§66. Mechanical Properties of Candidate Materials for the Large-Scale Superconducting Magnets at Cyrogenic Temperatures

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i) Cryomechanics of Woven Glass-Epoxy Laminates

(a) In conjunction with the cryogenic plane-strain fracture toughness (K_{IC}) test, a damage mechanics analysis was conducted to predict fracture and deformation for models of the compact tension specimens[1]. Correlations between experimental and analytical results were made, in terms of the load - displacement response and the extent of damage growth. The predictions show that the fracture behavior is strongly influenced by temperature rises associated with individual damage events at 4K.

(b) The double cantilever beam (DCB) tests were carried out at room temperature, 77K and 4K to evaluate the interlaminar fracture toughness (G_I) of woven glass-epoxy laminates[2]. These tests were conducted in accordance with JIS K 7086. Fig. 1 shows the average G_{IR} value at each temperature. In Fig. 1, G_{IR} is the interlaminar fracture toughness for crack propagation, a_0 is the initial crack length, L is the length, B is the width and $2H$ is the thickness of the DCB specimen. A finite element model was used to perform the delamination crack analysis. The effects of geometrical variations on G_I were also experimentally investigated and the results were correlated with the theoretical predictions.

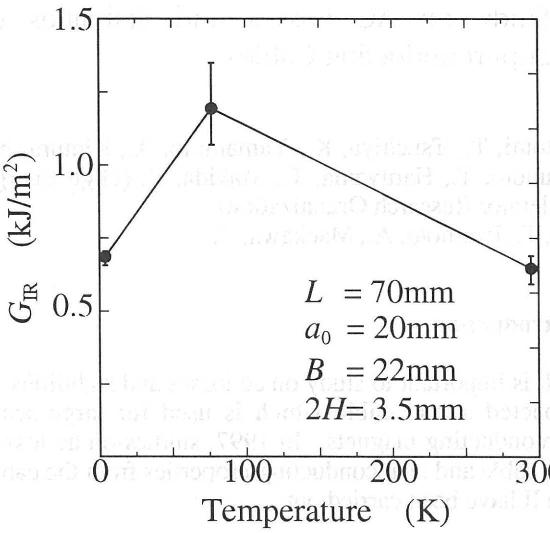

Fig. 1. Temperature effect on G_{IR}

ii) Cryogenic Fracture Toughness of Structural Alloy welds

(a) The use of the small punch (SP) test to estimate the elastic-plastic fracture toughness (J_{IC}) of structural alloys and weldments for superconducting magnets in fusion energy systems was studied[3]. SP tests were performed with thin plate specimens of 10×10×0.5mm at 4K. Correlations between SP energy, equivalent fracture strain, and J_{IC} were assessed. A finite element analysis was also performed to convert the experimentally measured load - displacement data into useful engineering information. The criterion for fracture used is the strain energy density (strain energy absorbed per unit volume) required to produce crack initiation in a solid, uncracked specimen. This criterion is then applied (as a crack initiation criterion) to the crack tip of a standard compact tension specimen, loaded via computer simulation. Comparisons of the predicted J_{IC} with actual measurements were made.

(b) In order to evaluate the fracture toughness of austenitic stainless steel welds, tensile tests were performed at 4K with small round bar specimens having an electro discharge machined notch[4]. Correlations between notch tensile strength, J_{IC}, and yield strength were assessed. A finite element analysis was also performed to compute directly the J-values. The numerical findings were then correlated with the experimental results.

References

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3) Sugo, T. et al. :Proc. of Symposium on Welded Constructions '97(1997) 459.
4) Shindo, Y. et al. : Preprints of the National Meeting of J.W.S. 62(1998) 140.