
An Experimental Investigation on Flexural and Interlaminar Shear Behavior of Glass Fiber Reinforced Polymer Composites under Extreme Environments

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Abstract

This paper studies the flexural and interlaminar shear properties of glass fibre-reinforced polymer (GFRP) composites under extreme environments. The aerospace industry utilizes polymer-based composites (GFRP, CFRP) abundantly in primary and secondary applications in various satellite and spacecraft structural designs for space exploration because of their attractive thermo-mechanical properties, high strength-to-weight ratio, and corrosion resistance. Commercial flight operates in the temperature range from +50°C to -50°C (1). The supersonic aircraft's Mach number is more than 2, and its skin temperature often increases by 120°C. In this work, GFRP composites were fabricated by hand lay-up method, and for the curing process, an Autoclave moulding machine was used with curing parameters of 80°C for 30 mins and 6 bar pressure for 3 hours (2). GFRP composites have improved mechanical and thermal properties over other traditional materials (metals). Despite their advantages over conventional materials, composites are not entirely used in spacecraft and satellites because of limited knowledge of materials' behaviour under extreme temperatures. A three-point bending and short-beam shear test were done in UTM at temperatures ranging from -75°C to 100°C to determine the flexural strength and interlaminar shear strength, which are essential for proving their structural integrity in demanding applications. The findings showed significant effects of temperature on stiffness and strength. The flexural strength of GFRP at -50°C increased by 41.8% and decreased by 80% at 100°C when compared to room temperature (30°C). Interlaminar shear strength of GFRP at -50°C increased by 44% and decreased by 86% at 80°C when compared to 30°C. At ultra-low temperatures, polymer chains of matrix material (Epoxy resin) are more rigid, and the fibre-matrix interface gets a strong bond, which leads to increased stiffness and strength. In contrast, at higher temperatures beyond T_g, the epoxy resin softens, and the interfacial bond weakens, resulting in lower mechanical properties. Dynamic mechanical analysis (DMA) testing was done to determine the glass transition temperature (T_g), storage modulus (E'), loss modulus (E'') and damping factor (tanδ), which are used to study the thermo-mechanical characterization of the materials (3). The T_g and E' values of GFRP were around 87°C and 26.47 GPa, respectively. Scanning Electron Microscope (SEM) images were used to study the fractography behaviour of damaged specimens. At -50°C, delamination, matrix cracks, fibre/matrix rupture and fracture were shown, and at elevated temperatures, delamination occurred in the SEM images.

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