DETERMINATION OF DYNAMIC PROPERTIES OF LAMINATED RUBBER-METAL SPRING CIRCULAR PLATE

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DECLARATION

I declare that this project report entitled "Determination Of Dynamic Properties Of Laminated Rubber-Metal Spring Circular Plate" 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 (Design & Innovation).

Signature	:.	....
Name of Supervisor	:	....
Date	:	....

DEDICATION

To my beloved mother and father.

ABSTRACT

The laminated rubber metal spring (LR-MS) is an equipment used on the mass structure such as building, railway, and huge machining. LR-MS act as an isolator of the structure and help to reduce vibration receive from external force, for preventing form damage on the structure. LR-MS consist of interlayer of rubber layer and stainless-steel layer which is repeatable arranged to form a LR-MS isolator. The stainless-steel layer is a metal plate used to provide strengthens for the LR-MS to withstand heavy structure. This study is done to determine the damping ratio of stainless-steel circular plate which is interlayer with rubber in the LR-MS. The damping ratio of the circular plate will be determined by using two methods are Logarithmic Decrement method and Half-Power Bandwidth method, and the data compute from the DeweTrans software of the experiment will be acquired from the dynamic properties experiment on the circular plate. The analyzed result will be compare to determine the percentage of error occur in this experiment. The result of damping ratio of the experiment on the cantilever beam shows the difference on both theoretical value and experimental value with the 21.13% percent of percentage of error. The experiment consist error during the experiment work was carried out, the error in this experiment are random error, and systematic error that cause the data taken was inaccurate and the experiment categories as unsuccessful test. The propagation of maximum amplitude in 10 cycles in each experiment done, all the peak amplitude is damped constantly varies with time. For maintaining the precision of the result, the experiment has been repeated three times and the average result among the total experiment was taken and recorded in the table. Both methods successfully proving the reliable data and result for determining the damping ratio for stainless-steel circular plate during this study.

ABSTRAK

Spring logam berlamina Getah (LR-MS) adalah satu alat yang digunakan pada struktur seperti bangunan, kereta api dan mesin besar. LR-MS bertindak sebagai penyerap getaran pada struktur dan membantu mengurangkan getaran diterima dari daya luar, bagi mengurangkan kerosakan pada struktur akibat daripada getaran. LR-MS terdiri daripada beberapa lapisan getah dan lapisan keluli tahan karat yang diulangi dan disusun untuk membentuk sebuah penyerap getaran iaitu LR-MS. Lapisan keluli tahan karat adalah satu plat logam yang digunakan untuk menguatkan lagi lapisan getah dalam LR-MS bagi menahan struktur yang berat. Kajian ini dijalankan untuk menentukan nisbah redaman plat bulatan keluli tahan karat yang dilapisan dengan getah dalam LR-MS. Nisbah redaman plat bulatan akan ditentukan dengan menggunakan dua kaedah, iaitu kaedah Logaritmic Decrement dan kaedah Half-Power Bandwidth, dengan mendapatkan data dari perisian Dewetrans. Hasil ujikaji akan diperolehi daripada penentuan sifat dinamik pada plat bulatan. Hasil yang dianalisis akan bandingkan untuk menentukan peratusan ralat berlaku dalam ujikaji ini. Eksperimen ke atas redaman menunjukkan perbezaan pada kedua-dua nilai teori dan nilai eksperimen dengan 21.13% daripada peratusan ralat. eksperimen terdiri ralat semasa kerja eksperimen telah dijalankan, kesilapan dalam eksperimen ini adalah ralat rawak dan ralat sistematik yang menyebabkan data yang diambil adalah tidak tepat dan kategori eksperimen sebagai ujian tidak berjaya. Penyebaran amplitud maksimum dalam 10 kitaran dalam setiap eksperimen dilakukan, semua amplitud pada puncak sentiasa berubah dengan masa. Untuk mengekalkan ketepatan keputusan, percubaan telah diulangi tiga kali dan hasil purata antara jumlah percubaan itu diambil dan direkodkan kedalam jadual. Kedua-dua kaedah berjaya membuktikan data yang boleh dipercayai dan menyebabkan untuk menentukan nisbah redaman untuk keluli tahan karat plat bulat semasa kajian ini.

