UNIVERSITI PUTRA MALAYSIA

NUMERICAL SIMULATION AND EXPERIMENTAL STUDIES ON THE BALLISTIC IMPACT CHARACTERISTICS OF CERAMIC/ARAMID HYBRID COMPOSITE

AYAD ABED RAMADHAN

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NUMERICAL SIMULATION AND EXPERIMENTAL STUDIES ON THE BALLISTIC IMPACT CHARACTERISTICS OF CERAMIC/ARAMID HYBRID COMPOSITE

By

AYAD ABED RAMADHAN

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

June 2012

Dedicated to

My dearest Family (Father and Mother)

For their extraordinary love and their endless care

My Brothers and Sisters for their supporting, encouragement, and prayer

My wife for her patience

Thank You

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

NUMERICAL SIMULATION AND EXPERIMENTAL STUDIES ON THE BALLISTIC IMPACT CHARACTERISTICS OF CERAMIC/ARAMID HYBRID COMPOSITE

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Chair: Associate Professor Abd Rahim Abu Talib, PhD

Faculty: Engineering

Enhancement of the influence of epoxy resin by adding 10% Alumina powder (Al_2O_3) in the mixture to obtain good mechanical properties of tensile and compression strength has been investigated in this research. The effect of fiber orientation ($0^o/90^o$ and $+45^o/-45^o$) on the composites (kevlar-29/epoxy and kevlar-29/epoxy-Al_2O_3) and different (45, 50, 55 and 60 %) volume fractions (v_f) on the behavior of tensile and compression strength have been studied experimentally in comparison with each other. In addition, the tensile strength testing of Kevlar-29/epoxy-Al_2O_3, glass/epoxy-Al_2O_3 and carbon/epoxy-Al_2O_3 composites using 50% volume fraction was studied and compared the results obtained of these composites of fiber-epoxy without Al_2O_3.

An application of this research was the study of the fabrication of a novel Hybrid (Ceramic/Aramid) composite based on fiber/metal laminates FML (Kevlar-29/epoxy-Al_2O_3/Al 6061-T6) that may be comparable to the ARALL-2 (Aramid- Aluminum alloy composite) or GLARE (Glass-Al alloy) composites used in aerospace applications. High velocity impact loading with a range of velocities (160-400 m/s) has been experimentally and numerically investigated.

The energy absorption on the ballistic impact characteristics of Hybrid composites has been investigated in this work. The results obtained show that the energy absorption is higher for Kevlar-29/Epoxy backed with 6061-T6 Al alloy with 7.3% at front Al alloy and (5 -6%) reduction in the density and quantity (for 20 mm thickness laminated plates) of Kevlar respectively.

The predictions of the energy absorption simulation model using ANSYS AUTODYN 3D v.12.1 are compared with the experimental work. Good agreement is generally obtained with error of 8.7% where it has been shown that these novel sandwich structures exhibit excellent energy absorbing characteristics under high velocity impact loading conditions. Hence the FML presented in this work may be considered as a suitable composite for some aircraft structures.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijata Doktor of Falsafah

SIMULASI BERANGKA DAN KAJIAN EKSPERIMEN BERKENAAN TENTANG SIFAT IMPAK BALISTIK KOMPOSIT HIBRID SERAMIK/ARAMID

Oleh

AYAD ABED RAMADHAN

Jun 2012

Pengerusi: Profesor Madya Abd Rahim Abu Talib, PhD

Fakulti : Kejuruteraan

Peningkatan pengaruh resin epoksi dengan menambahkan 10% serbuk Alumina (Al_2O_3) dalam campuran itu memperoleh sifat-sifat mekanikal iaitu ketegangan dan kekuatan mampatan telah disiasat dalam penyelidikan ini. Kesan orientasi serat ($0^o/90^o$ and $+45^o/45^o$) di komposit (Kevlar-29 / epoksi dan Kevlar-29 / epoksi Al_2O_3) dan berbeza (45, 50, 55 dan 60%) pecahan-pecahan jumlah (v_f) di tingkah laku tegang dan kekuatan mampatan telah dikaji secara eksperimen dalam perbandingan dengan satu sama lain. Sebagai tambahan, kekuatan tegangan menguji Kevlar-29 / epoksi Al_2O_3, kaca / epoksi Al_2O_3 dan karbon/komposit epoksi Al_2O_3 menggunakan 50% pecahan isipadu telah dikaji dan compeered keputusan-keputusan memperolehi epoksi serat komposit ini xy tanpa Al_2O_3.

Satu permohonan penyelidikan ini ada kajian rekaan satu Hybrid novel (Ceramic / Aramid) rencam berdasarkan serat / logam melapisi FML (Kevlar-29 / epoksi Al_2O_3/

Al 6061-T6) yang mungkin setanding kepada ARALL-2 (Aloi Aluminum Aramid komposit) atau GLARE (Kaca Al aloi) komposit menggunakan dalam aplikasi-aplikasi aeroangkasa. Pemuatan kesan halaju tinggi dengan satu julat halaju-halaju (160-400 m/s) secara eksperimen dan dari segi bilangan disiasat.

Penyerapan tenaga di ciri-ciri kesan balistik komposit Hybrid telah disiasat dalam tugas ini. Keputusan-keputusan memperolehi pertunjukan yang penyerapan tenaga berada lebih tinggi untuk Kevlar-29 / Epoxy menyokong dengan 6061-T6 Al aloi dengan 7.3% di hadapan Al aloi dan (5-6%) pengurangan dalam ketumpatan dan kuantiti (untuk 20 mm ketebalan bersalut plat-plat) Kevlar masing-masing.

Ramalan-ramalan model simulasi penyerapan tenaga menggunakan ANSYS AUTODYN 3D v.12.1 dibandingkan dengan kerja eksperimen. Perjanjian baik amnya mendapat dengan ralat 8.7% di mana ia telah ditunjukkan bahawa struktur-struktur sandwic novel ini mempamerkan tenaga cemerlang mengasyikkan ciri-ciri di bawah keadaan-keadaan pemuatan kesan halaju tinggi. Oleh itu FML menyampaikan dalam tugas ini boleh dipertimbangkan sebagai satu gabungan sesuai untuk beberapa struktur-struktur pesawat.

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I certify that a Thesis Examination Committee has met on **19th June 2012** to conduct the final examination of **AYAD ABED RAMADHAN HAMD** on his thesis entitled "**Numerical Simulation and Experimental Studies on the Ballistic Impact Characteristics of Ceramic/Aramid Hybrid Composite**" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U. (A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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DECLARATION

I declare that the thesis is 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 other institution

AYAD ABED RAMADHAN

Date: 19 June 2012

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