NEW DESIGN OF TUNED VIBRATION ABSORBER FOR WIDE FREQUENCY RANGE APPLICATION

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ABSTRACT

Vibrations are undesirable in machines and structures because they increased stresses, energy losses, cause added wear, increase bearing loads, induce fatigue, create passenger discomfort in vehicles. Uncontrolled vibrations can leave a bad impression to the machine, structure, and human. Vibration on machine can damage the equipment, decrease the machine lifetime and also causing the safety factor problems. In this research, a tuned vibration absorber (TVA) was chosen to be studied where the amount of vibration reduced was determined through finite element analysis (FEA) and validated with the experimental result. A actual scale of tuned vibration absorber was developed and applied on the structure to reduce the vibration. It is expected that by using the new design of tuned vibration absorber, the vibration of the structure can be reduced extensively. The objective of this project is to design and fabricate a newly tuned vibration absorber (TVA) that address a broad frequency range of application, light in weight, small-scale and suitable for mobile purposes. In order to achieve this aim, the preliminary design analysis was performed using finite element analysis before validated by experimental test. There are two design proposed in this study which is design 1 and design 2. The design concept was designed by using SolidWorks® and simulation test was done in this phase as well. From these two design, only one design was selected to be manufactured and tested. Design 1 was selected to be manufactured due to its performance in finite element analysis. DEWEsoft-201 were used as an equipment in experimental phase where the equipment will measure and generate graph data based on vibration performance. This experiment done several times according to the mass distance which is from 0 to 40 sequently. All the data were validated to ensure that the data from the finite element analysis and experimental are matched or even better. The data obtained shows good matched where the data gained are almost the same. The new vibration absorber has a weight of 620.6 kg and it is suitable for mobile purposes.

ABSTRAK

Getaran merupakan perkara yang tidak diingini terjadi pada mesin dan sesuatu struktur kerana ianya meningkatkan tekanan, kehilangan tenaga, meningkatkan beban galas, dan mewujudkan suasana tidak selesa penumpang di dalam kenderaan. Getaran yang tidak terkawal boleh meninggalkan kesan yang tidak baik kepada mesin, struktur, dan manusia. Getaran pada mesin boleh merosakkan peralatan, mengurangkan jangka hayat mesin dan juga menyebabkan masalah faktor keselamatan. Dalam kajian ini, penyerap getaran boleh laras (TVA) telah dipilih untuk dikaji di mana jumlah getaran yang dikurangkan akan ditentukan melalui analisis unsur terhingga (FEA) dan disahkan dengan keputusan eksperimen. Skala sebenar penyerap getaran yang dilaras telah dibangunkan dan digunakan pada struktur untuk mengurangkan getaran. Dijangka dengan menggunakan reka bentuk baru penyerap getaran boleh laras, getaran pada struktur boleh dikurangkan secara meluas. Objektif projek ini adalah untuk mereka bentuk dan membina penyerap getaran boleh laras (TVA) yang berpotensi untuk menangani jumlah getaran yang besar, ringan, kecil dan sesuai untuk tujuan mudah alih. Untuk mencapai matlamat ini, analisis reka bentuk awal telah dilakukan dengan menggunakan analisis unsur terhingga sebelum disahkan dengan melakukan ujian eksperimen. Terdapat dua reka bentuk yang dicadangkan dalam kajian ini iaitu reka bentuk 1 dan reka bentuk 2. Konsep reka bentuk direka dengan menggunakan SolidWorks® dan ujian simulasi telah dilakukan dalam fasa ini. Dari kedua-dua reka bentuk, hanya satu reka bentuk telah dipilih untuk dihasilkan dan diuji. Design 1 telah dipilih untuk dihasilkan kerana prestasinya dalam analisis unsur terhingga yang baik berbanding design 2. DEWEsoft-201 telah digunakan sebagai peralatan di dalam fasa ini di mana ianya berfungis untuk mengukur dan menghasilkan data graf untuk menunjukkan prestasi getaran. Eksperimen ini dilakukan beberapa kali mengikut jarak pemberat yang bermula dari (0-40) mm secara mengikut aturan. Semua data telah dibandingkan untuk memastikan data daripada simulasi dan eskperimen adalah sama atau lebih baik. Penyerap getaran baru ini mempunyai berat 620.6 kg dan ianya sesuai untuk tujuan mudah alih.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Most vibrations are undesirable in machines and structures because they increased stresses, energy losses, cause added wear, increase bearing loads, induce fatigue, create passenger discomfort in vehicles, and absorb energy from the system. Rotating machine parts need careful balancing in order to prevent damage from vibrations.

Uncontrolled vibrations can leave a bad impression to the machine, structure, and human. Vibration on machine can damage the equipment, decrease the machine lifetime and also causing the safety factor problems. Some examples of failure due to vibration are imbalanced helicopter blades due to high speed spinning can lead to catastrophic failure of the helicopter blades. Other industrial machinery such as pumps, compressors, turbo engine can cause excessive vibration surrounding structures, which cause inefficient operation of the machine and also produces excess noise that can cause human discomfort.

Vibrations can be classified into three categories which is free vibrations, forced vibrations, and self-excited vibrations . Free vibration of a system is vibration that occurs in the absence of external force. An external force that acts on the system causes forced vibrations. In this case, the exciting force continuously supplies energy to the system. Forced vibrations may be either deterministic or random. Self excited vibrations are periodic and deterministic oscillations. Under certain conditions, the equilibrium state in such a vibration system becomes unstable, and any disturbance causes the perturbations to grow until some effect limits any further growth. In contrast to forced vibrations, the exciting force is independent of the vibrations and can still persist even when the system is prevented from vibrating.