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LR-MS	Laminated Rubber – Metal Spring
FEM	Finite Element Method
FEA	Finite Element Analysis
DAQ	Data Acquisition
ICP	Integrate Circuit Piezoelectric
BNC	Bayonet Neill – Concelman
FFT	Fast Fourier Transform

LIST OF SYMBOL

T	=	Time period
A	=	Amplitude
f	=	Frequency
δ	=	Logarithmic decrement
ζ	=	Damping ratio
N	=	Number of cycle
Q	=	Q factor
π	=	Pi
t_n	=	Peak time
F	=	Force
M	=	Mass
ω_d	=	Damped natural frequency
ω_n	=	Natural frequency
ω_α	=	Undamped natural frequency

CHAPTER 1

INTRODUCTION

1.1 Introduction Of Study

The invention of laminated rubber – metal spring (LR-MS) have helped to hold on of supporting a variety of structures such as building, bridges, huge machining, tanks or including high-precision tools, analytical equipment, instate of stability mount for base structure in order to reduce the acceleration incurred from earthquake, traffic or mechanical vibration.

Conventionally, a LR-MS used for decreasing acceleration transmitted directly to affected structures, one way of functioning as a vibration – proof supporter. This LR-MS was conventional, consist a structure composed of alternately soft rubber – like elastic plates and laminated rigid plates made of steel having negligible effect of compressive permanent strain. In order to decrease acceleration incurred from earthquake and protect the upper structure from destructive force generated by earthquake the laminated rubber structure is inclined between upper and lower structures to support the upper structure.

The situation of damping performance and stability against vertical which is, extremely important factors in any used for protection preventing destructive force generated by phenomenal vibration (A. Putra et al., 2013).

Figure 1.1: Laminated Rubber – Metal Spring (LR-MS).

1.2 Problem Statement

This project has been carried out to analyses the dynamics properties of circular plate, widely used in laminated rubber-metal spring (LR-MS) as the interlayer between metal plate and rubber layer. Furthermore, to investigate how the circular plate effect on the transmissibility performance on LR-MS, also the conversion of mechanical energy of vibrating structure into thermal energy, called as damping which is the lost to the structure's environment.

1.3 Objective

The objectives of this project are as follows:

i. To determine the dynamic properties of circular plates by using accelerometers to measure vibration response of a fixed-free circular plates.
ii. To measure the transient vibration that will illustrate the concepts of damping ratio in solid circular plates.

1.4 Scope of Study

The scopes of this project are:

i. To conduct the experiment: Measurement of damping properties to investigate the circular plates.
ii. To calculate logarithmic decrement method and half-power bandwidth method to evaluate the damping ratio and Q factor, respectively.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter comprises of the research study of this experiment. It includes the history of earlier dynamic properties experiment conducted, application of seismic isolation system, previous research, and detail information on base isolation of laminated rubber metal spring due to structural vessel because of vibration and seismic motion. Relevant sources from online articles and websites are compiled and cited to complete this literature review.

A literature review includes the current knowledge of a particular topic, contributed by theoretical and methodological findings. Searching, managing, synthesizing and writing the assessment of the literature are the few processes involved in doing a literature review. The purpose of literature review is to define and establish the area of study or research topic.

2.2 Fact and finding

From the past researcher, they have considered various situation of seismic isolation to reduce horizontal and vertical seismic load for bridges, building, railway and etc., and its effects on structure their occupants, for several detailed studies have been undertaken. Studies of the vibration transmission between the source and the structure will be considering noise and vibration in the structure. Based on the literature review, its gives the overview of the previous research in this field, with some emphasis on the task direct relevance to base-isolated structures. Various factor that influence the behavior of vibration occur, example is an earthquake on building, heavy moving vehicle on the railway, this will be dealing with problem and methods of reducing its effects.

2.2.1 Seismic isolation system

Nowadays, the further researcher from Korea Atomic Energy Research Institute by (Y. Choun et al., 2014), they found that the response of seismic isolation system effect on the variability of the mechanical properties of lead rubber bearings, the response depends on the movement for different ground motions. The researcher state that the variation in the mechanical properties of base isolator will result significant influence on the shear resistance and the acceleration response of the structure.

