Detection of delamination healing of a thermoplastic ionomer interlayer in a model CFRP composite by advanced ultrasonic techniques

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One of the major disadvantages of the use of fibre reinforced polymer composites (FCRPs) is that they are highly susceptible to impact events, leading to barely visible impact damage and delaminations which can ultimately result in catastrophic failure. The use of thermoplastic interlayers in between the composite plies is one of the possible strategies to improve the impact resistance and fracture toughness of FPRCs. A further, barely explored, advantage of such thermoplastic interlayers is that they can be made from intrinsically self-healing polymers thereby increasing the overall lifetime of the composites. However, as long as self-healing interlayers for CFRPs are in their development stage, there will be a need to non-destructively monitor the extent of delamination and internal damage in a quantitative manner. And even though this requirement seems evident, the amount of studies that investigate the self-healing behaviour of composite materials with non-destructive testing (NDT) is still rather limited.

This work reports on a comparative study on the detection of healable delaminations in model CFRP sandwich composites by ultrasonic non-destructive techniques and destructive compression testing. A thermoplastic ionomer was selected to serve as the interlayer due to its good processing, impact absorbing and self-healing characteristics. During the production of these CFRP-ionomer composites, synthetic delaminations of various areal dimensions, 250 to 1600 mm^2, and nature, CFRP-ionomer and ionomer-ionomer interfaces, were introduced.

The extent of the synthetic delaminations and the healing thereof was monitored by both air and water coupled ultrasonic transmission C-scan experiments as well as by the monitoring of the local defect resonance (LDR). All ultrasonic techniques employed show that healing starts from local points of contact which then grow into larger zones of healed area. To illustrate this, Figure 1 shows the delaminated area within the ionomer interlayer as a function of the accumulated healing time at 100°C for two different sized initial, as determined by water coupled ultrasonic (WCU) transmission C-scanning. The figure shows that there is a certain minimal healing time before the healing becomes detectable and that this minimal time is longer for the larger diameter delamination. The figure shows that in both cases the healing for long annealing times has not led to complete disappearance of the delamination as some ultrasonic scattering centres remain at the delamination site.

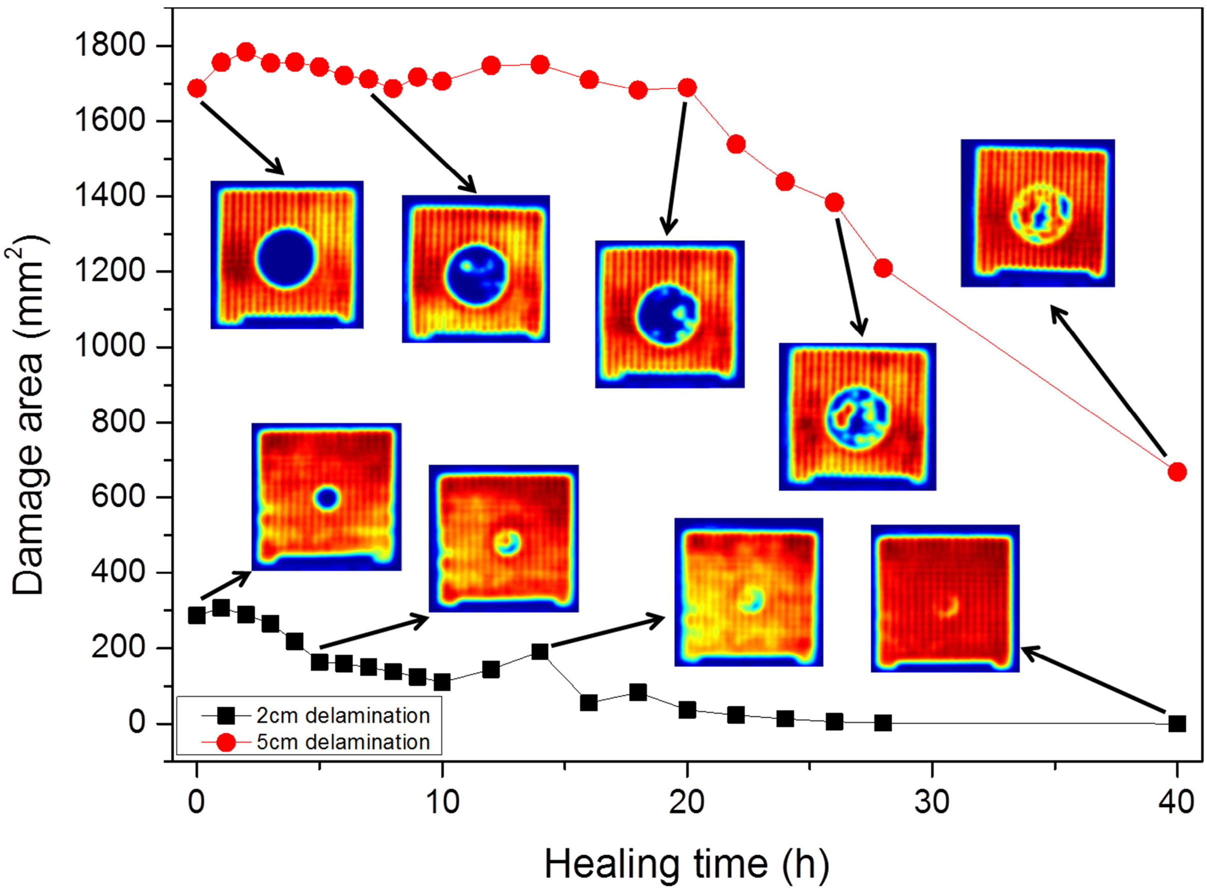

Figure 1 Delaminated area as function of the accumulated healing time at 100 °C for both the 5 cm and the 2 cm diameter initial ionomer-ionomer delaminations, as determined by WCU.

