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Implementation of hybrid crack element on a general finite element mesh and in combination with XFEM. (English) Zbl 1173.74448

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Summary: The hybrid crack element (HCE) is one of the most accurate and convenient finite elements (FEs) for the direct calculation of the stress intensity factor (SIF) and coefficients of the higher order terms of the Williams expansion. In its implementation, the HCE is generally designed first at each crack tip and then the whole domain is meshed taking into account the boundaries of the domain as well as those of the HCE. This complicates the meshing task and hinders the incorporation of the HCE into commercial FE packages. In this paper, the implementation of the HCE on a general FE mesh and its incorporation into commercial FE packages is detailed and extensively validated. Furthermore, it is shown how to couple the HCE with the extended/generalized finite element method (XFEM). The HCE is used for the crack tip region, while the XFEM is used for modelling crack faces outside the HCE independent of the mesh with jump functions. The coupled method retains the advantages of both the HCE and XFEM. Numerical results are presented to validate the coupled method.

MSC:

74S05 Finite element methods applied to problems in solid mechanics
74R10 Brittle fracture

Keywords:

extended/generalized finite element method (XFEM); finite element (FE); higher order terms; hybrid crack element (HCE); stress intensity factor (SIF); T-stress

Software:

XFEM

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References:

[1] Williams, M.L., On the stress distribution at the base of a stationary crack, ASME J. appl. mech., 24, 109-114, (1957) · Zbl 0077.37902

[2] Owen, D.R.J.; Fawkes, A.J., Engineering fracture mechanics: numerical methods and applications, (1983), Pineridge Press Swansea, UK

[3] Karihaloo, B.L.; Xiao, Q.Z., Accurate determination of the coefficients of elastic crack tip asymptotic field by a hybrid crack element with \textit{p}-adaptivity, Engrg. fract. mech., 68, 1609-1630, (2001)

[4] Karihaloo, B.L.; Xiao, Q.Z., Linear and nonlinear fracture mechanics, (), 81-212, (Chapter 2.03) · Zbl 1209.74049

[5] Larsson, S.G.; Carlsson, A.J., Influence of non-singular stress terms and specimen geometry on small-scale yielding at crack tips in elastic – plastic materials, J. mech. phys. solids, 21, 263-277, (1973)

[6] Rice, J.R., Limitations to the small scale yielding approximation for crack tip plasticity, J. mech. phys. solids, 22, 17-26, (1974)

[7] Du, Z.Z.; Hancock, J.W., The effect of non-singular stresses on crack tip constraint, J. mech. phys. solids, 39, 555-567, (1991)

[8] Chao, Y.J.; Zhang, X.; Piascik, R., Constraint effect in brittle fracture, Astm stp 1296, Fatig. fract. mech., 27, 41-60, (1997)

[9] Dyskin, A.V., Crack growth criteria incorporating non-singular stresses: size effect in apparent fracture toughness, Int. J. fract., 83, 191-206, (1997)

[10] Karihaloo, B.L.; Abdalla, H.M.; Xiao, Q.Z., Size effect in concrete beams, Engrg. fract. mech., 70, 979-993, (2003)

[11] Karihaloo, B.L.; Abdalla, H.M.; Xiao, Q.Z., Deterministic size effect in the strength of cracked concrete structures, Cement concrete res., 36, 171-188, (2006)

[12] Tong, P.; Pian, T.H.H.; Lasry, S.J., A hybrid element approach to crack problems in plane elasticity, Int. J. numer. methods engrg., 7, 297-308, (1973) · Zbl 0264.73113

[13] Xiao, Q.Z.; Karihaloo, B.L.; Liu, X.Y., Direct determination of SIF and higher order terms of mixed mode cracks by a hybrid crack element, Int. J. fract., 125, 207-225, (2004) · Zbl 1187.74246

[14] Q.Z. Xiao, B.L. Karihaloo, Determination of the complete displacement field inside a hybrid crack element, Engrg. Fract. Mech., in press. · Zbl 1325.74145

[15] B.L. Karihaloo, Q.Z. Xiao, Implementation of HCE on a general FE mesh for interacting multiple cracks, in: Proc. ECCOMAS 2004, 24-28 July, Jyväskylä, Finland, 2004, CD-ROM.