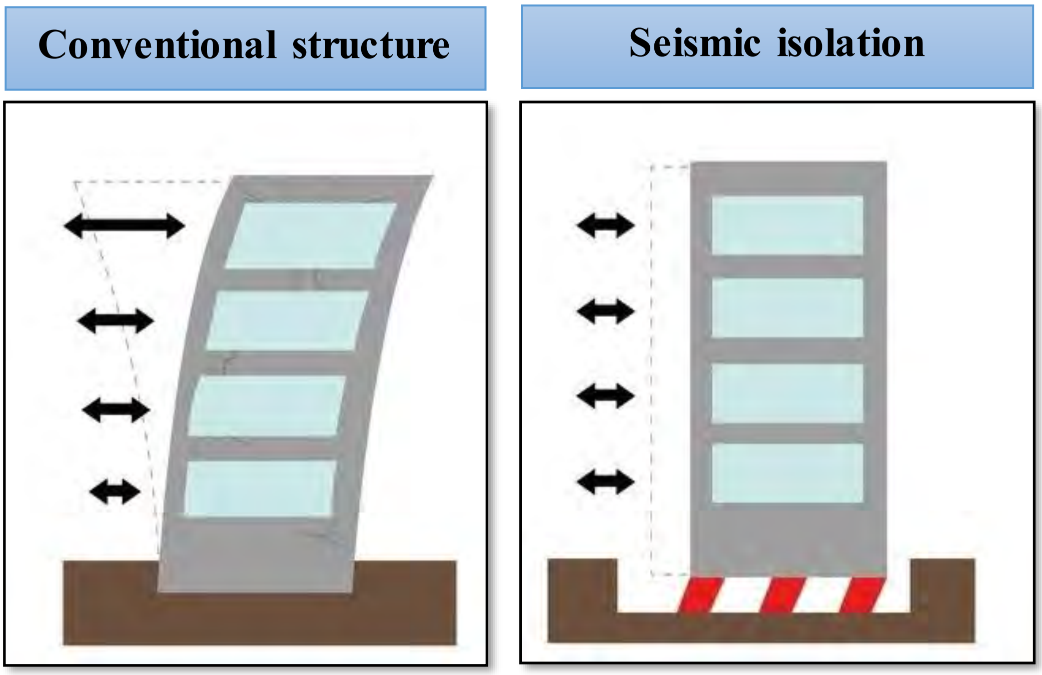

Figure 2.1: Conventional structure and Seismic isolation structure from the source (http://www.did.org.tr/eng/?page_id=47)

In the application of seismic isolation system, the building structures need to be related with safety, the different type in the materials and mechanical properties of the isolation system must be carefully controlled, furthermore to minimize the accidental torsion caused by the different similarity stiffness of variation isolators.

The factor of aging, environmental effects, and temperature in mechanical properties will contributes the stiffness and characteristic of isolation rubber metal, those the stiffness and damping values of the metal plate used for construction should be varies from other values used for design. Practically, the stiffness distribution, of based isolated system and the mass distribution of structures at the ground level can be unbalance. A low natural frequency response of structure, such as seismically isolated structures is highly sensitive to the frequency input ground motion.

2.2.2 Laminated rubber – metal spring (LR-MS)

From a previous researcher in Universiti Teknikal Malaysia Melaka, laminated rubber-metal spring is the multiple layer of rubber layer and metal plate were arranged alternating, the number of layer are determined based on the frequency vibration condition.(Chiu & Shong, 2006) By using dynamic analysis of finite element method (FEM), the performance of vibration transmissibility of LR-MS can be determined.

