CHARACTERISATION OF WIDEBAND NONLINEAR VIBRATION ABSORBER USING ADJUSTABLE MAGNETIC STIFFNESS

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This report is submitted
in fulfillment of the requirement for the degree of
Bachelor of Mechanical Engineering (Plant & Maintenance)

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

JUNE 2017

DECLARATION

I declare that this project report entitled "Characterisation of Wideband Nonlinear Vibration Absorber Using Adjustable Magnetic Stiffness" is the result of my own work except as cited in the references

Signature	:	....
Name	:	....
Date	:	....

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Plant & Maintenance).

Signature :. ....

Name of Supervisor : ....

Date : ....

DEDICATION

To my beloved father and mother

ABSTRACT

Linear dynamic vibration absorber can only suppress vibration of primary structure at one frequency. At other frequency it will amplify the vibration of primary structure. Nonlinear dynamic vibration absorber was introduced to increase the operational bandwidth of absorber. In this project, nonlinear dynamic vibration absorber was characterized using adjustable magnetic stiffness. Thisproject starts with identification first vibration mode of primary structure. Then Operating Deflection Shape (ODS) for the first vibration mode was constructed. Then, nonlinear dynamic vibration absorber was characterized using three different variables. They are effect of gap between magnets, effect of input level from shaker and effect of length of absorber beam. Lastly, performance of nonlinear dynamic vibration absorber on primary structure was investigated at three different points and three different gap levels.

ABSTRAK

Penyerap getaran linear hanya boleh menyekat getaran struktur utama pada satu frekuensi sahaja. Pada frekuensi lain ia akan menguatkan getaran struktur utama. Penyerap getaran tak linear telah diperkenalkan untuk meningkatkan jalur lebar operasi penyerap. Dalam projek ini, penyerap getaran tak linear dicirikan menggunakan kekukuhan magnet laras. Projek ini bermula dengan pengenalan mod getaran pertama struktur utama. Kemudian 'Operating Deflection Shape' (ODS) untuk mod getaran yang pertama telah dibina. Kemudian, penyerap getaran tak linear dicirikan menggunakan tiga pembolehubah yang berbeza. Mereka adalah kesan sela antara magnet, kesan tahap input dari penggoncang dan kesan panjang rasuk penyerap. Akhir sekali, prestasi penyerap getaran tak linear pada struktur utama telah disiasat di tiga tempat yang berbeza dan tiga tahap sela yang berbeza.

ACKNOWLEDGEMENT

I would like to convey my sincere gratitude to my supervisor Dr. Roszaidi Ramlan for giving me this opportunity to do this final year project under his supervision. He always encourages and gives me confidence to finish this project successfully. Whenever I encountered problem, he never hesitated to give me advice and guidance.

Secondly, I would like to thank Assistant Engineer Mr Johardi for his kindness in giving me time I needed to use the VibroAcoustics laboratory to complete my project. Also, I would like to thank a senior master's degree student Lim Kah Hei for giving me guidance in conducting experiment and sharing his knowledge in the field of vibration.

Finally, I would like to thank my parents and friends who give me encouragement and be patient with me during the past 1 year.

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LIST OF ABBREVIATIONS

DVA	Dynamic vibration absorber
TVA	Tuned vibration absorber
ATVA	Adaptive tuned vibration absorber
MRE	Magnetorheological elastomer
MR	Magnetorheological
FRF	Frequency response function
PZT	Zicronite titanate
LVDT	Linear variable differential transformer
DR	Delayed resonator
FENE	Finite extensibility elastic
NDVA	Nonlinear dynamic vibration absorber
ODS	Operating deflection shape
SDOF	Single degree of freedom
MDOF	Multiple degree of freedom

LIST OF SYMBOLS

x_1	Deflection of primary structure
r	Ratio of primary structure natural frequency over absorber natural frequency
m_1	Mass of primary structure
K_1	Stiffness of primary structure
K_2	Stiffness of absorber
m_2	Mass of absorber
x_2	Deflection of absorber
F(t)	Force applied to primary structure
C	Damping coefficient of absorber
Z	Relative motion of absorber
β	Optimum tuning parameter
ζ	Optimum damping ratio
μ	Mass ratio
K_3	Nonlinear stiffness constant
x^3	Cubic stiffness of nonlinearity
E	Young's modulus
I	Second moment of inertia
m	Mass per unit length
L	Length

F_m Magnet restoring force

ρ Density

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Vibration in structure is an unwanted situation because it can potentially cause damage to the structure. When the structure excited by external force at its natural frequency, a phenomenon called resonance will occur. At this frequency, damping element of structure will be at minimum and energy of structure will be at maximum. A small auxiliary mass-spring system known as dynamic vibration absorber (DVA) is normally used to mitigate the vibration of the structure. This DVA needed to be tuned to match the natural frequency of primary structure to effectively suppress the unwanted vibration of primary structure (Ji, 2011). Linear DVA can be further divided into undamped and damped DVA. In undamped DVA, there will only be auxiliary mass and spring element. In damped DVA damper will be added in parallel to the spring in the setup of DVA.