Furthermore, it was found that the LDR approach can be used to detect the early stage recovery of the delaminations while ultrasonic C-scanning techniques are very effective to determine the extent of healing in the final stages of the repair process. In addition, the experiments revealed that LDR only detects delaminations between the CFRP-ionomer interface but internal delaminations in the ionomer interlayer are not 'seen' by this technique. Finally, Figure 2 shows that for the large delaminations explored in this study, a linear relation can be observed between the delaminated area measured with ultrasonic transmission C-scanning and the compressive failure strength that is obtained by destructive testing. This correlation indicates that the contribution of the healed delamination to the compression strength equals that of the pristine interlayer.

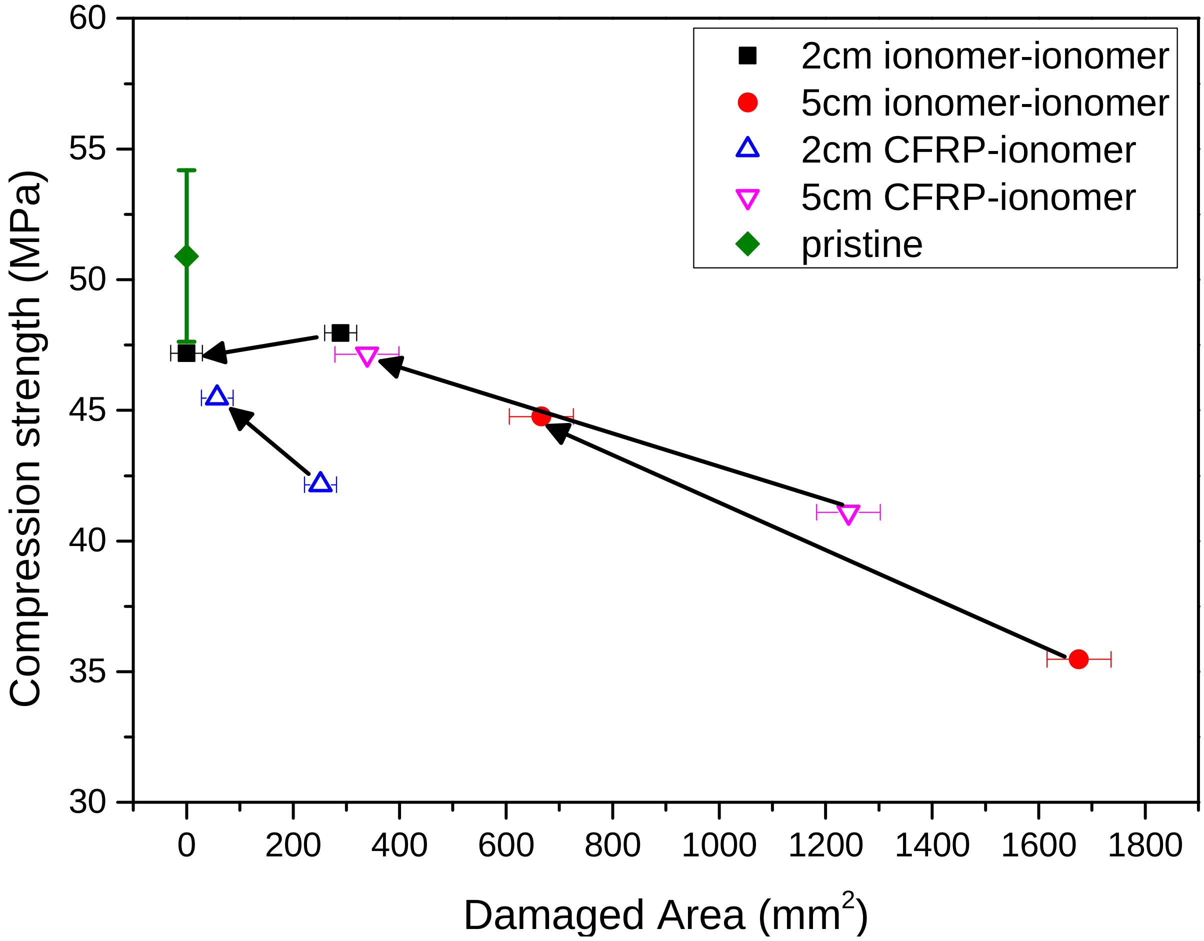

Figure 2 Relation between the compression strength and the delaminated area for the CFRP-ionomer composites tested. Results prior to thermal healing and after the full sequence of healing steps are shown for two different types of delaminations and two different initial sizes. Arrows indicate the effect of the thermal healing treatment (40 hours at 100°C, with intermittent stops).