Modelling of crack propagation in layered structures using extended finite element method

H. Nasaj Moghadam[1,*]- A. Keyhani [1] - I. Aghayan[1]
[1] Department of Civil Engineering, Shahrood University of Technology, Shahrood, Iran.

ABSTRACT

Crack propagation in structures is an important issue which is engineers and designers should consider. Modeling crack propagation in structures and study the behavior of this phenomenon can give a better insight to engineers and designers for selecting the construction's materials. Extended finite element method (XFEM) was used successfully in the past few years for simulating crack initiation and propagation in sophisticated and complex geometries in elastic fracture mechanics. In this paper, crack propagation in three-point bending beam including initial crack was modeled based on ABAQUS software. The following consequences were attained through the study of simulation data. First, the effects of young's modulus and fracture energy on force-displacement curve at three-point bending beam were investigated. It was observed that, by increasing the value of young's modulus and fracture energy, three-point bending beam was showed more load carrying against initiation. Second, in multi-layer beam, the effect of young's modulus on force-displacement curve was investigated. In case I (the thin upper layer is harder than the substrate) the value of young's modulus in substrate was kept constant and the amount of young's modulus in thin layer was risen in each step rather than the substrate, the peak in force-displacement curve was ascended and three-point bending beam resisted better against crack initiation. Next, similar conditions was considered in case II (the thin upper layer is softer than the substrate), by decreasing the value of young' modulus in top layer, peak in force-displacement curve was declined and crack initiation was happened in lower loading in each step. Finally, sensitivity analysis for thickness of top layer was conducted and the impact of this parameter was studied.

Keywords: Extended finite element method (XFEM), Fracture, Three-point bending beam, crack propagation.

1. INTRODUCTION

One of the most significant aspects of structures is their ability to resist the service loads that are subjected to them. The most prevalent reasons that cuase early failure in structures are: environmental conditions, construction's error, voids, microscopic flaws, and cracks. Modelling crack propagation is a practical solution to predict failure in structures. Finite element method (FEM) implements different cracks which are occurred in various shapes, sizes, and locations. The requirement of re-meshing the discontinuous of crack's domain is the notable restriction of FEM, which leads to lots of problems for modeling the crack propagtion in complex geometry. In order to mitigate the difficulties of computational crack propagation in FEM, Belytschko and Black [1] suggested the extended finite element method (XFEM), as a powerful method to resolve the problem of FEM by enriching in the proximity of the crack and simulate the domain without requiring to re-mesh which is based on the partition of unity. Later, XFEM was boosted by Moes et al. [2] and Sukumar et al. [3]. Computer implementation of XFEM was defined by Sukumar et al. [4] then Areias et al. [5] Developed the XFEM to 3D. Dolbow et al. [6] modeled fracture with frictional contact on the carck face and Modeling dynamic crack propagation was done by Belytschko et al. [7, 8], Grégoire et al. [9], and Prabel et al. [10]. XFEM is powerfull and more effective than boundary element method [11], Re-meshing method [12, 13] and element deletion methods [14], these advantages convinced the researchers to select this method. This paper was presented an XFEM procedure to investigated 2D crack propagation in elastic, homogenous and isotropic three-point bending beam with initial crack. The modeling was done by the finite element software ABAQUS version 6.10.1.

2. Extended finite element method

2.1. Basic formulation

High accuracy and independence to mesh refinement in crack's domain caused this method has been preferred to the other methods. The enriched displacement approximation in 2D crack modeling is written as following: [1]

* Corresponding author
E-mail address: Hesamnasaj@shahroodut.ac.ir