Journal for Multiscale Computational Engineering, 11 (6) vii (2013)

SPECIAL ISSUE

MULTISCALE METHODS IN FRACTURE MECHANICS WITH EXTENDED/GENERALIZED FINITE ELEMENTS

Guest Editor

Haim Waisman

PREFACE

The extended finite element method (XFEM), also known as the generalized finite element method (GFEM), has been a popular area of research since the late 1990s, as evidenced by high volumes of journal publications, organized minisymposiums in leading conferences, and special workshops and conferences dedicated to this field. The key idea of XFEM/GFEM is to locally enrich the standard finite element approximation space with local enrichment functions which are chosen according to the physics of the problem at hand. For fracture problems that involve cracks, dislocations, and other types of strong discontinuities, it provides two main advantages over conventional finite element methods. That is (i) accurate fields in the vicinity of the discontinuities and (ii) mesh independence with respect to the modeling and propagation of discontinuities. Thus this class of methods offers unprecedented flexibility in fracture mechanics, addressing many shortcomings and limitations of the classical FEM.

The purpose of this special issue is to report on some of the latest developments in multiscale modeling of fracture problems that incorporate extended/generalized finite element methods. The manuscripts in this special issue address a range of multiscale problems, from dislocations to shear bands, to cracks with length scales ranging from atomistic to microscopic, and to continuum scales. While the scope of multiscale methods covered in this issue is broad, a common aspect being emphasized is the advantage of XFEM/GFEM in modeling strong discontinuities as compared to conventional FEM. The following is a short description of the manuscripts included in this special issue.

Moseley et al. propose a new procedure based on the extended finite element method for modeling interactions among dislocations and nanosized cracks in the framework of the dynamically evolving bridging domain method (DEBDM), which concurrently couples atomistic and continuum scales. The authors show several examples of interacting dislocations and nanocracks to demonstrate the flexibility and efficiency of their method. Talebi et al. propose another interesting method to couple a three-dimensional continuum domain to a molecular dynamics (MD) domain and dynamically simulate propagating cracks. The coupling is also done in the framework of the bridging domain method (BDM), where XFEM is used to handle discontinuities in the continuum scale. The viability of their approach is shown on a three-dimensional crack problem with an atomistic region around the crack front.

Tabarraei et al. develop a two-scale method for modeling adiabatic shear bands in rate-dependent materials. Shear bands are modeled as macroscopic discontinuities using XFEM with cohesive, rate-dependent traction-separation laws. These laws are are obtained at microscale and are injected to the macroscopic scale. This approach becomes important in the design of continuum systems, as the propagation of shear bands is accounted for in the design; however, microscopic features within the bands, which are computationally expensive to resolve, can be avoided.

Kabiri and Vernerey introduce an XFEM-based adaptive multiscale methodology for fracture of heterogeneous media in which both macroscopic and microscopic deformation fields strongly interact. In this context they propose an embedded representative volume element formulation with appropriate boundary conditions to enforce the coupling between the scales. The accuracy and relatively low computational cost of their method is shown on fracture problems with heterogenous elastic mediums.

1543–1649/13/$35.00

Gupta et al. develop two-scale, global-local enrichment functions for GFEM modeling of fractures involving confined plasticity in three dimensions. The enrichment functions employed are computed numerically by solving fine-scale boundary value problems defined around the localized regions undergoing plastic deformations. The authors show that their approach provides accurate nonlinear solutions with reduced computational costs compared to standard finite element methods.

Chevaugeon et al. focuse on two improvements of the X-FEM method in the context of linear fracture mechanics. The first is a new enrichment strategy, replacing the traditional enrichment function, and the second discusses the integration of the stiffness operator when singular functions such as their proposed functions are used. They demonstrate the efficiency of their method by studying convergence of straight and curved crack problems.

Finally, Waisman and Berger-Vergiat describe a domain decomposition algorithm to solve crack propagation problems which are modeled with XFEM. While brute force application of an algebraic multigrid (AMG) on systems arising from XFEM will often lead to poor convergence, the domain decomposition methodology enables any black-box AMG solver to be applied. The authors consider multiple propagating cracks and develop an algorithm that adaptively updates the subdomains. They show convergence rates that are significantly better than a brute force application of AMG to the entire domain.

Despite the increased research activity in the past few years, extended/generalized finite element methods for fracture problems is likely to remain a fertile field of study in the future. I thank all the authors for their valuable contributions to this special issue, and the referees who have reviewed the manuscripts on such short notice.

Assistant Professor Haim Waisman
Department of Civil Engineering & Engineering Mechanics,
Columbia University, New York, USA
waisman@civil.columbia.edu