
**UNIVERSITI PUTRA MALAYSIA**

***PROGRESSIVE DAMAGE ANALYSIS OF WOVEN COMPOSITE PANELS SUBJECTED TO TENSILE LOADING***

**SULAIMAN KAMARULAZIZI**

# PROGRESSIVE DAMAGE ANALYSIS OF WOVEN COMPOSITE PANELS SUBJECTED TO TENSILE LOADING

**By**

**SULAIMAN KAMARULAZIZI**



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**Chairman: Rizal Zahari, PhD**

**Faculty: Engineering**

A research on the progressive damage analysis subjected to tensile load for woven composite plates is conducted using the finite element method. A progressive failure algorithm is employed in the finite element to model damage and material non-linearity in the woven composite laminates. In order to achieve this, three types of stress based failure criteria namely Tsai-Wu, Tsai Hill and maximum stress are included in the finite element analysis via user subroutines which is coded in FORTRAN programming language and is then linked with ABAQUS finite element software. Series of coupon tests are carried out for C-glass/epoxy, carbon/epoxy, and hybrid carbon/C-glass/epoxy laminates according to ASTM3039 to obtain their mechanical and strength properties which are required as input parameters in the finite element analysis. The finite element progressive damage analyses are performed on flat composite laminates made of C-glass/epoxy, carbon/epoxy, and hybrid carbon/C-glass/epoxy which are clamped on one end and free on the other

end. It is observed that the results obtained from the finite element analysis using the three failure criteria are in excellent agreement with the experimental results. Glass sample with orientation (0,0,0,0)s and (0,90,0,90)s shows that Tsai-Wu is the best failure theory when compared to the experimental result. Comparison between first ply failure and total failure found that for the case of flat plates the differences in the first ply failure load and ultimate failure loads are very small which is less than 10% over range between 0 to 90 degrees of fiber layup orientations. Visual inspections of the damage specimens using microscopic camera LEICA MS5 are also carried out for certain type of composite laminates mentioned above to investigate the mode of failures. From the inspections it was observed that in general all of the samples exhibit almost similar types of failure modes such as fiber breakage, delamination, and matrix cracking. Finally, a progressive damage analysis of woven hybrid stiffened plates under tension is conducted to investigate the load carrying capabilities up to total failure as well as the energy absorption capabilities for various types of fiber orientations. Fourteen different types of angle ply layup have been studied with the conclusion that layup orientation of $(0,90)_4$ has the highest maximum load of 33209.4N and energy absorption of 1048.49 J/kg while $((45)_4,(-45)_4)$ has the lowest maximum load of 6506.7N and $(75)_8$ has the lowest energy absorption of 185.37 J/kg. The comparison between first ply failure and total failure of the laminates found that between the ranges of 0 to 90 degree ply layup, 45 degree angle ply has the highest percentage difference of 35.72% for maximum load and 32.39% for energy absorption between first ply failure and final ply failure. $(0)_8$ and $(90)_8$ degree ply layup shows no difference between first ply failure and final ply failure which indicates that this type of layup has the characteristic of a very brittle material.

Abstrak tesis ini dikemukakan kepada pihak Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

