CHARACTERIZATION OF A WIDEBAND NONLINEAR VIBRATION ABSORBER USING CURVED CONSTRAINED CANTILEVER BEAM

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DECLARATION

"I hereby declare that the work in this thesis is my own except for summaries and quotations which have been duly acknowledged."

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SUPERVISOR APPROVAL

"I hereby declare that I have read this thesis 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) with honours"

Signature : ....

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ABSTRACT

In many industrial structure or appliances and also other structure such as a building, are involved in having an unwanted vibration such as from earthquake and hard storm. This unwanted vibration will cause a severity to the structure when the structure is excited to its natural frequency. In order to counter with the problem a device called vibration absorber is introduced. The vibration absorber is installed on the structure will suppress the unwanted vibration that occur. There is two type of absorber which is the linear absorber and the nonlinear absorber. The nonlinear absorber study is conducted and from the previous study it proves that the nonlinear absorber have a better performances than the linear absorber which is having wider safe operating frequency range. The study conducted is the characterization of a wideband nonlinear dynamic vibration absorber using curved constrained cantilever beam. The hardening method is used in order to have a nonlinear behaviour of the vibration absorber. The hardening method is by the application of profile curved block with quadratic profile of x^3, x^4, and x^6 on the designed vibration absorber. The designed absorber consist of a cantilever beam that is lies between two curved block and having a mass at the free end of the beam. From the theoretical and analytical study, the curve will constrain the deflection of the absorber beam thus hardened the absorber beam stiffness and make the absorber behave nonlinearly. However in the characterization conducted the profile block curved used on the designed vibration absorber is not stiffen up the deflection of the absorber beam thus the absorber behave linearly. The modification of the nonlinear absorber is taken place by attaching a stopper on the curved block profile to assist in constraining the deflection of the absorber beam. There will only the suppression of the first mode of vibration on the primary structure will be conducted which is modelled by a beam. The first mode of vibration of the primary structure beam is determined to find its natural frequency. The designed nonlinear absorber is tuned to have the same natural

frequency with the primary structure in order to suppress the vibration at its first mode of vibration thus the characterization of the absorber done. From the study conducted, it is proved that the designed nonlinear absorber by using the curved block with some modification is able to suppress the vibration on the first mode of vibration of the primary structure and providing a wider operating frequency range on the primary structure.

ABSTRAK

Banyak struktur industri atau peralatan dan juga struktur lain seperti bangunan, terlibat dengan getaran yang tidak diingini seperti gempa bumi dan ribut. Getaran yang tidak diingini ini akan menyebabkan bencana pada struktur apabila struktur mengalami gegaran pada frekuensi tabii. Untuk mengatasi masalah tersebut peranti dipanggil penyerap getaran diperkenalkan. Penyerap getaran dipasang pada struktur akan menyerap getaran yang tidak diingini. Terdapat dua jenis penyerap getaran iaitu penyerap getaran linear dan penyerap getaran tak linear. Kajian penyerap getaran tak linear dijalankan dan daripada kajian sebelumnya, ia membuktikan bahawa penyerap getaran tak linear mempunyai prestasi yang lebih baik daripada penyerap getaran linear yang mempunyai julat frekuensi operasi selamat yang lebih luas. Kajian yang dijalankan adalah mengenai pencirian sifat-sifat tak linear bagi penyerap getaran dinamik menggunakan rasuk julur yang dikekang oleh blok melengkung. Penyerap getaran yang direka terdiri daripada rasuk yang dikekang antara dua blok lengkung dan mempunyai sebuah jisim di hujung bebas rasuk tersebut. Kaedah pengerasan digunakan untuk menghasilkan tingkah laku tak linear penyerap getaran. Kaedah pengerasan dilakukan dengan aplikasi blok lengkung dengan profil kuadratik x^3, x^4, dan x^6 pada penyerap getaran yang direka. Kajian secara teori dan analisis, rasuk akan dikekang oleh blok lekuk lalu ia akan mengeraskan rasuk penyerap getaran dan membuatkan penyerap getaran bersifat tidak linear. Walau bagaimanapun dalam pencirian yang dijalankan blok profil melengkung digunakan pada penyerap getaran tidak berfungsi seperti yang sepatutnya. Pengubahsuaian penyerap getaran tak linear dilakukan dengan menambah penahan padai profil lengkung blok bagi membantu mengekan pesongan rasuk penyerap getaran. Hanya penyerapan mod pertama getaran pada struktur utama akan dijalankan yang dimodelkan oleh rasuk. Mod pertama getaran struktur rasuk

utama ini telah dipilih untuk mencari frekuensi semula tabii. Penyerap tak linear direka untuk mempunyai frekuensi semula jadi yang sama dengan struktur utama untuk menyerap getaran pada mod pertama.. Daripada kajian yang dijalankan, ia membuktikan bahawa penyerap getaran tak linear yang direka dengan menggunakan lengkung blok dengan beberapa pengubahsuaian boleh mengurangkan getaran pada mod pertama getaran pada struktur utama dan menyediakan julat frekuensi operasi yang selamat yang lebih luas ke atas struktur utama.

