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NUMERICAL METHODS FOR FRACTURE/CUTTING OF HETEROGENEOUS MATERIALS

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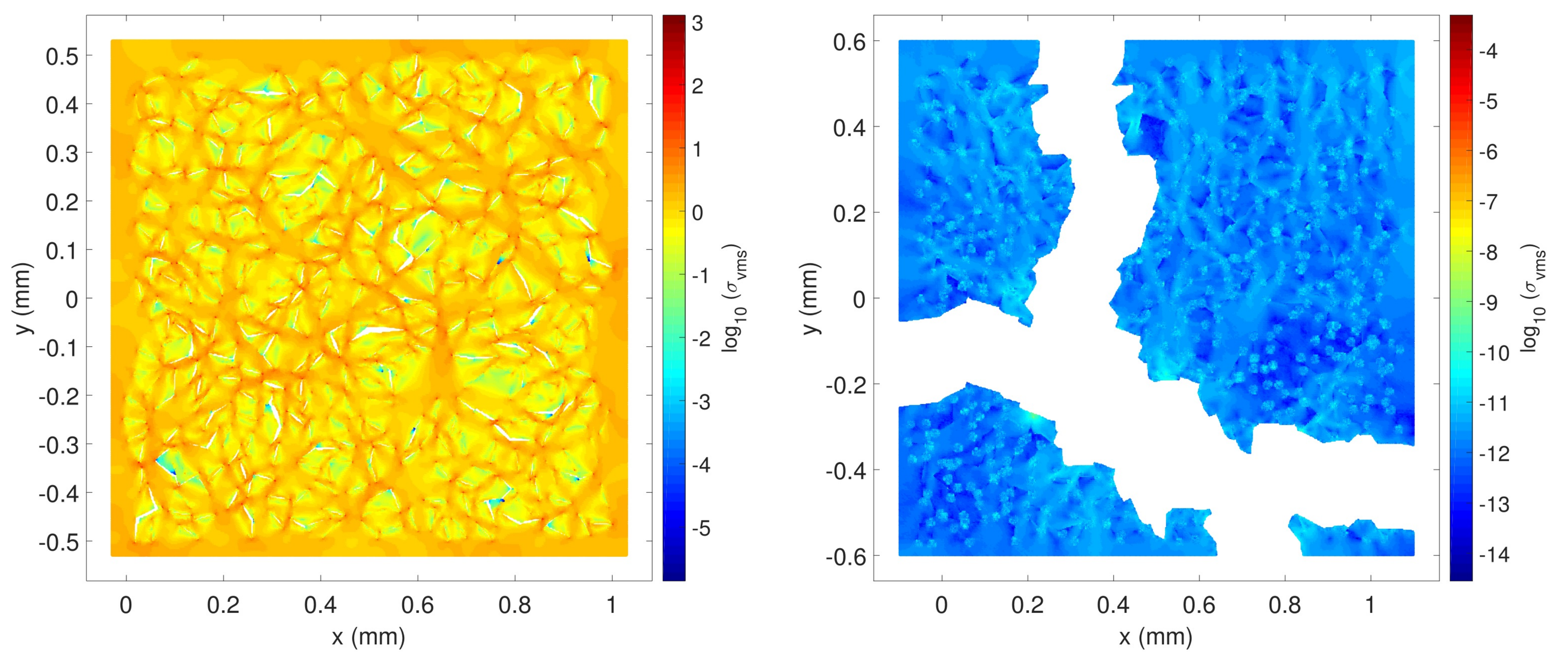
MESH INDEPENDENT MODELING OF CRACKS USING THE EXTENDED FINITE ELEMENT METHOD (XFEM)