There is a methods use in order to control the vibration. The common approach to mitigate vibration, is by adding absorber to the structure. Passive, active and hybrid vibration absorber is a control methods approach used to absorbing the vibration. Passive control devices is system which does not required speed variations during operation and limited in range and effectiveness while active control is a devices that control dynamic performance and it consists of sensors, actuators and controller. Hybrid control devices is a combination between passive and active control devices and it is more flexible with the frequency range.

In this research, a tuned vibration absorber (TVA) is chosen to be studied where the amount of vibration reduced will be determined through finite element analysis (FEA) and validated with the experimental result. A actual scale of tuned vibration absorber will be developed and applied on the structure to reduce the vibration. It is expected that by using the new design of tuned vibration absorber, the vibration of the structure can be reduced extensively.

1.2 Problem Statement

Vibration control has been and remains an important field of study in engineering. The harmonic vibration of a machine is an undesirable effect of rotating out of balance mass within the system. However the vibration of the machine can be suppressed by attaching vibration absorber whose natural frequency is tuned to be equivalent to the excitation frequency of the machine. Although it was proved to reduce structural vibration significantly, the conventional design of the vibration absorber is only working at one particular forcing frequency. This means that if the forcing frequency beyond the tuning frequency range of absorber, the absorber will not be able to reduce the vibration. On top of that, the conventional design of vibration absorber employed a heavy metal to fabricate, this produce drawback of adding additional weight to the structure. For lightweight structure application, such as aircraft, automotive and submarine, the adding weight will effect on the fuel consumption of vehicle. In fact, due to the large size and heavyweight of conventional absorber, it is not suitable to be carried anywhere easily. A way of overcoming this problem is by designing a tuned vibration absorber (TVA) which can be tuned, light in weight and suitable for mobility purposes.

1.3 Objective

The aims of this project is to design and fabricate a newly tuned vibration absorber (TVA) that address a broad frequency range of application, light in weight, small-scale and suitable for mobility purposes. In order to achieve this aim, the preliminary design analysis will be performed using finite element analysis before validated by experimental test.

1.4 Scope of Study

The scopes of this project are:

i. To design and fabricate a new tuned vibration absorber.

ii. In prior to fabrication, details structural vibration analysis of the designs is carried out by using SolidWorks®.

iii. The selection criteria of TVA is based on the frequency range, weight, and degree of freedom.

iv. The weight of TVA is not exceeding than 1 kg and can bring anywhere for mobility purposes.

v. The size of TVA in the range of 100mm x 100mm.

vi. The fabricated TVA is be tested in-house laboratory

vii. The TVA is tuned to the first frequency mode of the primary structure and the research study will only be done in the frequency range of 0-1000 Hz.

1.5 Significant of Study

In this study, the unwanted vibration that can cause fatigue on a plate structure is reduced by using tuned vibration absorbers (TVA). The parameters that concern in the study of vibration are amplitudes, which may be expressed as displacement, velocity or acceleration and excitation force. Since all the structures vibrate such as machines, it is importance for us to know detail whether the vibration will be a problem or not. This research is proposed about the tuned vibration absorbers to reduce and minimize the vibration frequency of the machine and obtained the optimum number of vibration required to achieve global reduction of the machine. With the existence of this tuned vibration absorber, it will help to reduci vibration on the machine.

CHAPTER 2

LITERATURE REVIEW

2.1 Theory of Vibration

Vibration is a mechanical phenomenon that happens in a phase of solid, liquid or gas. Virtually, all of available and existing machine have parts which were moving and relocating and this situation can be considered as vibration. The ability of a things or parts to move will cause a vibration phenomenon where an object will turn in the shift from a state of equilibrium. In general, acceleration, velocity and displacement are the common elements related to vibration. Essentially, forces and mass oscillations motion are the main concepts of vibration which means that any mass with elasticity is capable to vibrate [1-4].

The mass-spring-damper model or single-degree-of freedom is the simplest vibration model. The model consists of a simple mass that is suspended by an ideal spring with stiffness (K) and dashpot damper from fixed support. This can be illustrated through simple mass spring damper vibration model as shown in Figure 2.1. A dashpot damper is like a shock absorber in a car or motorcycle. The dashport damper will produce an opposing force that is proportional to the velocity of the mass. The characterization of mass (M), stiffness (K) and damping ratio (C) are completely the factors that affect the vibration.

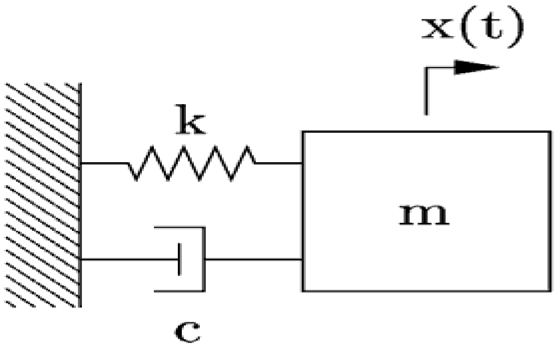


Figure 2.1 : Simple Mass-Spring-Damper Vibration Model [5]

2.2 Source of Vibration

Vibration, which is commonly referred to as noise, can be segregated into three main categories which is ground vibrations, acoustic vibrations, and forces applied directly to the load on the working surface. Seismic vibrations include all sources that make the floor under the experimental setup vibrate. Common seismic vibration sources are foot traffic, vehicular traffic, wind blowing the building, and building ventilation fans, to name a few. Many of the sources that generate seismic vibrations also generate acoustic vibrations [6-8].

