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Toughening and Self-diagnostic Carbon Nanotubes Interleave Manufactured from Industrial Masterbatch

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Introduction

- Fiber reinforced composites are widely used in increasing quantities in various applications because of their excellent in-plane mechanical properties. However, they suffer from poor out-of-plane properties, which result in delamination which reduces the strength and stiffness, affecting the overall performance of composite structure and possibly leading to a catastrophic failure.
- Due to this, recently a lot of interest has been received on developing a modification method to address the delamination problem and also to offer an additional possibility of self-diagnostic and *in-situ* damage monitoring of delamination in-service.
- Here, we present a nanoscale modification by industrially available carbon nanotubes (CNTs) masterbatch to solve the problem of delamination and presents with an additional capability to perform self-diagnostic and monitoring fracture of composite laminate in Mode I loading.
- Compared to conventional methods of introducing CNTs into laminate, the application of industrially available masterbatch is scalable, provides safer handling and cleaner production, easier manufacturing as pre-dispersed form of CNTs gives mixing consistency and stability.

Experiments

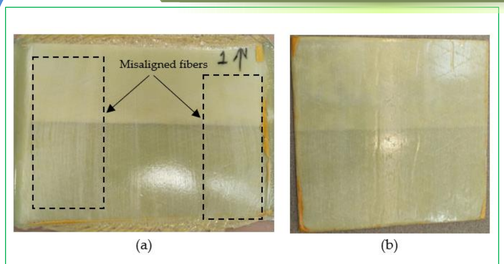


Fig.1. Composite laminate fabricated by press molding (a) without frame (b) with frame support

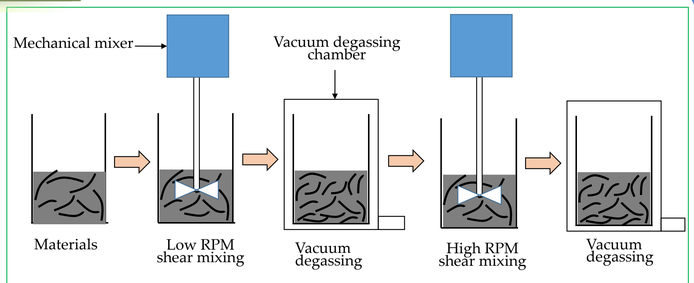


Fig.2. Schematic representation of mixing masterbatch to produce interleaves.

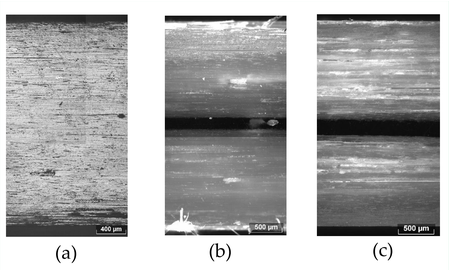


Fig.3. Optical microscopic image of (a) baseline (b) LC interleaved (c) HC interleaved laminates.

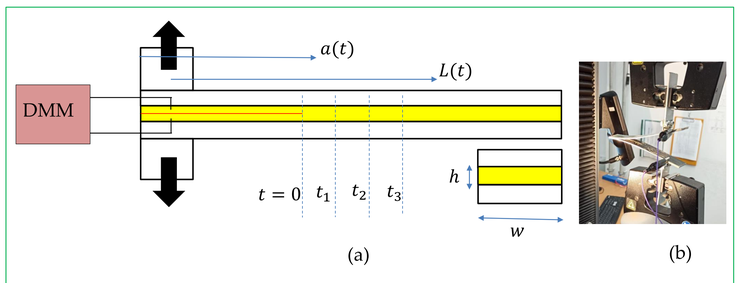


Fig.4. Conductivity test during Mode I DCB test (a) schematic diagram (b) experimental setup.

Two types of interleaves with low concentration (LC) and comparatively high concentration (HC) of CNTs were produced and interleaved in the baseline unidirectional glass fiber prepreg composite laminates produced by press molding.

