Vibration Training System Performance Test – Two Mass Absorber System Experiment

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Abstract. Two mass absorber is a vibration control system designed to enhance structural stability by strategically placing additional masses to effectively absorb and dampen vibrations. This technology mitigates resonance and harmful amplitude, reducing the risks of structural failure and operational inefficiencies in diverse engineering applications. Through this innovative approach, structures can withstand dynamic forces and operate efficiently in various fields. The TM 150 unit is used for conducting various experiments related to vibration phenomena. In this paper, experiments are carried out on a flexible beam that is oscillated using an unbalanced mass in the frequency range of 6 Hz to 18 Hz to see at which frequency the flexible beam will resonate. Another variation is to provide two mass absorbers under the flexible beam to see the difference. The experimental resonance graph was produced that was in accordance with the theoretical one, but with different amplitude units due to equipment limitations. The resulting graph shows before the absorber, the flexible beam resonates at its natural frequency. Afterward, small vibrations occur at that point, while resonance shifts. Furthermore, the performance of the vibration test unit is very good in showing the phenomena that occur in accordance with the theory.

1 Introduction

In the industrial world, nearly every activity involves vibrations. By definition, vibrations are repetitive motions occurring at specific intervals. Mechanical vibrations are a critical factor influencing the performance of a machine. These vibrations can significantly impact the smoothness of a mechanical system, reduce the lifespan of its components, and produce disruptive noise [1].

External vibrations that occur in a machine or building, when they have the same frequency as the natural frequency of that machine or structure, can lead to resonance, which can result in deflections exceeding limits and damage to people who operate the machine or even lead to failure [2–4]. The natural frequency of a machine or structure can be determined from the vibration response due to variable frequency excitation. There is an increase in vibration amplitude when the excitation frequency approaches the natural frequency [5].

Vibration testing is a crucial process in the development and maintenance of various types of products, ranging from vehicles and aircraft to electronic equipment and industrial machinery [6, 7]. This testing is carried out to measure and control the effects of vibrations on the components and structures of products, ensuring their reliability, performance, and safety [8]. Regardless of the probability of failure in a structure, vibration testing is necessary [9].

The research focuses on comparing experimental results of the two-mass absorber system on the Vibration Training System with theoretical calculations, gauging alignment, and reliability. Simultaneously, it evaluates the overall performance of the Vibration Training System in executing the two-mass absorber system experiment, seeking to assess its practical utility and effectiveness. The dual research purposes involve analyzing results for comparative insights and testing the functionality of the Vibration Training System's vibration testing equipment in real-world applications. This study aims to contribute to a comprehensive understanding of the system's accuracy and reliability in experimental settings.

2 Theoretical basis

An elastic system subjected to external forces and exhibiting oscillations is referred to as forced vibration. When the system experiences damping or energy dissipation, it is termed damped forced vibration [10]. The portion of motion that fades away after some time is called transient. The part of the motion that remains after the transient has vanished is known as steady-state vibration [11].

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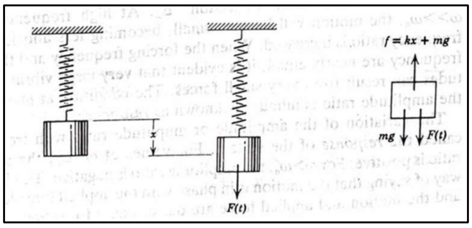

Fig. 1. Harmonic forced oscillations free body diagram.

When 2 degrees of freedom of the system are subjected to a harmonic force, the system will produce a response similar to a single degree of freedom [12]. Resonance occurs when the excitation force frequency matches the natural frequency of the system [13].

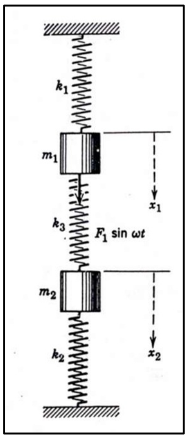

Fig. 2. A simple model of a two-degree-of-freedom system in forced vibration.