FIGURE 1



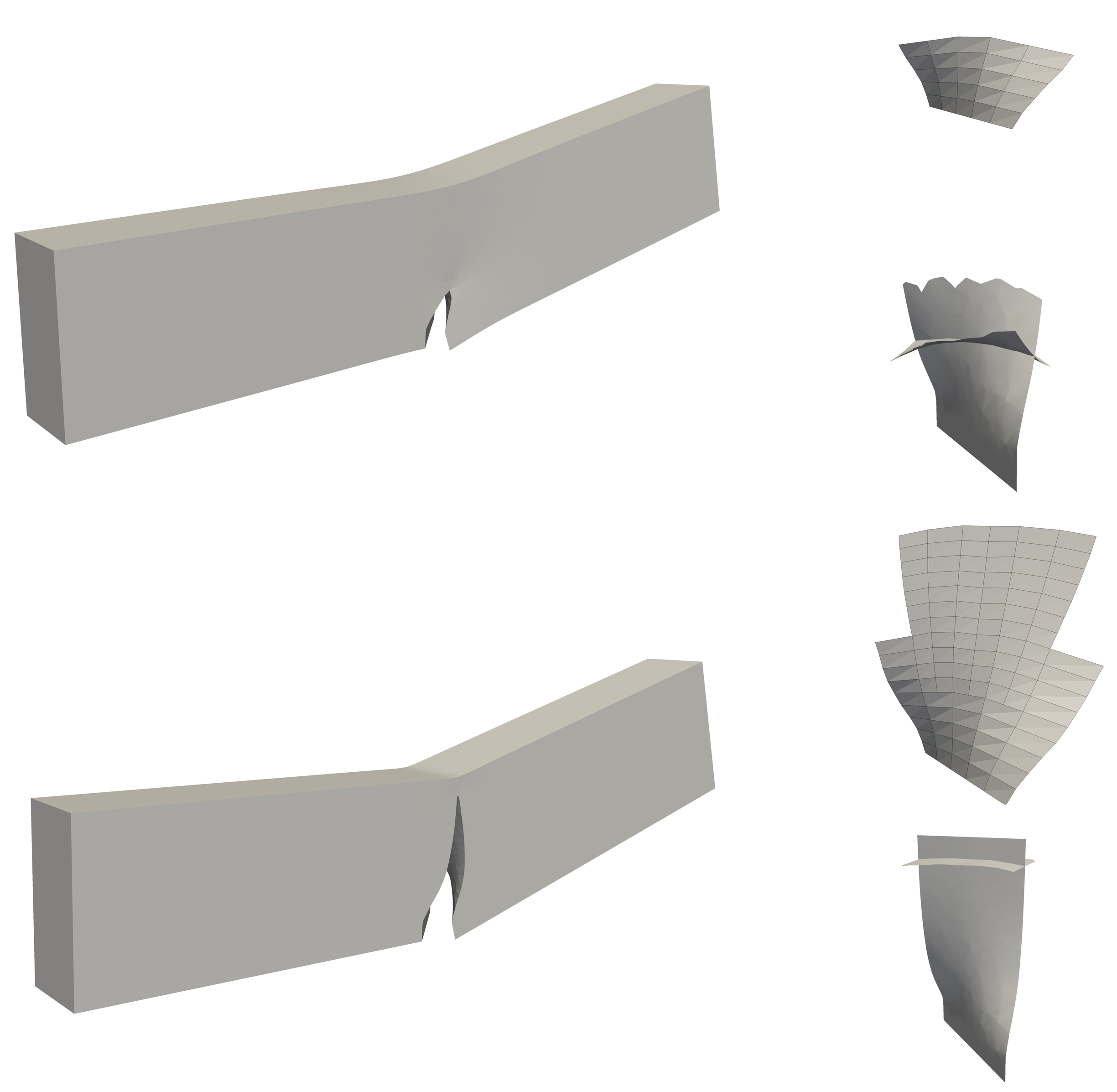
Here is a pre-cracked plate with over 400 randomly distributed cracks subjected to a bi-axial load. The figures above show the deformation and the von-Mises stress field before and after slitting by multiple crack coalescence. The discontinuous displacement field approximation in XFEM is achieved by enriching the classic finite element basis (e.g. over a regular grid of quadrilateral elements) with discontinuous Heaviside functions (H^i) and singular crack tip functions ($B^{i,l}$) for each crack in order to reproduce the characteristic displacements of a cracked solid:

$$\mathbf{u}^h(\mathbf{x}) = \sum_{I\in\mathcal{N}_u} N_I(\mathbf{x})\mathbf{u}_I + \sum_{i=1}^{n_{\text{crack}}} \sum_{I\in\mathcal{N}_a^i} N_I(\mathbf{x}) \left(H^i(\mathbf{x}) - H^i(\mathbf{x}_I)\right)\mathbf{a}_I^i + \sum_{i=1}^{n_{\text{tip}}} \sum_{l=1}^{4} \sum_{I\in\mathcal{N}_b^i} N_I(\mathbf{x}) \left(B^{i,l}(\mathbf{x}) - B^{i,l}(\mathbf{x}_I)\right) R^i(\mathbf{x})\mathbf{b}_I^{i,l}, \qquad (1)$$

NON PLANAR CRACK PROPAGATION IN 3D SOLIDS USING AN XFEM VARIANT

An XFEM variant for 3D fracture is developed employing existing techniques as well as some novel concepts to allow the application of geometrical enrichment in 3D problems without causing conditioning problems. The method provides increased accuracy and reduced computational cost and by coupling to an appropriate crack representation technique, such as the 3D version of the vector level set method, can be used to solve crack propagation problems (Figure 2).

