Understanding the Effects of Lamina Stacking Sequence on Structural Response of Composite Laminates

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Abstract : Structural weight reduction with improved functionality is one of the targeted desires of engineers, which drives materials and structures to be lighter. One way to achieve this objective is through the replacement of metallic structures with composites. The main advantages of composite materials are to be lightweight and to offer high specific strength and stiffness. Composite materials can be classified in various ways based on the fiber types and fiber orientations. Fiber reinforced composite laminates are prepared by stacking single sheet of continuous fibers impregnated with resin in different orientation to get the desired strength and stiffness. This research aims to understand the effects of Lamina Stacking Sequence (LSS) on the structural response of a symmetric composite laminate, defined by [0/60/-60]s. The Lamina Stacking Sequence (LSS) represents how the layers are stacked together in a composite laminate. The [0/60/-60]s laminate represents a composite plate consists of 6 layers of fibers, which are stacked at 0, 60, -60, -60, 60 and 0 degree orientations. This laminate is also called symmetric (defined by subscript s) as it consists of same material and having identical fiber orientations above and below the mid-plane. Therefore, the [0/60/-60]s, [0/-60/60]s, [60/-60/0]s, [-60/60/0]s, [60/0/-60]s, and [-60/0/60]s represent the same laminate but with different LSS. In this research, the effects of LSS on laminate in-plane and bending moduli was investigated first. The laminate moduli dictate the in-plane and bending deformations upon loading. This research also provided all the setup and techniques for measuring the in-plane and bending moduli, as well as how the stress distribution was assessed. Then, the laminate was subjected to in-plane force load and bending moment. The strain and stress distribution at each ply for different LSS was investigated using the concepts of Macro-Mechanics. Finally, several numerical simulations were conducted using the Finite Element Analysis (FEA) software ANSYS to investigate the effects of LSS on deformations and stress distribution. The FEA results were also compared to the Macro-Mechanics solutions obtained by MATLAB. The outcome of this research helps composite users to determine the optimum LSS requires to minimize the overall deformation and stresses. It would be beneficial to predict the structural response of composite laminates analytically and/or numerically before in-house fabrication.

Keywords : composite, lamina, laminate, lamina stacking sequence, laminate moduli, laminate strength
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