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Simulating ductile crack growth in carbon steel using an extended finite element method (XFEM)

Muhammad Shariq Hassan, Suhaib Salawdeh, Jamie Goggins

College of Engineering & Informatics, National University of Ireland Galway, Ireland

Ryan Institute for Environmental Marine and Energy Research, National University of Ireland Galway, Ireland

Centre for Marine and Renewable Energy Ireland (MaREI), Galway, Ireland

Contact: jamie.goggins@nuigalway.ie

Abstract

A novel methodology for simulation of crack growth in a 3D steel model is presented. This methodology is vital for the safe and full design of steel elements under harsh environment. The methodology, which is based on the extended finite element method (XFEM), neither requires the updating mesh over the course of the analysis, nor the priori definition of a crack length. Many other methods require the definition of crack and/or location of the crack to predict fracture. The methodology was validated against measurements from conventional static tests. The tests were carried out on the coupons of structural hollow tubes that are fabricated of 40x40x2.5SHS, 50x25x2.5RHS, 20x20x2.0SHS (mm) sections. Predictions of crack growth are used to study the behaviour of axially loaded steel to fracture. A major benefit is that the proposed method can be advanced for modelling fracture/fatigue of moderate to large structures to earthquakes.

Keywords: Extended finite element method; ductile fracture; steel coupons; structural hollow sections; steel braced frames.

1 Introduction

Simulation of a crack/discontinuity is crucial in determining the life of steel elements under fatigue loading. It also facilitates a better understanding of the phases of crack progression under static/fatigue loading, which is beneficial for structural repair and health monitoring applications. Several numerical techniques have been proposed in the literature for the analysis of crack growth in steel. For example, the element deletion, adaptive re-meshing and mesh free methods. Briefly, the element deletion method is one of the built-in capabilities in finite element packages [1] that removes failed elements from the damaged region in finite element models. The technique has yielded good performance in identifying the damaged region (see, for example, [2]). However, the method fails to represent exact orientation and propagation of cracks in metallic metals. Alternatively, adaptive re-meshing schemes were introduced in order to simulate crack propagation (see, for example, [3]). Although these techniques have also yielded good performance, the requirement of re-meshing makes these techniques difficult for geometries that are complex and large. On the other hand, the mesh free method, which has alleviated deficiencies of the aforementioned methods, were found to be appropriate for crack growth in metals [4]. However, a priori definition of crack is still required to implement this method in practice, which would become more difficult when employed for moving cracks. Attempts have been made to enhance the crack simulation

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