The closest example of mechanical human sources is such as the masses of people walking up and down in a same time will caused a big structure like a stadiums facing a serious problems because it had been done without considering the dampening measures. Heavy industrial machinery, generators and diesel engines will caused vibration occurred which it can also raises problems structural integrity especially if mounted on steel structure or floor.

2.3 Vibration Control Techniques

There is many methods use to control the vibration of a machine. The vibrations can be limit to a level that can be accepted if it is made particularly stiff and massive and the fundamental frequency may be high to limit the vibrations. The cost usually too high for that approach, although many structures and machine built by 19th century had relatively few vibration problems because the massive scale. The structures tend to be as light as can be achieved with the necessarily lowering stiffness even more than the mass is reduced, so the resonance frequencies can emerge where the excitation forces high [9]. It is necessary to calculate such the corresponding modes and the frequencies of vibration and as the response for expected excitation forces and the modern finite element are well suited for this task. In this way, most structure and machines can be designed to behave well in the expected operational environments. The same codes can be and are used to estimate the effect of selected engineering changes, such as changes of metal thickness and other dimensions. The role of good design in creating systems which suffer a minimum of vibration problems cannot be underestimated [10].

From a design and practically view, mechanical vibration can be reduced or controlled by several techniques such as control of natural frequencies to avoid salon with the excitation frequency. Preventing the system from the excessive response, although at resonance with introducing energy dissipating mechanism or a damping. Besides that, reducing the transmission by using the vibration isolator for the excitation forces from one part machine to another part.

2.4 Vibration Absorber

Another common solution to protect the device from steady state harmonic disturbance at a constant frequency is by using a vibration absorber. This approach will assist the natural frequency of the system by shifting it away from the excitation frequency in order to the resonance and surpluses vibration does not take place of it [11]. Figure 2.2 indicates a machine model before and after adding vibration absorber. The minimum motion of the original mass influenced on the choosing of the values of the absorber mass and it stiffness. This was attached with substantial motion while added the absorber system as illustrated. Absorbers are frequently used on the machines which run at the constant speed such as sanders, compactors, reciprocating tools and electric razors [12].

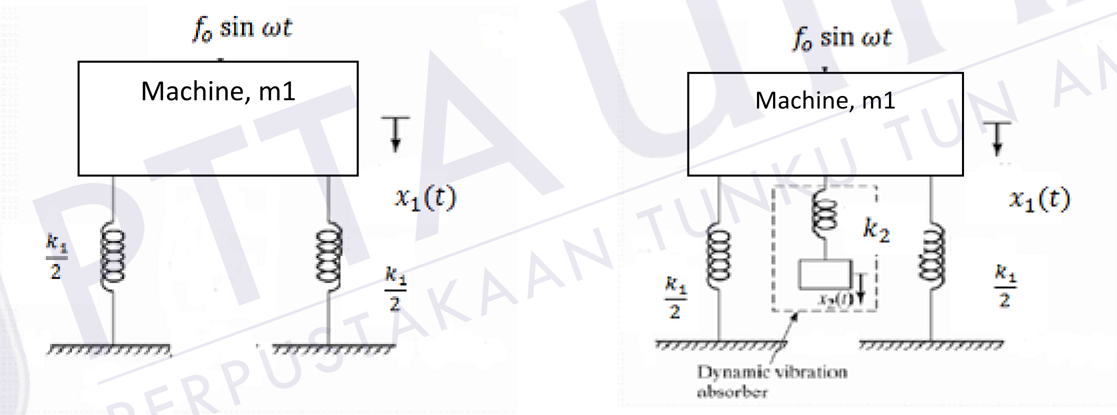


Figure 2.2 : Machine model shows before and after adding a vibration absorber [13]

2.4.1 Passive Vibration Absorber

Theoretically, by adding the structural modification, it can produce the passive control that can be thought. Therefore, to improve the vibrational response of the system by chosen α which represents added stiffness then it can be declared that as a passive control procedure. The use of added power or energy can distinguished between passive control and active control. Generally, the vibration absorber is the most common passive control device and apart from that the other methods of passive control are by adding mass and changing stiffness values [14]. A mass spring subsystem coupled to a superstructure to control its oscillations under the action of periodic excitation is known as a passive vibration absorber. As in Figure 2.3 indicates of a simple form of this arrangement where $m1$ is a mass emulating the superstructure and K_1 is its mounting spring. Hence, The second mass, M_2 the coupling spring K_2 and a viscous damper d constitute the absorber system. the harmonic base motion with amplitude A and angular frequency was driven the superstructure. After that, let x_1 be the displacement of M_2 and x_2 the displacement of M_2 and as thus far the elementary books on linear vibration theory prove that the problem is well known [15].

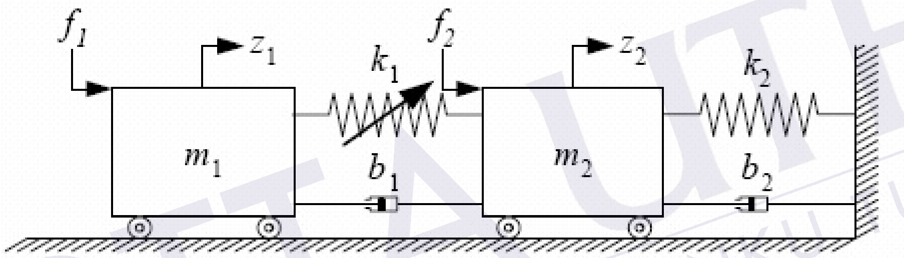


Figure 2.3 : Mechanical model with Passive Vibration Absorber [16]

2.4.2 Active Vibration Absorber

Active control system which cause the mechanical vibration absorber is so called as active vibration absorber. The resonance can control to achieved desire vibration on structure. The less mass adding into the system will give the larger effective strokelength of active vibration absorbers. Active vibration absorber consisting of sensors, actuators and controller [17].