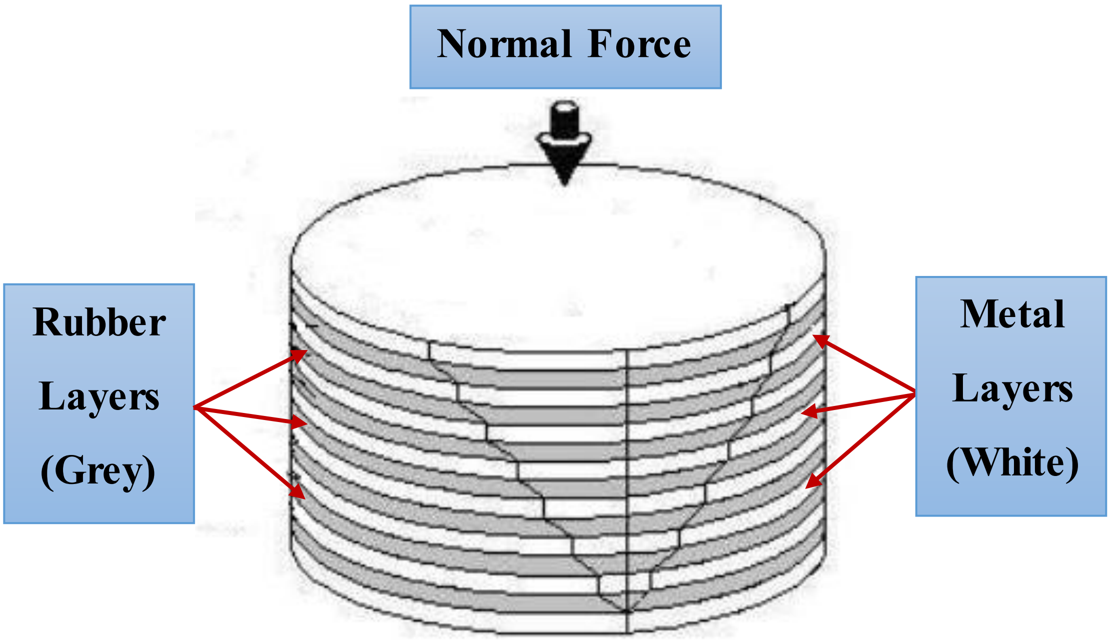

Figure 2.2: Layer of cylindrical solid rubber isolators. from the source (http://randolphresearch.com)

Previously, Statement from Salim et al (2016) the finite element analysis (FEA) method has good accuracy for analyzing cylindrical solid rubber and LR-MS isolators" and "More interlayer metal plate inside LR-MS has better transmissibility performance at higher frequency.

There are many applications used a LR-MS as their vibration absorption on superstructure to avoid for collapsing and disaster because of resonance frequency its self onto the superstructure. (Antaratana, 2015) One of the example is Penang second bridge is designed to transfer the resonant frequency of the structure away from ground earthquake vibration frequency.

Figure 2.3: Penang second bridge.

Figure 2.4: Application of LR-MS on Penang second bridge.

The behavior of LR-MS is very famous due to the capability in handling a large amount of force exerted and absorbing a vibration frequency by a natural resonance of an earthquake.(James & Kelly, 2011) Penang second bridge, Malaysia is an achievement of using LR-MS as a isolator system to the bridge and LR-MS were focused at preventing the stemming effects from the natural environment problem, such as ground motion by an earthquake (M. A. Salim et al., 2016).

2.2.3 Dynamic properties experiment

The dynamic properties experiment is a testing usually conducted to determine the vibration response of a fixed solid metal to measure the transient vibration that illustrate the concepts of damping ratio in solids (Mevada & Patel, 2016). The experiment used an accelerometer to measure the vibration response on the solid metals to capture the vibration movement occur. The same experiment method used by the previous researcher on topic determination of dynamic properties of railway tracks, shows the apparatus used to determine the frequency-dependent dynamic properties by using infinitely long embedded method on rail and supporting structures (J. Kim et al., 2014).

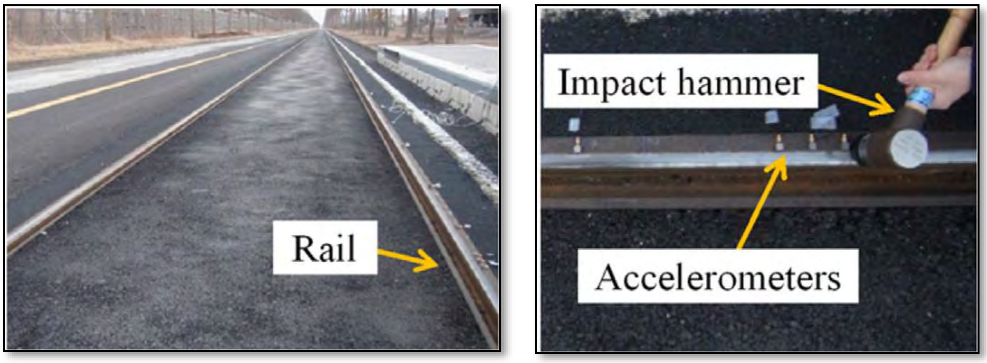

Figure 2.5: Infinitely long embedded rail and apparatus setup

The rail track were directly supported by the base pad and joined by clamping equipment, the pinned – pinned resonance frequency vibration response occur during measurement and the wavelength is equal to the half of the railway, account at high frequencies (J. Park et al., 2014).

