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A NUMERICAL TWO-SCALE MODEL TO EVALUATE THE THERMAL EXPANSION COEFFICIENTS IN CRACKED CROSS-PLY LAMINATES

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Abstract. Laminated plates made in Fiber Reinforced Polymers (FRP) are used in structural engineering to save weight and to replace assemblies with single components. The mechanical performance of these laminates has been of main interest to researchers over the last decades. Experimental and theoretical analysis has been performed to elucidate the elastic and damage behaviors. The transverse matrix cracking is one of the first damage modes appearing when a plate is subject to thermal changes, membrane and/or bending loads. In the early works it was found that transverse matrix cracking reduces the membrane plate stiffness and modifies the Coefficients of Thermal Expansion (CTE). However, there are just a few studies on the CTE of composite laminates. This work presents a numerical two-scale model to evaluate membrane and bending CTE in unsymmetrical cross-ply laminates. The model makes use of two scales of analysis: a smaller scale (meso-scale) accounting for the transverse cracks, and a larger scale (macro-scale) which uses the classical model for laminated plates (Kirchhoff model). The domain at the meso-scale is restricted with periodic boundary conditions. The stress resultants at the macro-scale are obtained with equations based on the equivalence of mechanical power between scales (i.e. Hill-Mandel Principle). Following mesh convergence studies, the model was validated with numerical data taken from the literature for the membrane CTE's. The model produced results for bending CTE's meeting the inter-relationships for CTE's published in the literature. A parametric study on the influence of the Laminate Staking Sequences (LSS), the transverse crack density, and the material properties in unidirectional laminas is presented. It was found that the bending CTE's grow with crack density approaching the Ply Discount values. The obtained values may serve as benchmarks for other studies.