Effect of In-Plane Fiber Tow Waviness in the Strength Characteristics of Different Fiber Reinforced Composites

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The purpose of this study was to investigate the strength and effectiveness of certain composite materials when induced with 'in-plane fiber tow waviness' in a composite ply. Fiber waviness is usually induced by infusion processes and inherent in fabric architectures. Composite structural details like ply drops and ply joints can cause serious fiber misalignment. These are usually dependent on parameters such as ply thickness, percentage of plies dropped, and location of ply drop, the gap between the plies, mold geometry and pressure, and pressure of the resin which slides the dry fibers during resin transfer molding process. Fiber disorientation due to fiber tow waviness in ‘in-plane’ direction has been the subject of recent studies on wind turbine blade materials and other aerospace laminates with reports of compression strengths and failure strains that are borderline, depending upon the reinforcement architecture, matrix resin and environment. Waviness is expected to reduce compressive strength due to two primary factors. The fibers may be oriented in such a way that the geometry that results because of the orientation may exacerbate the basic fiber, strand, or layer buckling mode of failure. The waviness could also shift the fiber orientation off the axis of the ply longitudinal direction which eventually results in matrix dominated failures for plies normally orientated in the primary load direction (00). The longitudinal tension and compression behavior of unidirectional carbon fiber composite laminates of different materials (different grades of carbon, glass and Kevlar with different resins) were investigated using finite element analysis tool ABAQUS. Both global and local stress and strain values generated by the finite element model were validated by the traditional mechanics methods using ply/local stiffness matrix and global/reduced stiffness matrix. A precise geometry of waviness on different materials was modeled with different wave severity factor and a parametric study was conducted. Three different defects were modeled where the angle of misalignment ranged from 5 to 15 degrees with a wavelength ranged from 1 inch to 1.5 inch and amplitude which ranged from 0.03 inch to 0.1 inch. This revealed the effect of 'in-plane fiber tow waviness' on the stress distribution and loss of strength in carbon-reinforced composite materials. The results clearly show that the effect of ‘in-plane fiber tow waviness' leads to resin rich areas which causes high stress concentrations and decrease in the strength ratio, leading to delaminations, and damage of the composite panels that are unacceptable for applications that require prolonged environmental exposure and stress cycles.