PhD Dissertation Defense Announcement
Mechanical and Aerospace Engineering Department
University of Texas at Arlington

REAL-TIME MATERIAL STATE ASSESSMENT OF COMPOSITES USING ARTIFICIAL INTELLIGENCE AND ITS CHALLENGES

By

Muthu Ram Prabhu Elenchezhian

Dissertation Advisor: Dr. Kenneth Reifsnider

12:00 PM C.D.T, Thursday, April 29th, 2021

Click here to Join Microsoft Teams Dissertation

Abstract

Over several decades of careful experimental investigation and exhaustive development of discrete damage analysis methods including integrated computational mechanics methods, our community knows a great deal about how discrete defects such as matrix cracks and defect growth (e.g. delamination) can be predicted in structural composites. For many practical situations controlled by laminated multiaxial composite structures, the loss of performance and "sudden death" end of life is controlled by defect coupling which becomes a precursor to fracture plane development. These interaction sequences are highly dependent on local details of manufacture, design configurations, and loading for a given application material and influenced by small variations in loading history and other applied conditions.

Therefore, it is difficult to create a general analysis approach which relates real time measurements of a material variable which can be directly related to remaining strength and life. The solution to this puzzle requires a two-step advance in the reliability analysis and active control of in-service structural composites. First, a material state variable has to be identified that is easily measured and directly, precisely, and uniquely related to the coupling process that defines remaining strength and life. And second, a methodology must be defined to use that variable to calculate remaining strength and life in real time, for arbitrary loading types and histories.

The present research work addresses both of these challenges by identifying dielectric response as a material state variable that is easily measured on composite structures in real time and uniquely related to the defect coupling process that marks "the beginning of the end", and then by proposing an Artificial Intelligence (AI) method of using a continuous real-time record of that variable to predict residual strength and life, and further achieve real time control and system reliability. This is achieved by using the Broadband Dielectric Spectroscopy method and Fiber Optic distributed Sensors to measure the dielectric property and strain respectively. These state variables are used to establish a method to identify damage in the composite material, predict the characteristic damage state (CDS) and residual strength, life of material with uncertainty estimates. Interpretable machine learning methods are utilized to identify the contributing features to model and explain the predictions.