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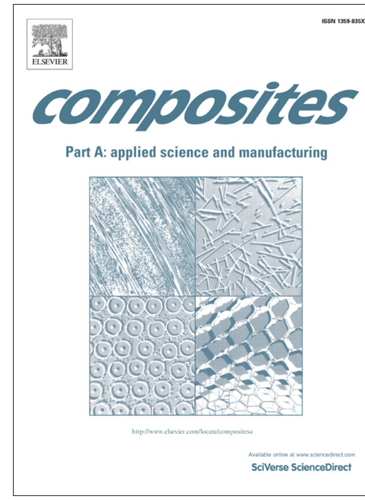

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Effective stiffness concept in bending modeling of laminates with damage in surface 90-layers

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Abstract

Simple approach based on Classical Laminate Theory (CLT) and effective stiffness of damaged layer is suggested for bending stiffness determination of laminate with intralaminar cracks in surface 90-layers and delaminations initiated from intralaminar cracks. The effective stiffness of a layer with damage is back -calculated comparing the in-plane stiffness of a symmetric reference cross-ply laminate with and without damage. The in-plane stiffness of the damaged reference cross-ply laminate was calculated in two ways: 1) using FEM model of representative volume element (RVE) and 2) using the analytical GLOB-LOC model. The obtained effective stiffness of a layer at varying crack density and delamination length was used to calculate the *A*, *B* and *D* matrices in the unsymmetrically damaged laminate. The applicability of the effective stiffness in CLT to solve bending problems was validated analyzing bending of the damaged laminate in 4-point bending test which was also simulated by 3-D FEM.

Keywords: B. Bending stiffness; Transverse cracking; C. Analytical modelling; Finite element analysis (FEA)

1 Introduction

During service life a structural element made of laminated fiber reinforced composites is subjected to various combinations of thermo-mechanical and environmental loads causing microdamage in layers as well as between layers (interlayer delamination). The most typical and earliest damage mode in layers is intralaminar cracking often referred also as matrix cracking, tunneling cracks or transverse cracking, see Fig.1. The latter name reflects the fact that the crack plane is usually transverse to the laminate middle-plane. The crack runs parallel to fibers in the layer and often (especially in thick layers) it covers the whole thickness of the layer (arrested at the interface with a layer of different fiber orientation) and the width of the specimen. On microscale these cracks are built by coalescence of many fiber/matrix interface failure events (debonds) via matrix cracks linking them.