A dynamic vibration damper is a mechanical device used to reduce or eliminate mechanical vibrations [14]. The best application of this damper is to synchronize machines. Dynamic dampers are set at a specific frequency and are only effective within a narrow frequency range [15].

In its simplest form, a dynamic damper consists of a spring and a mass. The damper is installed in a single-degree-of-freedom system as shown in Figure 3 below.when the excitation force frequency matches the natural frequency of the system.

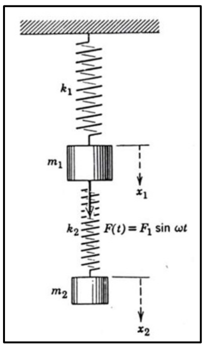

Fig. 3. Simple model of dynamic vibration absorber system.

3 Methodology

In these two mass absorber research, the setup can be seen in Figure 4 and Table 1.

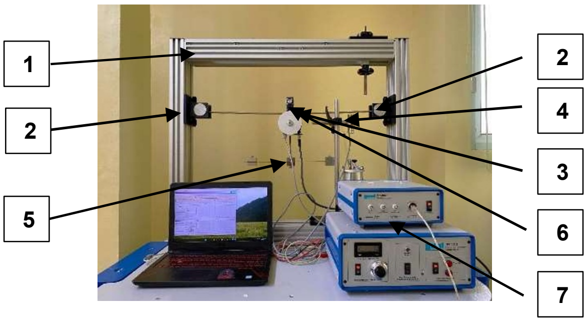

Fig. 4. Two mass absorber system experimental equipment setup

Table 1. Parts of the two mass absorber system experimental equipment.

Number	Name
1.	Frame profile
2.	Adjustable bearing
3.	Flexible beam
4.	Vibration sensor
5.	Absorber
6.	Motor exciter
7.	Data acquisition tool

Specimen specifications:

Flexible beam
Height x width = 4 mm x 25 mm
Length = 700 mm
Mass = 620 g = 0,62 kg

Motor *exciter*
Frequency range = 0 – 50 Hz
Mass unbalance = 100 g
eccentricity e = 0 – 10 mm
Unbalace m.e = 0 – 1000 mmg
Total mass m = 772 g

Absorber
Ballast mass = 368 g
Total mass = 1100 g

Leaf spring
Height x width = 1,5 mm x 20 mm

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The frequency range is given as 1.5 – 13 Hz for without absorber and 1.5 – 17 Hz with absorber with a distance of 0.5 Hz in each range. So 23 and 31 amplitude data are needed (additional data on the way to resonance is needed). The following is the experimental procedure for forced vibrations on a flexible beam.

1. Prepare tools and specimens.
2. Install the flexible beam on the adjustable bearings at both ends
3. Install the exciter motor at a distance of 350 mm from the end of the adjustable bearing.
4. Place the vibration sensor 200 mm away from the adjustable bearing and set the distance to the beam at 15 mm.
5. Turn on the switch on the data acquisition device and frequency control device. Then connect the USB cable from the data acquisition tool to the PC device that has the data acquisition application installed.
6. Open the application and go to the "magnification function" window
7. Turn on the exciter motor and set the motor at a frequency of 1.5 Hz. Then, if it is stable, press the "record" button on the application.
8. Carry out step 7 until you reach a frequency of 13 Hz. Then record the results of the application in the table provided. To install the next plot, press the "delete" button on the application.
9. Install two mass absorbers under the exciter motor.
10. Carry out step 7 until you reach a frequency of 17 Hz and get 31 amplitude data. Then record the results of the application in the table provided. To install the next plot, press the "delete" button on the application.

The data that has been taken is entered into the table with the appropriate two mass absorber variations, then continued with data processing.

