UNIVERSITI PUTRA MALAYSIA

PERFORMANCE OF FRONT BUMPER AND HOOD SYSTEM WITH PEDESTRIAN SAFETY SUBJECTED TO FRONTAL IMPACTS

MAI NURSHERIDA BINTI JALALUDDIN

PERFORMANCE OF FRONT BUMPER AND HOOD SYSTEM WITH PEDESTRIAN SAFETY SUBJECTED TO FRONTAL IMPACTS

By

MAI NURSHERIDA BINTI JALALUDDIN

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

September 2011

DEDICATIONS

My dearest parents;

Haji Jalaluddin Bin Haji Udin and Hajjah Sharipah Sapiah Binti Syed Hassan Al-Jamalulail.

My husband;

Mohd Rosdan Bin Sulaiman

My dearest children;

Aishah Umairah Binti Mohd Rosdan & Akid Naqiuddien Bin Mohd Rosdan.

My beloved brother and sisters;

Mai Juzilin Binti Haji Jalaluddin, Mai Jasmina Binti Haji Jalaluddin, Mai Shahzima Binti Haji Jalaluddin, Mior Nur Izam Bin Haji Jalaluddin and Allahyarhammah Leftenan Mai Elny Sefrina Binti Haji Jalaluddin

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

PERFORMANCE OF FRONT BUMPER AND HOOD SYSTEM WITH PEDESTRIAN SAFETY SUBJECTED TO FRONTAL IMPACTS

By

MAI NURSHERIDA BINTI JALALUDDIN

September 2011

Chairman: Professor Barkawi Bin Sahari, Ir. PhD

Faculty: Faculty of Engineering

A performance of front bumper and hood system with pedestrian safety subjected to frontal impacts is presented and discussed in this project. The aim of this study is to analyze the effect of steel, aluminum and composite material on energy absorption and pedestrian safety of automotive front bumper system and hood. The front bumper beams and hood made of e-glass/epoxy composite and carbon epoxy composite are studied and characterized by impact modeling using LS-DYNA V971, according to United States New Car Assessment Program (US-NCAP) frontal impact velocity and based on European Enhanced Vehicle-safety Committee.

The most important variable of this structure are mass, material, head injury criteria, leg injury criteria and Specific Energy Absorption (SEA). The results are compared with bumper beam and hood made of mild steel. Three types of materials are used in the present study which consists of mild steel as references material, Aluminum AA5182, E-glass/epoxy composite and carbon fiber/epoxy composite with three different fiber orientations $[0^o/60^o]_S$, $[0^o/30^o/60^o]_S$ and $[0^o/30^o/60^o/90^o]_S$.

The beams were subjected to impact loading to determine the internal energy and SEA. The in-plane failure behaviors of the composites were evaluated by using Tsai Wu failure criterion. The results for the composite beams are compared to that of the reference beam to find the best material with highest SEA. LS-DYNA Finite Element Analysis software was used. The results showed that carbon fiber/epoxy composite bumper can reduce the bumper mass and has the highest value of SEA followed by glass fiber/epoxy composite, aluminum AA5182 and mild steel.

For the pedestrian safety, the dummy was subjected to frontal impact to determine the head injury criteria. The results for the composite materials and aluminum AA5182 are compared to that of the reference material to find the best material with lowest value of Head Injury Criterion (HIC). The results showed that aluminum AA5182 with thickness 1.0 mm hood has the lowest HIC value with 549.70 for HIC15 and 883.00 for HIC36 followed by mild steel with 657.40 for HIC15 and 980.90 for HIC36, glass fiber/epoxy composite with 639.60 for HIC15 and 921.70 for HIC36 and carbon fiber/epoxy composite bumper with 1197.00 for HIC15 and 1424.00 for HIC36. From the present work, the carbon glass fiber/epoxy bumper beams and aluminum AA5182 hood are proposed since it met the European New Car Assessment Programme (N-CAP) criteria.

