Accepted Manuscript

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PII: S1359-8368(16)30829-0

DOI: 10.1016/j.compositesb.2016.09.099

Reference: JCOMB 4591

To appear in: *Composites Part B*

Received Date: 27 May 2016

Revised Date: 21 July 2016

Accepted Date: 29 September 2016

Please cite this article as: Yousefsani SA, Tahani M, Relief of edge effects in bi-adhesive composite joints, *Composites Part B* (2016), doi: 10.1016/j.compositesb.2016.09.099.

Relief of Edge Effects in Bi-adhesive Composite Joints

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ABSTRACT

Three-dimensional thermo-mechanical stress analysis of composite joints with bi-adhesive bonding is presented using the full layerwise theory. Based on three-dimensional elasticity theory, sets of fully coupled governing differential equations are derived using the principle of minimum total potential energy and are simultaneously solved using the state space approach. Results show that bi-adhesive bonding substantially relieves the edge effects. Moreover, series of parametric studies reveal the nonlinear effects of bonding length ratio and the relative stiffness and coefficient of thermal expansion of the mid- and side-adhesives. It is also concluded that the optimum design of a bi-adhesive joint crucially depends on the loading/boundary conditions.

Keywords: A. Laminates; B. Stress concentrations; C. Analytical modelling; E. Joints; Bi-adhesive bonding

1. Introduction

In previous studies, accurate analytical solutions in the framework of full layerwise theory (FLWT) were presented for thermo-electro-mechanical stress analysis of adhesively bonded composite joints [1-5]. The interfacial (transverse) shear and peel stresses are nonlinearly distributed along the bond-lines with peek values near the end points rigorously varying through the thickness of the adhesive layer, a phenomenon named "the edge effects". This nonlinearity is more intensive in structures with thicker substrates made up of different materials or composite layups with different fiber angles from one layer to another one [3].

The most challenging problem associated with design of adhesively bonded joints is the potential adverse consequences of the edge effects in increasing the level of stress concentrations at the ends of the bond-lines [6]. To estimate the bonding strength, an accurate prediction of the interfacial stress distributions in conjunction with a suitable failure criterion is needed. Failure in an adhesively bonded joint generally begins in form of propagating microcracks at these small regions due to the high-value peek stresses [7]. Although these local

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