

ASSESSING THE REPAIRABILITY OF GLASS FIBRE REINFORCED VITRIMER MATRIX COMPOSITES AFTER DELAMINATION AND IMPACT

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ABSTRACT

Glass fibre reinforced polymers (GFRPs) enable the design and realisation of wind blades that would have been unfeasible with metals [1]. However, the extensive adoption of GFRPs resulted in a troubling composite waste increase, arising from manufacturing and from end-of-life (EoL) structures, either because of design limit or unrepairable damage [2]. The application of the circular economy principles [3] is impeded by the irreversible molecular bonds' nature of conventional thermoset matrices. EoL GFRP structures can be remanufactured or repurposed into new products [4] or reprocessed into cement kilns [5]. However, their repair is only possible if the damaged area is removed and substituted with a new material patch [6]. The development of vitrimers has enabled the creation of inherently repairable composites. In the event of damage confined to the matrix, such as delamination, the adaptive nature of the covalent bonds allows to restore of material continuity through the application of heat and pressure.

This paper presents an investigation into glass fibre reinforced vitrimer matrix composite (GFRV) laminates repairing efficiency, with focus on delamination damage induced by mode I and mode II loading and by impact. In light of previous studies [7,8,9], VITRIMAX T130TM, produced by Mallinda Inc, was selected as matrix. This is an epoxy-based resin combined with an amine-terminated oligomer with embedded imine hardener. A 160 g/m², 1/1 twill woven E-glass fibre fabric was selected as reinforcing material due to its translucence and effective impregnation capability. Given the high viscosity and the short gel-time of the resin, panels were prepared, including PTFE inserts when needed, by hand lay-up to ensure uniform and complete impregnation. The panels were then cured by closed mould hot pressing at a temperature and pressure of 180°C and 14 bar. The specimens were waterjet cut to the required dimensions, and, where necessary, tabs were bonded using high temperature resistant epoxy. Preliminary tensile and three-point bending tests were conducted following ASTM standards 3039 and 7264, while the mode I and II delamination was induced following ASTM standards 5528 and 7905. The impact behaviour was investigated according to ASTM standard 7136, utilising energies of 8J and 12J to avoid severe and extensive fibre damage. Additionally, undamaged, damaged and repaired specimens were subjected to compression after impact (CAI). The delamination damage was repaired by subjecting the specimens to a temperature of 150°C and pressure of 3.5 bar for 15 minutes.

The produced GFRV, with a fibre volume fraction of approximately 27.5%, exhibited a tensile stiffness of 13.7±0.2 GPa and a strength of 207±8 MPa. The repairing efficiency (*RE*) of the GFRP subjected to bending, delamination and impact is defined as P_R/P_V (%), where P_V and P_R are the pre- and the post-repair property values, respectively. The resulting *RE* values are presented in Figure 1. It can be

concluded that, overall, the use of a vitrimeric matrix allows for the restoration of composite material performance to a significant extent, provided that the fibres are not severely damaged.

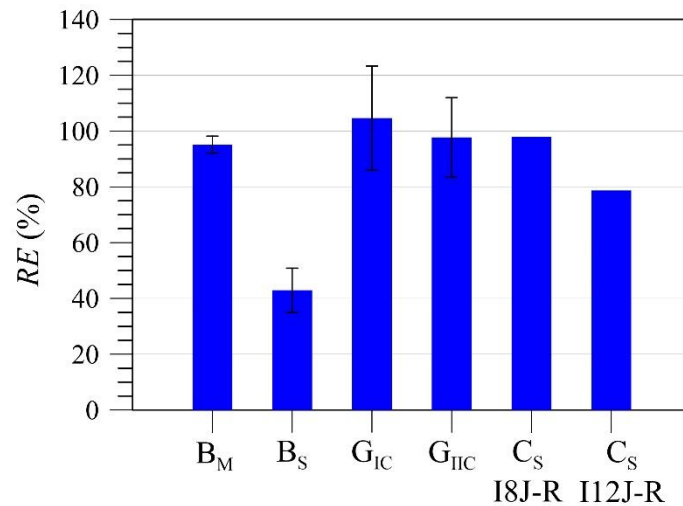


Figure 1: Repairing Efficiency (RE) of the material GFRP subjected to bending (B_M and B_S are the bending modulus and strength), delamination (G_{IC} and G_{IIC} are fracture toughness for mode I and mode II) and compression after impact and after repair (C_S -I8J-R and C_S -I12J-R are the compression strength after impact with energy 8J and 12J).

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