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STRUCTURAL AND ECONOMICAL OPTIMIZATION OF THE STACKING SEQUENCES OF HYBRID COMPOSITE STRUCTURES UNDER VARYING LOADING CONDITIONS

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Summary: The evolution of composite structures has led to the logical sequel involving hybridization of reinforcements and matrices to enhance their structural and economical tailoring potential. The behavior of hybrid composites is a weighted sum of its individual components which adopts the most favorable balance between the inherent advantages and disadvantages of its constituents. Typically, this is a balance between stiffness, toughness, durability, strength and most importantly, cost which can be quite difficult to find as it depends on characteristics which tend to contradict each other and strongly depend on the selection of parameters from a large design space. For example, these parameters could be the individual stacking sequences based on established design rules for composite structures, types of reinforcement materials used, and the volume fraction of these materials in each layup. This optimum balance would also depend on the type(s) of loading experienced in service for that specific layup. The most efficient way to account for all these constraints is the use of numerical methods such as genetic algorithms coupled with high fidelity computations such as finite element techniques to identify the optimum configurations.

The present study proposes a methodology to optimize multi-material inter-ply hybridization of long fiber reinforced polymers for large scale industrial applications. The purpose of the study was to apply specific design and manufacturing rules to aide in the selection of hybrid stacking sequences for structures under multiple loading conditions using a bi-level optimization to minimize the cost and weight while ensuring the structural integrity of the component. The optimization considers a single matrix system with Glass, Carbon and/or Aramid fabric reinforcements with varying volume fractions across the structure. The local level optimization is used to identify the optimum hybrid stacking sequences over multiple zones constrained by design and manufacturability rules where the number of plies per zone and the volume fractions of each constituent per zone is fixed. This local optimization is performed using an in-house ply shuffling tool which uses a method of elimination to identify valid stacking sequences across a multi-laminate structure. The global level optimization minimizes the cost and mass while ensuring that the structural integrity constraints are respected. To successfully assess the structural integrity of the component, a high-fidelity finite element analysis is incorporated into the global surrogate based parametric optimization chain over a range of laminate parameters. The high-fidelity model assesses loading conditions such as buckling, aerodynamic pressure loading and low velocity impact behavior at specific locations on the structure. The final proposed optimum solutions for mass and cost are presented as the engineering plies for the manufacturing of the component and respect all specified constraints.