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DVA	Dynamic Vibration Absorber
NLDVA	Nonlinear Dynamic Vibration Absorber
FRF	Frequency Response Function
ODS	Operational Deflection Shape

LIST OF SYMBOL

m	Mass
m_a	Absorber mass
k	Stiffness
c_a	Absorber Damping Coefficient
ζ	Damping Ratio
x_a	Absorber Displacement
x	Displacement
$\dot{x}$	First derivatives of x
$\ddot{x}$	Second Derivatives of x
f_t	Harmonic Force
f^*	Tuning Frequency
ζ^*	Optimal Damping Ratio
μ	Mass Ratio
E	Modulus of Elasticity
I	Moment of inertia
L	Beam Length

CHAPTER 1

INTRODUCTION

1.0 BACKGROUND

Vibration is a non-desired phenomenon because of it can caused a disturbance, damage and sometimes might resulting destruction in machinery and structure as well. This unwanted phenomenon must be controlled or should be eliminated from the system of machinery or structure. The widely application used in reducing or eliminating the disturbance vibration occur in a system is by implementing the vibration absorber which is also known as dynamic vibration absorber (Liu & Liu, 2005). The dynamic vibration absorber (DVA) is a vibration control device consisting mass and stiffness which is as an auxilary system that is attached on a primary structure that needs to be control and protected from an unwanted vibration. The DVA can be devided into undamped DVA which consist of mass-spring system and damped DVA which consist of mass-spring-damper introduced by Ormondroyd and Den Hartog (Bekdaş & Nigdeli, 2013).

Besides that, the case of the optimum DVA are also the important strategies in vibration control. The optimization of a DVA icludes several parameters that must be consider such as mass, stiffness and damping (Bekdaş & Nigdeli, 2011). Various of study have been conducted by past and recent researchers in order to optimize the design parameter to improve the performance of the vibration absorber. By implementing the optimum tuning parameters of the absorber, it will provide larger suppression of resonant vibration amplitude of the primary system and also will generating wider safe operating frequencies range of the primary system.

Although the absorber mention above which is categorized as a linear 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 (Viguié & Kerschen, 2009). 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 were developed for their performance ability to widen the suppression bandwith (Viguié & Kerschen, 2010).

In this research, a cantilever beam is used as an absorber in the characterization of a wide-band non-linear vibration absorber and the stiffness of the cantilever beam is to be consider in order of the absorber optimization. The hardening of the beam stiffness will be associated by a curve metal in which will constrain the deflection of the absorber when vibration was excited. The absorber will lies against the solid curve, thus shortening its free length and becoming stiffer. Hence, its force characteristic becomes steeper for increasing deflection. Then, the performance of the absorber when put on the vibrating structure will be studied as well as the bandwith of the response.

1.1 **PROBLEM STATEMENT**

Undesired vibration in practical life can be found in many mechanical structure and machinery that can cause destruction of a structure. The implementation of vibration absorber when perfectly tuned will mitigate the undesired vibration in the primary system due to the supression of the vibration amplitude and thus providing a safe operating frequency range. Due to the primary mass which is at it initial state was a single degree of freedom system is attached with an auxilary single degree of freedom system (absorber) make the system constitute a two degree of freedom system and will have two natural frequencies. Due to the vibration absorber is tuned to only one particular frequency, it is only effective only over a narrow band of frequencies or safe operating frequency range as shown in Figure 1. Hence, this research will conduct an experimental study on the performance of the non-linear vibration absorber which is based on related work of research claimed that the non-linear absorber have a better performance than the linear absorber. Knowledge of the nonlinear characteristics of a vibration absorber is important if its performance is to be predicted accurately when connected to a host structure. This can be achieved theoretically, but experimental validation is necessary to verify the modelling procedure and assumptions. This research describes the characterization of such an absorber using an. experimental procedure

