§14. Cryogenic Interlaminar Tension-Tension Fatigue 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) composites as electrical and thermal insulation, and structural support. Polymer matrix composites are typically multi-layered materials, and a major disadvantage of laminated composites is their high susceptibility to interlaminar failure because such composites lack through-thickness reinforcement. Since the interlaminar properties of laminated composites can govern the design of composite structures when multi-axial states of stress are experienced, the through-thickness characterization of laminated composites is essential for adequate and reliable structural design.

There are some studies on the through-thickness tensile behavior of composite materials[1,2], mainly at room temperature. Recently, Takeda et al.[3] studied the mechanical response of woven GFRP composite laminates under through-thickness tension at cryogenic temperatures. The purpose of this research is to characterize the interlaminar tension-tension fatigue behavior of GFRP composite laminates at cryogenic temperatures.

2. Procedure

National Electrical Manufacturers Association (NEMA) grade G-11 woven GFRP composite laminates were considered. A cross specimen was employed for experiments, and the geometry and dimensions of the cross specimen for through-thickness tension-tension fatigue 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. In this study, the specimen with T_g = 2 mm and T_b = 6 mm was used.

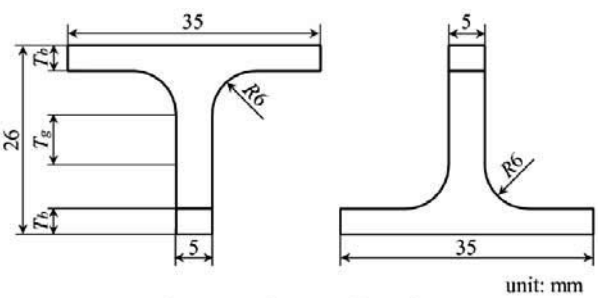

Fig. 1. Specimen configuration.

Fig. 2 shows the experimental setup for through-thickness tension-tension fatigue tests. The test specimen was supported at two points and loaded at two points. The tension-tension fatigue tests were performed at room temperature and liquid nitrogen temperature (77 K). The specimens were loaded cyclically in a sinusoidal waveform at a frequency of 4 Hz and a constant load ratio of R = 0.1. The load ratio is defined as $R = P_{min}/P_{max}$, where P_{max} and P_{min} are the maximum and minimum applied loads, respectively.

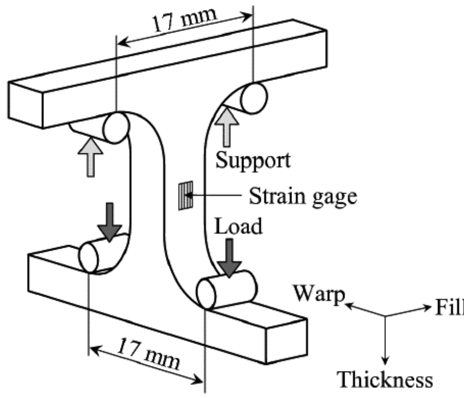

Fig.2. Experimental setup.

3. Results

Figure 3 shows the maximum through-thickness stress $\sigma_{max} = P_{max}/W^2$ versus the number of cycles to failure N (S-N diagrams) at room temperature (RT) and 77 K, where W = 5 mm is the gage section width. The tensile failure stress (tensile strength) at RT and 77 K are also plotted at N =1. The S-N curves can be described by a linear curve on a semi-logarithmic plot. The fatigue life increases as the temperature decreases from RT to 77 K.

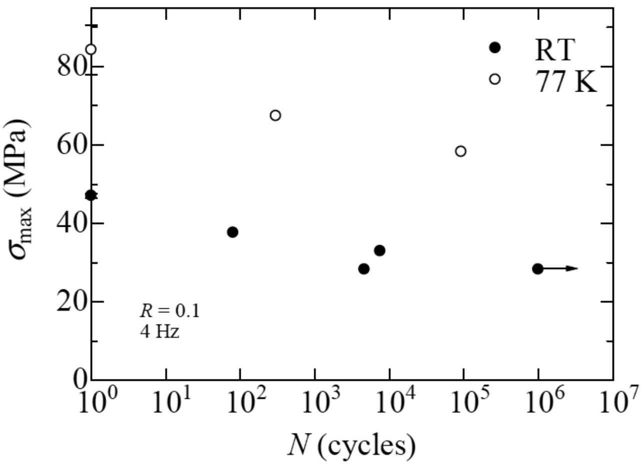

Fig. 3. S–N diagrams at room temperature and 77 K.

1) Abot, J. L. et al.: J. Compos. Mater. **38** (2004) 543.
2) Daniel, I. M. et al.: Compos. Sci. Tech. **69** (2009) 764.
3) Takeda, T. et al.: Compos. B **78** (2015) 42.