PhD Dissertation Defense Announcement

Mechanical and Aerospace Engineering Department

University of Texas at Arlington

FINITE ELEMENT BASED METHODOLOGY TO PREDICT FATIGUE COMPRESSION FAILURE IN COMPOSITE BASED ON FIBER KINKING DAMAGE MODEL

By

MD SADDAM HOSSAIN

Thesis Advisor: Dr. Andrew Makeev

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Teams Meeting (online): Meeting Link

Abstract

Advanced polymer matrix composites are widely used in designing high-performance and light weight spacecraft, rotorcraft, and automotive structures, due to its superior performance such as specific stiffness, specific strength, and toughness, which are appealing in reducing the weight of these structures. One critical factor that limits the efficient design of structures composed of fiber reinforced composites (FRP) is the vulnerability of the material under compression loading, since compressive strength of FRP material are typically lot less compared to the tensile strength. Moreover, composite structure may undergo compression loading either by accidently or by deliberately, large margins of safety are usually imposed in composite design process, causing in heavyweight and inefficient design. Therefore, the advantage of high elasticity and strength of FRP cannot be fully utilized.

Understanding, modeling and finally predicting the compressive response of composite material is a long-standing as it is one of the most complex and widely studied yet unresolved issue. Additionally, the multiplicity of damage modes, their interaction and complex failure mechanism limits the accurate failure prediction and life assessment of composite structures under compression loading. The uncertainty due to complexity of failure mechanism, impose risk in composite design process that cannot be improved by lengthy and expensive testing. Validated analysis techniques capturing the proper mechanism of compressive damage and interaction from initiation to ultimate strength and fatigue failure are essential to provide accurate life assessment of composite structure. Not to mention, it may assist to identify rooms for improvement to the material system.

The objective of this research is to develop a finite element-based methodology to predict fibercompression fatigue failure which is well recognized weakness of carbon-offer reinforced composites. In order to achieve proper fatigue failure prediction in compression loading, preliminary studies have been performed to see if the implemented fiber kinking model can predict the compression failure in quasi-static loading. Therefore, two different carbon/epoxy materials were tested according to ASTM standard and the CT scan images were compared with the computational prediction. It was found that including fiber-kinking theory in the computational model help captures the fundamental failure mechanisms such as compression strength, crack location-propagation and large fiber rotation after failure initiation. The study also shows that accurate prediction of fiber rotation angle which drives the compression failure play a significant role in capturing the proper material behavior under compression. Based on these outcomes fatigue tests were performed in short beam shear specimen for two different carbon/epoxy material systems. Through these tests the key parameter contributing to the change in the material mechanical property during fatigue is identified as the accumulation of permanent shear deformation. Therefore, fiber-kinking theory is extended and modified to include this change of mechanical shear property during fatigue loading. Additionally, the proposed fatigue model is implemented in the material constitutive model at the fiber misalignment frame using ABAQUS/Explicit FE formulation. Finally, ASTM standard test method D6484 Open Hole Compression are performed, and model predictions are corelated with the test results.

The proposed fatigue model based on continuum damage mechanics offers a strong promise in resolving the weakness of the currently available meso-scale fatigue model to predict fatigue compression failure. Furthermore, the proposed model has the ability to predict compressive strength and fatigue behavior in multidirectional laminate which not only increases the confidence in the material allowable but also has a strong potential to tremendously reduce qualification testing and expand the material composition and layup design space.