



**UNIVERSITI PUTRA MALAYSIA**

**DEVELOPMENT OF COMBAT ARMOR FROM RAMIE-ARAMID-  
POLYESTER COMPOSITE**

**ZAINAB SHAKER RADIF**

**FK 2009 66**



**DEVELOPMENT OF COMBAT ARMOR  
FROM RAMIE-ARAMID-POLYESTER COMPOSITE**

**By**

**ZAINAB SHAKER RADIF**

**Thesis submitted to The School of Graduate Studies, Universiti Putra  
Malaysia, in Fulfillment of the Requirement for The Degree of  
Master of Science**

**JUNE 2009**



## DEDICATION

*I would like to present my scientific effort in this research for my lonely love*

### **IRAQ**

*my Continuous sacrifice will be until the last driblet from my blood for his  
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**Sarah, Mohamed and Yeser.**



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**Chairman : Dr. Aidy Ali**

**Faculty : Engineering**

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Whereby, reduction of resistance results in the increase of temperature. The range of temperatures was between 20 °C to 70 °C. A limited delamination was generated under multiple shots. Targets geometry plays a main role in increasing impact response. Hence, the results were presented high resistant impact for pairs from panels with total thickness of 15 mm  $\pm$  3mm. This body armor is one of most economical armor products in that; common materials were used in its production especially to the reduction of the using Kevlar amount that led to decrease in its cost. On the other hand this armor met the ballistic threats under 623 m/s of 15 mm  $\pm$  3 mm target thickness and 837.5 m/s of 25 mm  $\pm$  2 mm. Thus, the armor is equivalent to third level of protective ballistic limits in National Institute of Justice (NIJ) standards.



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

**PEMBANGUNAN PERISAI BADAN  
DARI SERAT RAMIE-ARAMID-POLIESTER**

Oleh

**ZAINAB SHAKER**

**JUN 2009**

**Pengerusi : Dr. Aidy Ali**

**Fakulti : Kejuruteraan**

Di dalam kajian ini, bahan lapisan komposit dibangunkan dari serat ramie-aramid yang diperkukuhkan dengan resin poliester. Kajian ini bertujuan untuk membangunkan perisai badan dengan menggunakan struktur rekabentuk komposit yang diperkukuhkan dengan ramie-aramid. Rekabentuk perisai badan tersebut dapat memenuhi keperluan tahanan balistik yang spesifik. Matrik yang terhasil dari komposit yang dibangunkan adalah resin poliester yang diperkukuhkan dengan serat ramie-aramid semulajadi. Komposit ramie-aramid ini didedahkan kepada kelajuan yang berimpak tinggi. Sasaran diuji dengan tembakan dari senjata gas dan kelajuan projektil dirakamkan dengan menggunakan peralatan kamera. Bagi mencapai matlamat kajian, beberapa eksperimen telah dijalankan untuk menganggar had kalis peluru, serapan tenaga yang maksimum, mod kegagalan komposit, keruntuhan jangka hayat, geometri sasaran dan kesan terhadap persekitaran.



Keputusan eksperimen ini menunjukkan had maksimum kalis peluru adalah pada kelajuan impak diantara 250 m/s hingga 656.8 m/s bagi tahap perlindungan ke dua. Sasaran diperbaiki dalam lingkungan maklumbalas impak dengan peningkatan kelembapan relatif di antara  $50\% \pm 20\%$  ; di mana pengurangan ketahanan menyebabkan peningkatan suhu di antara  $20\text{ }^{\circ}\text{C}$  hingga  $70\text{ }^{\circ}\text{C}$ . Pelekangan yang terhad diperolehi dari pelbagai tembakan. Geometri sasaran memainkan peranan penting dalam meningkatkan maklumbalas impak. Oleh itu keputusan menunjukkan impak ketahanan tinggi bagi pasangan lapisan yang mana jumlah ketebalannya adalah di antara  $15\text{ mm} \pm 3\text{ mm}$ . Perisai ini merupakan produk perisai yang paling ekonomi kerana bahan-bahan biasa yang digunakan untuk menghasilkannya terutama bagi pengurangan penggunaan amaun Kevlar yang menyebabkan kos berkurangan. Selain itu, kalis peluru ini memenuhi hentaman balistik di bawah 623 m/s dari  $15\text{ mm} \pm 3\text{ mm}$  ketebalan sasaran dan 837.5 m/s dari  $25\text{mm} \pm 2\text{mm}$ . Oleh itu, perisai tersebut adalah sama dengan tahap ketiga had perlindungan balistik mengikut piawaian Institut Kehakiman Kebangsaan (NIJ).

