DEVELOPMENT OF EMPIRICAL MODEL FOR THE IMPACT OF MOTORCYCLE FRONT WHEEL-TYRE ASSEMBLY

By

TAN KEAN SHENG

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

December 2004

To

My parents, my teachers and my friends

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

DEVELOPMENT OF EMPIRICAL MODEL FOR THE IMPACT OF MOTORCYCLE FRONT WHEEL-TYRE ASSEMBLY

By

TAN KEAN SHENG

December 2004

Chairman: Wong Shaw Voon, PhD

Faculty: Engineering

In engineering terms, the residual deformation on structural component is correlated to the dissipated energy, the change of momentum, or the change of speed during the impact. Many force-deflection models have been successfully developed for automobiles. However, such engineering model is not well developed for two-wheel motor vehicles due to lack of correlation information between the change of velocity and the structural damage, especially the frontal components such as wheel-tyre assembly which encounter the first and direct impact in frontal collision. The present study has thus been conducted which intended to lay out a route for developing the empirical models for motorcycle front wheel-tyre assembly that can be utilized to assess the impact velocities or change of velocities of a motorcycle in frontal collision based on the post-impact residual deformation of the wheel-tyre assembly.

An experimental approach has been adopted for the present study. The test specimens used was the original front wheel-tyre assembly of Malaysia national motorcycle, KRISS 110. The impact tests on motorcycle wheel-tyre assembly have been successfully conducted by

employing a pendulum impact test apparatus developed in-house in order to better suit to the experiment requirements. High-speed camera has been used to capture the deformation progress of the wheel-tyre assembly during the impact phase at a rate of 500 frame-per-seconds. Statistical computer program, Minitab Version 13, has been adopted to support the entire experimental process. Five out of eight parameters that are predetermined to be important on impact responses of wheel-tyre assembly have been identified as design factors. These factors are impact speed, impact mass, tyre inflation pressure level, contact geometry of striker, and vertical offset distance of impact location from a wheel axle. A 2_V^{5-1} fractional factorial design has been incorporated in the experimental design. Four response variables have been selected, which are, maximum residual crush sustained by the wheel-tyre assembly, normalized area of deformation of the wheel, squared change of velocity of the striker and dissipated impact energy of the wheel-tyre assembly.

Regression analysis has been performed in order to yield various possible empirical models in relating dissipated energy to either maximum residual crash or normalized area of deformation. The analysis shows good correlation in which the values of R^2 and R_{Adj}^2 are greater than 96% for all responses, except that in linear regression for the response $\Delta\tilde{A}$, which is about 83%. Factorial analysis has also been performed and the significant factors influencing the impact responses of the wheel-tyre assembly have been identified. The corresponding empirical models for predicting the deformation sustained by the wheel within the experimental design region have also been established. Based on the developed models, dynamic impact characteristics of the wheel-tyre assembly under various impact conditions were discussed.

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

PEMBANGUNAN MODEL EMPIRIKAL BAGI IMPAK KE ATAS STRUKTUR RODA-TAYAR DEPAN MOTORSIKAL

Oleh

TAN KEAN SHENG

Disember 2004

Pengerusi: **Wong Shaw Voon, PhD**

Fakulti: **Kejuruteraan**

Dalam istilah kejuruteraan, kecacatan kekal pada komponen struktur berkorelasi terus dengan tenaga impak terbebas, perubahan momentum, atau perubahan kelajuan objek semasa impak. Pelbagai model kejuruteraan daya-sesaran telah berjaya dibangunkan bagi kenderaan penumpang. Walau bagaimanapun, model kejuruteraan sebegini tidak dibangunkan dengan sempurna bagi kenderaan bermotor dua roda. Ini adalah kerana kekurangan maklumat dan pengetahuan korelasi di antara perubahan kelajuan dan kerosakan struktur, terutamanya komponen-komponen depan seperti struktur roda-tayar yang menerima impak pertama secara langsung dalam perlanggaran hadapan. Kajian ini dijalankan untuk membangunkan model empirikal bagi struktur depan roda-tayar motorsikal yang dapat digunakan untuk menjangka kelajuan motorsikal dalam perlanggaran hadapan dengan berdasarkan deformasi kekal lepas-impak pada struktur roda-tayar.

