AN ENRICHED MESHLESS METHOD FOR NONLINEAR FRACTURE MECHANICS

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In recent years, various Galerkin-based meshless methods have been developed or investigated to solve fracture-mechanics problems without the use of a structured grid [1,2]. Since element connectivity data is not required for the construction of meshless shape functions, burdensome meshing or remeshing characteristic of the finite element method is avoided, thereby significantly simplifying crack-propagation analysis. However, most development in meshless methods to date has been focused on only linear-elastic fracture mechanics (LEFM) problems [1,2]. The use of enriched basis functions, typically used to capture the LEFM singularity [1,2], is not appropriate for solving nonlinear fracture-mechanics problems. The singularity of crack-tip field in elastic-plastic fracture mechanics (EPFM) is different than that in LEFM and depends on the material hardening characteristics. This implies that material properties could be embedded in the development of new or improved basis functions for meshless EPFM analysis.

This paper presents an enriched meshless method for fracture analysis of cracks in homogeneous, isotropic, nonlinear-elastic, two-dimensional solids, subject to mode-I loading conditions. The method involves an EFGM formulation and two new enriched basis functions (Type I and Type II) to capture the Hutchinson-Rice-Rosengren singularity field in nonlinear fracture mechanics. The Type I enriched basis function can be viewed as a generalized enriched basis function, which degenerates to the linear-elastic basis function when the material hardening exponent is unity. The Type II enriched basis function entails further improvements of the Type I basis function by adding trigonometric functions. Four numerical examples are presented to illustrate the proposed method. The boundary layer analysis indicates that the crack-tip field predicted by using the proposed basis functions matches with the theoretical solution very well in the whole region considered, whether for the near-tip asymptotic field or for the far-tip elastic field. Numerical analyses of standard fracture specimens by the proposed meshless method also yield accurate estimates of the J-integral for the applied load intensities and material properties considered. Also crack-mouth opening displacement evaluated by the proposed meshless method is in good agreement with finite element results. Furthermore, the meshless results show excellent agreement with the experimental measurements, indicating that the new basis functions are also capable of capturing elastic-plastic deformations at a stress concentration effectively.

References

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