**ANALISA PROGRESIF KEROSAKAN TERHADAP ANYAMAN KOMPOSIT PANEL YANG DIKENAKAN TEGANGAN**

**Oleh**

**SULAIMAN KAMARULAZIZI**

**Julai 2012**

**Pengerusi: Rizal Zahari, PhD**

**Fakulti: Kejuruteraan**

Satu kajian progresif kerosakan yang dikenakan regangan terhadap gentian anyaman komposit plat menggunakan cara analisa unsur terhingga. Progresif kerosakan algoritma telah disertakan ke dalam analisa unsur terhingga bagi membentuk kerosakan dan ketidakstabilan didalam komposit hibrid tersebut. Bagi menjayakan analisa ini, tiga jenis ciri kerosakan iaitu Tsai-Wu, Tsai Hill dan Tegasan Maksimum telah disertakan ke dalam analisis unsur terhingga melalui subrutin yang ditulis menggunakan perisian FORTRAN dan dimuatkan ke dalam perisian ABAQUS unsur terhingga. Beberapa ujian telah dijalankan ke atas sampel C-kaca/epoksi, karbon/epoksi, dan karbon/C-kaca/epoksi hibrid menurut ASTM3039 bagi mendapatkan nilai-nilai asas sifat bahan tersebut sebagai nilai input bagi analisis unsur terhingga. Analisa unsur terhingga progresif kerosakan telah dijalankan ke atas plat rata yang diperbuat dari kaca/epoksii, karbon/epoksi, dan karbon/C-kaca/epoksi hibrid. Plat ini melalui proses regangan di satu hujung dan pemberhenti di hujung lain. Graf beban dan pergerakan dan tenaga penyerapan telah diperolehi bagi setiap

jenis komposit dan bagi setiap jenis orientasi. Dari ujian-ujian tersebut, dapat dilihat bahawa analisis unsur terhingga menggunakan ketiga-tiga teori kegagalan menunjukkan keserasian yang baik dengan hasil ujikaji. Bagi ujian C-kaca/epoksi dengan orientasi (0,0,0,0)s dan (0,90,0,90)s Teori kegagalan Tsai-Wu menunjukkan persamaan terbaik dengan hasil ujikaji. Perbandingan antara kerosakan pertama dan kerosakan akhir dilihat bagi kes plat rata menunjukkan perbezaan bagi kerosakan pertama dan kerosakan terakhir adalah terlalu kecil dimana peratusan perbezaan adalah di bawah 10% bagi siri 0 sehingga 90 darjah. Pemeriksaan visual menggunakan mikroskop kamera LEICA MS5 juga telah dijalankan bagi komposit-komposit pilihan bagi menentukan mod kerosakan. Dari pemeriksaan ini dapat dilihat bahawa dasarnya semua komposit mempunyai ciri-ciri kerosakan yang sama iaitu kerosakan gentian, nyahlapisan, rekahan penyambung, takukkan matriks retak. Akhirnya satu analisis progresif kerosakan bagi komposit anyaman hibrid plat T di bawah bebanan telah dijalankan untuk menentukan kekuatan sehingga kerosakan akhir dan juga nilai tenaga serapan bagi beberapa jenis orientasi gentian. Empat belas jenis susunan telah dikaji dengan hasilnya menunjukkan bahawa orientasi $(0,90)_4$ mempunyai maksimum beban tertinggi iaitu 33209.4N dengan tenaga serapan 1048.49 J/kg manakala $(45_4,-45_4)$ mempunyai maksimum beban terendah iaitu 6506.7N dan $(75)_8$ mempunyai nilai tenaga serapan terendah iaitu 185.37 J/kg. Perbandingan antara kerosakan pertama dan kerosakan terakhir dilihat bahawa antara 0 sehingga 90 darjah orientasi, 45 darjah mempunyai nilai peratusan perbezaan tertinggi iaitu 35.72% bagi maksimum beban dan 32.39% bagi tenaga serapan antara kerosakan pertama dan kerosakan terakhir. 0 dan 90 darjah orientasi tidak menunjukan sebarang perbezaan antara kerosakan pertama dan kerosakan akhir dan ini menunjukan bahawa orientasi ini bersifat sangat rapuh.

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I certify that and Examination Committee has met on 13 July 2012 to conduct the final examination of Sulaiman Kamarulazizi on his Master Degree thesis entitled " Progressive Damage Analysis of Woven Composite Hybrid Panels Subjected to Tensile Loading " in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulation 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science.
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## DECLARATION

I declare that this thesis is my original work except for quotations and citation which have been duly acknowledge. I also declare that it has not been previously or is not concurrently, submitted for any other degree at Universiti Putra Malaysia or any other institution.

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**SULAIMAN BIN KAMARULAZIZI**
**Date: 13 July 2012**

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