2.2.4 Logarithmic decrement method

In estimation, the damping ratio from time based the logarithmic decrement were used, to find the propagation and uncertainties in various quantities can impact damping ratio estimates. The analysis will take the number of periods in one cycle between the first and final amplitudes then the range of multiple data use for measurement uncertainties and damping ratios.(Theses & Holman, 1969) The data will be show graphically which provides the ideal number for calculation. The calculation was applied to experiment result calculated from image processing to provide the estimation of damping ratio.

$x(t)$

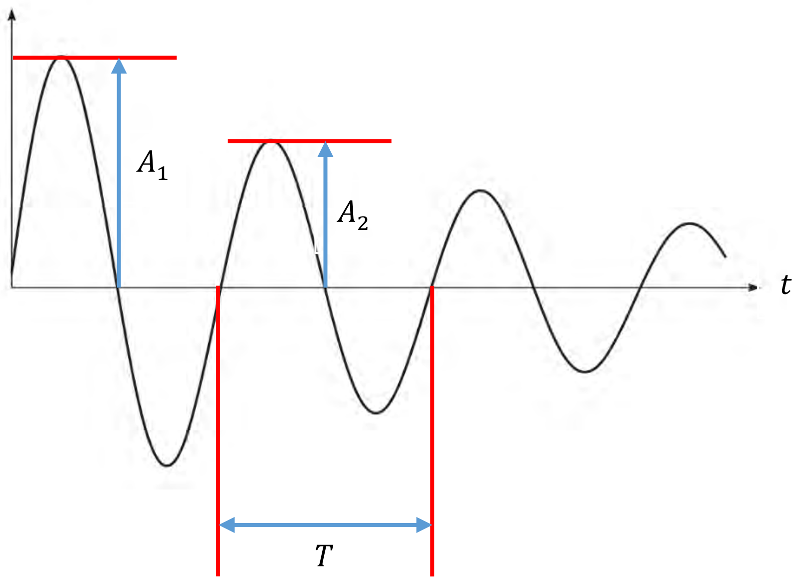

Figure 2.6: The measurement taken in logarithmic decrement.

To determine the main relationship between the selective data of final amplitudes periods from the first amplitude, measurement error, and damping occur, an analysis is apply on the logarithmic decrement method for uncertainties in the period and measurement of the displacement and general conclusion will generate in the form of a figure for a system (D. Tweten et al., 2014).

The natural frequency, ω_n and the damping ratio, ζ in damped vibration system can be represent as free vibration response. The system can be modeled by an expression:

$$x(t) = Ae^{-\omega_n t} \cos(\omega_d t - \theta) \quad (1)$$

where A is the amplitude at a peak position and θ is a phase angle of the system. The Figure above shows the plot of damped oscillation, the damped natural frequency, ω_d can be found from the oscillation period:

$$\omega_d = 2\pi f_d = \frac{2\pi}{T} \quad (2)$$

where T is the damped oscillation period of one cycle. The damped natural frequency is also can derive by

$$\omega_d = \omega_\alpha \sqrt{1-\xi^2} \tag{3}$$

where ω_α is undamped natural frequency.

The response at the peak times, t_k of each oscillation cycle, next thee amplitude of those points decays exponentially. Since the cosine function will be maximum points, therefore,

$$x(t_n) = Ae^{-\omega_n t_n} \tag{4}$$

Thus, the vibration decays with a first order system and the time between successive oscillation cycle is given by,

$$t_{n+1} - t_n = \frac{2\pi}{\omega} \tag{5}$$

Therefore, the factional amount of amplitude reduction that we see after one cycle of motion has elapsed and N is a cycle,

$$\frac{x(t_{n+N})}{x(t_n)} = \exp\left(-\frac{2\pi\xi N}{\sqrt{1-\xi^2}}\right) \tag{6}$$

The log decrement is derived as

$$\delta = \frac{1}{N}\ln\left(\frac{x(t_n)}{x(t_{n+1})}\right) \tag{7}$$