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Linking bilinear traction law parameters to cohesive zone length for laminated composites and bonded joints

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Abstract. A theoretical exploration for determining the characteristic length of the cohesive zone for a double cantilever beam (DCB) specimen under mode I loading was conducted. Two traction-separation laws were studied: (i) a law with only a linear elastic stage from zero to full traction strength; and (ii) a bilinear traction law illustrating a progressive softening stage. Two analytical solutions were derived for the first law, which fit well into two existing solution groups. A transcendental equation was derived for the bilinear traction law, and a graphical method was presented to identify the resultant cohesive zone length. The study using the bilinear traction law enabled the theoretical investigation of the individual effects of cohesive law parameters (i.e., strength, stiffness, and fracture energy) on the cohesive zone length. Correlations between the theoretical and finite element (FE) results were assessed. Effects of traction law parameters on the cohesive zone length were discussed.

Keywords: cohesive zone length; traction law; theoretical solutions

1. Introduction

Adhesive bonding, in lightweight sandwich construction and structural bonded joints, has been used for decades for the assembly of aircraft components. There has been a recent increase in the application of adhesive bonding in modern aircraft, largely driven by the usage of advanced carbon fibre composite materials. However, in-service experience has shown that the durability of bonded structures and adhesively bonded repairs varies dramatically, with some structures and repairs providing life-of-type service and others failing in a very short time, leading to a reluctant acceptance by aircraft operators as pointed by Davis and Bond (1999). In addition, due to difficulty in detecting the damage evolution of the adhesive bond and delamination, catastrophic failure could occur in the laminated structures (Ashtonm 1996, Li *et al.* 2012, Li 2013).

Delamination and disbond belong to the most important damage mechanisms in laminates and bonded laminated joint structures. To understand the performance of composite structures and associated delamination onset and propagation, standard tests combined with finite element (FE) simulations have been widely conducted. Numerical methodologies using FE methods integrated with techniques such as the virtual crack closure technique (VCCT) and/or cohesive zone models (CZMs) using cohesive elements or surfaces have been developed to capture the crack onset and to simulate progressive failure (Rybicki and Kanninen 1977, Krueger 2004, Mi *et al*. 1998, Alfano

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