## Acknowledgments

Firstly, thank for Allah who support me by the force. Specially, in the crucial time, and let my have a good stand in spied of my tremendous weakness.

I wish thank the many people who helped me at first them my committee who support me by encouragement and care many time. When I feel in the failure and despair. All the assistance received from my chairman, Dr. Aidy Bin Ali , for his guidance, his advance insight, encouragement and his permanent support.

I would also like to thank the members of my dissertation committee for their service: Dr. Khalina Abdan with my appreciation for her tremendous patience, understanding and generous support and deeply appreciate Prof. Mohd Sapuan for his assistance.

I would thank the president of Kufa University Prof. Abud Razaq Abud Al Essa, who was built the knowledge towers beside the Kufa university buildings and paved the ways to me for completion my study. Also deeply thanks for Dr. Ali Al-Sabea the head of materials department for his scientific support. Many thanks for all the brothers that were stopped beside me and were always the warm hands to treat my injuries, Dr. AbdulJalil M.Khalf, Dr. Munther Abdullah and Zaman Abud Malik and all the Iraqi brothers in Malaysia that I didn't mention their names (May Allah will bless and award them). Finally, deeply thanks for all the technicians of UPM for continuous assistance.





## **APPROVAL**

I certify that an Examination Committee has met on 29<sup>th</sup> September 2009 to conduct the final examination of Zainab Shaker Radif on her Master of Science thesis "The Development of Combat Armor from Ramie-Aramid-Polyester Composite" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree.

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School Of Graduate Studies  
University Putra Malaysia

Date:



## DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citation 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.

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**ZAINAB SHAKER RADIF**

Date:

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## LIST OF ABBREVIATIONS / GLOSSARY OF TERMS

KRP	Kevlar29 –Ramie Fiber Reinforced Polyester
UP	Unsaturated Polyester
FEA	Finite Element Based Analyses
MMC	Metal Matrix Composite
CMC	Ceramic Matrix Composite
PMC	Polymer Matrix Composite
$V_f$	Fiber Volume Friction
$V_m$	Matrix Volume Friction
$V_{li}$	Composite Volume Friction
$G_{li}$	Composite Shear Modulus
$\nu_{it}$	Composite Poisson Coefficient
$\nu_f$	Fiber Poisson Ratio
$\nu_m$	Matrix Poisson Ratio
$e_{warp}$	Elastic Modulus of Warp Direction
$e$	Total Layer Thickness
$n_1$	Number of Warp Yarns Per Meter
$n_2$	Number of Fill Yarns Per Meter
$e_{fill}$	Elastic Modulus of Fill Direction
$E_x$	Elastic Modulus of x Direction
$E_t$	Elastic Modulus of Transverse Direction
$E_l$	Elastic Modulus along The Direction of Fiber



$G_{xy}$	Shear Modulus in Two Directions
$G_{it}$	Shear Modulus
$V_{xy}$	Volume Friction in Two Direction
C	Velocity of Longitudinal Strain Wave
E	Dynamic Modulus of Elasticity
$\rho$	Yarn Density
$V_b$	Ballistic Limit Velocity
$N_{PLY1}$	Number of Nylon Plies
$N_{PLY2}$	Number of Humpt Plies
MEKP	Mety1 Ethy1 Ketone Peroide
NIJ	National Institute of Justice
OSP	One Separated Panel
TSP	Two Separated Panels
FTP	Flexible –Tough Panels
$P_a$	Cylinder Gas Pressure
D	Diameter of The Projectile
$E_{abs}$	Energy Absorption
m	Mass of The Projectile
$V_{imp}$	Strike Velocity
b	Target Thickness
FMJ	Full Metal Jacket
ACP	Automatic Colt Pistol
AP	Armor Piercing

JHP	Jacketed Hollow Point
JSP	Jacketed Soft Point
LR	Long Rifle
LRN	Lead Round Nose
RN	Round Nose
S&W	Smith & Wesson
$S_1$	Longitudinal Wave
$S_2$	Transverse Wave

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