The vibrating mechanical system as shown in Figure 2.4, which consists of an active undamped dynamic vibration absorber (secondary system) coupled to the perturbed mechanical (primary system). The generalized coordinates are the displacements of both masses, x_1 and x_2 respectively. The u is represents the force control input and $f(t)$ some harmonic perturbation, possibly unknown. Here m_1, k_1 and c_1 denote mass, linear stiffness and linear viscous damping on the primary system, respectively. Similarly m_2, k_2 and c_2 denote mass, stiffness and viscous damping of the dynamic vibration absorber. When u=0 the active vibration absorber becomes only a passive vibration absorber [18, 19].

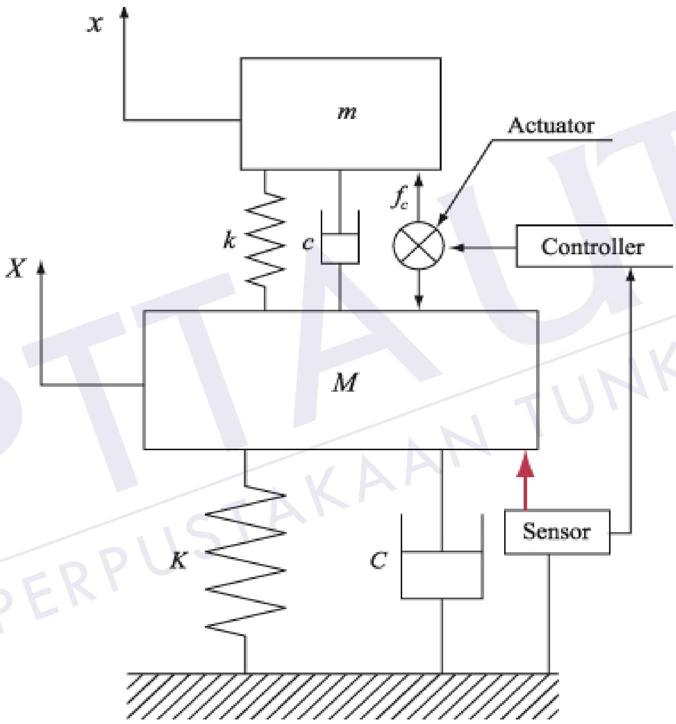


Figure 2.4 : Mechanical model with Active Vibration Absorber [20]

2.4.3 Hybrid Vibration Absorber

Hybrid vibration technology is a combination of active and passive vibration. This structural control systems come from the natural evolution of passive control technologies and passive energy dissipation. The possible use of active control systems and some combinations of passive and active systems, so called hybrid systems, as a means of structural protection against wind and seismic loads has received considerable attention in recent years. Hybrid control systems are force delivery devices integrated with real-time processing controllers and sensors within the structure [21, 22]. They act simultaneously with the hazardous excitation to provide enhanced structural behavior for improved service and safety. An hybrid structural control system consists a sensors to measure either external excitations, structural response variables, or both. This system also has a devices to process the measured information and able to compute necessary control force needed based on a given control algorithm. The actuators usually powered by external sources, to produce the required forces. Figure 2.5 shows the hybrid vibration absorber structure.

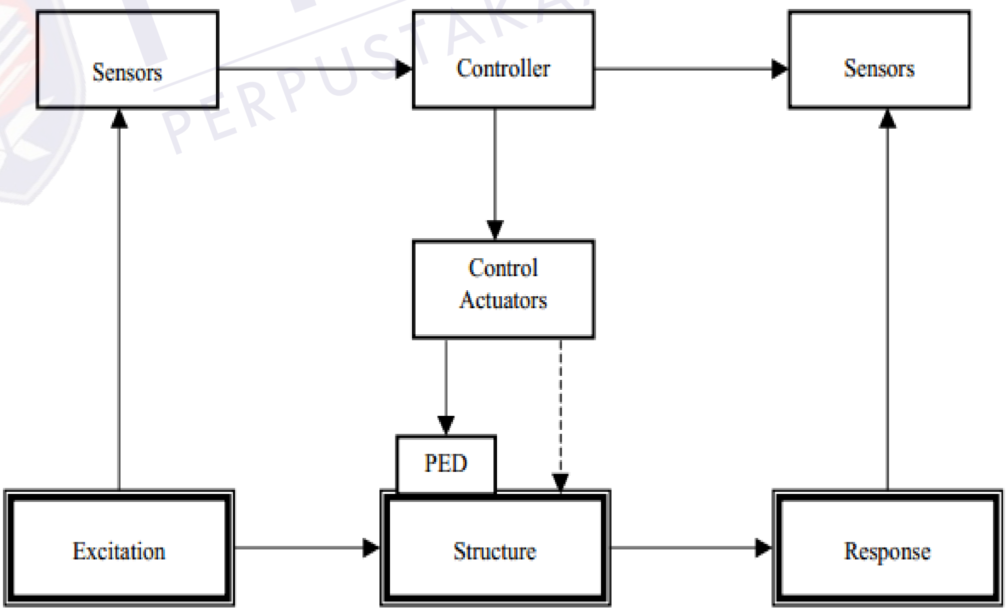


Figure 2.5 : Hybrid vibration absorber structure [23]

