UNIVERSITI PUTRA MALAYSIA

EXPERIMENTAL AND FINITE ELEMENT ANALYSIS OF THE PRESSURE CARRYING CAPACITY OF REINFORCED COMPOSITE THICK-WALLED MATERIAL TUBES

ABDALLA F. HAMED

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By

ABDALLA F. HAMED

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of philosophy

February 2009

Special Dedication

This thesis is dedicated to
My affectionate parents and my beloved family for their patient love and support

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

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Chairman: Professor Megat Mohamad Hamdan Megat Ahmad, PhD

Faculty : Engineering

Presently modern composites using continuous fibers in a resin matrix are important candidate materials for cylindrical structures like pipes and pressure vessels. These materials are lighter, stronger, corrosion resistance and more cost effective when compared with the traditional materials like metals. These structures are commonly subjected to internal pressure and there are some applications where structures subjected to complex loading conditions which are resulted from internal pressurization and superimposed axial loads during installation and/or operation. Most of the previous works were concentrated on the thin shell structures while less work was carried out on thick shell structures under internal pressure loading. The use of hybrid structures in this application is limited and also a limited research work is available for multi-directional tubular composite structures compared with single lay-up configuration. The effects of the different winding angle, different materials and hybridization, different number of layers and different stacking sequence of multi-layered angles on the carrying capacity of thick shell composite tube under internal pressure loading have been studied. The composite materials used were

glass/epoxy and carbon/epoxy. In this study it was found that the optimum winding angle for filament wound pipes depends primarily on the loading modes applied. The experimental results showed that the optimum winding angle is 550 for biaxial pressure loading (mode II), 750 for hoop pressure loading (mode I) while 850 is suitable for biaxial pressure with axial compressive loading (mode III). The test results also show that the carrying capacity of the composite tube increases as the number of the number of layers increase and the percentage difference for all loading modes is about 46% and 63% for four layers and six layers compared by two layers of glass/epoxy respectively. Changing the stacking sequence of multi-layered composite tube enhance the internal pressure carrying capacity for different loading modes and the percentage difference for all loading modes is about 5% and 13%. Using different materials for the composite tube shows that the internal pressure carrying capacity is enhanced. The carrying capacity is about 9% to 19% increased if hybrid composite tube made from two different materials; glass/epoxy and carbon/epoxy are used compared with composite tube made from glass/epoxy alone for all loading modes. On the other hand the carrying capacity is increased by 32% to 38% for the composite tube wound with two and four layers of carbon/epoxy compared with composite tube wound with two and four layers of glass/epoxy for all loading modes. The finite element analysis has been used to analyze the composite tube under internal pressure load for different loading modes. ANSYS finite element software was used to perform the numerical analysis for the different arrangements of composite tubes. The predicted results gave good agreement with the experimental results, the percentage differences between the experimental and the finite element analysis results are approximately 4%-25% for different loading modes.

Abstrak tesis yang dikemukan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

EKSPERIMEN DAN ANALISIS UNSUR TERHINGGA BAGI KEUPAYAAN PENANGGUNGAN TEKANAN BAGI TIUB KOMPOSIT BERDINDING TEBAL DIPERKUAT GENTIAN

