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A comparative SFEM- and IGA-based numerical prediction of the stress concentration factor in plates with discontinuities

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In this contribution we present a numerical analysis of the Stress Concentration Factor (SCF) K_T and the stress distribution around holes and discontinuities in plane state structures. The stress concentration in discontinuous zones is known to be a very significant issue in strength problems. Indeed, the presence of a discontinuity makes even a simple structure model complicated to analyze, regardless of the method being used. The Finite Element Method (FEM) is the most common tool in engineering for treating such problems. However, a very fine mesh is generally required for a realistic prediction of stresses around critical zones as cracks or discontinuities. Despite the large use of the FEM as numerical approach to predict stress concentrations, the problem is still open. Here two innovative numerical techniques are proposed as computationally more efficient alternatives to determine the SCFs with a limited number of degrees of freedom, which may significantly decrease the computation time. A limited number of degrees of freedom is due to a higher order scheme carried out by the SFEM. On the contrary, the standard FEM employs local low order polynomials for the approximation of solution, and special functions are generally implemented for stress concentration problems. More in detail, the local and global strong formulation finite element method (SFEM), and the isogeometric approach (IGA) based on quadratic Non-Uniform Rational B-Spline (NURBS) basis functions, are herein applied for the purpose, as proposed for other applications in [1,2] for the SFEM, and [3-5] for IGA, respectively.

In order to demonstrate the accuracy of the two proposed methodologies, some classical examples are studied, which consider rectangular plates with different discontinuities, e.g. circular holes, U-holes, or V-notches. All the numerical results obtained in terms of stress distribution and K_T are compared with the theoretical predictions from the literature as well as the numerical solutions provided by FEM. The numerical solutions for the K_T are based on a linear interpolation of the stresses near the discontinuities within a certain distance of interpolation, and agree very well with the exact computations available in the handbooks. A comparative evaluation of numerical results based on the IGA, SFEM and FEM approaches is illustrated in Figures 1 and 2, in terms of stress distributions and K_T for a U-notched plate subjected to a uniform loading and for different degrees of freedoms (DOFs). The numerical results provided by SFEM and IGA methods are very close to the ones found with FEM, thus confirming the potentials and accuracy of the two proposed methods to capture the stress concentrations in fracture mechanics, also for coarse mesh discretizations.

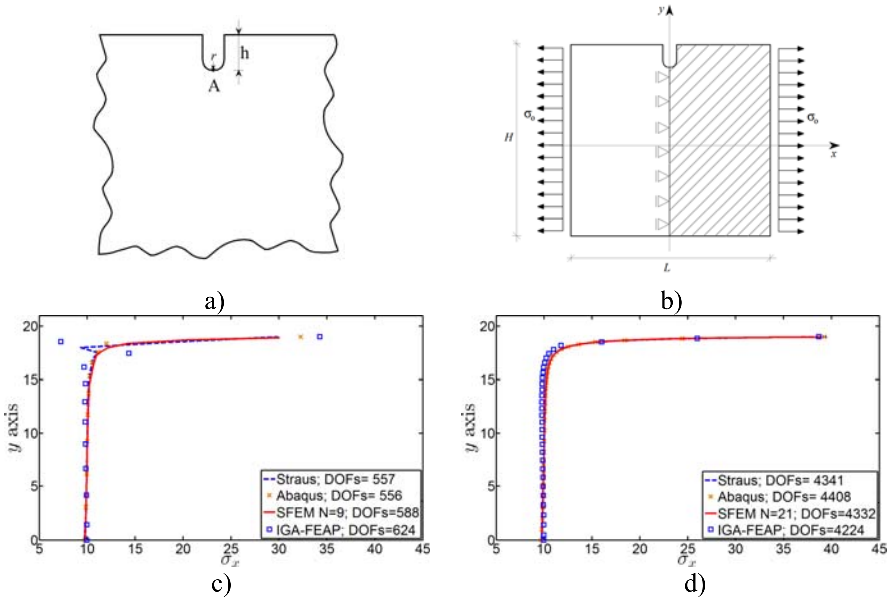

Figure 1: U-notched plate under a uniform loading: geometry (a-b) and σ_x distributions (c-d).

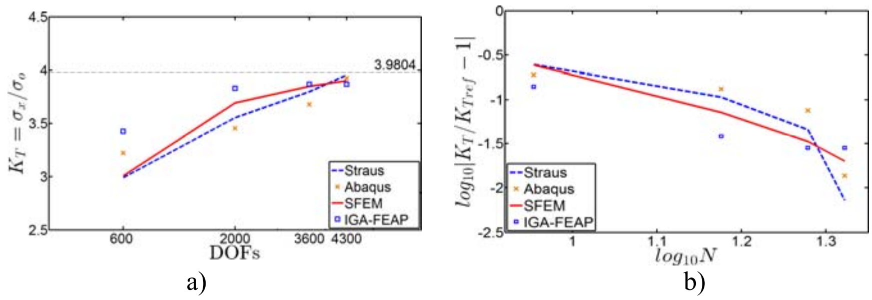

Figure 2: U-notched plate under a uniform loading: K_T (a) and error estimation (b).

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