3.1 Equation on natural frequency

$$\omega_1 = \frac{1}{2\pi}\sqrt{\frac{k_1}{m_1}} \qquad (1)$$

3.2 Equation on amplitude of flexible beam without absorber

$$X = \frac{F_1}{m_1({w_1}^2 - w^2)} \qquad (2)$$

3.3 Equation on amplitude of flexible beam with absorber

$$X_1 = \frac{F_1}{k_1}\frac{\left(1-\frac{w^2}{{w_2}^2}\right)}{\left(1+\mu\frac{{w_2}^2}{{w_1}^2}-\frac{w^2}{{w_2}^2}\right)\left(1-\frac{w^2}{{w_2}^2}\right)-\mu\frac{{w_2}^2}{{w_1}^2}} \qquad (3)$$

4 Research Results and Discussions

From the 2 variations of experiments that have been carried out, data on the amplitude of oscillations on the rigid beam and theoretical calculations were obtained which were then processed into the graph below.

The resulting amplitude data is in the form of Volts, in the amplitude calculation it cannot be changed because the position of the vibration sensor is near the support and it is not possible to place it in the middle of the beam. So the data taken will only be used to compare resonance phenomena without comparing the exact number of experimental amplitudes in meters.

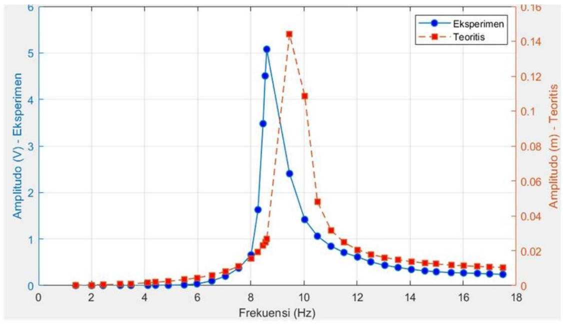

Fig. 5. Comparison graph of the experimental amplitude of two mass absorbers without an absorber.

Based on Figure 5, it can be seen in the experiment that resonance occurs at a frequency of 8.6 Hz. Meanwhile, in theoretical calculations, resonance occurs at the point 9.46 Hz. This difference occurs due to theoretical calculations, the natural frequency of the flexible beam is 9.69 Hz, so that resonance occurs when the exciter motor oscillates close to that frequency.

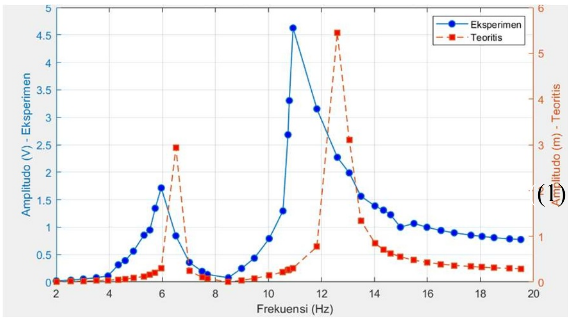

Fig. 6. Comparison graph of the experimental amplitude of two mass absorber absorber.

Based on Figure 6, it can be seen in the experiment that there was a shift in resonance, initially before the absorber was installed, the resonance was at a frequency of 8.6 Hz and 9.46 Hz, then after the absorber was installed at this frequency, only very small vibrations occurred. As a result, the resonance is shifted to 2 frequency points, namely 5.96 Hz in the experiment and 6.51 Hz in the theoretical, and 10.93 Hz in the experiment and 12.6 Hz in the theoretical. This difference occurs due to differences in natural frequencies in the two mass absorber and flexible beam.

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5. Conclusions

The resonance point in the flexible beam before being given an absorber is at a point in line with its natural frequency. However, after being given an absorber, very small vibrations occur at the natural frequency point, while the resonance point halves and moves to before and after the natural frequency of the flexible beam. The experimental amplitude value is still in volts because the possible amplitude data collection point is at the end near the support, while the increase in amplitude value on the rod is not linear so it is quite complicated to convert it into meters. Therefore, in this experiment we can only compare the phenomena that occur, namely the resonance point without error comparison.

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