DYNAMIC MODEL UPDATING OF BODY-IN-WHITE STRUCTURE USING SENSITIVITY ANALYSIS

NOOR AM ZURA BINTI ABDULLAH

Master of Science

UNIVERSITI MALAYSIA PAHANG

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science in Automotive.

_____

(Supervisor's Signature)

Full Name : DR. MOHD SHAHRIR BIN MOHD SANI

Position : SENIOR LECTURER

Date :

STUDENT'S DECLARATION

I hereby declare that the work in this 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 Universiti Malaysia Pahang or any other institutions.

_____

(Student's Signature)

Full Name : NOOR AM ZURA BINTI ABDULLAH

ID Number : MMA 14003

Date : 10 JULY 2017

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LIST OF SYMBOLS

λ_i	Vector of Eigenvalues
S_i	Eigen frequency sensitivity
K	Stiffness matrix
M	Mass matrix
ω	Circular natural frequency
ϕ	Eigenvector
f	Natural frequency
W	Mode weighting factor

LIST OF ABBREVIATIONS

BIW	Body-in-white
CAD	Computer aided design
CAE	Computer aided engineering
DAQ	Data acquisition
EEMKE	Element modal kinetic energy
EEMSE	Equivalent modal strain energy
EMA	Experimental modal analysis
FE	Finite element
FEA	Finite element analysis
FEM	Finite element method
FFT	Fast Fourier Transform
FRF	Frequency response function
IESM	Inverse sensitivity method
LSMR	Least square minimal residual
MAC	Modal assurance criterion
MCI	Miscorrelation index
MDOF	Multi degree of freedom
NI	National instrument
NVH	Noise, vibration and harshness
OMA	Operational modal analysis
PCB	Printed circuit board
SDOF	Single degree of freedom

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ABSTRAK

Sesebuah struktur yang besar dan kompleks seperti struktur badan kenderaan (BIW) adalah terdiri daripada beberapa komponen utama yang diperbuat daripada kepingan logam nipis yang dilekatkan bersama oleh beberapa jenis sambungan mekanikal seperti kimpalan bintik dan sambungan bolt. Sementara itu, model unsur terhingga untuk sesebuah struktur dibina untuk meramalkan tingkah laku struktur sebelum struktur tersebut difakbrikasi. Eksperimen akan dilakukan ke atas struktur yang telah difabrikasi dan data yang diukur akan dibandingkan dengan analisis pengiraan pada model unsur terhingga bagi struktur itu. Walau bagaimanapun, dalam kes struktur yang kompleks seperti BIW, ramalan unsur terhingga tidak selalu menunjukkan perbandingan yang baik dengan keputusan eksperimen disebabkan oleh faktor anggaran tidak tepat keadaan sempadan, sifat fizikal struktur dan proses bersirat. Kepelbagaian pembuatan yang wujud antara struktur ukuran yang sama, seperti dalam pengeluaran besar-besaran struktur badan kenderaan, tidak dapat dielakkan. Tesis ini bertujuan untuk memberi tumpuan menunjukkan kaedah yang disebut sebagai mengemaskini model untuk mengurangkan percanggahan timbul. Pada mulanya, model unsur terhingga struktur BIW dibina dengan cara mudah. Model pertama telah dibina tanpa melibatkan apa-apa elemen yang menghubungkan untuk mewakili komponen bersama mekanikal. Dalam fasa seterusnya dalam pemodelan, elemen rasuk (CBAR) dan elemen spring penyambung (CELAS) termasuk dalam model untuk mewakili komponen bersama. Ciri-ciri modal model unsur terhingga diwujudkan iaitu BIW diperolehi dan dibandingkan dengan sifat-sifat yang modal diukur dalam analisis modal eksperimen. kerja eksperimen melibatkan penggunaan ujian kesan tukul untuk mengukur tindak balas mod. Beberapa pendekatan dan persediaan digunakan semasa kerja-kerja eksperimen untuk memastikan kualiti tindak balas yang diukur boleh dipercayai untuk tujuan korelasi. Akhir sekali, prosedur mengemaskini model pada semua model BIW dicipta dilakukan dengan bantuan analisis sensitiviti bagi mendapatkan parameter yang berpotensi untuk dipilih sebagai parameter dipertingkatkan. Peratusan awal kesilapan dalam semua model adalah di bawah 10%. Tahap peningkatan ditunjukkan selepas prosedur model pengemaskinian dilakukan pada semua model BIW menunjukkan bahawa peratusan purata ralat dalam setiap mod adalah kurang daripada 5%. Di antara semua kerja tiga mengemaskini, prosedur pengemaskinian dilakukan ke atas model BIW dengan elemen sambungan menunjukkan pengurangan ralat yang lebih baik. Pada akhirnya, prosedur pengemaskinian model dengan bantuan analisis sensitiviti pada parameter yang dipilih telah terbukti menjadi alat yang berkesan untuk mengurangkan percanggahan antara ramalan dan data eksperimen dan dapat menyetempatkan sumber andaian yang tidak tepat dan ketidaktentuan.

