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

A. Bhushan[1], Dr. S. K. Panda[1], S. K. Singh[1], Dr. D. Khan[1]
1. Indian Institute of Technology (BHU), Varanasi - 221005, Uttar Pradesh, India

Introduction: Effect of bi-modularity on *J*-integral in cracked three point bend specimen has been presented here.

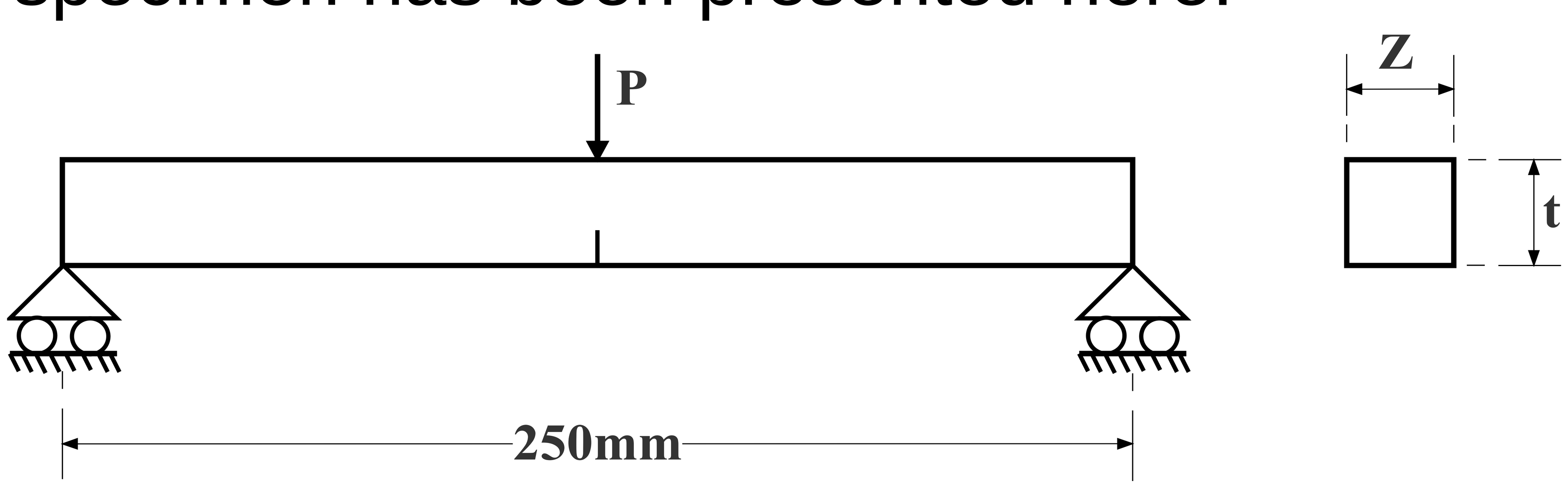


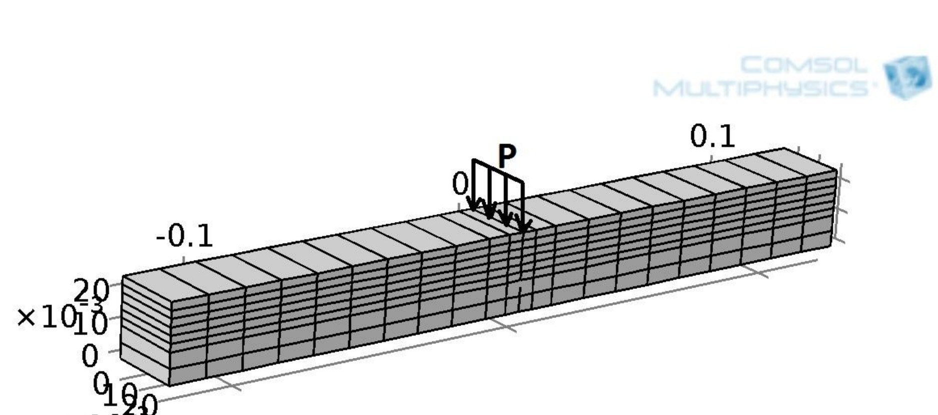
Figure 1 Cracked three Point Bend

Computational Methods: The problem is solved by stress dependent elasticity considering different Young's modulus of elasticityin tension and compression shown in table 1. *J*-integral for 3D geometry has been evaluated following equation in elastic bi-modular region given by Dodds, in1987 [1]