FIGURE 2



Inclined edge crack in a beam under tension. The deformed beam and two different representations of the crack surface are illustrated after 5 (top) and 16 (botom) steps of crack propagation.

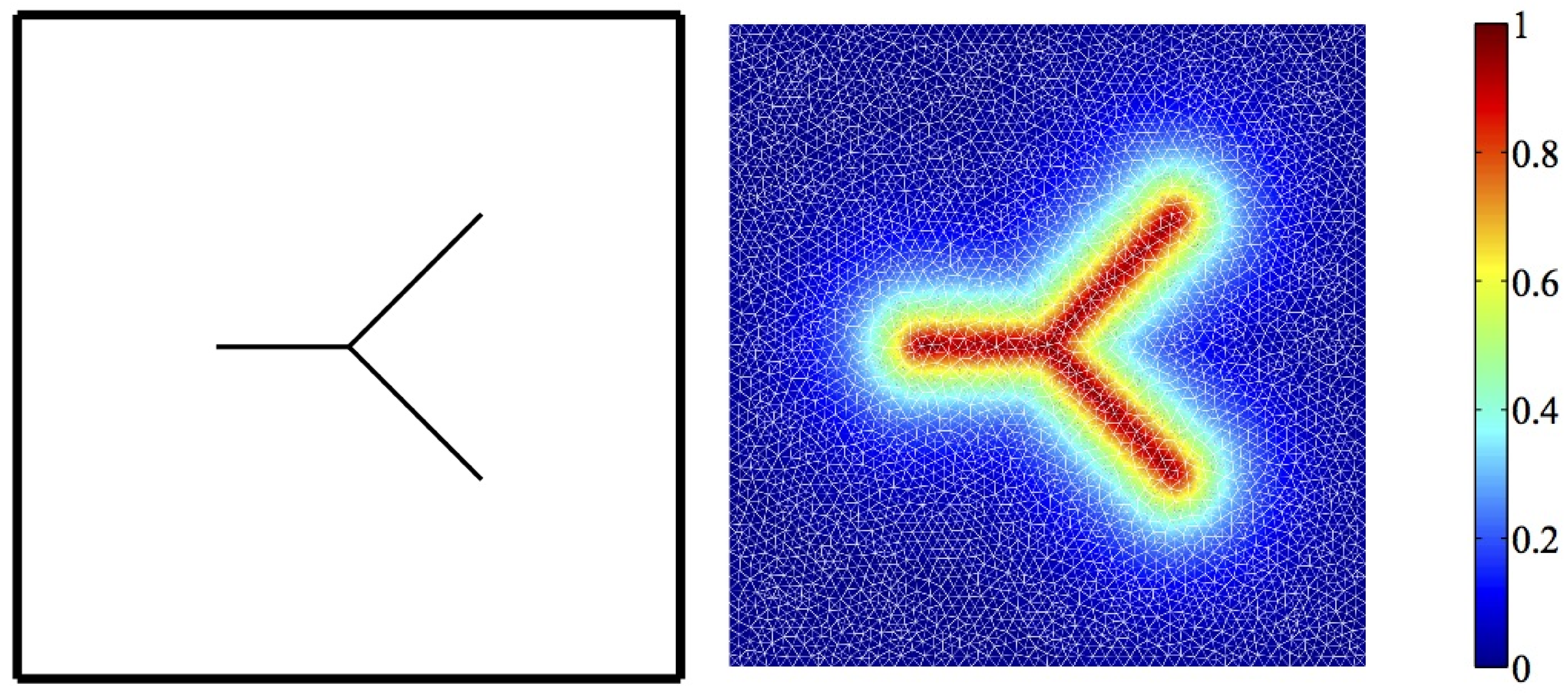
PHASE FIELD METHOD

In essence, phase field models for fracture employ a continuous field variable, called the *phase field*, to represent cracks.

The main advantage of using a phase field is that the evolution of fracture surfaces follows from the solution of a coupled system of partial differential equations.

In contrast to explicit descriptions of cracks, phase field descriptions do not require explicitly tracking the discontinuities in the displacement field. This significantly reduces implementation complexity, and is anticipated to be particularly advantageous when multiple branching and merging cracks are considered in three dimensions.

