UNIVERSITI PUTRA MALAYSIA

DESIGN AND FABRICATION OF A TROPICAL MOTORCYCLE HELMET

FARAG MOHAMED SHUAEIB

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By

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

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DEDICATION

To my daughter "**Esra**"

I hope that "**ALLAH**" will protect you and

make your life happy as you gave me the happiness and hope with your smile

during the dark days

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: **Associate Professor Abdel Magid Salem Hamouda, Ph.D.**

Faculty: **Engineering**

The present work is devoted to the design and evaluation of a new crashworthy motorcycle helmet taking into consideration the tropical climate of Malaysia. A multi-discipline literature review on the design problems of motorcycle helmet was carried out and current problems were formulated. Based on the literature review findings, a new shell and liner designs were then proposed to overcome or eliminate these problems.

The shell design improvements consisted of developing hybrid natural fiber composite (NFC) shells which were fabricated and evaluated by the standard dynamic penetration test. The results of the new design were found to be satisfactory according

to the related helmet standards. Three additional methods have been developed to assess the new shells performance in a more quantified manner. These tests are the helmet quasi-static penetration, the helmet rigidity, and the helmet crushing. All these tests were performed and the results confirmed the superior performance of the new natural fiber shell helmets as compared to the market dominant ABS shell helmets. Other factors also supported this design improvement such as cost, and the utilization of environmental friendly material.

In the liner design improvement, the shell was kept to the current ABS shell and the EPP foam as a liner. A 3D finite element algorithm has been developed using LS-DYNA-3D software. Based on the simulation results, the helmet with EPP foam liner was found to be satisfactory according to the related helmet standards. A parametric study of the helmet design was performed using the Response Surface Methodology in the Design of Experiment (DOE) statistical method. From this parametric study, the foam thickness and the foam density were found to have more significant effect on the helmet energy absorption than the shell effects. Design optimizations were also conducted and optimum design was obtained.

Finally, thermal analysis for commercially available helmet without ventilation system and the new helmet design with ventilation system were made, from which it was found that helmet ventilation is essential to avoid possible health problems. A design chart for helmet with ventilation system to obtain the minimum cross sectional area required for ventilation nozzles has been developed. This chart is suitable for a

wide span of amounts of heat generated from the motorcyclist head. The effect of adding the ventilation system to the helmet has been structurally investigated by the finite element simulation and found to positively improve the energy absorption performance of the helmet.

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

REKABENTUK DAN PEMBUATAN BAGI TOPI KELEDAR MOTOSIKAL TROPIKA

Oleh

FARAG MOHAMED SHUAEIB

Julai 2003

Pengerusi : Profesor Madya Abdel Magid Salem Hamouda, Ph.D.

Fakulti : Kejuruteraan

Kajian ini adalah untuk merekabentuk dan menilai topi keledar motosikal yang mengambil kira keadaan iklim tropika di Malaysia. Kajian dasar telah dijalankan terhadap masalah yang dihadapi oleh pengguna motosikal masakini. Daripada kajian tersebut, satu rekabentuk baru cengkerang dan liner telah dicadangkan untuk mengatasi masalah ini.

Pembaharuan rekabentuk cengkerang terdiri daripada pembangunan cengkerang komposit hybrid gentian asli (NFC) dimana ia telah difabrikasi dan dinilai dengan ujikaji piawai penembusan dinamik. Keputusan yang diperolehi memenuhi keperluan ujian piawai topi keledar masakini. Selain itu, tiga kaedah telah dibangunkan untuk menilai prestasi cengkerang yang direkabentuk. Ini kerana kaedah ujikaiji penembusan dinamik tidak dapat memberikan keputusan yang diharapkan. Kesemua keputusan menunjukkan kekuatan cengkerang gentian asli adalah lebih baik berbanding dengan

cengkerang ABS. Faktor yang lain juga menunjukkan bahawa kelebihan utama rekabentuk ini adalah kos yang rendah dan penggunaan bahan mesra alam.

Dalam rekabentuk liner, ABS telah digunakan sebagai cengkerang asal dan elemen tidak terhingga (prototaip maya) berdasarkan LS-DYNA3D telah disediakan bagi pembaharuan rekabentuk cengkerang dengan penyerap EPP. Keputusan simulasi menunjukkan prestasi yang amat memuaskan bagi topi keledar yang direkabentuk. Satu kajian parametrik telah juga dijalankan dengan menggunakan kaedah respon permukaan yang terdapat dalam kaedah statistik Rekabentuk Sesebuah Experimentasi (DOE). Daripada kajian ini, ketebalan dan ketumpatan penyerap didapati mempunyai pengaruh yang kuat dari segi penyerapan tenaga berbanding cengkerang. Optimasi rekabentuk juga telah dilakukan.

Akhir sekali, analisis terma telah dilakukan dan perbandingan antara rekabentuk baru berbanding rekabentuk sedia ada telah dijalankan. Satu carta rekabentuk juga telah dibangunkan untuk mencari luas keratan rentas yang minimum bagi muncung ventilasi. Ini telah didapati bahawa ia amat berguna bagi penyebaran haba pada keratan rentas topi keledar pengguna. Kesan penambahan system ventilasi telah dikaji dan didapati telah menambahkan prestasi penyerapan tenaga pada topi keledar tersebut.

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First of all and before every thing , I submit in humility and gratitude to my beloved creator " **ALLAH** " for having looked after me during all my life and protected me from major catastrophes in this life.

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Finally, I could not find suitable words to express my sincere thanks to my beloved wife **Entisar Idris Sharif** for here suffering and struggling on looking after me and also taking care of my three children **Mohamed, Muad, and Esra**. Therefore, I leave this to "**ALLAH**" to reward here and compensate her in this life and hereafter.

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NOTATIONS AND ABBREVIATION

EPS	is the expanded polystyrene foam
EPP	is the expanded polypropylene foam
PP	is the polypropylene
PE	is the polyethylene
Pb	is the polybutylene
PC	is the polycarbonate plastic
ABS	is the acrylonitrile butadiene styrene copolymer
GRP	is the glass reinforced Plastic
CRP	is the carbon reinforced Plastic
WR	is the woven roving
E	is the young's modulus
σ	is the stress
ε	is the strain
σ_y	is the foam yield stress
F	is the force
D	is the relative density of the foam
m	is the mass
a	is the acceleration
g	is the gravitational acceleration
t	is the shell thickness
ε_D	is the densification strain
h	is the drop height
A	is the contact area under the anvil
V	is the impact velocity
R	is the helmet radius