A computational methodology for predicting failure initiation from V-notch edges in 3D brittle elastic materials

†*B. Mittelman[1], Z. Yosibash[1]

[1]Dept. of Mechanical Engineering, Ben-Gurion University of the Negev, Be'er Sheva, Israel

*Presenting and †Corresponding author: brigit@post.bgu.ac.il

Abstract

Failure criteria for crack initiation from cracks or sharp V-notches contain 2D assumptions, which do not enable description of failure initiation under general loading conditions including out-of-plane-shear (mode III). We suggest a 3D failure initiation criterion in brittle materials containing a sharp V-notch, which provides both the force at fracture and spatial angles of failure initiation at every location along the V-notch edge (except for the vertices) [1]. The criterion, which is based on stress and energy considerations, is a generalization of a 2D finite fracture mechanics criterion by Yosibash et. al (modes I+II) [2], and Leguillon (mode I) [3].

Energy considerations involve the rate of change in potential energy $\delta\Pi$ in a V-notched domain as a result of a crack created at a point along the V-notch edge in different orientations (Fig. 1).

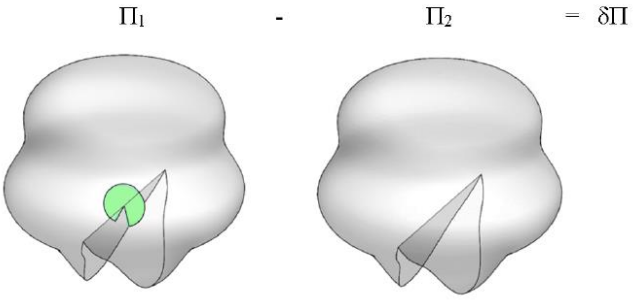

Figure1. Considered domains for δΠ

Using asymptotic analysis, we provide an expression for $\delta\Pi$ as a function of quantities that depend explicitly on the failure initiation orientation, virtual crack area and V-notch generalized stress intensity functions. All possible failure orientations initiating at any point along the V-notch edge (except for vertices) are accounted for, and explicit solutions for a V-notched domain with a small virtual crack inclined at any orientation at a V-notch tip are unnecessary. The asymptotic analysis was verified by FE methods.

The components in the expression for $\delta\Pi$ that depend on the crack spatial orientation, material properties and V-notch opening angle are obtained from high order p-FE models which represent the vicinity of the crack location ("zoom in") – see Fig. 2:

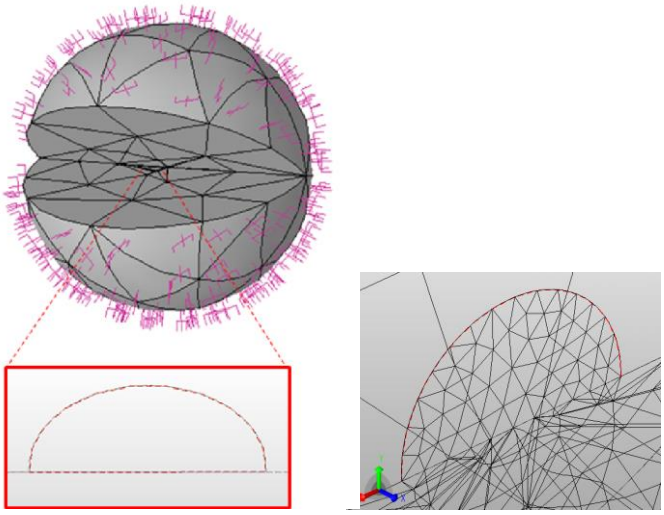

Figure 2. The FE model for calculation of quantities required for the ERR criterion and zoom-in on the crack at the center of the V-notch tip (crack borders marked in red).

The asymptotic analysis of $\delta\Pi$ will be presented, along with its verification by comparing to FE analyses [4]. Detailed calculations for circular cracks and notch opening angle of 45^o will be presented. The 3D criterion will be presented, and compared to experimental results obtained from several quasi-brittle materials and geometries which involve all three loading modes (mode I- tension, mode II – in-plane shear, and mode III – out-of-plane shear). We will demonstrate that the developed criterion predicts well the experimental force at fracture, and shows experimental trends (and rough estimations) of the failure initiation orientations.

Keywords: V-notch, failure criterion, 3D singularities, potential energy, mixed mode.

References

[1] Z. Yosibash and B. Mittelman (2015) A 3-D Failure Initiation Criterion from a Sharp V-notch Edge in Elastic Brittle Structures, *submitted to European Journal of Mechanics – A/Solids on November 2015*.

[2] Z. Yosibash, E. Priel, and D. Leguillon. (2006) A failure criterion for brittle elastic materials under mixed-mode loading, *International Journal of Fracture*, **141**, 291–312.

[3] D. Leguillon. (2002) Strength or toughness? A criterion for crack onset at a notch, *European Journal of Mechanics and Solids*, **21**, 61–72.

[4] B. Mittelman and Z. Yosibash. (2014) Asymptotic analysis of the potential energy difference because of a crack at a V-notch edge in a 3D domain, *Engineering Fracture Mechanics*, **131**, 232-256.