2.5 Available Vibration Absorber in Market

2.5.1 Tuned Mass Dampers

Tuned mass dampers (TMD) also known as harmonic absorber are resonant devices used to suppress or absorb vibration. When installed properly on a machine or structure, they draw away vibrational energy from the structure or machine and dissipate it internally, reducing the motion of the machine. Their application can prevent discomfort, damage, or outright structural failure. They are frequently used in power transmission, automobiles and buildings. Tuned mass dampers stabilize against violent motion caused by harmonic vibration [24, 25]. A tuned damper reduces the vibration of a system with a comparatively lightweight component so that the worst-case vibrations are less intense. Figure 2.6 shows the tuned mass dampers that available in the market.

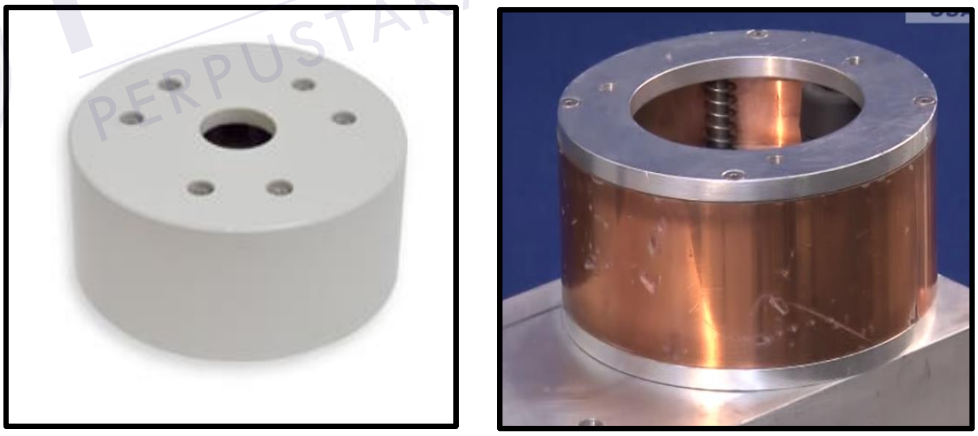


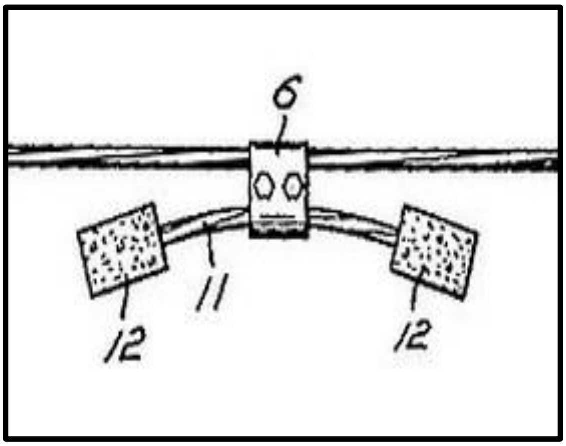
Figure 2.6 : Tuned mass dampers [26]

As solutions to vibration problems, the tuned mass dampers (TMD) have a number of attractive features which is :

- They are inherently compact, modular devices that can have a simple interface to the base structure.
- They can be added readily to a base structure that is already designed or even built.
- Added weight can be kept to a minimum.
- The tuned device does not impact the static strength or stiffness of the base structure.
- It is often possible to characterize the base structure by inexpensive test or analysis

2.5.2 Stockbridge Damper

A stockbridge damper is a tuned mass damper used to suppress wind-induced vibrations on taut cables, such as overhead power lines. The dumbbell-shaped device consists of two masses at the ends of a short length of cable or flexible rod, which is clamped at its middle to the main cable. The damper is designed to dissipate the energy of oscillations in the main cable to an acceptable level. Its distinctive shape gives it the nickname "dog-bone damper". In this mechanism, vibrations in the main cable were passed down through the clamp and into the shorter damper. This would flex and cause the symmetrically placed concrete blocks at its ends to oscillate [27, 28]. Modern designs use metal bell-shaped weights rather than stockbridge's concrete blocks. The bell is hollow and the damper cable is fixed internally to the distal end, which permits relative motion between the cable and damping weights. To provide for greater freedom of motion, the weights may be partially slotted in the vertical plane, allowing the cable to travel outside the confines of the bell. In some installations, the weights are unequal, allowing damping over a greater frequency range. Since Stockbridge dampers were economical, effective and easy to install, they became used routinely on overhead lines. Figure 2.7 shows the stockbridge damper for a) original design b) modern design.



Original design Modern Design

Figure 2.7 : View of stockbridge damper [29]

2.5.3 Bridge Vibration Absorber

A bridge vibration absorber are used to increase the effective structural damping beyond its cut-off value of the synchronization effect observed in the excitation process of pedestrian bridges. Due to the trend of constructing ever lighter load-carrying structures, footbridges are becoming more susceptible to vibrations caused by pedestrians or wind [30]. Usually, these vibrations impact only the serviceability of the bridges since the desired level of comfort is no longer attained. However, in some cases, the vibrations of the bridges are so extreme that damages can arise or, in extreme cases, the structural integrity of the bridge can be at risk. The primary reason for the occurring, perturbing vibrations is resonance. Figure 2.8 shows the bridge vibration absorber.

