Graphene and related Nano Materials for Aerospace Applications

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Abstract
Due to superior weight efficiency when compared to other structural materials, most commercial and military aircraft of today use a significant amount of carbon fiber/thermoset plastic materials in primary and secondary airframe applications. Fiber composites may account for 25 to 50% of the aircraft structural weight and more than 75 % of the aircraft outer surface area in contact with the air stream.

Aerospace-grade carbon fiber/epoxy composite materials generally have excellent in-plane mechanical properties, but less impressive out-of-plane laminate properties can limit their use in many applications. This is due to the brittle nature of both commonly used matrix materials and carbon fibers but also due to lack of structural reinforcement in the laminate z direction. The anisotropic properties of layered carbon fiber laminates allow for optimized designs with low weight and high structural efficiency, but they also present significant challenges in design, especially for complex geometry airframe structures with out-of-plane loads. Most airframe components need to be joined with other components to form a large assembly of parts. A critical laminate property, affecting the design and weight of structural joints using mechanical fasteners is the low bolt bearing strength of carbon fiber composites. It makes bolted joints in carbon fiber structures heavier than corresponding joints in Aluminum structures. Also, laminate electrical properties of these composite materials, controlled by the resistive carbon fibers and the insulating epoxy matrix, are highly anisotropic. Carbon fiber laminates in typical aircraft applications such as wing skin panels and wing leading edges therefore need a metallic surface mesh for lightning strike protection and currently used anti-ice and deicing systems for carbon fiber wings rely on metallic layers for resistive heating. Thermal properties such as conductivity and expansion of carbon fiber laminates are also anisotropic.

A combination of carbon fiber polymeric composites and metals, e.g. Aluminum and Titanium alloys, is often used in order to meet airframe functional requirements. Such multifunctional designs can be complicated due to significant differentials in thermal expansion, risk of galvanic corrosion or other effects of dissimilar or conflicting material properties. Thermal stresses in the out-of-plane z direction may result in matrix cracks and local delaminations in low fracture toughness composites. In addition to mechanical loads, airframe components must survive certain in-service impacts and brittle composite materials, in contrast to metals, lack plastic deformation as an energy absorbing mechanism.

Future multifunctional airframe components benefit from the use of new efficient multifunctional composite materials and Saab Aeronautics, with partners, have focused recent materials research and development on nano-engineered carbon fiber composites. Based on testing and evaluation of early versions, this new class of multifunctional nanocomposite materials can be used to overcome the limitations of currently used carbon fiber/epoxy prepreg materials.

The use of aligned carbon nanotubes, dispersed graphene flakes or combinations of nanotubes and graphene in carbon fiber/epoxy composite prepreg materials is a strong candidate solution when multifunctional composite materials and structures are developed for future aerospace applications. This class of nano-engineered composite materials combine the mechanical properties of carbon fibers with mechanical, electrical and physical properties of carbon-based nano materials. Nano-scale reinforcement of ply interfaces in carbon fiber/epoxy laminates with aligned carbon nanotubes and/or dispersed graphene can significantly increase interlaminar fracture toughness and other mechanical properties. Electrical conductivity of carbon fiber composites can be improved and tailored through the addition of graphene flakes in the resin matrix phase of the composite materials. Future multifunctional airframe composites using engineered matrix reinforcement from carbon nanotubes and graphene have the potential to outperform currently used materials in terms of weight, cost and overall efficiency.

References
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Composites Science and Technology, Volume 133, 14 September 2016, Pages 33–39,
In-plane strength enhancement of laminated composites via aligned carbon nanotube interlaminar reinforcement