Oleh

ABDALLA F. HAMED

Februari 2009

Pengerusi : Profesor Megat Mohamad Hamdan Megat Ahmad, PhD

Fakulti : Kejuruteraan

Pada masa ini, komposit moden yang menggunakan gentian berterusan dalam damar matriks adalah calon bahan penting untuk struktur silinder seperti paip dan bejana tekanan. Bahan ini adalah lebih ringan, lebih kuat, tahan karat dan lebih murah berbanding bahan-bahan lazim seperti logam. Struktur ini umumnya dikenakan tekanan dalaman dan terdapat beberapa aplikasi di mana struktur dikenakan keadaan bebanan kompleks yang terhasil daripada tekanan dalaman dan bebanan paksi tertindih semasa pemasangan dan/atau operasi. Kebanyakan kajian sebelum ini difokuskan ke atas struktur kelompang nipis sementara tidak banyak kajian dibuat ke atas struktur kelompang tebal di bawah beban tekanan dalaman. Penggunaan struktur hibrid dalam aplikasi ini masih terbatas dan begitu juga dengan penyelidikan dalam struktur komposit tiub berbilang arah berbanding tatarajah bengkalai tunggal. Kesan daripada perbezaan sudut belitan, perbezaan bahan dengan penghibridan, perbezaan jumlah lapisan, dan perbezaan urutan tindanan bagi sudut berbilang lapis ke atas keupayaan menanggung tiub komposit kelompang tebal di bawah bebanan

dalaman telah dikaji. Bahan komposit yang telah digunakan dalam kajian ini adalah gentian kaca/epoksi dan gentian karbon/epoksi. Dalam kajian ini didapati bahawa sudut belitan optimum bagi paip terbelit filamen sangat bergantung kepada mod bebanan yang dikenakan. Hasil eksperimen menunjukkan bahawa sudut belitan optimum adalah 550 untuk beban tekanan dua-paksi (mod II), 750 untuk beban tekanan gegelang (mod I) dan 850 untuk beban mampatan paksi (mod III). Hasil pengujian juga menunjukkan keupayaan menanggung bagi tiub komposit meningkat sejajar dengan peningkatan jumlah lapisan dan perbezaan peratusan untuk semua mod bebanan adalah 46% dan 63% untuk empat dan enam lapisan berbanding dengan dua lapisan kaca/epoksi. Perubahan dalam turutan tindanan tiub komposit berbilang lapisan meningkatkan keupayaan menanggung tekanan dalaman untuk mod bebanan berbeza dan perbezaan peratusan untuk semua mod pembebanan adalah kira-kira 8% dan 11%. Penggunaan bahan komposit yang berbeza bagi tiub komposit menunjukkan peningkatan keupayaan menanggung tekanan dalaman. Keupayaan penanggungan bertambah kira-kira 9% ke 19% jika tiub komposit hibrid yang dibuat daripada dua bahan berbeza, kaca/epoksi dan karbon/epoksi digunakan berbanding tiub komposit dibuat daripada kaca/epoksi sahaja untuk semua mod bebanan. Sebaliknya keupayaan penanggungan meningkat 32% hingga 38% untuk tiub komposit yang dibelit dengan dua atau empat lapis karbon/epoksi berbanding paip komposit dengan dua atau empat lapis kaca/epoksi untuk semua mod pembebanan. Analisis unsur terhingga telah digunakan untuk menganalisis paip komposit di bawah beban tekanan dalaman untuk pelbagai mod bebanan. Perisian unsur terhingga ANSYS telah digunakan untuk menjalankan analisis berangka bagi komposit dengan susunan berbeza. Keputusan yang dijangkakan memberikan persetujuaan yang baik dengan keputusan eksperimen, dan perbezaan peratusan

antara eksperimen dan analisis unsur terhingga adalah kira-kira 4%-25% untuk mod bebanan yang berbeza.

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Completion of this thesis was both grueling and rewarding. The rewards far exceeded the pains, so I am satisfied with the entire process required to achieve this goal. I would like to thank my advisor, Associate Prof. Dr. Megat Mohamad Hamdan bin Megat Ahmad for his assistance, valuable advices and timely corrections.

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I certify that an Examination Committee met on 10-2-2009 to conduct the final examination of Abdalla F. Hamed on his Doctor of Philosophy thesis entitled "Experimental and Finite Element Analysis of the Pressure Carrying Capacity for Reinforced Composite Thick Walled Material Tubes" in accordance with Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the Doctor of Philosophy.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirements for the degree of Doctor of Philosophy. The members of the Supervisory Committee ware as follows:

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Date: 14 May 2009

DECLARATION

I hereby declare that the thesis based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

ABDALL F. HAMED

Date:

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