Figure 2.8 : Bridge vibration absorber [31]

2.6 Patent Search

2.6.1 Patent 1 – Composite Low Rate Spring & Absorber (US 3,130,964) [32]

This machine was invented by Frederick W. Johnson from United States in 7th June 1962. This invention relates in general to shock absorbers and in particular to shock pads which might be used, for example, in air dropping military or other equipment. Such operations must be carried outwith a minimum jar or shock to the equipment. A feature of this invention is found in the provision for a pair of parallel-spaced plates which are mounted between means for limiting the maximum distance between the plates and with a plurality of prestressed spring means mounted between the plates to bias them apart and with the space between the plates being filled with a plastic foam material to form a shock pad. The springs are selected so that they are prestressed in compression sufficiently to support the vibration of the body to make the plate less vibrating. Figure 2.9 shows the patent of vibration absorber mechanism.

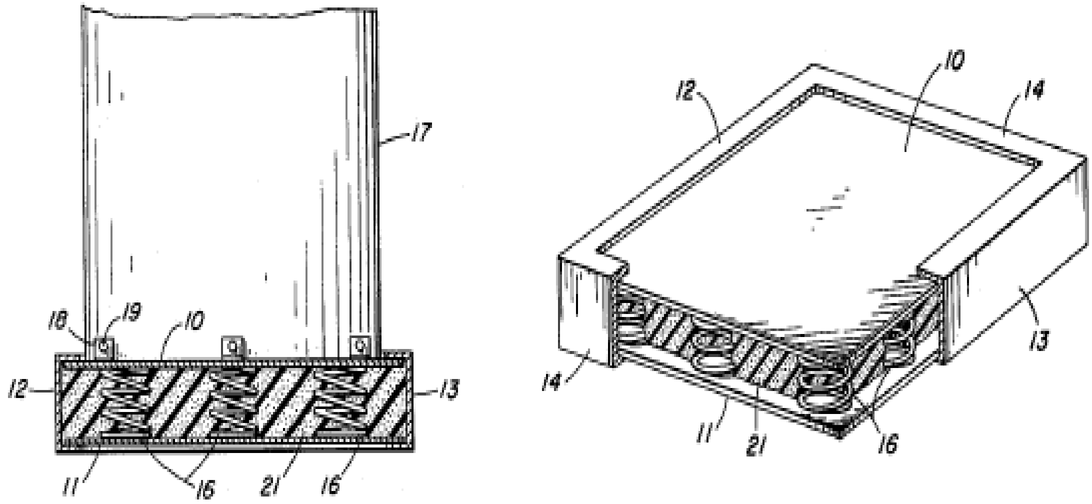


Figure 2.9 : Composite Low Rate Spring & Absorber

2.6.2 Patent 2 – Selective Tuned Vibration Absorber (US 6,279,679 B1) [33]

This device was invented by Leonard N. Thomasen from California, United States in 28th August 2001. A selectively tuned vibration absorber comprising a stack of viscoelastic polymer damping plates, secured together with spacers at both ends and having metal tuning weights attached onto the topmost plate in the stack. The apparatus is secured to the low frequency drive unit of an in-wall loudspeaker With a metal mounting plate between the vibration absorber and the low frequency drive unit. Both ends of the vibration absorber are cantilevered over a tuning mounting plate centered between the ends of the unit, the degree of cantilever and the mass in the metal weights added to the topmost damping plate being variable such that the vibration absorber may be tuned to resonate at the fundamental resonance frequency of the low frequency drive unit. Figure 2.10 shows the vibration absorber unit of the invention while Figure 2.11 shows the two metal plate positioned while vibrating.

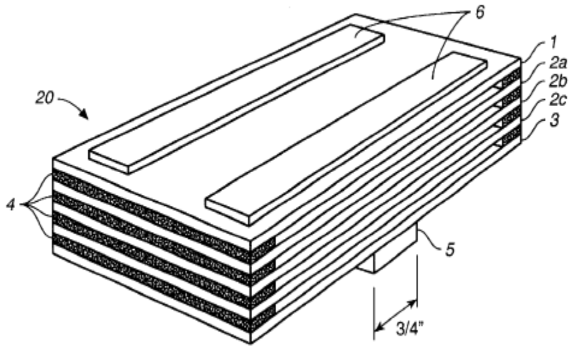


Figure 2.10 : Vibration absorber unit

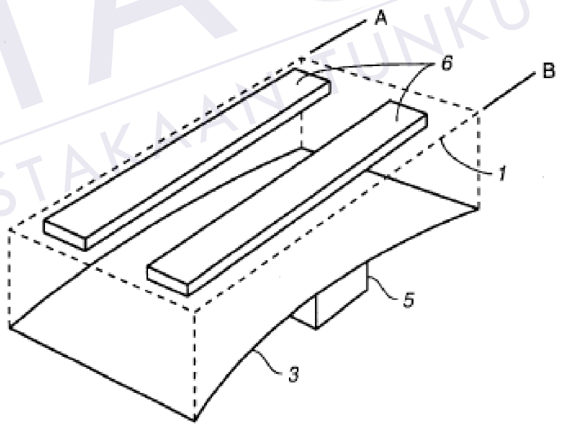


Figure 2.11 : Two metal plate positioned while vibrating

2.6.3 Patent 3 – Shock Absorber and Auxiliary Spring Unit

(US 3,263,983) [34]

This device was invented by Charles V.Bliven and Wayne from United States in 30 Dec 1963. The main purpose of this device is to give car stability, steering control and improve comfort which is isolated from road noise,bumps and vibratios. This device present invention relates to vehicle suspension systems and more particularly to that class of suspension spring. The suspension allows the wheels to move up and down independently from the rest of the car. That will keep the wheels on the road while hit bumps and protect the vehicle from damage and wear. Figure 2.12 shows the hand and power screw-press mechanism.

