DEVELOPMENT OF A FINITE ELEMENT BASED DELAMINATION ANALYSIS FOR LAMINATES SUBJECT TO EXTENSION, BENDING, AND TORSION

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Delamination is a common failure mode of laminated composite materials. This type of failure frequently occurs at the free edges of laminates where singular interlaminar stresses are developed due to the difference in Poisson's ratios between adjacent plies. Typically the delaminations develop between 90 degree plies and adjacent angle plies.

Edge delamination has been studied by several investigators using a variety of techniques. Pipes, et. al. [1,2] first identified this problem when they predicted the interlaminar stresses in a laminate loaded in tension. O'Brien [3], Raju and Whitcomb [4] analyzed this problem using a quasi-three-dimensional finite element technique. They calculated the fracture toughness of the laminate in addition to calculating the interlaminar stress distributions. Armanios and Rehfield [5] employed an approximate elasticity solution to solve this problem.

Recently, Chan and Ochoa [6] applied the quasi-three-dimensional finite element model to the analysis of a laminate subject to bending, extension, and torsion. This problem is of particular significance relative to the structural integrity of composite helicopter rotors. Such a test would employ a servo-hydraulic tension/torsion machine to apply a twisting moment to O'Brien's EDT specimen [7].

The task undertaken this summer was to incorporate Chan and Ochoa's formulation into Raju's Q3DG program [8]. The resulting program will be capable of modeling extension, bending, and torsional mechanical loadings as well as thermal and hygroscopic loadings. The addition of the torsional and

bending loading capability will provide the capability to perform a delamination analysis of a general unsymmetric laminate containing four cracks, each of a different length.

The solutions obtained using this program will be evaluated by comparing them with solutions from a full three-dimensional finite element solution. This comparison will facilitate the assesment of three-dimensional affects such as the warping constraint imposed by the load frame grips. It will also facilitate the evaluation of the external load representation employed in the Q3D formulation. The external loads are formulated in terms of the twisting curvatures and laminate theory. The resulting load vector in laminate theory is dominated by the twisting moment term. This term appears to violate the natural boundary condition at the free edge of the laminate. This is of particular interest, since these edges contain the cracks, and thus it is this area where stresses must be most accurately modeled. Finally, strain energy release rates computed from the three-dimensional results will be compared with those predicted using the quasi-three-dimensional formulation.

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