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Nano composites at extreme (space) environment

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Introduction: Polymer-based advanced composites always suffer from degradation at extreme temperature 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 meteoroid attack, in which many tiny particles left over from the formation of the solar system and they are travelling at very high speed 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 pyrolyzing 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 pyrolzing 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 invited 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.

Biography

Alan Kin-Tak Lau joined the Hong Kong Aircraft Engineering Company Ltd. (HAECO) where he was employed as a craft apprentice for 4 years. He 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. He then 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. Currently, he is also Advisor of the Centre of Excellence in Engineered Fibre Composites (CEEFC), Australia, and Visiting Chair Professor of the London South Bank University, UK for its Doctor of Business Administration (DBA) programme. Based on his outstanding research performance in the fields of advanced composites, he has received numerous research awards including the international research leader award in composite structures and also most cited paper awards (4 papers) issued by Elsevier Science. Due to his significant contribution to the field of science and engineering, he was elected as a Member of the European Academy of Sciences in 2007, and was the first scholar in Hong Kong to receive this honor. Currently, he has received over 2400 citations (non-self cited) with h-index and citations per paper of 25 and 19, respectively.

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