Investigation of Compressive and Interlaminar Fracture Properties of GF/Acrylic Thermoplastic Composites Under Sea Water Ageing Effect

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Abstract: The present work investigates the compressive and mode-I interlaminar fracture properties of the GF/Acrylic thermoplastic composites under the influence of both dry and seawater ageing (SWA) effects. All samples were fabricated using vacuum assisted resin infusion technique and immersed in sea water. The digital image correlation (DIC) techniques were used to measure the developed internal strain fields and strain values under the application of compressive load in the compression specimens. The compressive properties of thermoplastic acrylic matrix, in dry and seawater aged condition, revealed interesting observations that are different to more conventional thermoset matrices like epoxy.

1. Introduction

Recently, acrylic resin-based thermoplastic composites are gaining attention in marine and renewable energy applications due to their recyclability, thermoformability, and low-viscosity (100–200 mPa.s) at room temperature. Consequently, these materials are suited to processing by liquid composite moulding techniques using room-temperature tooling, which were once exclusively used for thermoset composite production. In addition, the acrylic based thermoplastic composites are also suitable for thick-section composites, which led to the design and development of thermoplastic composite blade components for the renewable energy application [1]. During its lifespan, the offshore wind blade experiences adverse environmental conditions such as temperature, moisture absorption, corrosion, humidity, etc. These factors significantly affect the mechanical, thermal, and fracture properties of the blade structures. Marine structures also undergo severe water ageing during its service life. Therefore, the investigation of mechanical properties various under environmental conditions is essential for their wider acceptance in renewable energy and marine sector. There are several papers that report on the tensile, flexure and interlaminar shear strength of dry and water aged GF/acrylic composites [2,3]. But compressive and mode-I fracture toughness properties of GF/acrylic composites in dry and water aged conditions are scarce and need more research for an in-depth understanding. This study fits in that area.

2. Material and Method

2.1 Manufacturing and Sample Preparation

All laminates were prepared using the standard vacuum assisted resin infusion technique using four layers of E-glass fiber (U-E-1200g/m²-190mm wide glass fabric from Seartex/John Manville), which contained acrylic compatible sizing agent. The acrylic resin used was (Elium® 191 XO/SA) and the initiator was peroxide type (MEKP Butanox M50 as an initiator). The mixing ratio of XO:SA resin was 50:50 by weight(%); similarly, the initiator was 100:3 ratios by weight(%). The laminates made for mode-I fracture toughness test(Double Cantilever Beam) were fabricated with an initial pre-crack in the mid-plane. In order to create the pre-crack in the laminate, a thin PTFE film with a 13 µm thickness was inserted into the mid-plane of the laminates during fabrication.

2.2 Sea Water Ageing

All compression and mode-I double cantilever beam (DCB) specimens were conditioned keeping immersed in filtered natural sea water inside an environmental chamber at 50 °C. The sea water was collected from Portobello Beach, Edinburgh, Scotland. The SWA specimens were removed from the chamber and weighed at regular intervals of 24 hours until it reached the saturation level. A dry cloth was used to neatly wipe the surface of all the samples to ensure that no water was present on the surface of the samples before the test.

3. Testing

3.1 Compression Tests

Compression tests were carried out for [0º] and [90º] composite specimens in accordance with ASTM D6641[4]. All compression tests were conducted on speckled specimens at 1.3 mm/min cross head speed using an Instron 50KN machine. The full-field compressive strain field was measured during the tests using DIC techniques. Fig. 1 shows the 2D strain mapping of compression test specimens. All the compression test results are tabulated in Table 1. It was noted that there is a reduction in compressive moduli and notable increase in [90º] compression strength due the effect of sea water ageing. This increase in compression strength might be attributed to the fact that acrylic matrix gets plasticized under the effect of sea water and behaves in a ductile leading to an increase in compression strength acrylic resin behaves ductile in nature under the effect of SWA in case of [90] compression strength. Further research will be carried out in future to understand the effect of plasticisation on the compression behaviour of amorphous thermoplastic acrylic matrix.

3.2 Mode-I Fracture Toughness Tests

Mode-I fracture toughness tests were performed on DCB specimens using an Instron 10KN machine following the ASTM D5528 [5]. All the Mode-I tests were performed under displacement-controlled mode at a constant crosshead speed of 3 mm/min. The load-displacement response was recorded during the tests. The DIC technique was used to monitor crack growth position during the tests and record the crack growth data using a video extensometer. The mode-I test setup and the corresponding load-displacement curves of all DCB samples are shown in Figs. 2 and 3, respectively.

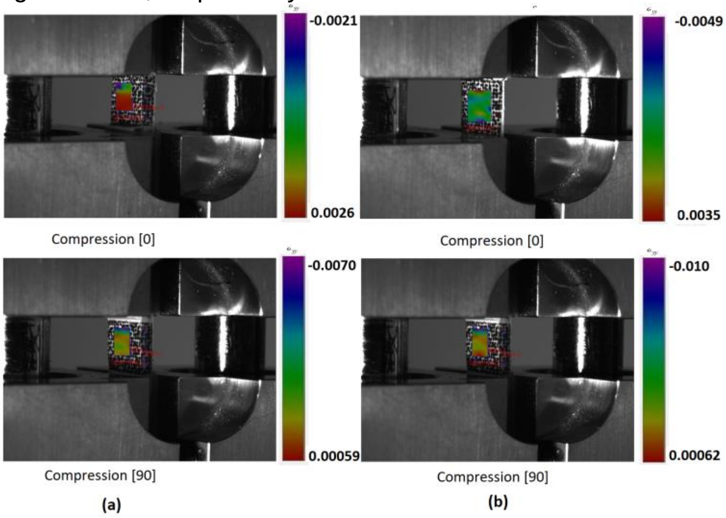
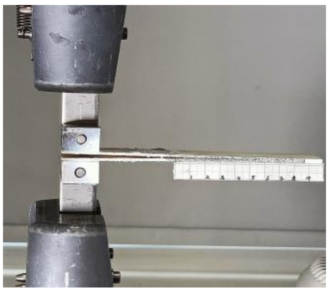


Fig.1 2D Strain maping using DIC techniques, (a) Strain ε_{yy} value for 0.02%, and (b) 0.04% of ε_{xx} strains.

Table 1: Compression tests results

Properties	Dry	SD	SWA	SD	(%) Drops	V_f(%)
Comp. Modulus [0º], [GPa]	40.667	4.66	30.678	6.60	-24.5	56
Comp. Modulus [90º], [GPa]	9.696	1.32	9.806	2.66	-1.13	56
Comp. Strength [0º], [MPa]	558.33	57.33	572.28	36.04	+2.44	56
Comp. Strength [90º], [MPa]	95.54	10.68	119.50	4.76	+25	56



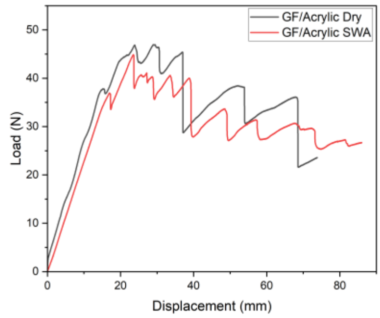


Fig.2 Mode-I fracture test setup. Fig.3 Load-displacement response of Dry and SWA samples.

4. Conclusion

This study reports of the compression and mode-I fracture toughness results of dry and SWA GF/acrylic specimens. The GF reinforcement contained acrylic tailored sizing agent which plays a key role during water immersion. Seawater ageing was found to have a significant effect on both compression and mode-I fracture toughness properties of the composites. Further details on the fracture toughness results will be included in the presentation.

References

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