ABSTRACT

This Thesis focuses on the influence of thermoelastic interaction of curing stresses and mechanical loadings on the mixed-mode interlaminar delamination propagation characteristics in laminated FRP composites. Individual modes of strain energy release rates have been used as the defining parameters for investigating the interface delamination crack growth behavior. This has been accomplished by conducting two sets of three-dimensional sequential coupled field finite element analyses. Apart from it, 3D FE analyses also have been performed for studying the free-edge delamination and interlaminar penny-shaped delamination crack growth under various loading conditions. Layered solid elements with incompatible modes have been used to develop the FE models. Multi-point constraints have been used along the delamination front for maintaining the interface continuity. By a sequential release of these constraints, self-similar delamination progression has been realized. 3D node-to-node contact elements are used inside the delamination region for preventing the interpenetration of neighboring plies along the delaminated interface. Modified Crack Closure Integral techniques based on the concepts of linear elastic fracture mechanics have been employed to evaluate each mode of strain energy release rate. Analyses have been performed for both penny-shaped (circular) and peanut-shaped (elliptical) delaminations embedded along the interfaces of several laminated FRP composites and subjected to either a tensile or quasi-static impact loading. Low velocity non-penetrating impact induced displacements, strains and stress fields developed in laminated interply hybrid FRP composites have also been analyzed.

It is found that parameters such as fiber orientation, stacking sequence, ply thickness, delamination shape and size, delamination location, material anisotropy and loading type characterize the thermoelastic mixed-mode fracture behavior of delaminated FRP composites. The asymmetries and mismatch of strain energy release rate plots along the delamination front are ascribed to the curing stresses developed due to a negative change of temperature. Significant differences in the impact responses among the interply hybrid laminates are observed due to the arbitrariness of ply clustering and impactor aspect ratio.

Keywords: Curing stresses, Delamination damage, Fracture Mechanics, FRP laminate, Impact response, Strain energy release rate, Thermoelastic FE analysis