For Leg Injury criteria determination, the legform model was used to stimulate accidents against the front of the car. The European New Car Assessment Program (NCAP) parameter was used to simulate accidents involving pedestrian impact at 40km/h, where dummy models or legform served as impactors. For legform simulation results, the tibia acceleration 91.5 g, 4.2 mm shear displacement and 12.0˚

bending angle graphs are below the regulation limit. It is because there are no contact between the front bumper beam and the legform, so that the injury is less. This is shows that the clearance between the bumper shell and front bumper beam are enough. The appropriate value is 75 mm. As a conclusion, the minimum clearance between the leg and the bumper

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

PRESTASI BUMPER DEPAN DAN SISTEM KAP ENJIN DENGAN KESELAMATAN PEJALAN KAKI DIKENAKAN DAMPAK HADAPAN

Oleh

MAI NURSHERIDA BINTI JALALUDDIN

September 2011

Pengerusi: Profesor Barkawi Bin Sahari, Ir. PhD

Fakulti: Fakulti Kejuruteraan

Sebuah prestasi bumper depan dan sistem kap enjin dengan keselamatan pejalan kaki yang mengalami kesan dampakan hadapan dipersembahkan dan dibincangkan dalam projek ini. Tujuan kajian ini adalah untuk menganalisis pengaruh besi keluli dan bahan komposit pada penyerapan tenaga dan keselamatan pejalan kaki sistem automotif bumper depan dan kap enjin kereta. Bumper depan dan rasuk kap enjin yang diperbuat dari e-glass/epoxy komposit dan karbon epoksi komposit yang dipelajari dan ia dipercirikan dengan pemodelan impak menggunakan LS-DYNA V971 dan menurut kriteria impak kelajuan hadapan "United States New Car Assessment Program" (US-NCAP) dan berdasarkan "European Enhanced Vehicle-safety Committee".

Pembolehubah yang paling penting dari struktur ini adalah jisim, bahan, kriteria kecederaan kepala, kriteria kecederaan kaki dan "Specific Energy Absorption" (SEA). Keputusan yang diperolehi dibandingkan dengan rasuk bumper dan kap enjin yang diperbuat daripada besi keluli lembut. Tiga jenis bahan yang digunakan dalam

kajian ini yang terdiri daripada besi keluli lembut sebagai bahan rujukan, Aluminium AA5182, E-glass/epoxy komposit dan karbon / epoxy komposit dengan tiga orientasi komposit yang berbeza iaitu $[0^o/60^o]_{S,}$ $[0^o/30^o/60^o]_S$ dan $[0^o/30^o/60^o/90^o]_S$.

Rasuk menjadi subjek utama di dalam bebanan impak untuk menentukan tenaga dalaman dan SEA. Perilaku kegagalan dalam rasuk yang diperbuat daripada komposit dinilai dengan menggunakan kriteria kegagalan Tsai Wu. Keputusan untuk rasuk komposit dibandingkan dengan rasuk rujukan untuk mencari bahan terbaik dan diukur dengan nilai SEA yang tertinggi. Analisis dilakukan dengan menggunakan perisian “LS-DYNA Finite Element Analysis”. Keputusan kajian menunjukkan bahawa rasuk bumper yang menggunakan serat karbon/epoksi komposit dapat mengurangkan jisim rasuk dan mempunyai nilai SEA yang tertinggi diikuti dengan serat glass / epoxy komposit, aluminum AA5182 dan besi keluli lembut.

Untuk keselamatan pejalan kaki, “dummy” menjadi sasaran di dalam perlanggaran impak hadapan untuk menentukan kriteria kecederaan di kepala. Keputusan simulasi dibandingkan diantara bahan-bahan komposit, aluminium AA5182 dan bahan rujukan untuk mencari bahan terbaik dengan nilai “Head Injury Criteria” (HIC) yang terendah. Keputusan kajian menunjukkan bahawa kap enjin yang menggunakan bahan aluminium AA5182 dengan ketebalan 1.0 mm memiliki nilai HIC terendah dengan 549.70 untuk HIC15 dan 883.00 untuk HIC36 diikuti dengan bumper besi keluli lembut dengan 657.40 untuk HIC15 dan 980.90 untuk HIC36, serat glass / epoxy komposite dengan 639.60 untuk HIC15 dan 921.70 untuk HIC36 dan karbon komposit/epoksi komposit dengan 1197.00 untuk HIC15 dan 1424.00 untuk HIC36. Dari kajian ini, serat gelas karbon / epoxy bumper angka dan aluminium kap

AA5182 dicadangkan kerana memenuhi kriteria European New Car Assessment Programme (N-CAP).