Results

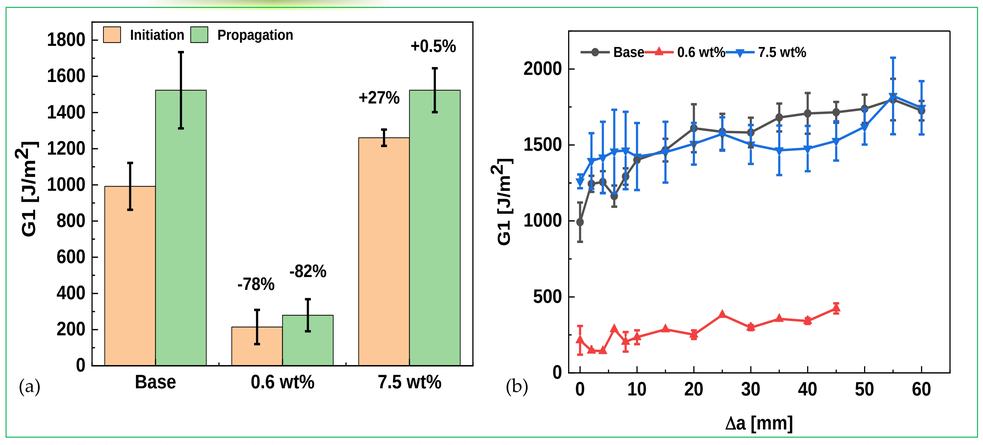
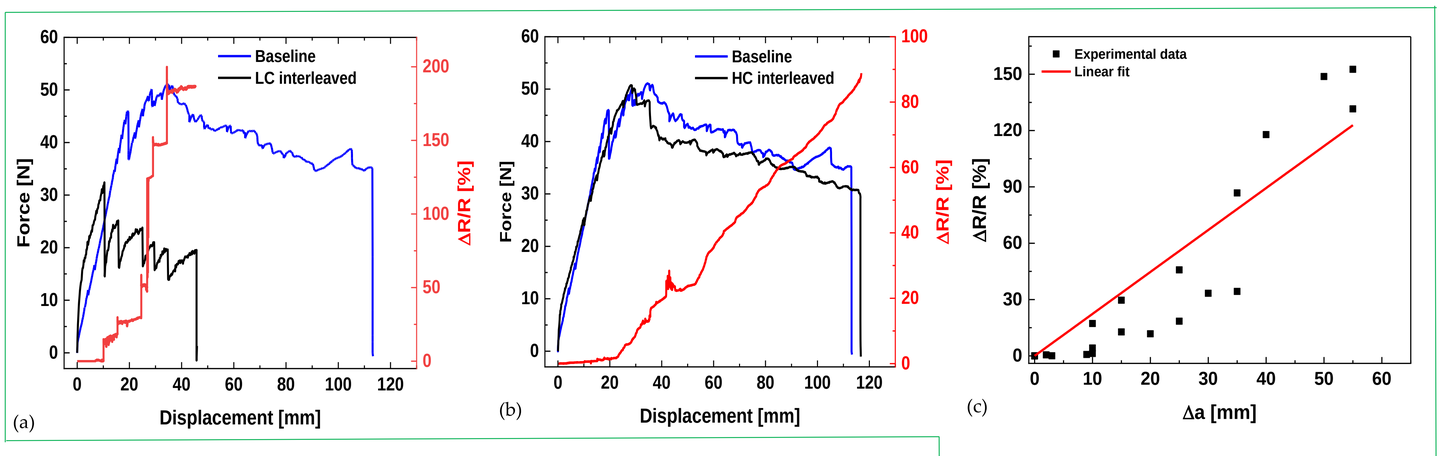


Fig.5. Comparison of (a) initiation, propagation Mode I fracture toughness and (b) R-curve of laminates.



