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Hybrid Thermoplastic Composites based on Elium® Resin and Carbon/Glass Reinforcements

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Abstract: Two types of hybrid laminates were manufactured using glass and carbon fiber reinforcements infused with liquid thermoplastic acrylic resin i.e., Elium®. X-ray computed tomography (XCT) analysis revealed a weaker interface between the Elium® and glass fibers, with GFRP specimens exhibiting a void content of 1.24%, in contrast to only 0.28% for CFRP specimens. The tensile strength and Young's modulus of the hybrid specimen showed 155% and 380% increases, respectively, when compared to the GFRP specimens. The tensile strain of the hybrid specimen having 2 carbon fabric layers surrounded by 3 glass fabrics on both sides (i.e., $G_3C_2G_3$ stacking sequence) was 37% higher than that of the CFRP specimens. The flexural test results also showed similar trends.

Introduction

Fiber reinforced polymer composites (FRPC) have become significantly popular in multiple structural applications over past few decades due to their unique properties [1]. Hybridization is one the most effective techniques to avoid catastrophic failure in high-performance composites.

In ongoing efforts to move towards sustainable composites, Arkema Industries has developed a low viscosity (100-200 mPa.s) infusible thermoplastic resin; Elium® [2].

Two different hybrid composites along with pure CFRP and GFRP specimens were manufactured to investigate the microstructural changes and mechanical performance of Elium® composites through micro-CT, flexural, tensile and SEM analysis.

Materials and Methods

Reinforcement: 3K-CFs (2 × 2 twill weave) and plain weave E-glass fibers.

Matrix: Elium®188 O, supplied by ARKEMA, China, and Luperox® ATC50 benzoyl per oxide (BPO) initiator.

Composite Manufacturing: Vacuum assisted resin transfer molding (VARTM) process (Fig. 1).

Characterization: Xray computed tomography (XCT) analysis and SEM.

Testing: Three-point bending (Fig. 2) and tensile tests with digital image correlation (DIC) approach.

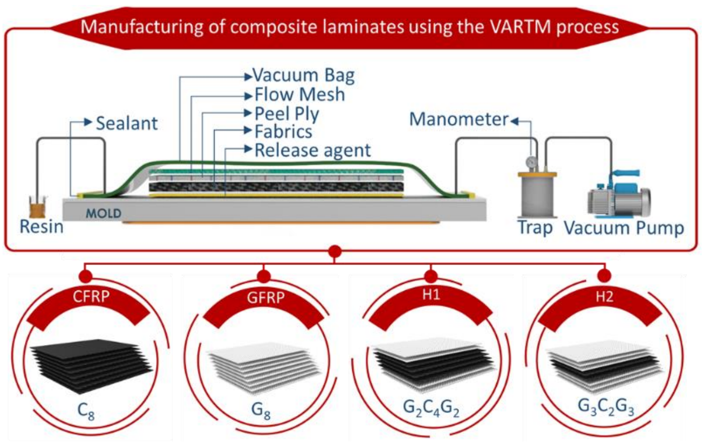

Fig.1. Layout of VARTM process and stacking sequences

Results and Discussion

Micro CT Analysis

- 3D models generated using GeoDict® analysis software (Fig.3).
- Only 0.28% porosity content in the CFRP specimens.
- 1.24% void content in the GFRP specimens.
- H1 specimens having 4 carbon fabric layers surrounded by 2 glass fabric layers on both sides (i.e., $G_2C_4G_2$) and H2 ($G_3C_2G_3$) specimens showed 0.90% and 1.20% porosity, respectively.

Flexural Tests

- 254% increase in flexural strength of H1 specimens (449 MPa) compared to GPRP specimens (127 MPa).
- 121% increase for H2 specimens (281 MPa) (Fig. 2).
- Highest flexural strength for CFRP (658 MPa) but catastrophic brittle failure.
- Hybridization eliminated the catastrophic failure.

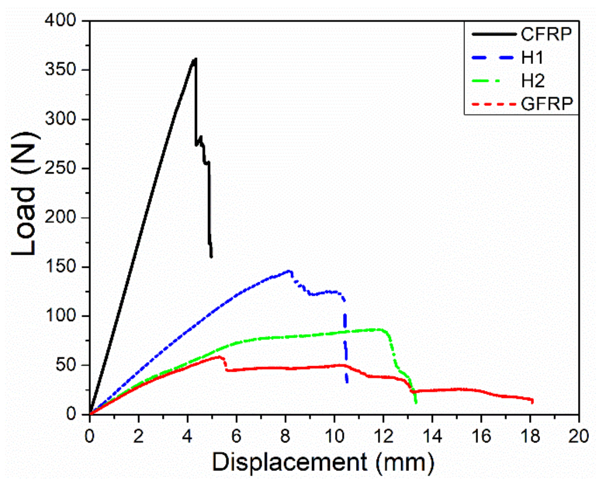

Fig. 2. Flexural test results

Tensile Tests

- Highest tensile strength for CFRP specimens (607 MPa).
- Lowest tensile strength for GFRP specimens (180 MPa).
- 155% and 78% increases in tensile strength for H1 and H2 specimens, respectively (Table 1) (Fig.3(c)).