Untuk penentuan kriteria kecederaan di kaki, model “legform” digunakan untuk merangsang kemalangan terhadap bahagian depan kereta. Parameter yang digunakan adalah berdasarkan “European New Car Assessment Program” (NCAP) untuk mensimulasikan kesan kemalangan yang melibatkan pejalan kaki pada 40km / j, di mana model “dummy” atau “legform” menjadi sebagai “impactor”. Untuk hasil simulasi “legform”, percepatan tibia 91.5 g, perpindahan luncurkan dengan nilai 4.2 mm dan 12.0 ˚ untuk pembengkokan sudut di bawah batas regulasi. Hal ini kerana tidak ada hubungan antara rasuk bumper depan dan legform, oleh sebab itu, kecederaan adalah kurang. Hal ini menunjukkan bahawa jarak antara rangka luar bumper dan rasuk bumper depan sudah mencukupi. Nilai yang sesuai dan diterima adalah 75 mm.

ACKNOWLEDGEMENTS

"In the name of Allah, Most gracious, Most merciful".

First of all, great thanks and praises are due to Allah, the Lord of all that exists. May Allah's peace and blessings be upon His final prophet and messenger, Muhammad, his family and his companions.

I would like to thank my supervisor, Professor Ir. Dr. Barkawi Bin Sahari, for the continual guidance and encouragement during my master study and for his effort in this research. I also greatly appreciated the financial support through Special Graduate Research Assistant (SGRA). I would also like to acknowledge my supervisory committee, Dr Nuraini Binti Abdul Aziz for her outstanding advices and assistance throughout the years. Also thanks to my beloved parents and family for their support and blessing during my hardness time in completing this research.

Special thanks to Mr. Mohd Syazwan Abdul Samad, Mr. Nazrul Abdullah, Assoc. Professor Dr. Aidy Ali and all staffs from Department of Mechanical and Manufacturing Engineering and Institute Teknologi Maju (ITMA) for their support, help and suggestions throughout my work. Not forgetting to Mrs. Salwani Binti Mohd Salleh, Mr. Syazwan Safaai, Mr. Azim Azizi, Miss Siti Aini Satuan, Miss Nabila and Miss Shahliza for their contribution upon completion this research. Lastly, thanks to Miss Nurhaniza, Miss Suraya, Mrs. Nor Hanifawati, Miss Yusriah, Mr. Khairul Azhar, Mr. Sahari, Mr Mohamad Ridzwan, Mr. Umar, Mr. Mohd Fairuz and to all my friends who help in completing this research project.

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 at any other Institution

MAI NURSHERIDA BINTI JALALUDDIN

Date:

I certify that a Thesis Examination Committee has met on (26th September 2011) to conduct the final examination of Mai Nursherida Binti Jalaluddin on her thesis entitled "Performance of Front Bumper and Hood System With Pedestrian Safety Subjected to Frontal Impacts" 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 Masters of Science.

Members of the Thesis Examination Committee were as follows:

Ir. Mohd Sapuan bin Salit, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Aidy Bin Ali, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Mohd Khairol Anuar Bin Mohd Ariffin, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Shahrum Bin Abdullah, PhD
Professor
Faculty of Engineering
Universiti Kebangsaan Malaysia
Malaysia
(External Examiner)

BUJANG KIM HUAT, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of **Master of Science.** The members of the Supervisory Committee were as follows:

Barkawi Bin Sahari, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Nuraini Binti Abdul Aziz, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Member)

BUJANG BIN KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

TABLE OF CONTENTS