ABSTRACT

A large and complex structure such as vehicle body-in-white (BIW) structure consists of several major components made from thin metal sheets that are joined together by several types of mechanical joint such as spot welds and bolted joints. Meanwhile, a finite element model of a structure is built to predict the behaviour of the structure before fabrication of the structure. Experimental work will be performed on the fabricated structure and the measured data are compared with the computational analysis on its finite element model counterparts. However, in case of complex structure such as BIW, the finite element prediction is not always in good agreement with the experimental results due to inaccurate approximation of boundary condition, physical properties of the structure and meshing process. This thesis intends to focus on demonstrating a method called model updating in order to reduce the discrepancies. Initially, the finite element model of BIW structure is constructed in simplified manner. The first model is constructed without including any connecting elements to represent the mechanical joint components. In the next phase of modelling, beam element (CBAR) and spring connector element (CELAS) is included in the model to represent the joint components. The modal properties of the created finite element models of BIW is obtained and compared to the modal properties measured in experimental modal analysis. Experimental work involves the application of impact hammer test for measuring the modal response. Several approaches and set up are used during experimental work which includes different experimental set up and number of sensor used in measuring response, in order to ensure that the quality of the measured response is reliable for correlation purpose. Finally, the procedure of model updating on all created BIW model is performed with the aid of sensitivity analysis in order to identify the potential parameters to be chosen as the updating parameters. Initial percentage of error in all model are below 10%. After model updating procedure is performed on all BIW models, the average percentage of error in every mode are successfully reduced to below 5%, a significant level of improvement. Among all three updating work, the updating procedure performed on BIW model with joint elements shows better error reduction. At the end, the model updating procedure with the aid of sensitivity analysis on the selected parameters has proved to be an effective tool to reduce the discrepancies between prediction and experimental data and able to localize the source of inaccurate assumptions and uncertainties.

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APPENDIX A
LIST OF PUBLICATION

1. M.S.M. Sani, **N. A. Z. Abdullah**, S.N. Zahari, J.P. Siregar, & M.M. Rahman. "Finite Element Model Updating of Natural Fibre Reinforced Composite Structure in Structural Dynamics", MATEC Web of Conf. 83 03007 (2016). Doi: 10.1051/matecconf/20168303007. **(SCOPUS indexed)**

2. **N. A. Z. Abdullah**, M. S. M. Sani, M. M. Rahman & I. Zaman. "A Review on Model Updating in Structural Dynamics", IOP Conf. Ser. Mater. Sci. Eng. 100, 012015 (2015). Doi: 10.1088/1757-899X/100/1/012015. **(SCOPUS indexed)**

3. M.S.M. Sani, N. A Nazri. S. N. Zahari, **N. A. Z. Abdullah** & G. Priyandoko. "Dynamic Study of Bicycle Frame Structure", IOP Conf. Ser. Mat. Sci. Eng. 160, 012009 (2016). Doi: 10.1088/1757-899X/160/1/012009. **(SCOPUS indexed)**

4. **N. A. Z. Abdullah**, M. S. M. Sani, M. M. Rahman & I. Zaman. "Correlation of Numerical and Experimental Analysis for Dynamic Behaviour of a Body-in-white (BIW) Structure", MATEC Web of Conf. 90 01020 (2017). Doi: 10.1051/matecconf/20179001020. **(SCOPUS indexed)**

5. M. H. N. Izham, **N. A. Z. Abdullah**, S. N. Zahari,& M. S. M. Sani, "Structural Dynamic Investigation of Frame Structure with Bolted Joints", MATEC Web of Conf. 90 01043 (2017). Doi: 10.1051/matecconf/20179001043. **(SCOPUS indexed)**

6. **N. A. Z. Abdullah**, M. S. M. Sani, N. A. Husain, M. M. Rahman & I. Zaman. "Model Updating of Go-kart Structure in Structural Dynamics", 3rd International Conference on Recent Advances in Automotive Engineering & Mobility Research (ReCAR 2015), 1-3 December, Melaka, Malaysia, 2015

7. **N. A. Z. Abdullah**, M. S. M. Sani, & I. Zaman. "Correlation of Structural Modal Properties of Go-kart Frame Structure using Different Type of Joint in Finite Element Modelling", International Conference on Computational Science

and Engineering (ICCSE 2016), 28-30 November, Kota Kinabalu, Sabah, Malaysia, 2016.