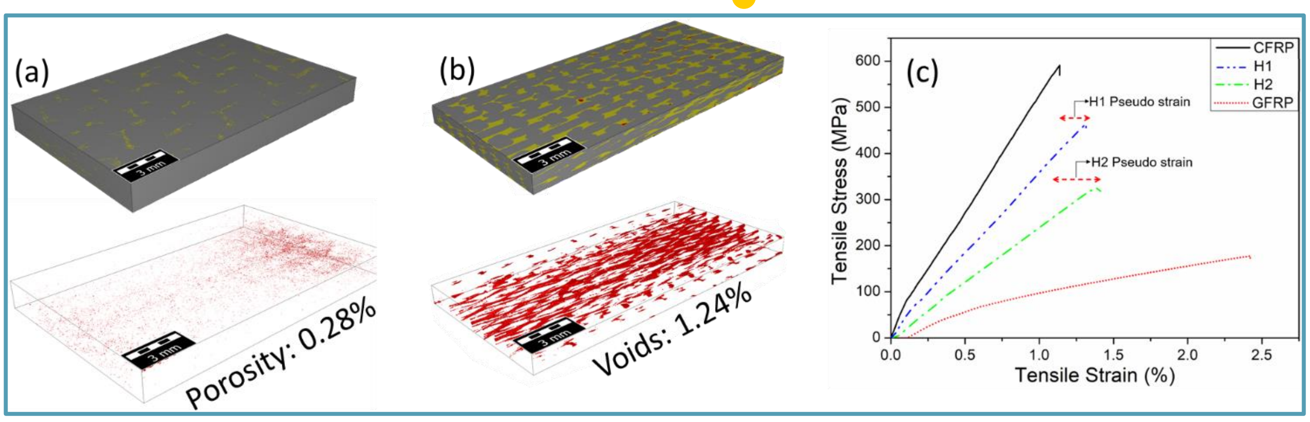

Fig. 3. 3D model of (a) CFRP and (b) GFRP showing void content and (c) stress-strain curves for tensile tests

Scanning Electron Microscopy

- Weak fiber-matrix interface in GFRP composites due to poor bonding between Elium® and glass fibers.
- Fiber pullout in GFRP and fiber fracture in CFRP.
- Mixed failure mode in hybrid laminates (Fig.4).

Table 1. Average tensile test results

Specimen	CFRP	H1	H2	GFRP
Peak Load (kN)	31.6	18.9	13.2	8.6
Tensile Stress (MPa)	607	459	321	180
Tensile Strain (%)	1.09	1.28	1.49	2.43
Modulus (GPa)	59.5	35.7	21.5	7.4

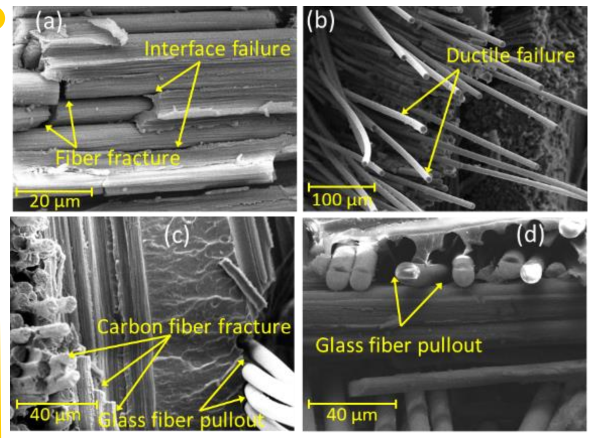

Fig.4. SEM images of (a) CFRP, (b) GFRP, (c) H1 and (d) H2 specimens after fracture.

Conclusions

- The effect of hybridization on the microstructure and mechanical performance of carbon/glass hybrid Elium® composites was investigated.
- The void contents in CFRP, H1, H2 and GFRP specimens were recorded as 0.28, 0.90, 1.20 and 1.24%, respectively.
- The void content increased as the ratio of glass fiber increased in the hybrid composites.
- The flexural strengths were recorded as 658, 449, 281 and 127 MPa, in the same order.
- Similar results were observed in terms of the tensile performance.

Acknowledgements

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