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An Isogeometric Symmetric Galerkin Boundary Element Method for Two-dimensional Crack Problems

B.H. Nguyen[1], H.D. Tran*[1], C. Anitescu[2], X. Zhuang[3,2], and T. Rabczuk[2]

[1] *Department of Computational Engineering, Vietnamese-German University, Binh Duong, Vietnam*
[2] *Institute of Structural Mechanics, Bauhaus-Universität Weimar, Germany*
[3] *Department of Geotechnical Engineering, Tongji Unviversity, Shanghai, R. P. China*

Abstract

The isogeometric analysis is applied for the weakly singular symmetric Galerkin boundary element method (SGBEM) to analyse quasi-static elastic problems including crack problems in two-dimensional domains. This method takes the advantages from the common boundary representation of the isogeometric analysis and the boundary element method. The background of the developed method is to use non-uniform rational B-splines (NURBS) for the Galerkin approximation of both geometry and field variables (i.e. the displacement and traction on the boundary). The basic ingredient of the method is a pair of weakly-singular weak-form integral equations for the displacement and traction on the boundary. These integral equations contain at most weakly-singular kernels of $\ln r$, where r is the distance from a source point to a field point. Various numerical examples are examined to validate the accuracy and efficiency of the proposed method. A model of crack propagation is also discussed to illustrate the use of the method for crack growth simulation. Through the numerical examples, it is observed that the isogeometric SGBEM produces highly accurate results yet it is simple to implement.

Keywords: Isogeometric analysis, NURBS, SGBEM, crack, weakly singular

1 Introduction

In recent years, isogeometric analysis (IGA) [20, 12] has been implemented successfully in several numerical methods, e.g. the Finite Element Method (FEM). The basic idea of IGA is that the analysis of structures (e.g. stress analysis, fracture modeling) inherits directly the geometry data from Computer Aided Design (CAD) models. This offers an opportunity to bypass the time-consuming *re-approximation* of the geometry and the 'meshing' procedure. Although the context of isogeometric finite element analysis has been studied intensively by many researchers, there still exists an incompatibility between the volumetric representation of FEM and the boundary representation of the CAD models. To overcome this, non-volumetric discretization approaches can be used with IGA. For example, the coupling of meshfree methods and IGA is presented in [29, 40], in which IGA represents the exact geometry whereas the Reproducing Kernel Particle Method (RKPM) is used for the interior domain. Besides, for fracture analysis, the combination of IGA and Extended FEM (XIGA) is successfully applied for stationary and propagating crack problems [16, 17, 8, 45, 5, 4]. Specifically, an analysis based on boundary integral equations such as Boundary Element Method (BEM) seems to be ideally suited for IGA as the surface representation provided by CAD can be directly used.
BEM has been used to solve a variety of engineering problems including elasticity [6], geomechanics [3] and especially fracture mechanics [7]. The classical BEM is based on collocation approximation which exhibits undesirable features, such as the lack of symmetry in matrix operators. The Symmetric Galerkin Boundary Element Method (SGBEM) is an improvement of the BEM in the sense that it provides a symmetric global coefficient matrix with advantages such as the use of a wider class of solvers and the improvement of robustness. Furthermore, for fracture analysis, the use of collocation approach is not suitable because of the absence of traction information on the crack face. This difficulty can be overcome by using of the dual BEM [27, 26]

*Corresponding author; Email: han.td@vgu.edu.vn