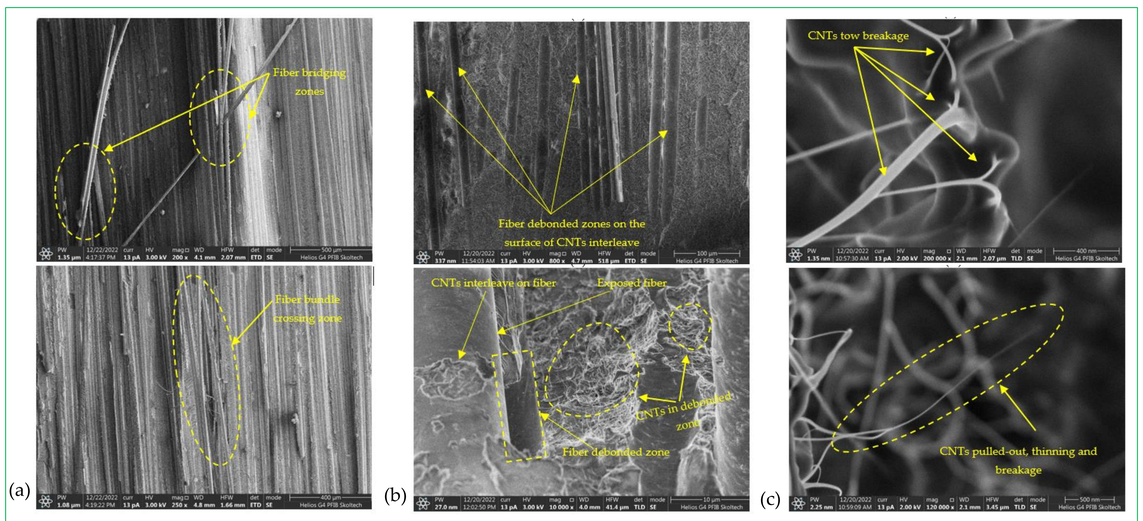


Fig.7. Fractography of (a) baseline (b) LC interleaved (c) HC interleaved laminate

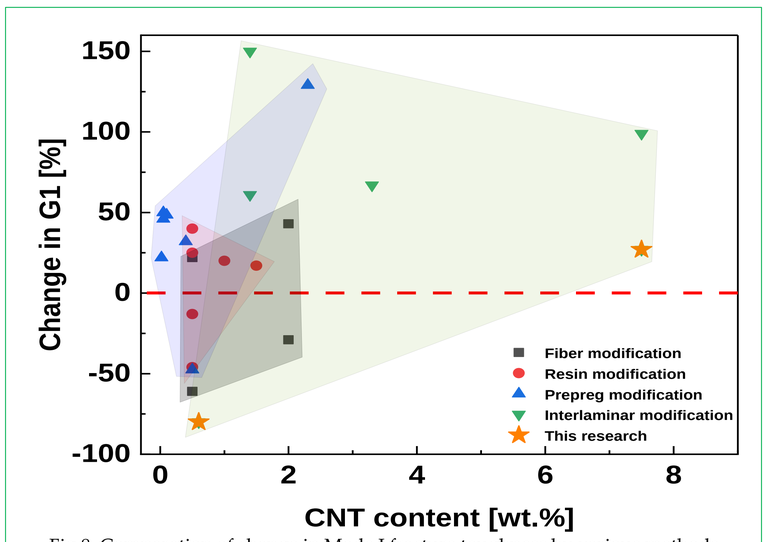


Fig.8. Comparation of change in Mode I fracture toughness by various methods

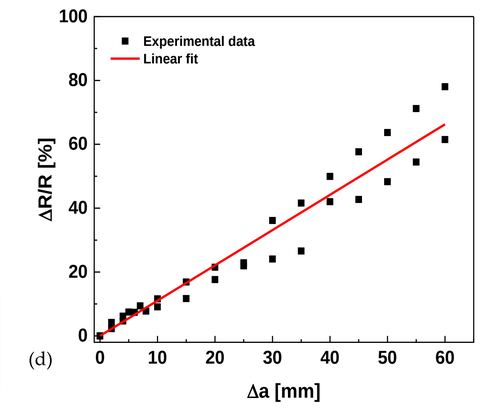


Fig.6. *In-situ* damage sensing and monitoring capability of (a) LC interleave (b) HC interleave; Linear fit to $\Delta R/R$ vs. Δa for (c) LC interleaved and (d) HC interleaved laminate.

Conclusions

- Interlaminar region modification of composite laminate by nanoscale modification method of introducing industrially available CNTs masterbatch is demonstrated.
- Various problems like CNTs filtration, agglomeration, health concerns related to handling CNTs do not appear in this method.
- CNTs masterbatch is available at industrial scale so it can be recommended for large composite structures hence a scalable method.
- This method shows an improvement in Mode I fracture toughness by 27% for initiation, with propagation fracture toughness unchanged, and provides with a possibility of *in-situ* damage sensing and monitoring suitable for structural health monitoring applications.