Finite Element Evaluation of J-integral in 3D for Nuclear Grade Graphite Using COMSOL Multiphysics ®

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Abstract

Even though the analysis of materials exhibiting different tension/ compression characteristics was recognized by Saint-Venant in 1864, the concept had not received much attention from the research community. The concept of a bi-modular material was revisited by Timoshenko in 1941, while considering the flexural stress in such a material undergoing pure bending. Moreover, the investigation of fracture related problems involving bi-modularity has apparently not been vigorously addressed in the literature so far. To the best of the authors' knowledge there have not been much work done for SIFs and J-integral for bi-modular materials like nuclear grade graphite. In the present study, COMSOL Multiphysics®, finite element analysis software has been used to evaluate the deformation, stress, and the J-integral in 3D for a bi-modular three point bend cracked specimen as shown in Figure 1. The properties of nuclear grade graphite material were available from graphite design hand book, 1988. It is well known that the computation of J for 3D is a challenging task even for a unimodular case due to the presence of additional area integral term. Due to the availability of stress dependent elasticity formulation required for the constitutive equation in bimodularity in COMSOL Multiphysics, the authors are motivated here for the studies of J-integral in 3D for nuclear grade graphite. Figure 2 represents the variation of the J-integral with respect to the ET/EC ratio for ten different integration contours around the crack tip. It is reflected that the path independency is well preserved here. The degree of path independency is going to be slightly inferior in nature as the ET/EC ratio deviates from the value of unity. Also it is observed that the Et/Ec ratio influences the value of the J-integral significantly. Fig. 3 describes variation of total J integral with respect to the load level at different ET/EC ratio. For very low load level, it is apparent that all the J-values merge into a single parabolic curve for different ET/EC ratio, however with increase in load level, strong divergence in the J-value occur for different ET/EC ratio. Therefore, it is concluded that the effect of the bi-modularity on the computation of J-integral values cannot be neglected.

Reference

1.B. Saint-Venant, Notes to Navier's Resume des lecons dela resistance des corps solids, 3rd Ed., Paris, 175(1864).

2.S. Timoshenko, Strength of materials, Part 2. Advanced Theory and Problems, 2nd Ed., Van Nostrand, Princeton, N.J., 362–369(1941).

3.General Atomics, Graphite design handbook, DOE-HTGR-88111(1988)

Figures used in the abstract

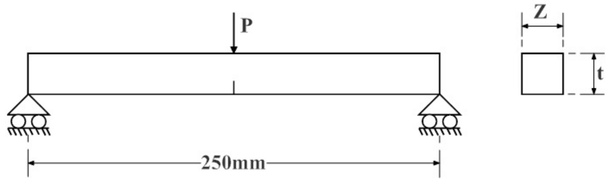

Figure 1: Cracked Three Point Bend Specimen.

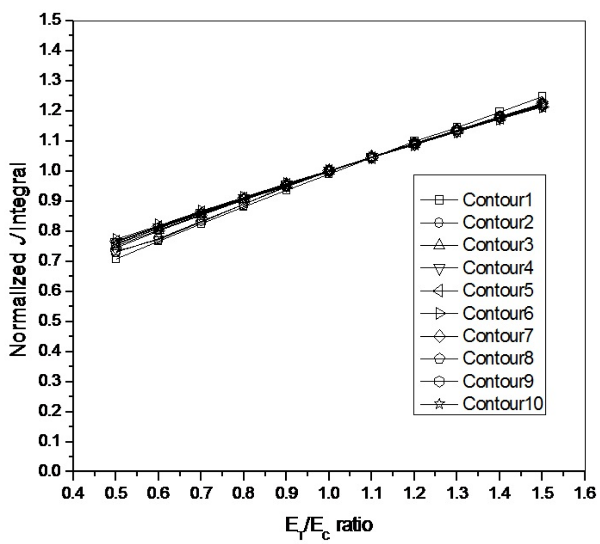

Figure 2: Normalized J vs. ET/EC Ratio at All Contours.

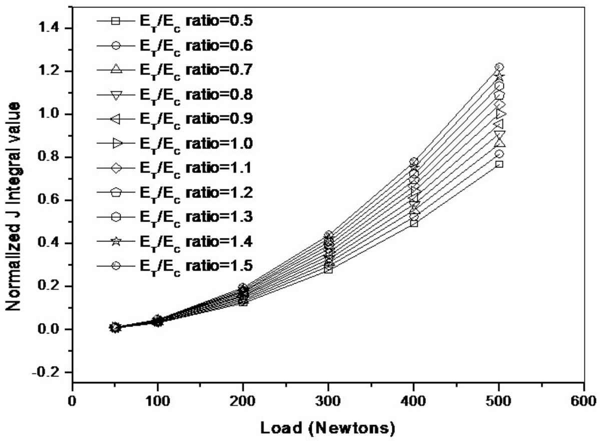

Figure 3: Normalized J vs. Different Loading at Different ET/EC Ratio.