UNIVERSITI TEKNOLOGI MARA

FINITE ELEMENT MODELLING AND UPDATING FOR THE DYNAMIC BEHAVIOUR OF A STRUCTURE WITH BOLTED JOINTS

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Thesis submitted in fulfilment of
the requirements for the degree of
Doctor of Philosophy
(Mechanical Engineering)

College of Engineering

August 2022

ABSTRACT

Bolted joints are widely used in various industries for assembling structural components because they are easy to assemble and disassemble, simple to configure and cost-effective. However, the presence of bolted joints in an assembled structure significantly changes the dynamic behaviour of the structure, which are natural frequencies and mode shapes. This change is due to two main factors, namely the stiffness of the contact surfaces and the bolts. These two important factors are not well understood and are very difficult to determine experimentally. To date, no attempt has been made to integrate these factors using FE model updating (FEMU) and experimental modal analysis (EMA) in accurately determining the dynamic behaviour of an assembled structure. Furthermore, the current bolted joint modelling for analysing the dynamic behaviour of an assembled structure using detailed models is very difficult, cumbersome and uneconomical as they require a large number of degrees of freedom, large data storage and high computational cost. This study proposes an efficient, economical and reliable scheme for modelling and predicting the dynamic behaviour of an assembled structure where the structural components are connected by bolted joints. In particular, it investigates whether 1D elements are able to represent the bolted joints with the two most important factors. In this context, CBEAM and CBUSH elements were used to represent the bolted joints and CELAS elements for the contact interfaces. The proposed scheme was tested on three assembled structures made of two different materials, namely 6061-T6 aluminium (aluminium) and A36 structural steel (steel), to investigate the effects of the bolted joints on the dynamic behaviour of the assembled structures using normal modes analysis and EMA. The results of the test, namely the natural frequencies and mode shapes, were used to determine the parameters of the bolted joints and the definitions of the contact interfaces using sensitivity analysis, FEMU and EMA. The accuracy of the proposed scheme was confirmed by comparing the predicted natural frequencies and mode shapes with their EMA counterparts. The difference in comparison was carefully examined using sensitivity analysis to determine the parameters of the FE model of the assembled structure to which the predicted results were very sensitive. The parameters identified were used as updating parameters to systematically correlate the accuracy of the predicted results as closely as possible with their EMA counterparts. The results of the sensitivity analysis and comparison between the FE model and the EMA model showed that the CBEAM elements were best for representing the bolted joints in the assembled aluminium structure and the CBUSH elements for the assembled steel structure. Another significant finding was that the FE model developed with the proposed scheme was able to predict the dynamic behaviour of the assembled structure with an accuracy of 86% in the frequency range from 0 to 1500 Hz. Furthermore, the proposed scheme was found to be remarkably effective and efficient with an accuracy of 97% in the frequency range of 0 to 400 Hz, which is of interest in most industries. These results show that the proposed scheme can be reliably and economically used to model and predict the dynamic behaviour of an assembled structure with bolted joints, which are common in most industries. By using the proposed scheme, the industry would benefit from faster decisions to improve product performance.

ACKNOWLEDGEMENTS

In the name of Allah, the Most Gracious and the Most Merciful. Alhamdulillah, praise be to Allah for His blessings in the completion of this thesis.

My special thanks to my supervisor, Dr. Muhamad Norhisham Abdul Rani, for his guidance, enthusiasm and constant support throughout these PhD studies. My sincere thanks to my co-supervisor Associate Professor Ir. Dr. Mohd Azmi Yunus for his guidance, advice and knowledge throughout these PhD studies. Thank you also for the black coffee from Gloria Jeans, which I enjoyed very much, and for the fruitful conversations during the coffee breaks.

Many thanks to Universiti Teknologi MARA (UiTM) and the Ministry of Higher Education (MoHE) of Malaysia for sponsoring these PhD studies through project grants and MyBrain15.

I would also like to thank the members of the Structural Dynamics Analysis and Validation (SDAV) group of the School of Mechanical Engineering, College of Engineering, UiTM for their support and cooperation in the use of facilities and equipment during my PhD studies. My special thanks also go to the members of the Machinery Technology Centre of SIRIM Berhad for their continuous support and inspiration during my PhD studies.

My deepest gratitude goes to my beloved wife, Norzilla Ahmad Kamaruzaman, for her endless love, understanding and encouragement. My deepest gratitude also goes to my children Khayrin, Khalisa, Khalief, Khadija, Khaizan and Khasyif for giving me strength and happiness in my life.

Not forgetting my beloved parents, Allahyarham Omar Hussin and Siti Rukiah Arifin, and my siblings Rohaidee and Rohaida for their constant prayers and moral support in my life. They are all one of the greatest blessings Allah has given me in this earthly life and InsyaAllah to the hereafter.

Last but not least, I would like to thank my friends who have contributed either directly or indirectly to these PhD studies.

Thank you very much.

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