20th World Summit on Nanotechnology and Expo

October 05-06, 2018 | Los Angeles, USA

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Noncontact structural damage sensing using nanocomposites and tomography

Aerospace and civil infrastructure components, particularly those built using fiber-reinforced polymer (FRP) composites, can suffer from subsurface damage modes that are difficult to detect and quantify during scheduled inspections. Subsurface damage includes matrix cracks, delamination, and manufacturing defects, such as voids, all of which has the potential to propagate during service and increase the risk for structural failure. In this study, a noncontact and noninvasive strain monitoring and damage localization technique are presented. Two components are needed. First, a patterned, passive, nanocomposite thin film was deposited and embedded in structural materials during component manufacturing. The embedded sensing element is passive in that it does not require any electrical connections to the thin film. In addition, the thin film was designed such that its electrical permittivity varied in response to applied strains. Second, an electrical capacitance tomography (ECT) algorithm and measurement system were implemented for mapping the permittivity distribution of cross-section of the film-enhanced FRP component. When the structure is undamaged, the embedded thin film's strain response was close to zero, since it was deposited near its neutral axis. However, when damage occurs, the distribution of strain along the cross-section would change, and the film would change its electrical permittivity in response to strains induced. The ECT software-hardware system was used to nondestructively image the electrical properties of the component. It was shown that the strain-induced permittivity change of the film was successfully detected, and the location of damage could be localized using ECT. In addition, other damage modalities could be realized by embedding different types of films whose electrical permittivity is sensitive to different damage modalities. The vision is that the entire system can be miniaturized so that inspectors can scan structural components, visualize, and localize damage in real-time.

Biography

Kenneth Loh is an Associate Professor in the Department of Structural Engineering and leads the Active, Responsive, Multifunctional, and Ordered-materials Research (ARMOR) Lab at the University of California-San Diego. He received his BS degree in Civil Engineering from Johns Hopkins University in 2004. His graduate studies were at the University of Michigan, where he completed two MS degrees in Civil Engineering (2005) and Materials Science & Engineering (2008), as well as a PhD in Civil Engineering in 2008. His research interests include multifunctional materials, nanocomposites, scalable nano-manufacturing, tomographic methods, and human performance sense. His recent honors include the NSF CAREER Award, Achenbach Medal, Fulbright Scholar, Joseph Wang Award, and SPIE Senior Member honor.

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