FIGURE 3

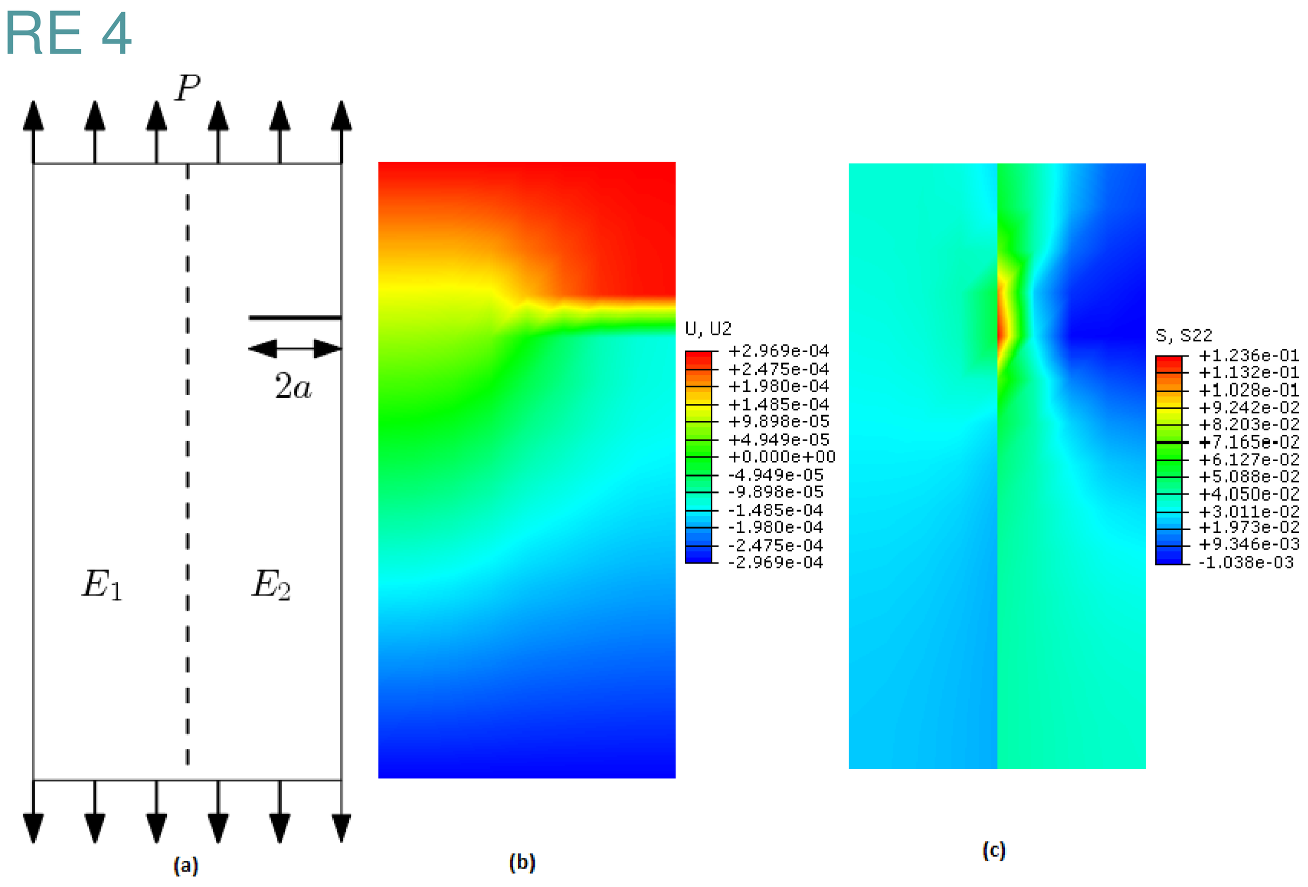


Contour plot of the equivalent phase field (right) of a branched crack (left). The equivalent phase field is the basis of the proposed crack detection algorithm.

ANALYSIS OF BI-MATERIAL PLATE WITH EDGE CRACK USING XFEM

The XFEM is a numerical technique developed by the Ted Belytschko and collaborators in 1999. It is an extension of the classical Finite Element Method (FEM) approach by enriching the solution space. The key advantage of the XFEM is to solve problems with strong discontinuity (cracks), weak discontinuity (material interfaces), moving boundary and localized features accurately without mesh refinement. Applicable to analyze the fracture problems in the bio-medical area which may arise due to accidents, aging, etc.

FIGURE 4



Bi-material plate with edge crack terminates at the interface:a) Geometry and boundary condition, b)Vertical displacement, c)Vertical stress.