UNIVERSITI TEKNOLOGI MARA

PERTURBATION STOCHASTIC MODEL UPDATING OF A BOLTED STRUCTURE

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ABSTRACT

The stochastic model updating (SMU) method based on perturbation theory offers many advantages in predicting the dynamic behaviour of an engineering structure under conditions of variability and uncertainty with high accuracy and at low cost solutions. However, the presence of high-dimensional uncertainty of the structural problem, such as a bolted structure, makes it difficult for the SMU method to provide an accurate prediction result, which usually leads to large errors, hard convergence and ill-condition problems. This high-dimensional uncertainty is due to the limited ability to obtain comprehensive knowledge about the bolted structure, especially about the initial properties of the contact interfaces. Moreover, it is almost impossible to determine the stiffness of the contact interfaces experimentally. In this study, a new scheme using the perturbation SMU method with multidimensional analysis was proposed to estimate appropriate initial values for the high-dimensional uncertain parameters in a FE model of a bolted structure. The scheme was developed by introducing a multidimensional analysis consisting of a systematic quasi-random sampling algorithm. The bolted structure used in this study was developed based on standard grade AISI 1020. The framework of this study includes systematic methods such as (1) identifying the measured dynamic behaviour of the components and the bolted structure using experimental modal analysis (EMA). The bolted structure was tested under deterministic and stochastic conditions. For the latter, the bolted structure was reassembled 100 times to evaluate the variability of the dynamic behaviour of the structure. Subsequently, (2) FE models of the structural components were developed and first updated using deterministic model updating (DMU), taking into account the experimental results, to minimise the uncertainties before reassembling them into the model of the bolted structure. Consequently, (3) FE models of the bolted structure were developed and an appropriate FE model was selected based on the EMA result counterpart. (4) The appropriate FE model was improved using multidimensional analysis by improving the poor correlation of the FE model with EMA, then the appropriate initial value of the high-dimensional uncertain parameters was extracted from the improved model. The SMU method based on the improved model was used to predict the variability of the dynamic behaviour of the structure. The accuracy of the predicted dynamic behaviour by the proposed scheme was evaluated from the EMA results and the high dimensional uncertain parameters in the bolted structure can be quantified. The comparison of the results between the updated dynamic behaviour of variability and EMA showed that the proposed scheme was highly able to improve the initial stochastic prediction of the bolted structure from 23.25 % to 1.5 % and 503.48 % to 9.69 % for mean and standard deviation respectively. The results show that the proposed scheme clearly highlights the ability of the SMU method to solve high-dimensional structural uncertainty problems, especially for bolted joints, which have rarely been reported before due to the difficulties in reducing dimensionality and identifiability uncertainties. In other words, the implementation of a multidimensional analysis to increase the knowledge of the uncertain parameters is undoubtedly necessary for the success of the SMU method. Moreover, the proposed scheme has demonstrated its ability to efficiently quantify the range of uncertainties in structural parameters. Finally, this study has a great impact on the engineering community by providing reliable analytical Big Data for the creation of intelligent prediction systems.

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CHAPTER ONE
INTRODUCTION

1.1 Motivation of the Study

The use of simulation technologies to drive advanced and intelligent analysis has become a major challenge for practitioners in engineering industries, such as heavy machining, automotive and aerospace, especially when it comes to providing an accurate approximation of real-world performance. Simulation modelling is an important method of analysis that is easy to understand and verify, as it provides clear insight into complex systems. Therefore, simulation technology can help industries meet expectations and performance at the product development stage while improving the product's decision-making capability. In addition, the application of simulation technology has enabled engineers to decentralise the entire product development process, giving engineers access to real-time information sharing between stages of the product life cycle. However, as products in the engineering industry become more complex due to their versatility and variations, especially when it comes to making products faster and more stable while reducing costs, simulation technology has proven to be the only solution that can meet these requirements.

Vibration is the mechanical oscillations of an object about a point of equilibrium. The effects of vibration are a critical issue in the design of structures. Understandably, the effects of vibration can lead to serious performance and safety problems in manufactured products. For example, the ride comfort of a car is highly dependent on the NVH levels of the vehicle. If the engine has resonance, the car will vibrate excessively and passengers in the car will feel uncomfortable, especially if the vibration frequencies match the natural frequencies of the human body. To solve the problem of vibration at the product development stage, vibration analysis-based simulation using mathematical modelling must be introduced to predict the potential of vibration problems for the system before manufacturing. Consequently, the product design can be effectively modified and improved to minimise the sources of harmful vibrations before the product is manufactured. In addition, the effects of vibration due to the influence of mechanical motion and structural resonance can be incorporated into the design to improve the performance of the product. However, the effects of vibration