UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF MULTI LAYER COMPOSITE ENERGY ABSORBER BLOCKS FOR AIRCRAFT CRASHWORTHINE.

SIAVASH TALEBI TAHER.

DEVELOPMENT OF MULTI LAYER COMPOSITE ENERGY ABSORBER BLOCKS FOR AIRCRAFT CRASHWORTHINESS

By

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DEVELOPMENT OF MULTI LAYER COMPOSITE ENERGY ABSORBER BLOCKS FOR AIRCRAFT CRASHWORTHINESS

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In this study, a novel concept of lightweight multi-layered composite energy-absorber blocks and beams have been developed that potentially can be retrofitted in aircraft and helicopter sub-floors in order to improve their crashworthiness performance. This novel structure encompassed of fibreglass fabric wrapped around two or three foam layer cores. This technique eventually prevented from core-to-facing debonding, especially during axial crashing, whereby the debonding tendency is controlled by a hoop stresses in fibreglass layers. Manufactured block can be used alone as an energy-absorber element in structure or a series of blocks integrate in the form of beam. Inline assembly of the fibre-reinforced blocks is covered with fabric glass fibre reinforcement in order to integrate the blocks in a beam configuration. Two types of triggering modifications had been applied to the developed composite structures and they are “bevel trigger” and

"groove trigger". In the experimental work the composite blocks and beams were subjected to a quasi-static crushing load. After obtaining the load-displacement curves and determination of crashworthy parameters, a finite element explicit dynamic analysis code module, incorporeity ANSYS/LS-DYNA implemented to the simulation of the quasi-static crash behaviour and energy absorption characteristics of the developed crashworthy composite structure. The results from the finite element analysis were validated against the experimental results and good agreement between two approaches was observed. A dynamic crash analysis was also conducted numerically in order to simulate the dynamic crash event and estimating crash behaviour and energy absorption characteristics of the multi-layered structures which are subjected to high velocity impacts. It has been observed that by increasing the crushing speed load and energy absorption of the structures will inherently magnify. From this research work, it has been demonstrated that, the double-layered and triple-layered block and beam sandwich design concept is a practical means of producing cost-effective sandwich structures, that crush in a stable, progressive manner with high crush force efficiency.

Crush force efficiency (CFE) for all specimen types changed between 0.5 to 0.78 and specific absorption energy (SAE) up to 12.78 kJ/ kg for blocks and 23.53 kJ/ kg for beams were recorded. Moreover the obtained quasi-static numerical results of axial compression model of composite blocks and beams are compared with actual experimental data of crash energy absorption, load-displacement history and crush zone characteristics, showing very good agreement with and without use of two types of the collapse trigger mechanisms. On the other hand, dynamic simulations also showed a

stable, progressive crushing with high crush force efficiency but less than quasi-static condition. Increasing the crushing speed magnified the resistant load and consequently energy absorption of the structures. For example, in a non-triggered beam with quasi-static SAE equal to 14.37 kJ/ kg, a magnification factor equal to 5.46 achieved in 20 m/s, i.e. SAE of structure was 78.5 kJ/ kg that is an excellent value in composite sandwich structures. High CFE and SAE of new design is desired feature of composite structures in crashworthiness applications.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
Sebagai memenuhi keperluan untuk ijazah Doctor Falsafah