Damped DVA initially developed by Den Hartog and Ormondroyd (1928). There is a term, called optimum tuned damped DVA in damped DVA section. In this optimum tuning method, several parameter such mass, stiffness and optimum damping ration must be considered (Bekdas.G & Nigdeli.S.M, 2011). Advantage of doing this optimum tuning is that, it will provide larger suppression of resonant vibration amplitude of the primary system and will generating wider safe operating frequencies range of the primary system. These damped and undamped DVA are called passive dynamic vibration absorber.

Then there are, semi-active and active type of dynamic vibration absorbers to effectively mitigate unwanted vibration at in primary structure. Semi-active type absorbers use smart materials control the absorbers. System parameters such as stiffness and damping element will be changed to change the dynamic response of the absorber. The system will be stable because it is constructed based on the passive DVA (Toshihiko.K, et al., 2016). In active type DVA, an actuator will be connected to the absorber. This actuator functions as control element to vary the stiffness and damper element of the absorber and adds flexibility to incorporate control theory to provide cancellation forces. (Chatterjee.S, 2010)

Although the absorber mention above which is categorized as a passive absorber is a famous and familiar device in mitigating unwanted vibration in mechanical structure, its only effective when it is precisely tuned to the frequency of a vibration mode and active and semi-active type DVA can be very complex in its development. Furthermore, the first study of non-linear absorber by Roberson, Pipes and Arnold have attract an attention in many literature and after realizing the limitations of linear absorbers, the non-linear vibration absorber was developed for their performance ability to widen the suppression bandwidth (Kerschen.G & Viguie.R, 2010).

In this project, magnets will be used in the characterisation of wideband nonlinear vibration absorber. One magnet will be attached to absorber beam and two more magnets will be attached to magnet wall. All the magnets will be setup facing different polarity, so that they will be attracted to each other. Three types of characterisation method will be investigated in this project. They are effect of gap between magnets, effect of level of input displacement and effect of length of absorber beam. Then, performance of absorber in mitigating vibration of primary structure will be investigated for first vibration mode of beam modelled as primary structure.

1.2 PROBLEM STATEMENT

Dynamic Vibration Absorber is an effective device used to suppress vibration in primary structures. Traditional DVA usually consist of mass and spring. DVA counteracts the motion of primary system by absorbing primary structure's vibration.

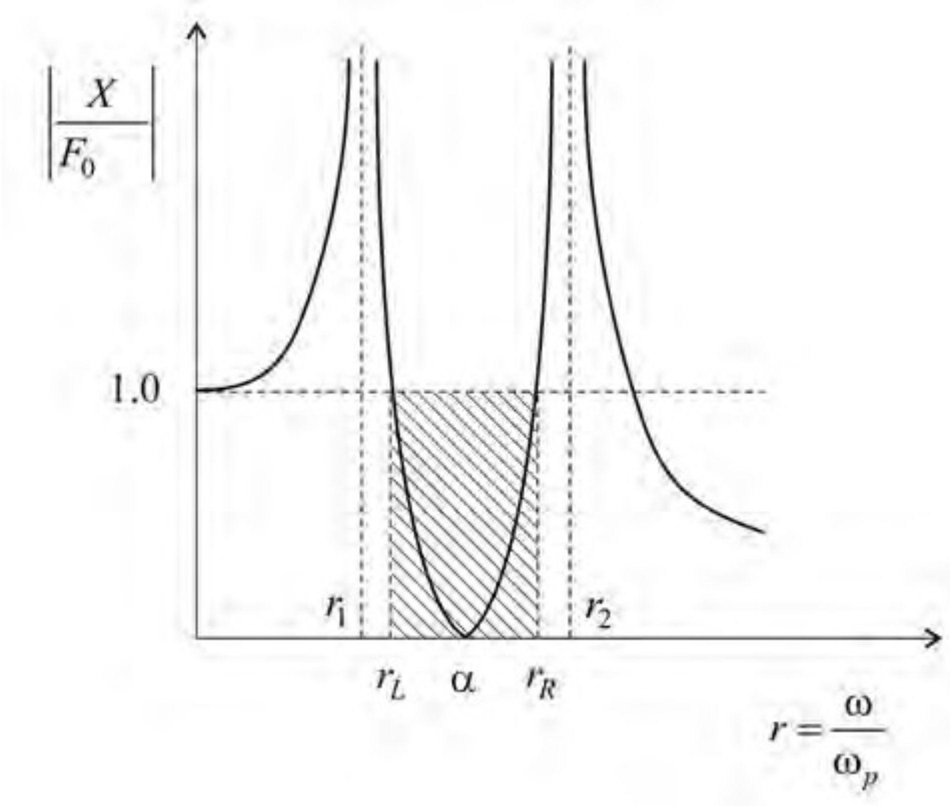

Figure 1.1: FRF for dynamic vibration absorber.

The problem with traditional undamped DVA is that it has a narrow bandwidth of operation as shown in Figure 1.1. Vibration of primary structure will be completely suppressed if the natural frequency of the absorber is perfectly tuned to the excitation frequency. In this case, it is assumed that receptance is below 1.0 is acceptable. As seen in the figure 1.1, absorber is only effective if r is between r_L and r_R because response of the system will be below 1.0 in this region. Other than the shaded region, transmissibility will be above 1.0 and it is not desired. If ω is