

UNIVERSITI TEKNOLOGI MARA

**NONLINEAR DYNAMIC
CHARACTERISATION OF JOINTED
STRUCTURES THROUGH
RESPONSE-CONTROLLED
SIMULATION AND
EXPERIMENTATION**

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

Faculty of Mechanical Engineering

September 2025

ABSTRACT

The dynamic characteristics of jointed structures are often predicted using linear methods. However, at high excitation levels, nonlinear effects become significant, making these linear assumptions invalid and the prediction more challenging. Stepped sine excitation is a reliable approach for detecting such nonlinearities, typically performed using the Force-Controlled Technique (FCT). Despite its effectiveness, FCT requires long data acquisition and computation time in both experiments and simulations, limiting its practicality for nonlinear analysis. In this study, a new methodology for investigating nonlinearity in jointed structures using the Response-Controlled Technique (RCT) is proposed. The methodology starts by performing the Swept Sine Testing (SST) technique with a large force. The relative acceleration response between two points in the region of the bolts is calculated and a cubic stiffness is estimated using the Acceleration Surface Method (ASM). FCT and RCT tests are then performed at various excitation levels. The Nonlinear Frequency Response Functions (NLFRFs) and the time required to perform the nonlinear tests are measured. A decrease in the resonance frequency, which is accompanied by an increase in the excitation level, shows softening nonlinearity. A comparison of the measurement time shows that RCT is more favourable than FCT, as the time required for data acquisition with RCT is less than with FCT. A methodology to incorporate RCT into a commercial software package MSC NASTRAN is introduced. A specific controlled displacement is simulated by applying an enforced motion value to the excitation point. The validation by comparing the FRFs between the RCT simulation and the RCT test has shown that the proposed methodology is very effective in predicting the nonlinearity corresponding to the displacement amplitudes. Furthermore, the computational time for RCT simulation is compared with the conventional FCT simulation. The comparison results show that the proposed methodology has a significant advantage as it requires much less computational time than the FCT simulation. In addition, the RCT computational time remains relatively constant across different displacement amplitudes, while the FCT computational time increases significantly at higher forces. In conclusion, the proposed methodology has the potential to significantly improve the experimental and computational challenges in the detection and characterisation of nonlinearity in structural dynamics.

ACKNOWLEDGEMENT

Firstly, Alhamdulillah for granting me to embark on my PhD and for allowing me to successfully complete this long and challenging journey. My sincere gratitude and heartfelt thanks go to my Main Supervisor, Associate Professor Ir. Dr. Mohd Azmi Yunus, and my Co-Supervisor, Dr. Muhamad Norhisham Abdul Rani, for their invaluable guidance, instruction, and motivation throughout this journey. Their continuous support not only shaped my research direction but also broadened my academic perspective beyond the laboratory and university. Before this PhD journey, I had limited exposure to academic activities outside my campus environment. Through their encouragement, I had the opportunity to attend international conferences, seminars, and trainings, which significantly enriched my research experience and professional development.

Special thanks to the Structural Dynamics Analysis & Validation (SDAV) research team members: Dr. Wan Imaan Izhan, Dr. Azam, Miss Crystall, Dr. Rohaizat, Mr. Syafiq and Mr. Khairul, for their support, assistance, and the cherished moments we shared in the SDAV research lab. Without their support and guidance, it would not have been possible.

I am deeply grateful to my parents, Haji Bahari and Hajah _____, for their endless love and support throughout my PhD journey. I also want to express my heartfelt appreciation to my entire family, my wife Salmiwati, and my three daughters Yana, Nuha, and Aida for the good times in my life. This achievement is dedicated to all of you. Alhamdulillah.

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CHAPTER 1

INTRODUCTION

1.1 Motivation of the Study

The continuous advancement of numerical techniques and experimental validation are crucial in engineering, particularly in the design and analysis of complex mechanical and aerospace structures. These advancements enable engineers and researchers to develop reliable methodologies and improve accuracy while minimising the cost and time of computation. In a fast-paced industrial environment, the role of numerical analysis is crucial as optimised designs, improved performance, and ensuring safety under different operating conditions are required. Therefore, continuous efforts are required to develop efficient numerical modelling techniques that can be integrated into existing methods.

Modern structures in mechanical engineering and aerospace increasingly consist of complex assemblies connected by joints. These assembled structures are designed to meet the demands of high performance operation. As these structures play a crucial role in advanced technological applications, they must function effectively under different operating conditions. Therefore, constant technological advancement and innovation through advanced modelling techniques are required to accurately predict the nonlinearities caused by joints, and ensure the development of more reliable and efficient structures.

The research in structural dynamics and nonlinearity is in line with the National Science, Technology, and Innovation Policy (DSTIN) 2021-2030 and has a direct impact on Malaysian industries that aim to transform Malaysia into a high-tech nation by 2030, particularly the automotive and aerospace sectors. This research contributes to improving the country's research and development landscape by generating new knowledge and methodologies, both in experimental and computational. This, in turn, supports the country's goal of becoming a hub for cutting-edge research and technological innovation.