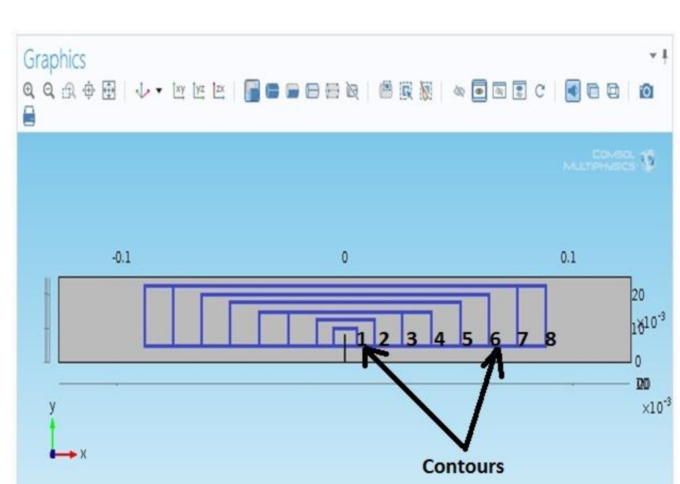
$$J(s)=\oint_{\Gamma}\left(W^{e}n_{1}+W^{p}n_{1}-u_{i,1}T\right)d\tau+\oint_{A}\left(\left(\sigma_{ij}\varepsilon^{p}_{ij,1}\right)-\left(\left(\sigma_{i3}u_{i,1}\right)_{,3}\right)-W^{p}_{,1}\right)dA$$

In elastic bi-modular region plastic stress strain terms vanishes and expression reduced to

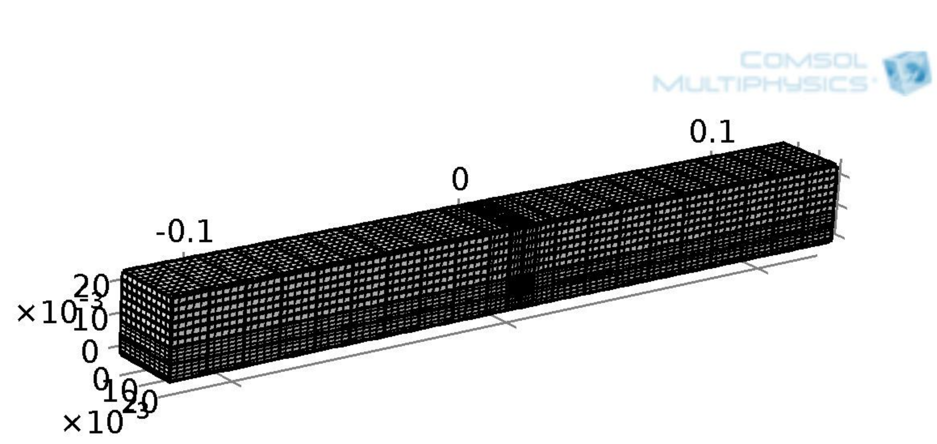
$$J(s)=\oint_{\Gamma}\left(W^{e}n_{1}-u_{i,1}T\right)d\tau-\oint_{A}\left(\sigma_{i3}u_{i,1}\right)_{,3}dA$$



a



b



c

Reference [3]	Value	Units
E_T	7.1457	GPa
E_C	3.8954	GPa

Table 1. Title of the table

Figure 2. (a)Comsol complex model for defining contour to evaluate J-integral, (b) Different contours, (c) Hexahedron Mesh representation

Results: Stress around the crack-tip is vary high n comparison to other part.