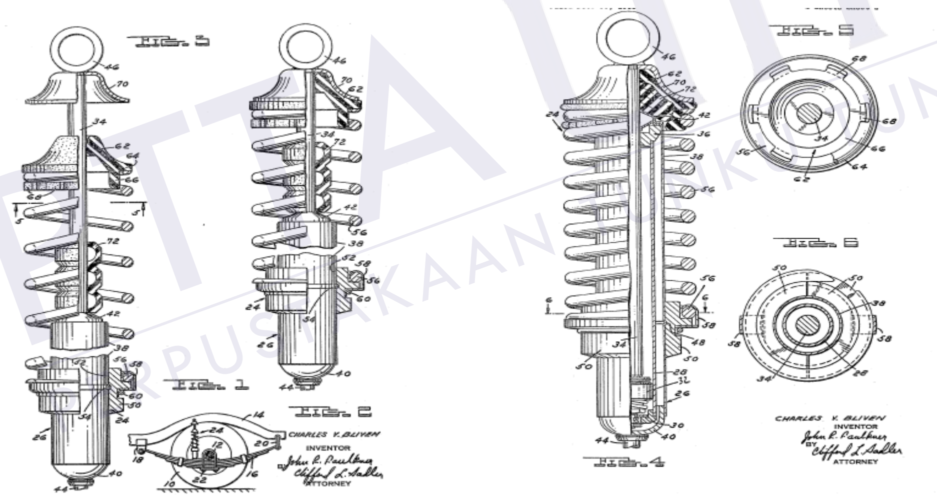


Figure 2.12 : Shock Absorber and Auxiliary Spring Unit

2.6.4 Patent Description

Table 1 describes the function of each patent related in the making of a new tuned vibration absorber. The description including the patent mechanism, the advantages and disadvantages on each concept. There are three patents placed in this study and that is the mechanism related in order to produce the new tuned vibration absorber. In addition, the description of these patent is al be a reference to developing a tuned vibration absorber.

Table 2.1 : Patent mechanism description

Patent	Patent 1	Patent 2	Patent 3
Title	Composite Low Rate Spring & Absorber	Selective Tuned Vibration Absorber	Shock Absorber and Auxiliary Spring Unit
Mechanism	This device use shock absorbers mechanism and in particular to shock pads	This device use damping plates method to absorb the vibration.	This device use spring mechanism to absorb vibration
Advantages	No need a power supply	No need a power supply	Available everywhere
Disadvantages	Limited to certain load weight	The product is big and require a lot of space	Limited to certain load weight

2.7 Previous Study

In this thesis, the important literature review has been carried out. Some of the literature review that had been studied are shown below:

A study of tuned mass dampers and vibration absorbers has been carried out by R. Kashani [35]. He investigated the interaction of tuned mass dampers with a structure by analyzed the vibration of a cantilever beam equipped with one tuned mass damper. The tuned mass damper was appended to the tip of the beam and used disturbance force to excite the beam at the tip. The first natural frequency of the beam was around 6Hz with 40% damping ratio. From the figure obtained from test, the frequency response function (FRF) of the cantilever beam without tuned mass damper recorded 20dB (magnitude), as the highest peak. After equipped with a tuned mass damper, the magnitude reduced to 7dB. Meanwhile, for vibration absorbers he did a study about vibration cancelation aspect of this device by appended a vibration absorber to one degree of freedom system. The flexible structure was subjected with disturbance force also. The result stated that by adding the vibration absorber to the original one degree of freedom system, it changed to a two degree of freedom system.

The present paper investigated the effect of the lightweight dynamic vibration absorber (LDVA) to reduce vibration of thin walled structure has been carried out by Muhammad Mohamed Salleh [36] . The free and forced vibration response of a rectangular thin plate were performed using finite element method. Subsequently, the effects of attached single and dual LDVA were analysed in depth. Results demonstrated that single LDVA attached at the centre of the plate succesfully attenuate vibration over the frequency range of 0- 600 Hz. By contrast, attached with dual LDVA only suppresses the resonance of the first second and fourth modes but not for third and fifth modes of thin walled structure. It was found that by simply increasing the weight of mass does not improve the vibration absorption over the entire frequency range. The study conclude that attached single LDVA are better than dual LDVA for vibration absorption of thin walled structure over the entire frequency range.

The aim of the work presented here is to develop a practical absorber which will reduce vibration that occurs along the structure. Moreover, many type of analysis conducted in order to reduce vibration such as developing a new tuned vibration absorber. In order to reach the goal, this project will be carried out in order to find the better solution to overcome the vibration.

CHAPTER 3

METHODOLOGY

This chapter will discuss about the steps to design and develop the tuned vibration absorber. Methodology is important work scope to conduct a project and make the process to implement in this research done in a proper way. The right sequences of the steps or procedures will lead us to run the project with more easier and smoother. All the procedure to accomplish this research are well explained in this chapter. There are some equipment that effect on this research need to be considered such as specification, stiffness, mass of the absorber and damping ratio. The equipment that use for this research need to be prepared in term of design, fabrication process and experimental as well.