Pendekatan secara ujikaji telah diambil dalam kajian ini. Spesimen ujikaji yang digunakan ialah struktur depan roda-tayar tulen motorsikal kebangsaan Malaysia, KRISS 110. Ujian-ujian

impak ke atas struktur roda-tayar telah dijalankan dengan meggunakan peralatan ujian impak ladung yang dibangunkan secara "*in-house*" supaya lebih menyesuaikan kepada keperluan-keperluan ujikaji. Kamera kelajuan tinggi telah digunakan untuk menangkap imej perkembangan kerosakan roda-tayar semasa fasa impak pada kadar 500 bingkai-per-saat. Perisian komputer statistik Minitab Versi 13 telah digunakan untuk menyokong seluruh proses ujikaji. Lima daripada lapan parameter yang dikenalpasti terlebih dahulu telahpun digunakan sebagai faktor-faktor rekabentuk. Faktor-faktor tersebut ialah kelajuan impak, jisim impak, tekanan udara tayar, geometri sentuhan pemukul dan jarak ofsek tegak impak pada roda. Faktorial pecahan 2_V^{5-1} telah digunakan dalam rekabentuk ujikaji. Empat pembolehubah respons telah dipilih, iaitu, maksima remukan kekal pada struktur roda-tayar, luas kecacatan normal pada roda, perubahan kelajuan kuasadua pemukul dan tenaga impak terbebas struktur roda-tayar.

Analysis regresi telah dijalankan bagi memperolehi pelbagai empirikal model yang mungkin bagi menghubungkan tenaga terbebas dengan maksima remukan kekal atau luas kecacatan normal. Analysis menunjukkan korelasi yang baik di mana nilai bagi R^2 dan R_{Adj}^2 adalah melebihi 96% bagi semua respons, kecuali dalam regresi linear bagi respons $\Delta\widetilde{A}$, iaitu lebih kurang 83%. Analisis faktorial juga dilakukan dan faktor-faktor penting yang mempengaruhi respons dinamik impak struktur roda-tayar telahpun dikenali. Model-model analitikal yang berkenaan bagi menjangka deformasi yang dialami oleh roda di bawah pelbagai keadaan impak dalam lingkungan rekabentuk ujikaji juga telah dibangunkankan. Berdasarkan kepada model-model yang dibangunkan, ciri-ciri dinamik impak struktur roda-tayar di bawah pelbagai keadaan impak telah dibincangkan.

ACKNOWLEDGMENTS

This study could not have been accomplished without the help of many fine individuals. It gives the author great pleasure to acknowledge the valuable assistance and contribution of the following peoples.

First of all, the author wishes to express his sincere gratitude and appreciation to his supervisory committee chairman, Dr. Wong Shaw Voon, for his patient and continuous supervision, valuable advice, and guidance throughout the course of the study. The author would also like to express his great thankfulness and appreciation to other supervisory committee members, Prof. Ir. Dr. R.S. Radin Umar, Assoc. Prof. Dr. M.M.H. Megat Ahmad and Assoc. Prof. Dr. A.M.S. Hamouda for their valuable suggestions and advice. The expertise and experience sharing by the supervisors had enhanced the author's knowledge in the field of study.

Special appreciation goes to Mr. Eugene Lai from LabTech Co. for his technical assistance and experience sharing in the construction of experimental apparatus. Not to forget is Mr. T.H. Law for his encouragement and constructive comments. The appreciation also extended to author's colleagues, friends and all other individuals who have directly or indirectly delivered their generous assistance in completing the study.

The author wishes to acknowledge the financial support from IRPA and MSP. The study would not have been accomplished without these funds.

Last but not the least, the deepest appreciation goes to author's family members, especially his mother, See Kee Hing, for her continuous support and encouragement.

I certify that an Examination Committee met on 7th December, 2004 to conduct the final examination of Tan Kean Sheng on his Master of Science thesis entitled "Development of Empirical Model for the Impact of Motorcycle Front Wheel-tyre Assembly" 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. Members of the Examination Committee are as follows:

Thamir Sabir Younis, PhD
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Barkawi Sahari, PhD
Professor
Head of Advanced Automotive Technology Laboratory
Institute of Advanced Technology
Universiti Putra Malaysia
(Member)

Yousif A. Khalid, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Masjuki Haji Hassan, PhD
Professor/Deputy Dean (Development)
Faculty of Engineering
Universiti Malaya
(Member)

GULAM RUSUL RAHMAT ALI, PhD
Professor/Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. Members of the Supervisory Committee are as follows:

Wong Shaw Voon, PhD
Faculty of Engineering
University Putra Malaysia
(Chairman)

Radin Umar Radin Sohadi, PhD
Professor
Faculty of Engineering
University Putra Malaysia
(Member)

Megat Mohamad Hamdan Megat Ahmad, PhD
Faculty of Engineering
University Putra Malaysia
(Member)

Abdel Magid Salem Hamouda, PhD
Faculty of Engineering
University Putra Malaysia
(Member)

AINI IDERIS, PhD
Professor/Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

DECLARATION

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

_____

TAN KEAN SHENG

Date:

TABLE OF CONTENTS