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Mechanical Effects of Buckypaper in Carbon Fiber Reinforced Multifunctional Composites

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Abstract:

Fiber reinforced composites have various structural applications, including aerospace vehicles, automobile frame components, and small airframe design apparatus. The central goal of these applications is to produce materials with high strength to weight ratios at a low cost. Recent trends in composite research include the development of structural materials with multiple functionalities. Typically, an increase in functionality requires additional material phases within one system. The presence of excessive phases can result in deterioration of individual or overall properties. True multi-functional materials must maintain all properties at or above the minimum operating limit, which can theoretically be achieved through volume fraction optimization. In new studies, novel materials are being designed, developed, modified, and implemented into composite designs. One example is buckypaper which consists of sheets of magnetically aligned carbon nanotubes. The addition of pre-aligned sheets can potentially address challenges related to CNT dispersion and volume fraction optimization. If agglomeration can be prevented, CNTs can theoretically decrease interfacial delamination and increase thermo-mechanical properties. As the need for multifunctional composites expand, the demand for more complex systems increases.

In this research, 11”x11” sheets of buckypaper were integrated into the design of 4 and 6-ply carbon fiber reinforced laminates. Buckypaper was placed between 12x12” plain weave carbon fiber sheets orientated at alternating 0° and 45° directions. The layup pattern was varied ([CF_3/CNT/CF_3], [CF_1/CNT_1/CF_4/CNT_1/CF_1], and [CF_2/CNT_1/CF_2/CNT_1/CF_2]) to determine the effect of buckypaper position on thermal and structural properties. Vacuum assisted resin transfer molding (VARTM) was performed with a Fiberglast 2000 epoxy cure resin and 20-minute reaction hardener. Samples were allowed to sit overnight to assure complete cure. Preliminary experimental data and finite element analysis shows the layup scheme does affect the mechanical and thermal response of the composites. TGA (thermogravimetric analysis) results show negligible increases in thermal degradation temperatures as the volume fraction of buckypaper increases. Mechanical properties unexpectedly decreased with the addition of buckypaper. These effects are most likely due to agglomeration of the aligned CNTs, buckypaper/epoxy interfacial interactions, and inherent brittleness due to the high vol % of CNTs. Further analysis will be conducted on different resin ratios to determine the effects of resin penetration throughout the buckypaper. An in-depth analysis of the structural behavior with respect to layup scheme will be investigated by tensile test, impact test, 3-point bending, and thermogravimetric analysis (TGA). Additionally, finite element analysis via COMSOL simulations will be conducted to validate and compare mechanical and thermal results.