2. Interestingly the peak load decreases exponentially with increasing impact, but after healing the load shows no recovery but decreases again sharply. However with continued impacting, the load becomes more stable and resists further reduction. Embedding the thermoplastic healing agent in top three layers has not been

able to restore impact properties, but it does greatly mitigate further damage that would otherwise not occur. Despite the overall lack of improvement in properties, the pressure delivery mechanism continues to operate. This is shown in Figure 2b) where large bubbles can be observed.



a)



b)

Figure 1. a)Mode I fracture toughness measurements before and after healing. b) restoration of peak load subsequent to mode II failure.

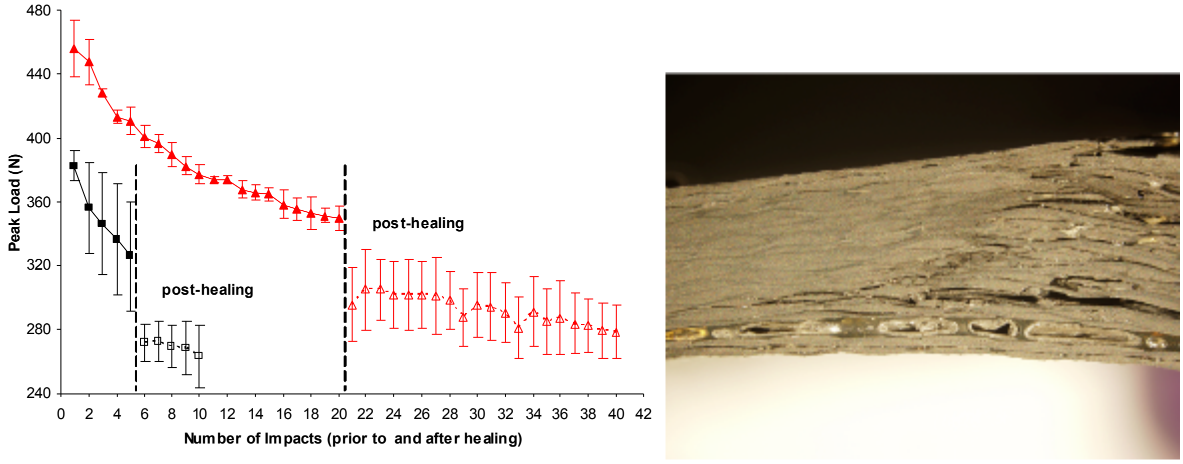


Figure 2. Load versus number of impacts for experiment 1 (5 impacts) and 2 (20 impacts) showing the behaviour before and after healing.

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