UNIVERSITI PUTRA MALAYSIA

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1999

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By

ASAD ABDULLAH KHALID

Thesis Submitted in Fulfillment of the Requirements for the Degree of Doctor of Philosophy in the Faculty of Engineering Universiti Putra Malaysia

April 1999

ACKNOWLEDGEMENTS

First of all I would like to thank my God (ALLAH) for every thing.

I would like to express my sincere gratitude and deep thanks to my supervisor Associate Professor Dr. Barkawi Bin Sahari for his kind assistance, support, advice, encouragement and suggestions throughout this work and during the preparation of this thesis.

I would like to express my appreciation to Dr. Mustafar Bin Sudin and Dr. Mageed Hammoda. Co-supervisors, for their help, suggestions and assistance during preparation of this thesis. My appreciation is also to Dr. Yousif A. Khalid for his assistance, constructive ideas and suggestions during my research projects.

I acknowledge the help from the head of mechanical and manufacturing engineering department Dr. Megat hamdan and the help from Dr. Shamsuddin Sulaiman.

Great thanks to the external examiner Prof. S. A. Meguid from the Department of mechanical Engineering / Toronto University, Canada for his effort, time spent, valid advice and thesis corrections.

Thank to Associate Prof. Baharuddin Hitam and Mr. Aznijar Ahmad for their help. Appreciation is also due to Puan Mahyon, Mr. Sharani, Mohamad Rashid, Tajul Arifin , Ahmed shaifuldeen, Zulkifli, Suliaman and Mr. John. for their help during the experimental work stage of this project.

I would like also to thank all the staff members of the UPM library for their assistance in providing the scientific papers required for this work.

Last but not least, I would like to extend my sincere appreciation to my family, my mother, sisters and my brothers.

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NOMENCLATURE

Symbol		Units
A	Cross-section rea	m^2
D_1, D_2	Internal and External Diameters of the Section Undergoing Crush	mm
D_I	Initial Diameter of the cone	mm
E	Young's Modulus	GN/m^2
E_f	Young's Modulus of fiber	GN/m^2
E_m	Young's Modulus of Matrix	GN/m^2
E_S	Specific Energy Absorption	KJ/Kg
E_1 or E_{11}	Longitudinal Young's Modulus (direction-1)	GN/m^2
E_2 or E_{22}	Transverse Young's Modulus (direction-2)	GN/m^2
E_3 or E_{33}	Transverse Young's Modulus in the Direction of Laminate Thickness (direction-3)	GN/m^2
$E_{\backslash}$	Transverse Young's Modulus at 45° to the Direction -1	GN/m^2
FEM	Finite Element Method	___
G_{12}	In-plane Shear Modulus (in the 1-2 Planes)	GN/m^2
G_{13}	Transverse Shear Modulus (in the 1-3 Planes)	GN/m^2
G_{23}	Transverse Shear Modulus (in the 2-3 Planes)	GN/m^2
h_C	Crush Distance	mm
K	Collapse Ability of the tube	___
L	Length	mm
M, m	mass	kg
M_a :	Apparent weight gain	kg
M_g :	Net weight gain	kg

M_L : Weight loss .... kg

N: Rotational Speed .... r.p.m

P: Applied load .... kN

$\overline{P}$: Mean Crush Load .... kN

PEEK: Polyether ether keton .... ___

Q_{ij}: Stiffness Matrix (i, j = 1, 2,....6).. ___

r: Radius .... mm

S_i: Initial Crush Distance .... mm

S_{ij}: Compliance matrix, (I, j=1,2,....6) .... ___

S, S_f S_b: Displacements at Arbitrary, Folded Zone, and at Fully Folded Tubes Respectively.. mm

