ABSTRACT

As carbon fiber (CF) composites continue to gain traction in engineering applications for their exceptional strength-to-weight ratio, challenges arise due to their inhomogeneous microstructures. During manufacturing, resin-rich layers can form between the carbon fiber layers, compromising mechanical integrity. Carbon nanotubes (CNTs) offer a promising advancement, not only enhancing the strength-to-weight ratio beyond that of carbon fiber but also adding multifunctional capabilities. This research explores the integration of CNTs into carbon fiber-reinforced polymers (CFRPs) to create scalable CNT/CFRP hybrid composites for potential aerospace applications. By embedding two-dimensional, randomly oriented CNT materials in the neutral plane (NP) of unidirectional CF composites, this study evaluates the manufacturability and quality of these hybrids, employing aerospace-certified resin matrices and standard autoclave/vacuum bagging processes. Two types of scalable floating catalyst chemical vapor deposition (FCCVD) derived CNT materials are used: a lightweight CNT sock with an aerial density of 0.57 g/m² and a denser CNT sheet at 8.09 g/m². IM7 carbon fiber prepregs are combined with CYCOM® 5250-4 bismaleimide and CYCOM® 977-3 toughened epoxy resins. These CNT/CFRP hybrid Composites with CNTs in the Neutral Plane (NP) are analyzed for laminate quality through ultrasonic C-scan and mechanical testing. The 977-3 Sheet laminate achieves a longitudinal flexural modulus of 135.5 ± 7.6 GPa, while the 5250-4 Sheet laminate achieves a transverse flexural strength of 150.0 ± 10.0 MPa, a 25% increase over the control. Short beam shear strength remains nearly identical across both resin systems and CNT material combinations, with the 5250-4 Sock laminate achieving 114.1 ± 1.51 MPa. Notably, the CNT-enhanced laminates demonstrate increased crack deflection, further enhancing structural integrity. This study confirms that aerospace-grade hybrid composites can be manufactured with scalable CNT materials in the

NP using industry-standard processes without compromising the inherent mechanical properties of carbon fibers. The research will further explore additional layup combinations as well as CNT yarn hybrid composite fabrication and property study. These findings advance the understanding of CNT/CF hybrid microstructures and their mechanical performance, paving the way for developing next-generation aerospace structural materials.