COHESIVE ZONE MODEL-BASED SIMULATION OF ADHESIVE JOINT FATIGUE DEBONDING*

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Abstract

The fatigue progressive debonding in bonded joints under mixed mode I/II conditions is simulated in this work using a specifically developed algorithm based on the use of cohesive zone modelling. The algorithm is implemented into the finite element software ABAQUS by means of the USDFLD subroutine. The fatigue damage accumulation law is obtained imposing the equivalence of the cyclic crack area increment and the increment of microcracks area over the cohesive process zone ahead of the crack tip, in turn related to the increment of damage in the process zone. The cyclic crack area increment is then calculated according to a Paris-like law, therefore in this way the experimental crack growth rate is related directly to damage evolution in the cohesive zone and no additional parameters have to be tuned beside the quasi-static cohesive zone parameters.

Keywords adhesive joint; debonding; fatigue; cohesive zone.

1. Introduction

Structural adhesive bonding is a leading technique for joining advanced materials and structures like airframes allowing also the use of parts of different alloys or materials (such as fiber-reinforced polymers, FRPs, and metals). The complexity of these structures and the strong impact on passenger safety, requires generally to a delivery process characterized by a severe experimental effort, possibly further amplified if a mix of materials is used in the construction. The reduction of the number of thanks to a virtual (i.e. simulated) screening of design and material solutions experiments is therefore of high interest for manufacturers. The possibility of performing such virtual material and structural testing passes therefore through the development of efficient and reliable predictive models, mostly based on the finite element method commercial softwares.

An efficient way to simulate the presence and the evolution of a defect at a bonded interface is the Cohesive Zone Model (CZM), that is incorporated into the so-called cohesive finite elements. According to this approach, the zone in front of the physical crack tip opens (slides) and then tears progressively apart following a given traction (shear) - separation (sliding) behaviour.

The CZ was recently used to model fatigue crack growth both in homogeneous bodies (Yang et al., 2001; Maiti and Geubelle, 2005; Ural et al., 2009) and at bonded interfaces (Roe and Siegmund, 2003; Muñoz et al., 2006; Turon et al., 2007) as a convenient alternative to the traditional FM techniques. The models belong essentially to two categories: i) integration of the damage law on a cycle-by-cycle basis (Yang et al., 2001; Ural et al., 2009; Roe and Siegmund, 2003); ii) integration of the damage law on a reduced time scale with respect to the number cycles (Maiti and Geubelle, 2005; Muñoz et al., 2006; Turon et al., 2007). The first type of models should allow a better representation of transients in fatigue damage and/or crack initiation, while the second one allows to reproduce large propagations with a relatively small computational effort.

In (Turon et al., 2007) the damage rate in the cohesive zone was related directly to the FCG rate therefore, no parameters have to be tuned on experiments. On the other hand, in that model the value of the applied strain