§24. Mechanical Properties of Candidate Materials for the Large-scale Superconducting Magnets at Cryogenic Temperatures

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i) Cryomechanics of Woven Glass-Epoxy Laminates

(a) Both the double-notch shear and short beam test methods for determining interlaminar shear strength of G-10CR woven glass-epoxy laminates at low temperatures were studied using a three-dimensional finite element analysis[1]. Effective elastic moduli were determined under the assumption of uniform strain inside the representative volume element. Double-notch shear test specimens[2] with lower notch separation-to-thickness ratios were found to yield more uniform distributions of shear stresses. For the short beam test specimen, the high local stresses near the loading and support points were observed.

(b) In order to investigate the cryogenic fractrure and damage behaviors in G-10 woven glass-epoxy laminates, fracture toughness tests[3] were carried out with compact tension(CT) specimens at room temperature and 77K. CT specimens with different widths and thicknesses were prepared and tested. These tests were conducted in accordance with ASTM E399-83 and E813-89. The results show that the apparent fracture toughness are strongly influenced by secimen size. The size effect on the cryogenic fracture behavior of G-10 must be taken into account. The damage morphology around the notch tip of tested specimens was characterized using a microscope. Damage growth was presented with increase of the applied load.

Photographs of 1TCT specimens surrounding the damaged notch root at room temperature and 77K are shown in Fig.1. At room temperature, the crack growth is a simple extension of the notch root. It is further observed that the complicated structure of damage zone around the notch tip (delamination and broken fiber, fiber pull-out and broken epoxy resin) masks the exact location of the real crack tip at low temperatures.

The fracture toughness and the temperature rise of G-10 at 4K were also evaluated[4]. Au-Chromel thermocouples were used to measure the temperature rise.

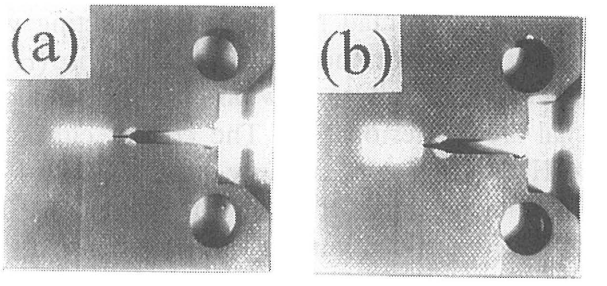

Fig. 1. Damage near the notch tip of 1TCT specimens:(a) at room temperature; and (b) at 77K.

ii) Cryogenic Fracture Toughness of Austenitic Stainless Steel Weld

J_{IC} tests[5] were carried out with 0.5TCT and 1TCT specimens at 4K to evaluate the fracture toughness of SUS316 type austenitic stainless steel electron-beam weld for the superconducting coil systems in the Large Helical Device. The SUS316 type austenitic stainless steel weld was tested and analyzed at three locations through the depth of a 75-mm-thick welding. The effects of specimen size, precracking temperature and ferrite content on the fracture toughness parameter were examined. Fracture surfaces were also examined by a optical microscope and a scanning electron microscopy to verify the failure mechanisms.

References

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