§22. Cryogenic Interlaminar Tensile Properties of Composite Insulation Systems for Superconducting Magnets

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1. Purpose

Superconducting magnets may use large quantities of woven glass fiber reinforced polymer (GFRP) composite laminates as electrical and thermal insulation, and structural support. Polymer matrix composites are typically multi-layer materials. A major disadvantage of laminated composites is their high susceptibility to interlaminar failure because such composites lack through-thickness reinforcement, and the interlaminar properties of laminated composites can govern design of composite structures when multi-axial states of stress are experienced. Therefore, the through-thickness characterization of composites is essential for adequate and reliable structural design. Although there exist some studies on the through-thickness tensile behavior of composite materials[1,2], mainly at room temperature, the cryogenic behavior is still unknown. The purpose of this research is to characterize the mechanical response of woven GFRP composite laminates under through-thickness tension at cryogenic temperatures.

2. Procedure

National Electrical Manufacturers Association (NEMA) grade G-11 woven GFRP composite laminates were considered in this study. A cross specimen was employed for experiments. The geometry and dimensions of the cross specimen for through-thickness tensile testing are given in Fig. 1. Here, T_g and T_b refer to the thicknesses of the gage section and the crossing beams, respectively. Two types of cross specimens were prepared: Type A specimen with T_g = 7 mm and T_b = 3.5 mm for Young's modulus measurements, and Type B specimen with T_g = 2 mm and T_b = 6 mm for tensile strength measurements.

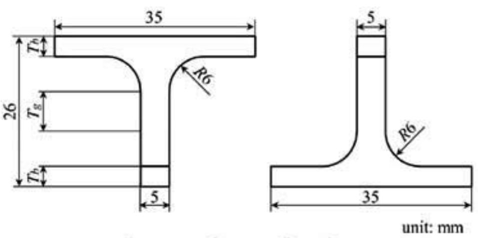

Fig. 1. Specimen configuration.

Fig. 2 shows the experimental setup for through-thickness tensile tests. The test specimen was supported at two points and loaded at two points. The tensile tests were performed at room temperature and liquid nitrogen temperature (77 K). For Type A specimen, the through-thickness strain was measured using electrical resistance strain gages that were mounted at the center of the gage section on the two opposite sides of the specimen. The stress was calculated from dividing the applied load by the cross-sectional area in the specimen gage section.

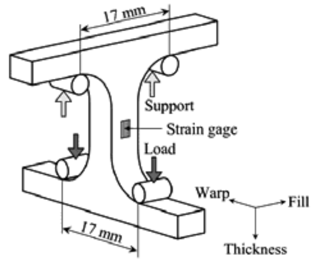

Fig.2. Experimental setup.

3. Results

At room temperature and 77 K, the stress-strain behavior is essentially linear and the composite specimen loses its load carrying capacity instantly after the peak load. Fig. 3 shows the through-thickness Young's moduli E at room temperature (RT) and 77 K from Type A specimens. The Young's modulus increases as temperature decreases from room temperature to 77 K. The through-thickness tensile strengths σ_B at room temperature and 77 K from Type B specimens are shown in Fig. 4. The tensile strength at 77 K is higher (roughly two times) than that at room temperature.

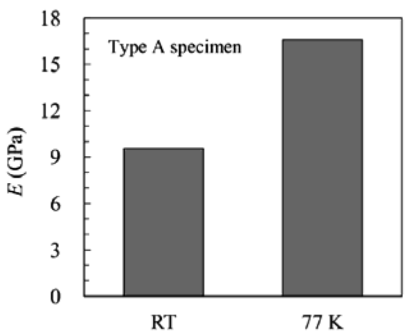

Fig. 3. Through-thickness Young's modulus.

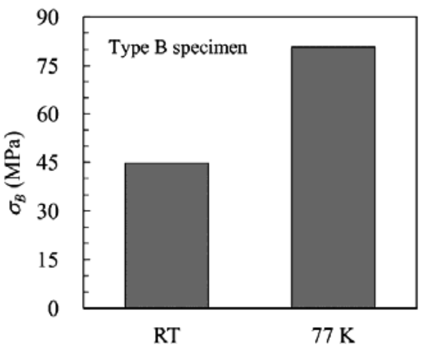

Fig. 4. Through-thickness tensile strength.

1) Abot, J. L. et al.: J. Compos. Mater. **38** (2004) 543.
2) Daniel, I. M. et al.: Compos. Sci. Tech. **69** (2009) 764.