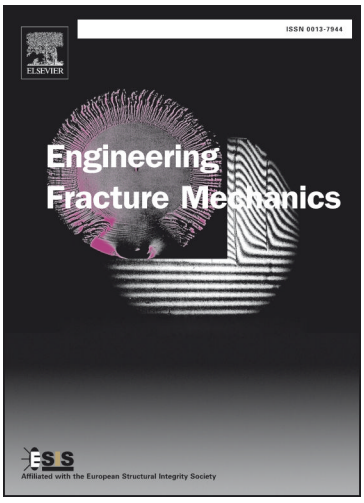

Experimental and variational-based analytical investigation of multiple cracked angle-ply laminates

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Experimental and variational-based analytical investigation of multiple cracked angle-ply laminates

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Abstract

A unit cell based method is developed based on variational principles to derive the stress state and effective mechanical properties of angle-ply laminates of type $[\theta_m^{(o)}/\theta_n^{(i)}]_s$ containing whether mid-ply or outer-ply matrix cracks positioning in a symmetric or staggered pattern through the laminate. All plausible matrix crack distribution patterns are considered and implementing the principle of minimum complementary energy, an admissible stress field is derived. For the first time effects of ply refinement technique, layup configuration and crack distribution pattern on the stress state and degradation of mechanical properties of angle-ply laminates are investigated and compared to finite element results. CFRP test specimens are prepared and optical microscopy is utilized to detect matrix crack densities during tensile tests. Obtained analytical stiffness reductions for different crack densities are confirmed to be in agreement with experimental observations.

Keywords: Matrix cracking, Variational principles, Crack distribution pattern, Stiffness degradation, Micro damage mechanics

1. Introduction

Many observations have confirmed matrix cracking as the first form of damage in general angle-ply laminates in tension [1–8]. Matrix cracks initiate and accumulate in off-axis plies and bring about more degradation in material properties during monotonic [1–3], cyclic [4–6] or thermal loading

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