Application of Helical Carbon Nanotubes for the Improvement of Mechanical Properties of Laminated Composites and Bonded Joints

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Composites materials are widely used in variety of high-performance engineering applications such as in aerospace, marine, renewable energy, sporting, and automotive industries. The use of composite materials has been growing with a very fast pace in aerospace industry, due to their light weight, excellent material properties and multifunctional characteristics. They are mainly used to build primary aircraft structural components of fuselage and wings such as skin, stringers, frames, spars, ribs, and other secondary components. Composites are known to have high mechanical properties such as strength, stiffness, fracture toughness, and impact resistance compared to the traditional homogenous material counterparts. However, they suffer from poor out of plane and interlaminar properties, which can lead to delamination of composite laminates and debonding of bonded assemblies. The composite industry is always looking for high-performance light-weight composite materials systems that can provide better properties. Previous research has shown that traditional composites can benefit from the use of nanomaterials and nanostructures as an additional reinforcement phase. Carbon nanotubes is one such nanomaterial which can significantly improve the overall properties of traditional composites. In our research, we have primarily focused on use of carbon nanotubes (CNTs) with helical shapes, due to their unique geometrical configurations. Our prior studies have shown that helical CNTs (HCNTs) perform much better than the straight CNTs, because of their unique interlocking mechanism that results from their helical configurations. Carbon nanotubes are chemically inert in nature, and this results in their poor dispersion and week bondings in polymeric resins. However, the dispersion quality/uniformity of CNTs can be improved by means of chemical functionalization that can also promotes their bonding to the polymer molecules. Our research group has done some extensive research in functionalization of HCNTs using various techniques and procedures. Test samples were fabricated with epoxy resin containing functionalized HCNTs with various weight percentages and then tested for tensile, fracture toughness, hardness, thermal, and electrical properties, based on the ASTM standards. The test results showed that the properties of certain samples were significantly improved when compared against neat epoxy samples. This was a proof that the CNT's helical configurations and chemical functionalization are very effective for the improvement of the properties of base resin systems. In the next step, the HCNTs were incorporated in laminated carbon fiber composites panels (i.e., within the resin and in between the fabric layers) and composite bonded joints (i.e., within the adhesive film) and then tested for flexural, interlaminar shear strength properties, based on ASTM standards. The results showed that the presence of CNTs with helical geometries are very effective in providing a mechanical interlocking mechanism between the HCNTs, micro-fiber reinforcements, and the resin, thus improving the overall properties of the laminated composite parts and assemblies.