At a starting point of this project, it is need to identify what pattern of tuned vibration absorber that wanted to use. In designing of the tuned vibration absorber, there are also initiative get from the reference that found. Then, design desired pattern of vibration absorber that can be produced vibration characteristic such as frequency and shape mode. The fabrication process clarified after done the pattern of vibration absorber. Selection of fabrication process according to pattern that suitable and easy to fabricate.

3.1 Methodology Flow Chart

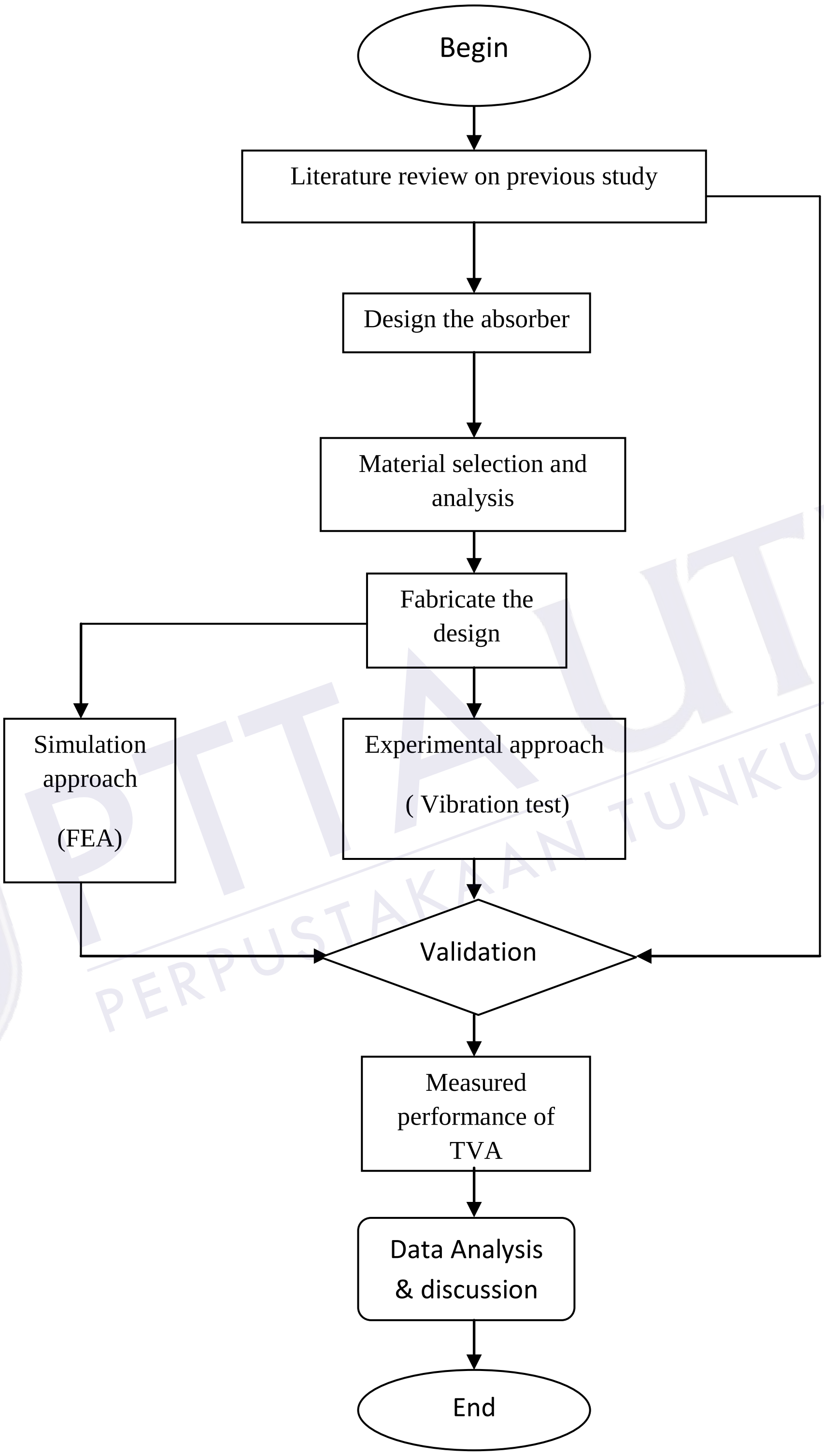


Figure 3.1: Methodology Flow Chart

As shown in Figure 3.1, during the literature review on previous study phase, all the information about previous study are collected such as related mechanism, patent search, available product and researchers study. Thereafter, the design concept is further developed by drawing through computer aided design (CAD) 3D modelling software by using SolidWorks®. The proposed software is then simulated in CAD software to determine the design workability. Futhermore the suitable material are selected for every component of the vibration absorber component with recommendation of manufacturing process and analyzing.

After the design process is completed, the author proceed to the fabrication phase. In this phase, the components on the prototype are fabricated using the dimension and material selection that had been determined earlier in the project. Then , the projects will undergoing simulation approach by using finite element method. After it finish, the projects will go to experimental phase which is vibration test take place. The project undergoes several of testing to ensure that it passed the minimum requirement that author had determined in the design process. All these experiment are done several times to get the average result. The result gained been analysed and go through validation process.

Since all the validation process have been done, the data are analysed to measure the performance of TVA and to know whether the purpose of the experiment is achieve or not. In the discussion phase, this is where change begins, a set of ideas and series of discussions to find a workable solutions. The phase ends with a decision about the solution to take forward.

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