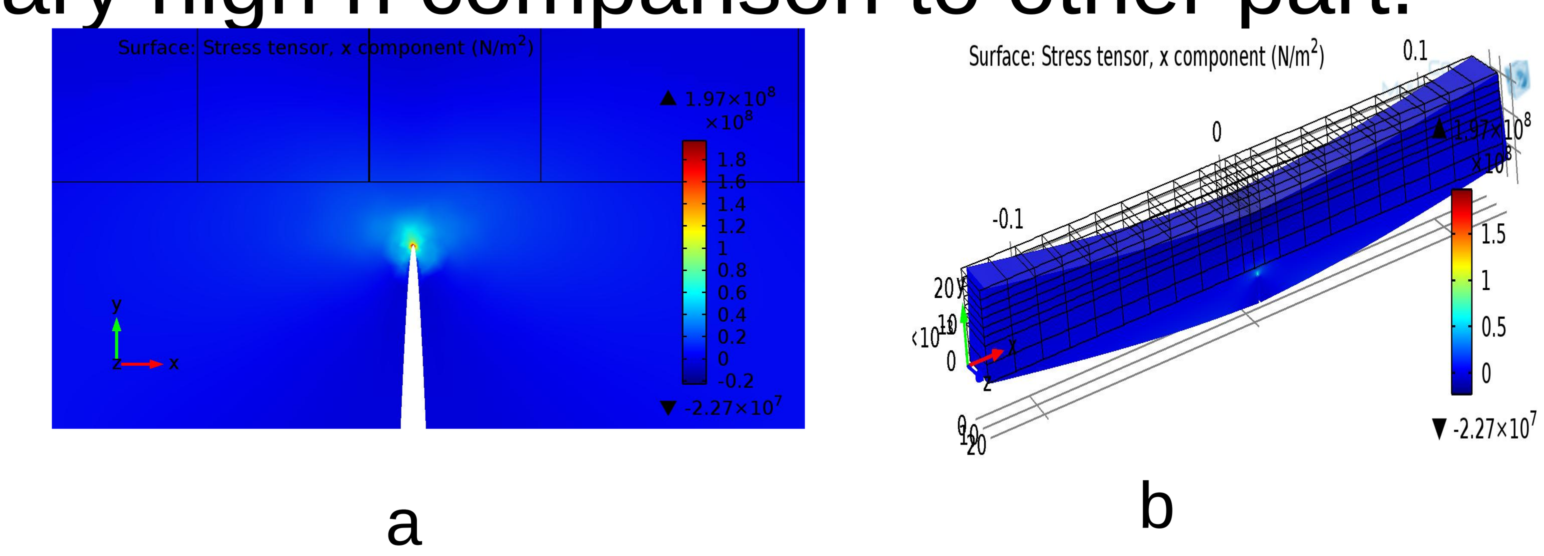


Figure 3. Normal stress distribution in x- direction (a) around the Crack tip (b) for whole geometry

