Short Communication Journal of Nanosciences: Current Research 2020 Vol.5 No.3

Advanced Materials 2018: Toughening of nanocomposites for applications in cryogenic fuel tank- Mohammad S Islam - The University of New South Wales

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Microcracks can occur in carbon fiber composite materials thanks to high thermal stresses induced by the massive difference of the coefficient of thermal expansion between the polymer matrix and therefore the carbon fibers. These micro-cracks can severely degrade the mechanical strength and gas permeability of composites, posing a big challenge to the utilization of fiber composites in liquid fuel tanks of launch vehicles. The aim of the study was to develop a multi-scale toughening method to deal with the micro-cracking problem by incorporating hybrid nano-scale materials to reinforce the fracture toughness and to scale back the coefficient of thermal expansion of the polymer matrix. Nanomaterials like nano-silica, graphene and metal oxide were selected supported their thermal properties and toughening effect. Tensile and Single Edge Notch Bending (SENB) testing of the polymer and nanocomposites were administered to review their tensile properties and bulk fracture toughness respectively, while Double Cantilever Beam (DCB) testing was administered to work out the critical energy release rate (GIC values) of the fiber-polymer laminates. The results show that nano-silica improved the fracture toughness of the composites while metal oxide nanoparticles provided the simplest improvement in thermal conductivity, lastingness, and fracture toughness.

Introduction: Carbon fiber reinforced resin matrix composite materials (CFRC) are getting used within the aerospace industry as a way of reducing vehicle weight. CFRC has advantages in high strength-to-weight and high stiffness-to-weight ratios. For future heavy-lift launch vehicles and space exploration structures, advanced lightweight composites are going to be fully utilized so as to attenuate vehicle weight, and CFRC in space applications requires rigorous development to demonstrate robustness, durability, and high factors of safety. the longer term heavy-lift launch vehicles require extremely high propellant mass fractions to realize the designed performance. This drives the designers to include lightweight materials into as many structures as possible. Propellant fuel tanks account for an outsized proportion of the launch vehicles, both structural mass and geometric space. Approximately 60% of the dry mass of a launch vehicle is that the fuel and oxidizer tanks. The implementation of composite cryogenic propellant fuel tanks (cryotank) for future heavy-lift launch vehicles could greatly reduce the vehicle's weight by replacing the identically sized cryo tanks constructed of metallic materials. United States' Committee on Materials Needs and R&D Strategy for Future Military Aerospace Propulsion Systems reported that composites offer the potential for the best mass reduction of all of the materials for the tank. For the case of Delta IV heavy-lift launch vehicle, as shown, compared to Li-Al fuel tank, the load saving of upper stage composite cryo tanks was 43 and 26%, respectively. additionally, composite design could reduce fabrication costs. Delta II faring, Delta III faring, and interstage production data have shown that composite launch vehicle structures are less costly than metal ones. Graphite-epoxy composite cryogenic tank development began at Boeing (then McDonnell Douglas) in 1987 and continues today, primarily for reusable launch vehicles (RLV) and heavy-lift vehicles. The cryogenic tanks are the dominating components of the vehicle structure. to realize a weight reduction of the next-generation launch vehicles, carbon fiber reinforced polymeric based composites are being explored for the cryogenic liquid fuel tank. A composite cryo tank structure can save 30% by weight than lithium aluminum alloy.

This work is partly presented at 22nd International Conference on Advanced Materials and Nanotechnology September on 19-21, 2018 held at Tokyo, Japan