Well Conditioned and Optimally Convergent Extended Finite Elements and Vector Level Sets for Three-Dimensional Crack Propagation

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ABSTRACT

A three-dimensional (3D) version of the vector level set method [1] is combined to a well conditioned and optimally convergent XFEM variant in order to deal with non-planar three dimensional crack propagation problems.

The proposed computational fracture method achieves optimal convergence rates by using tip enriched elements in a fixed volume around the crack front (geometrical enrichment) while keeping conditioning of the resulting system matrices in acceptable levels. Conditioning is controlled by using a three dimensional extension of the degree of freedom gathering technique [2]. Moreover, blending errors are minimized and conditioning is further improved by employing weight function blending and enrichment function shifting [3,4].

As far as crack representation is concerned, crack surfaces are represented by linear quadrilateral elements and the corresponding crack fronts by ordered series of linear segments. Level set values are obtained by projecting points at the crack surface and front respectively. Different criteria are employed in order to assess the quality of the crack representation.

References

[1] Ventura G., Budyn E. and Belytschko T. Vector level sets for description of propagating cracks in finite elements. *Int. J. Numer. Meth. Engng.* 58:1571-1592 (2003).
[2] Laborde P., Pommier J., Renard Y. and Salaün M. High-order extended finite element method for cracked domains. *Int. J. Numer. Meth. Engng.* 64:354-381 (2005).
[3] Fries T.P. A corrected XFEM approximation without problems in blending elements. *Int. J. Numer. Meth. Engng.* 75:503-532 (2008).
[4] Ventura G., Gracie R. and Belytschko T. Fast integration and weight function blending in the extended finite element method. *Int. J. Numer. Meth. Engng.* 77:1-29 (2009).