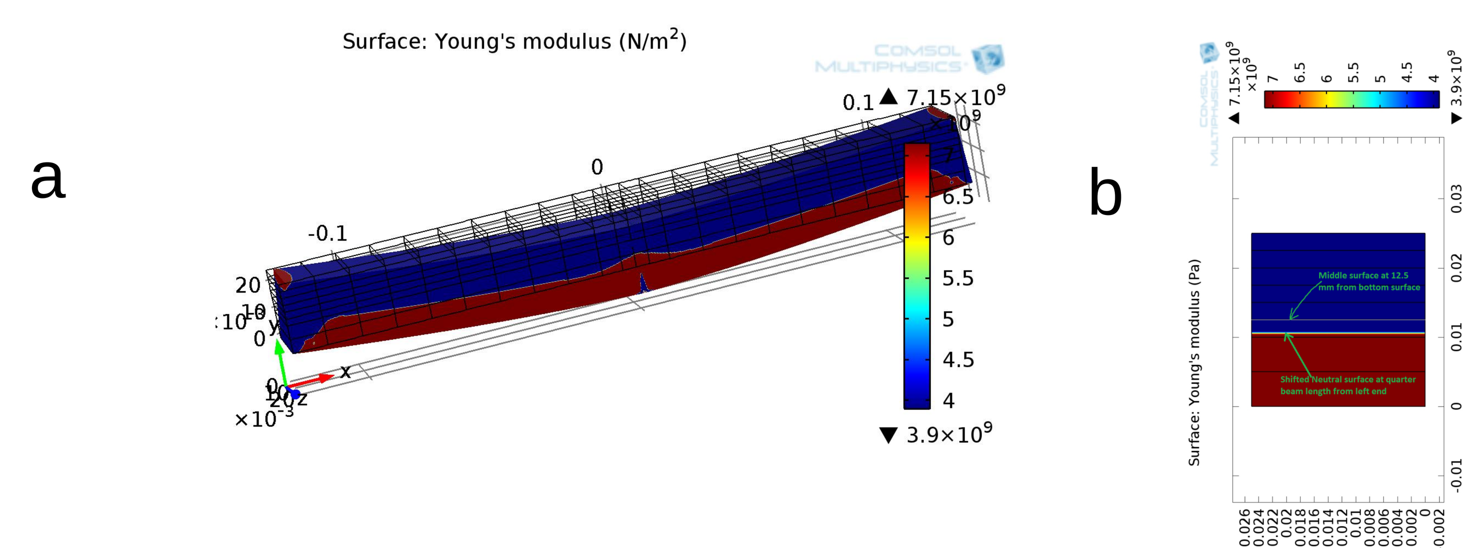


Figure 4. Young's Modulus plot (a) for the three point end specimen and (b) for x-section at quarter of the beam length at which neutral surface is represented

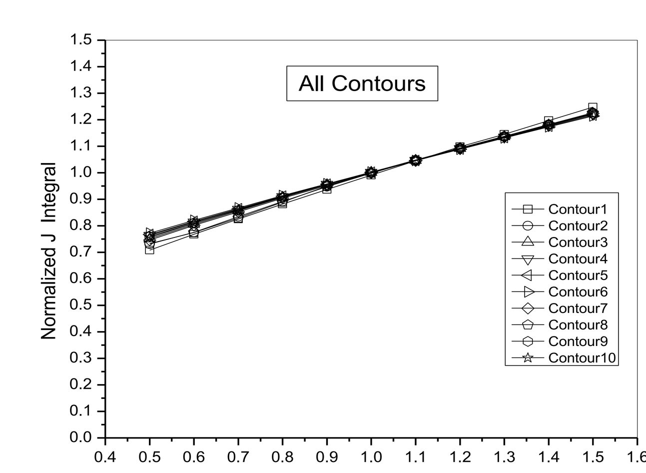


Figure 5. Normalized *J*-integral vsE_T/E_C ratio at all contours

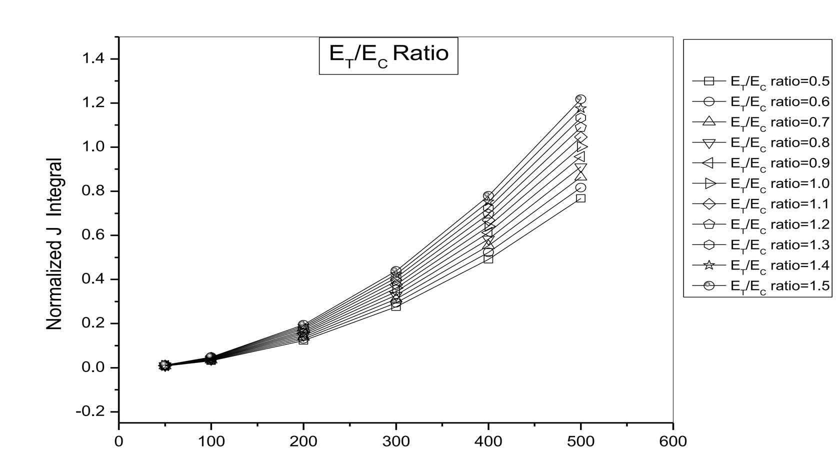


Figure 6. Normalized *J* vs. different loading at different E_T/E_C ratio.

Conclusions: The degree of path independency is going to be slightly inferior in nature as the E_T/E_C ratio deviates from the value of unity. The E_T/E_C ratio influences the value of the *J*-integral significantly.

For very low load level, it is apparent that all the *J*-values merge into a single parabolic curve for different E_T/E_C ratio, however with increase in load level, strong divergence in the *J*-value occur for different E_T/E_C ratio. Therefore, it is concluded that the effect of the bi-modularity on the computation of *J*-integral values cannot be neglected.

References:

1. Dodds, R.H., Jr., "Finite Element Evaluation Of J Parameters In 3D", International Journal of Fracture, vol. 33, pp. R7-R15, (1987).
2. Rice, J.R., "A path independent integral and the approximate analysis of strain concentration by notches and cracks." Trans. ASME, J. Appl. Mech., vol. 35, pp. 379-386, (1968).
3. General Atomics "Graphite design handbook", , DOE-HTGR-88111, (1988).