ABSTRACT

This Thesis deals with the thermoelastic interaction of curing stresses and mechanical loading on interlaminar delamination growth behaviour emanating from free (circular and elliptical) and pin-loaded holes in laminated FRP composites. Two sets of three-dimensional finite element analyses have been performed (one with the thermal residual stresses developed while curing the laminate and the other without thermal residual stresses i.e., with mechanical loading only) to calculate the interlaminar stresses and displacements which are responsible for delamination onset and propagation, along the annular shaped delaminated interface. Modified Crack Closure Integral (MCCI) method based on the concept of Linear Elastic Fracture Mechanics (LEFM) has been employed to calculate the three component modes of Strain Energy Release Rates (SERR). The strain energy release rate components G_I, G_{II} and G_{III} along the annular shaped delamination front due to residual thermal stresses developed while curing the laminate (i.e., cooling from an elevated temperature of thermosetting to the room temperature) and the subsequent mechanical loadings have been obtained by superimposing their respective effects. Numerical calculations are carried out for multi-layered cross-ply, angle-ply and quasi-isotropic FRP composite laminates with single and multiple delaminations emanating from the edges of the free and pin-loaded holes. The strain energy release rate variations demonstrate large asymmetries along the delamination front due to the interaction of residual curing stresses and superimposed mechanical loading.

It is found that parameters such as fiber orientation, stacking sequence, delamination shape and size, delamination location, material anisotropy and loading type characterize the thermoelastic mixed-mode delamination growth behaviour of delaminated FRP composites. The delamination growth characteristics emanating from elliptical holes exhibit peculiar and erratic pattern of SERR as compared to delaminations emanating from circular holes. There is significant difference in the delamination growth behaviour emanating from free and pin-loaded holes in laminated FRP composites. In most of the cases it is observed that the residual curing stresses have the effect of enhancing the behaviour of delamination growth. On subsequent loading this can be a potential source of causing premature failure due to the superimposed thermoelastic effects.

Interference fit of specific value with respect to specific geometry and material case reduces peak stresses around the edge of the pin-loaded holes in laminated FRP composites. Such effective interference fit fasteners introduce localized precompression stresses, thereby reducing the resultant tensile stresses after actual mechanical loading. Incase of fatigue situations, the reduction of the net stress range values, due to the above consideration would be considered as highly beneficial.

Keywords: Curing stresses, Delamination, Fracture Mechanics, FRP laminates, Interference fit, Pin-loaded holes, Strain energy release rate, Thermoelastic finite element analysis.