[16] Moës, N.; Dolbow, J.; Belytschko, T., A finite element method for crack growth without remeshing, Int. J. numer. methods engrg., 46, 131-150, (1999) · Zbl 0955.74066

[17] Strouboulis, T.; Copps, K.; Babuška, I., The generalized finite element method, Comput. methods appl. mech. engrg., 190, 4081-4193, (2001) · Zbl 0997.74069

[18] Karihaloo, B.L.; Xiao, Q.Z., Modelling of stationary and growing cracks in FE framework without remeshing: a state-of-the-art review, Comput. struct., 81, 119-129, (2003)

[19] Babuška, I.; Banerjee, U.; Osborn, J.E., Survey of meshless and generalized finite element methods: a unified approach, Acta numer., 12, 1-125, (2003) · Zbl 1048.65105

[20] Xiao, Q.Z.; Karihaloo, B.L., Recent developments of the extended/generalized FEM and a comparison with the FEM, (), 303-324

[21] Xiao, Q.Z.; Karihaloo, B.L., Improving the accuracy of XFEM crack tip fields using higher order quadrature and statically admissible stress recovery, Int. J. numer. methods engrg., 66, 1378-1410, (2006) · Zbl 1122.74529

[22] Béchet, E.; Minnebo, H.; Moës, N.; Burgardt, B., Improved implementation and robustness study of the X-FEM for stress analysis around cracks, Int. J. numer. methods engrg., 64, 1033-1056, (2005) · Zbl 1122.74499

[23] Laborde, P.; Pommier, J.; Renard, Y.; Salaün, M., High-order extended finite element method for cracked domains, Int. J. numer. methods engrg., 64, 354-381, (2005) · Zbl 1181.74136

[24] Liu, X.Y.; Xiao, Q.Z.; Karihaloo, B.L., XFEM for direct evaluation of mixed mode SIFs in homogeneous and bi-materials, Int. J. numer. methods engrg., 59, 1103-1118, (2004) · Zbl 1041.74543

[25] Xiao, Q.Z.; Karihaloo, B.L., Direct evaluation of accurate coefficients of the linear elastic crack tip asymptotic field, Fatig. fract. engrg. mater. struct., 26, 719-730, (2003)

[26] Xiao, Q.Z.; Dhanasekar, M., Coupling of FE and EFG using collocation approach, Adv. engrg. softw., 33, 507-515, (2002) · Zbl 1024.65113

[27] Chessa, J.; Wang, H.W.; Belytschko, T., On the construction of blending elements for local partition of unity enriched finite elements, Int. J. numer. methods engrg., 57, 1015-1038, (2003) · Zbl 1035.65122

[28] Lee, S.H.; Song, J.H.; Yoon, Y.C.; Zi, G.S.; Belytschko, T., Combined extended and superimposed finite element method for cracks, Int. J. numer. methods engrg., 59, 1119-1136, (2004) · Zbl 1041.74542

[29] Wu, C.C.; Bufler, H., Multivariable finite elements: consistency and optimization, Sci. China (A), 34, 284-299, (1991) · Zbl 0733.73060

[30] Pian, T.H.H.; Wu, C.C., Hybrid and incompatible finite element methods, (2006), Chapman \& Hall, CRC, Taylor \& Francis Group Boca Raton, USA

[31] Duff, I.S.; Reid, J.K., The multifrontal solution of indefinite sparse symmetric linear systems, ACM trans. math. softw., 9, 302-325, (1983) · Zbl 0515.65022

[32] Sih, G.C.; Liebowitz, H., Mathematical theories of brittle fracture, (), 67-190 · Zbl 0207.24801

[33] Pian, T.H.H.; Sumihara, K., Rational approach for assumed stress finite elements, Int. J. numer. methods engrg., 20, 1685-1695, (1984) · Zbl 0544.73095

[34] Pian, T.H.H.; Wu, C.C., A rational approach for choosing stress term of hybrid finite element formulations, Int. J. numer. methods engrg., 26, 2331-2343, (1988) · Zbl 0661.73045

[35] Karihaloo, B.L., On crack kinking and curving, Mech. mater., 1, 189-201, (1982)