t: Wall Thickness .... mm

V: Carriage Speed .... m/s

V_f: Fiber Volume Fraction.. ___

V_m: Matrix Volume Fraction.. ___

W_o: Weight of the dried specimen before immersion.. gm

W_w: Weight of the wet specimen after immersion.. gm

W_d: Weight of the dried specimen after immersion.. gm

ε : Strain.. ___

θ: Fiber orientation angle Relative to a Global Laminate Axis .... Degree

α: Cone Semivertex Angle .... Degree

σ: Crush Stress .... N/m^2

$\overline{\sigma}$: Mean Crush Stress .... N/m^2

$\sigma_1, \sigma_2, \sigma_3$	Normal Stress Components in the Direction of 1, 2 and 3	N/m^2
$\sigma_4, \sigma_5, \sigma_6$	Shear Stress Components in the Plane of 2-3 1-3 and 1-2	N/m^2
$\varepsilon_1, \varepsilon_2, \varepsilon_3$	Normal Strain Components in the Direction of 1, 2 and 3	N/m^2
$\varepsilon_4, \varepsilon_5, \varepsilon_6$	Shear Strain Components in the Plane of 2-3, 1-3 and 1-2	N/m^2
ρ	Density of the Composite material	(kg/m^3)
$\sum, \sum_C$	Specific Crush Stress	N m/kg
ν	Poisson's Ratio	___
ν_{ij}	Poisson's Ratio for Transverse Strain in the j Direction When Stressed in the i Direction	___
ν_{12}	Major Poisson's Ratio	___
ν_{13}	Transverse Poisson's Ratio	___
ν_{23}	Transverse Poisson's Ratio in the 2-3 Plane	___
ν_f	Poisson's Ratio of Fiber	___
ν_m	Poisson's Ratio of Matrix	___

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirements for the degree of Doctor of Philosophy

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ASAD ABDULLAH KHALID

April 1999

Chairman: Associate Professor Ir. Dr. Barkawi Bin Sahari, B.Sc. (Hons), Ph.D. MIEM, P. Eng.

Faculty : Engineering

An experimental and finite element investigation of cotton fiber/ epoxy and glass fiber/ epoxy composite cones and cylinders were carried out under axial compressive loading. A filament winding equipment have been designed and fabricated to produce the different cones and cylinders required for this project. Throughout this investigation, cones of 5°, 10° and 20° angles, for two fiber orientation angles of 90° and 80° were studied. The effect of quasi-static axial compressive load and specific energy absorption for single cylinder and cone were studied. Besides that, the effect of arrangement type for two cones on the standing load and energy absorption were also examined.

The effect of moisture absorption on the load capability and on the energy absorption of the composite cones have been carried out under axial loading. This was carried out for cones of 5° angle and 90° fiber orientation angle. Cones tested were preconditioned by total immersion in to a distilled hot water at 35 °C, 50°C, 65°C and 80°C for different periods ranging from 24 hour to saturation time.

Mechanical properties of the composite material were evaluated experimentally by the testing of tensile specimens for composites, fiber and matrix. Another set of specimens were also tested for the moisture content effect.

Results from this study show that cylinders under axial compression tests indicate better stable crushing behavior than cones. For all cases, glass/epoxy cones or cylinders show higher absorption energy than cotton/epoxy type by 5% to 12.5% for the different cases.

It was found that a significant improvement in the crushing load and energy absorption occurs when using single cones of fiber orientation angle of 80° instead of 90° and the difference was very significant when using cones angles of 20° instead of 5°. Cones arranged in ordinary parallel stands higher load of 27.7% and higher specific energy absorption of 28.3% than similar cones arranged in series for glass/epoxy type. These percentages were 29.7%and 29.4% respectively for cotton/epoxy cones.

Comparison for load-displacement relations. were done between cones with and without moisture preconditioning. It was found that the crushing energy absorption decreases with increase in moisture content

Finite element study has also been carried out for similar cones. Surface and side nodes displacements were obtained for cotton and glass/epoxy cones under axial compression loading. The slope of the elastic region for the different cones studied was compared with the experimental results and found in the range between 1.73% to 14.44%.

