DESIGN OF CFRP LAMINATES USING INVARIANTS

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Abstract: Carbon Fiber Reinforced Polymer (CFRP) composites have become the material of choice for many applications, particularly when superior specific strength and stiffness are design requirements. However, due to the inherent anisotropy of these materials, their mechanical characterization is rather complex, costly and time consuming and the design optimization solution of a structural component becomes material specific. This work discusses a design procedure for CFRP laminates using invariants. The optimal stiffness-based layup solution is determined using the invariant trace-normalized plane stress stiffness matrix. This optimal solution is then valid for any CFRP. Once optimal stiffness-based solution is determined, trace of the plane stress stiffness matrix is the only elastic material property required to calculate laminate stiffness. Laminate strength is calculated based on the unit circle failure criterion, which is invariant with respect to ply orientation. Unidirectional longitudinal tensile and compressive strains-to-failure are the strength parameters required. This invariant-based design approach was applied to smooth and open-hole plates and the results were compared to those obtained using the traditional design approach. It was demonstrated that the invariant-based design approach could make the design procedure of CFRP structural components much simpler and more efficient, using a reduced number of tests for material characterization.

Keywords: invariants, trace, unit circle.