DAMAGE MECHANICS OF COMPOSITE LAMINATES SUBJECTED TO CYCLIC FLEXUAL LOAD

SEYED SAEID RAHIMIAN KOLOOR

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ABSTRACT

Composite laminates are one of the advanced materials were faced problems to analysis mechanism of damage. The purpose of this study is to develop and validate damage mechanics model for composite laminate's failure and to establish the mechanics of carbon fiber reinforce polymer (CFRP) composite's failure model under flexural fatigue load. The processes of evaluating damage mechanism are to observe its initiation as well as propagation in composite laminates. Three additional cases of static loading were investigated to ensure accuracy of the results of experiment and simulation. The three cases are; a composite laminated beam under tension; a composite laminated plate with a hole at the middle of specimen under tension and a composite laminated beam under bending load. Delamination was focused as the main reason of damage which occurs in macro-mechanics level of composite laminates besides other types of damages have effect in composite laminate's failure.

Simulations have been conducted using finite element method. Ye's delamination criterion was used to develop a new criterion for predicting onset of delamination in composite laminates and power law criterion was used to develop a new principle to predict the propagation of delamination as well. The comparison of experimental and simulation results showed good accuracy indicating, however, the applicability and reliability of this method in delamination of composite laminates.

ABSTRAK

Komposit berlamina merupakan salah satu bahan termaju yang berhadapan dengan masalah analisis kegagalan mekanik. Tujuan kajian ini adalah bagi memajukan dan menilai model mekanik kerosakan bagi kegagalan komposit berlamina serta untuk membangunkan model kegagalan mekanik bagi gentian karbon diperkuat polimer dibawah pembebanan lesu. Proses penilaian mekanisma kerosakan adalah dengan memerhatikan kerosakan yang terjadi pada permulaan dan ketika perambatan kerosakan pada komposit berlamina. Penyiasatan tambahan juga dijalankan bagi 3 kes pembebanan statik, ianya adalah untuk memastikan ketepatan keputusan yang diperolehi daripada ujikaji dan simulasi. Ketiga-tiga pembebanan statik tersebut adalah; rasuk komposit berlamina dibawah pembebanan tegangan, plat komposit berlamina dengan lubang ditengah-tengahnya dibawah pembebanan tegangan dan rasuk komposit berlamina dibawah pembebanan lenturan. Pemisahan diantara lamina-lamina merupakan fokus utama kajian ini, kerana ianya merupakan kegagalan utama yang terjadi pada tahap mekanik-mikro kepada komposit berlamina disamping berbagai-bagai jenis kerosakan lain yang juga menyebabkan kegagalan kepada komposit berlamina.

Simulasi telah dijalankan menggunakan kaedah unsur terhingga. Kriteria pemisahan Ye telah digunakan bagi membangunkan kriteria pemisahan baru yang mana ianya boleh digunakan bagi meramal permulaan kegagalan pemisahan diantara lamina-lamina didalam komposit berlamina dan kriteria Hukum Kuasa (Power Law) juga digunakan membangunkan prinsip baru bagi meramal perambatan pemisahan diantara lamina-lamina. Perbandingan diantara keputusan simulasi dan ujikaji menunjukkan ketepatan yang baik, di samping kebolehgunaan dan kebolehpercayaan kaedah ini bagi meramal kegagalan pemisahan didalam komposit berlamina.

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CHAPTER 1

INTRODUCTION

1.1 An introduction to composite materials

Composite materials are materials that consist of two or more separate phases. In an advanced society like ours we all depend on composite materials in some aspect of our lives. The greatest advantage of composite materials is strength and stiffness combined with low weight. In fact, the demands made by the industry for materials that are both light and strong has been the main force driving the development of fiber-reinforced plastic composites.

The plies of a fiber-reinforced polymer composite can be stacked under different fiber angles to form a so called ‘laminate’ with desired stiffness and strength in different directions. For this reason the use of Laminated Composite Structures (LCS’s) in the aerospace and automotive industries has increased significantly over the last few decades. Since the material can be tailored to meet special demands, LCS can be lighter and made with superior characteristics when compared to traditional single-phase materials.

However, the use of these materials introduces new challenges in the design and analysis process along with the emergence of new damage mechanisms.

1.2 Problem background and significance

Composite materials are fabricated to have better engineering properties than the conventional materials, for examples, metals. Some of the properties that can be improved by forming a composite material are: stiffness, strength, Weight, corrosion resistance, and thermal properties, fatigue life and wear resistance. Most man-made composite materials are made from two materials: a reinforment material and a parent or matrix materials.

Composite materials are finding application in variety of system; including aircraft and submarine structures, space structures, automobiles, sport equipment, medical prosthetic devise and electronic circuit board. They are more suitable in application that requires high strength-to-weight and stiffness-to-weight ratio. With the increased use of composite in structural components studies involving the behavior of components made of composite are receiving considerable attention. Functional requirements and economic consideration of design are forcing engineers to seek reliable and accurate yet economical methods of determining static and dynamic characterization of the structural components.

The analytical study and design of composite materials requires knowledge of anisotropic elasticity, structural theories and failure/damage criteria. Unlike isotropic materials, anisotropic materials exhibit complicated mechanical behavior. Most real world problems involving composite structures do not admit exact solution, requiring one to find approximate, but representative solution.

The finite element method (FEM) is an affective approximate method of obtaining numerical solution to initial-value, boundary-value and eigen-value problems. The method is the most powerful numerical tool available today for prediction the response of composite structures.

The significance of this project is to present the composite laminated theories and their finite element models to study the deformation, strength and damage mechanism of composite structures for flexural loading conditions. Emphasis is placed on engineering aspects, such as the analytical descriptions, effective analysis tools modeling of physical features and evaluation of approaches used to formulate and predict the response of composite structures. [1]

1.3 Problem statement

A simple supported laminated composites which subjected to cyclic flexural load. This laminate can be in several types of angle-plies or cross-plies. Investigate the process of damage in static and cyclic flexural load. How does damage initiate and propagate in composite laminats under fatigue loading condition. The method which has to use is finite element method (FEM). Simulate the damage mechanism with software of Abaqus. Investigate what is the method of monitoring of damage in composite laminate and how it work.

1.4 Project aim

The aim of the project is:

To evaluate mechanism of damage, step by step in composite laminate when damage initiate and how it propagate.

1.5 Objective of project

This project follows two objectives:

- To develop and validate damage mechanics model for composite laminate failure.
- To establish the mechanics of carbon fiber reinforce polymer (CFRP) composite failure model under flexural fatigue load using FE method

1.6 Scope of project

This project is focusing on mechanism of damage in composite laminates. The scopes of this project are as follow:

1. Develop damage based mechanics model for composite laminates.
2. Perform mechanical tests on CFRP to extract model parameters.
3. Develop FE model of a composite laminate with and without crack.
4. Validate FE model and damage mechanics model for CFRP.

1.7 Organization of Reports

In the following chapters literature review, methodology and some initial result and work will be discussed respectively. In chapter two literature review will be discussed deeply and it is divided in to four parts, first there will be a description of composite materials, second there will be explained about mechanics of composite

materials, third there will be discussed about finite element method (FEM) in composite materials and finally in fourth part will be explained about mechanism of damage in composite materials. Chapter three will specify research methodology. And finally chapter four concentrates on preliminarily results.

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