Nanocomposites at Extreme (Space) Environment

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ABSTRACT: Polymer-based advanced composites always suffer from degradation at extreme temperatures in the range between 220 and 77 K and low atmospheric pressure. Within this temperature range, composite structures behave very brittle and many micro-cracks are easily formed due to differential thermal coefficients of expansion (CTEs) between polymer matrix and high strength reinforcements. Besides, at the Low Earth Orbit (LEO) environment the structures may also be subject to damages due to micro-meteoroid attack, in which many tiny particles left over from the formation of the solar system and they are travelling at very high speed (hyper-velocity) to cause serious impact and abrasion onto the structures. Out-gassing and high oxidation rate are also problems for polymers using at this environment. For atmospheric re-entry vehicles, due to their high speed return, the surface of the vehicles facing to the entry direction has to maintain its strength at very high temperature (~ 3500 K) when they are passing through the atmospheric layer within a short period of time. Different research works have been conducted to design ablators (thermal protection system, TPS) to minimize the weight and thickness of ablating, charring and pryrolyzing zones worldwide. Materials used for the ablators must efficiently cool the vehicles via energy absorption of the endothermic breakdown of the polymeric constituents, transpiration cooling as the pyrolysis gases percolate from the interior of the material toward the surface, and re-radiation from the hot char layer that forms on the surface. The geometry of the re-entry shape can minimize the heat induced by controlling the form (blunt body theory) of shock wave. Therefore, studies on using nano-particles to enhance the anti-cracking resistant properties and prolong the pryrolzing process are necessary. Besides, due to the increasing use of polymer-based nanocomposites at extreme environment condition, their inspectability becomes a hot topic, at least in coming 5 years to explore more real-time or remote health monitoring techniques to ensure the safety of structures. Embedded sensors, self-healing technology and smart structure designs are most prominent research fields for nanocomposite structures.

In this lecture, an overview on the nanocomposites, their mechanical, thermal and structural properties at different working environments is given. The following key items will also be introduced: (i) design of the heat shield's geometry for re-entry vehicles; (ii) shock wave effect in relation to the heat transmission to the vehicles; (iii) advantage of using Phenolic Resin Carbon Ablator (PICA); (iv) types of nanoparticles for property enhancement for the vehicles and (v) possibility of using nano-particles (nanotubes, nanoclay, nano-silica, silica-aerogel, etc) to enhance the effectiveness of pyrolyzing process of PICA to prolong the heat transfer. The potentiality of using different structural monitoring techniques to serve at the extreme environment will also be discussed.

Brief Biography

Professor Lau received his Bachelor and Master degrees of Engineering in Aerospace Engineering from the Royal Melbourne Institute of Technology (RMIT University, Australia) in 1996 and 1997, respectively. Within that period, he also worked for General Aviation Maintenance Pty Ltd, Australia, as an Engineer Trainee, and for the Corporative Research Centre for Advanced Composite Structures (CRC-ACS) Australia, as a Research Assistant designing a repair scheme for composite performs. Afterward, he received his Doctor of Philosophy (PhD) from The Hong Kong Polytechnic University in 2001. Thereafter, he was appointed Assistant Professor in 2002 and promoted to Associate Professor and Professor in 2005 and 2010, respectively. In 2015, he was appointed as Alex Wong/Gigi Wong Professor in Product Design Engineering and Associate Dean (Industrial Relation) in the Faculty of Engineering, PolyU. Currently, he is Pro-Vice-Chancellor (Research Performance and Development) of Swinburne University of Technology, Australia to look after its future research and ranking strategies. Professor Lau has received numerous research and teaching awards since 2002. This year, he has been elected as Fellow of the European Academy of Science and Arts. To date only three academics in Australia have received this honour. He has also been elected as International Vice President of The Institution of Mechanical Engineers (IMechE) and appointed as Independent Non-executive Director of Kingsflair International (Holdings) Limited.