Composite Delamination Imaging using Planar Electrical Capacitance Tomography and Machine Learning

Yening Shu[1], Kenneth Loh[1]

[1]Department of Structural Engineering, University of California San Diego, USA

Composites are extensively used for aircraft, automotive, and civil infrastructure systems because of their high strength- and stiffness-to-weight ratios. However, defects such as porosity and delamination could occur and propagate, especially when they are subjected to unpredictable impact, service, and/or environmental loads. To prevent these damage features from propagating and causing catastrophic structural failure, there is an urgent need to localize and evaluate the extent of these subsurface damage features. Conventional nondestructive evaluation and structural health monitoring systems, which require the use of discrete sensors and estimation of structural response, can be time and economically inefficient. In contrast, direct damage detection methods such as electrical capacitance tomography (ECT) could be used in a noncontact manner to directly visualize these subsurface damage features. The hypothesis is that delamination results in a localized change in dielectric property (i.e., permittivity) in the composite, which can be mapped using ECT. To test this hypothesis, the planar ECT method was used in this study in order to develop a portable, handheld nondestructive inspection system for carbon fiber-reinforced polymer (CRFP) composites. In short, planar ECT utilizes capacitance measurements of planar electrodes to reconstruct the volumetric permittivity distribution of the scanned object. Localized changes in permittivity correspond to cracks or delamination. However, the conventional planar ECT reconstruction algorithm suffers from intensive computational demand and low-resolution because of the ill-posed nature of the inverse problem. For inspection accuracy and time-efficiency, a supervised machine learning method that utilizes an artificial neural network was employed in the planar ECT solver. The results showed that high-resolution and real-time permittivity reconstruction could be achieved. Both numerical simulations and experimental results are presented in this work to verify the delamination damage mapping in CFRP composites.