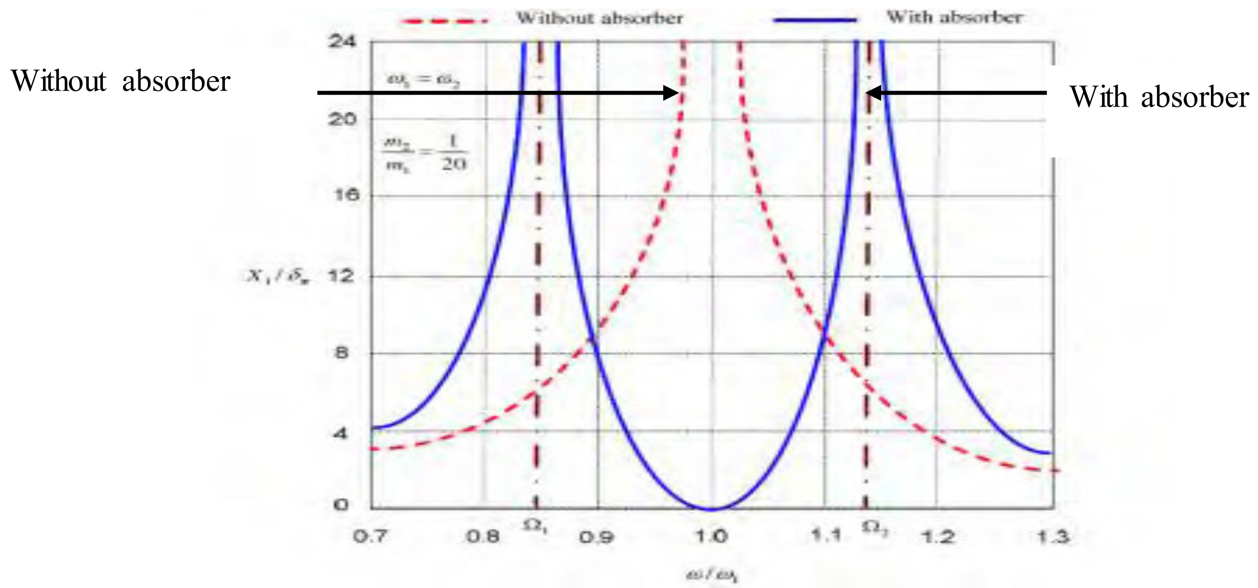

Figure 1.0 Vibration response of a primary structure when an absorber is attached

(red line = without absorber, blue line = with absorber).

1.2OBJECTIVE

The objective of research studies are:

1. To study the properties of a non-linear single degree of freedom system.
2. To characterize the dynamic properties of the proposed absorber.
3. To investigate the performance of the absorber when put on vibrating structure.

1.3 SCOPE OF PROJECT

Scope of this project are:

1. Characteristic of absorber investigated until first mode of vibration only.

2. Only nonlinear characteristic of stiffness is investigated.

CHAPTER 2

LITERATURE REVIEW

2.1 Dynamic Vibration Absorber

The dynamic vibration absorber (DVA) which is also known as tuned mass damper (TMD) nowadays are widely implemented as a vibration control device on a structure as a primary system in order to mitigate the vibratory movement or undesired vibration. Mostly, in practical applicaton DVA is designed in very small mass which usually of a few percentage of the primary structure (Hoang et al, 2008). The simplest form of DVA consist of a mass and spring. When a primary system is subjected to a harmonic force, it will experiencing an unwanted vibration and this severity which is the undesired vibration phenomenon can be suppressed by attaching a DVA.

Fundamentally let say before the DVA was attached on the primary system, the primary system was a single degree-of-freedom (Dof) system which is only have one natural frequency, thus the addition of DVA which supressed the vibration amplitude at once providing a safe operating frequency range, resulting in a new 2-Dof system and it will be also having 2 new natural frequencies. Therefore if the operating frequency coincides either one of these frequencies, the system will again be at resonance (Liu & Liu, 2005). Thus, in order to overcome this problem, a damper is added to the DVA so as to supressed the new vibration amplitude to remains small at resonance. Many of successful aplication of DVA installed on a structure can be found such as skyscrappers and towers to supress undesired vibration induced by wind force and etc. These structures include the CN Tower in Canada, The John Hancock Building, the tallest building in the world Taipei 101 and the Center-Point Tower in Sydney (Lee et al, 2006).

2.2 Optimal design of vibration absorber

The dynamic vibration absorber was mentioned in the previous section suppress the original resonance amplitude in the vibration system response of the machine then at the same time generating two new peaks. Thus, the machine will suffer large amplitude of vibration as it