MODEL EKSPERIMEN DAN KOMPUTASI BAGI BLOK KOMPOSIT PERLAGAAN YANG NOVEL

Oleh

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Di dalam kajian ini, suatu konsep inovatif blok dan rasuk penyerap-tenaga bahan rencam berbilang-lapisan yang ringan telah dibangunkan untuk digunakan di dalam sub-lantai bagi pesawat terbang dan helikopter bagi tujuan memperbaiki prestasi perlagaan. Di dalam struktur semasa, fabrik gentian kaca dibalut dengan menggunakan dua atau tiga lapisan teras busa bagi mengelakkan lekangan teras-kepada-permukaan iaitu semasa lagaan paksi kecenderungan lekangan dikawal oleh tegasan gegelang di dalam lapisan gentian kaca. Blok yang dibuat boleh digunakan dengan sendirinya sebagai elemen penyerap tenaga di dalam struktur atau sebagai suatu siri blok yang digabungkan di dalam bentuk rasuk. Himpunan blok gentian terkukuh dilapisi dengan fabrik gentian kaca tetulang untuk menggabungkan blok untuk menjadikannya sebagai konfigurasi rasuk . Juga, dua jenis pengubahsuaian pemicuan teleh dikenakan kepada struktur komposit tersebut. Di dalam kerja ekperimen blok komposit dan rasuk telah dikenakan

beban remukan kuasi-statik. Setelah lengkung beban – anjakan dan parameter pelagaan diperolehi, analisa unsur terhingga dinamik tak-tersirat menggunakan modul kod ANSYS/LS-DYNA telah dilaksanakan untuk mensimulasi kelakuan lagaan kuasi-statik dan ciri penyerapan tenaga bagi struktur komposit tersebut. Keputusan daripada analisa unsur terhingga telah disahkan dengan keputusan eksperimen dan kolerasi yang baik telah diperhatikan. Analisa pelagaan dinamik juga dijalankan secara berangka bagi mensimulasikan peristiwa perlagaan dinamik serta menganggarkan kelakuan lagaan dan ciri penyerapan tenaga bagi struktur berbilang lapisan, yang dikenakan impak halaju tinggi. Ianya telah diperhatikan bahawa dengan menambahkan kelajuan kehancuran akan menambahkan daya rintangan dan penyerapan tenaga struktur tersebut. Daripada penyelidikan ini, ianya telah ditunjukkan bahawa konsep rekebentuk apit blok dan rasuk dua dan tiga lapisan merupakan kaedah praktikal untuk menghasilkan struktur apit keberkesanan kos yang hancur secara stabil, progresif dengan kecekapan daya hancuran yang tinggi.

Kecekapan daya remukan (CFE) untuk semua jenis spesimen berubah di antara 0.5 dan 0.78 dan tenaga serapan tertentu (SAE) sehingga 12.78 kJ/kg untuk blok manakala 23.53 kJ/kg untuk rasuk dicatatkan. Tambahan lagi, keputusan berangka static-kuasi yang didapati daripada model mampatan paksi untuk komposit blok dan rasuk dibandingkan dengan data eksperimen yang sebenar bagi serapan tenaga remukan, sejarah daya-anjakkan dan ciri-ciri zon remukan, menunjukkan persetujuan yang baik dengan dan tanpa menggunakan dua jenis mekanisma cetusan runtuhan. Manakala, simulasi dinamik pula menunjukkan remukan progressif yang stabil dengan kecekapan daya remukan

yang tinggi tetapi lebih rendah daripada keadaan static-kuasi. Penambahan kelajuan remukan telah membesarkan daya rintangan dan seterusnya tenaga serapan struktur tersebut. Sebagai contoh, di dalam rasuk tanpa-cetusan dalam keadaan static-kuasi tenaga serapan tertentu (SAE) adalah bersamaan dengan 14.37 kJ/kg, suatu factor pembesaran bersamaan dengan 5.46 dicapai dalam 20 m/s iaitu SAE untuk struktur adalah78.5kJ/kg yang mana merupakan nilai yang memberangsangkan di dalam struktur sandwich. CFE dan SAE yang tinggi di dalam rekebentuk terbaharu adalah suatu ciri yang dikehendaki bagi struktur komposit di dalam aplikasi perlanggaran.

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I certify that an Examination Committee met on 4th July 2009 to conduct the final examination of Siavash Talebi Taher on his Doctor of Philosophy thesis entitled "Development of Multi Layer Composite Energy Absorber Blocks and Beams for Aircraft Crashworthiness" in accordance with Unversiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The committee recommends that the student be awarded the Doctor of Philosophy. The committee recommends that the candidate be awarded the relevant degree.

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DECLARATION

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

SIAVASH TALEBI TAHER

Date:

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