Abstrak tesis dikemukakan kepada Senat Universiti Putra Malaysia
Sebagai Memenuhi keperluan untuk Ijazah Doktor Falsafah

PENYIASATAN KEATAS KON RENCAM BENANG KAPAS/ EPOKSI DAN KACA/ EPOKSI YANG DIBAWAH BEBAN MAMPATAN PAKSI

Oleh

ASAD ABDULLAH KHALID

April 1999

Pengerusi: **Professor Madya Ir. Dr. Barkawi Bin Sahari, B.Sc. (Hons), Ph.D. MIEM, P. Eng.**

Fakulti : **Kejuruteraan**

Satu eksperimen dan pengkajian unsur terhingga komposit kon dan silinder bagi gentian kapas/ epoksi dan gentian kaca/ epoksi adalah dijalankan dengan bebanan tekanan sepaksi. Peralatan belitan filamen direkabentuk dan dipasang untuk menghasilkan kon dan silinder yang berbeza yang diperlukan untuk projek ini. Melalui pengkajian ini, kon bersudut 5°, 10° dan 20°, untuk dua orientasi gantian bersudut 90° dan 80° telah dikaji. Kesan beban tekanan kuasi-statik sepaksi dan penyerapan tenaga spesifik untuk silinder tunggal dan kon telah dikaji. Selain itu, kesan dari jenis penyesuaian untuk dua kon semasa beban berdiri dan penyerapan tenaga turut diperiksa.

Kesan penyerapan kelembapan ke atas keupayaan bebanan dan penyerapan tenaga bagi kon komposit telah dijalankan di bawah beban sepaksi. Ianya dijalankan bagi kon bersudut 5° dan orientasi gentian bersudut 90°. Kon-kon yang diuji telah dirawat dengan merendam keseluruhannya ke dalam air panas pada suhu 35°, 50°, 65° dan 80° untuk jarak masa yang berbeza dari 24 jam.

Sifat-sifat mekanikal untuk bahan komposit telah dinilai secara eksperimen dengan ujian tegangan spesimen untuk komposit, gentian dan matriks. Satu set eksperimen yang lain turut diuji untuk kesan kandungan kelembapan.

Keputusan daripada kajian ini menunjukkan bahawa ujian silinder yang ditindaki mampatan sepaksi menunjukkan tingkah-laku perlanggaran stabil yang lebih baik daripada kon. Untuk kesemua kes, kon kaca/ epoksi atau silinder menunjukkan penyerapan tenaga yang lebih tinggi berbanding untuk kes yang berbeza.

Diperolehi bahawa peningkatan yang nyata di dalam beban perlanggaran dan penyerapan tenaga muncul ketika menggunakan gentian kon tunggal berorientasikan sudut 80° dibandingkan dengan 90° dan perbezaan memang jelas nyata ketika menggunakan kon bersudut 20° berbanding 5^{0}. Kon-kon yang disusun secara selari menahan beban yang lebih tinggi sebanyak 27.7% dan penyerapan tenaga spesifik yang lebih tinggi sebanyak 28.3% daripada kon-kon yang serupa dan disusun secara bersiri bagi jenis kaca epoksi. Peratusan bagi kon benang kapas/ epoksi adalah 29.7% dan 29.4 % masing-masing.

Perbandingan untuk perhubungan beban-peralihan, telah dilakukan diantara kon-kon dengan dan tanpa lembapan. Telah diperolehi bahawa penyerapan tenaga perlanggaran berkurang dengan penambahan kandungan lembapan.

Kajian unsur terhingga juga dilakukan untuk kon-kon yang sama. Permukaan dan peralihan titik tepi telah diperolehi untuk benang kapas dan kon kaca/ epoksi di bawah beban mampatan sepaksi. Kecuraman kawasan elastik bagi kon berbeza yang dikaji telah dibandingkan dengan keputusan eksperimen dan diperolehi dalam nilai antara 1.73% ke 14.44%.