PROJECT REPORT

DESIGN LAB – II (ME306)

PROJECT: DYNAMIC SHOCK ABSORBER

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INTRODUCTION

The Dynamic Shock Absorber Project aims to showcase a practical application of vibration control through a 2-degree-of-freedom system. In this project, we have constructed a laboratory setup comprising two masses interconnected by springs. The key concept behind this project lies in manipulating the natural frequencies of these masses to effectively dampen vibrations.

When the natural frequencies of both masses align and match the frequency at which we vibrate the system using a motor, a phenomenon known as resonance occurs. At this precise moment, one of the masses comes to a complete standstill, while the other continues to oscillate. This means that the second mass absorbs all the vibrations, effectively preventing the first mass from vibrating.

The implications of this technology are far-reaching and applicable to numerous real-life scenarios. One of the most immediate applications is in the automotive industry, where dynamic shock absorbers can significantly improve ride comfort by reducing vibrations caused by uneven road surfaces. Moreover, this technology has potential uses in structural engineering, where it can be employed to mitigate the effects of seismic activity or strong winds on buildings and bridges. In manufacturing and industrial settings, dynamic shock absorbers can help minimize the impact of machinery vibrations, leading to increased equipment longevity and enhanced safety.

In summary, the Dynamic Shock Absorber Project showcases a fundamental principle of vibration control that has the potential to revolutionize various industries by providing innovative solutions for mitigating vibrations and improving overall performance and comfort.

Objective/Aim

The objective or aim of the Dynamic Shock Absorber Project is to design, construct, and demonstrate a 2-degree-of-freedom system in a laboratory setting for the purpose of understanding and applying vibration control principles. The project seeks to achieve the following key goals:

Construct a 2-Degree-of-Freedom System: The primary aim is to build a physical system consisting of two masses connected by springs, creating a 2-degree-of-freedom setup that can replicate real-world vibration scenarios.

Investigate Resonance Behaviour: The project aims to study the behaviour of the system under varying frequencies of external vibrations to explore the concept of resonance. Specifically, we want to understand how and why one mass stops vibrating while the other continues when the natural frequencies match the excitation frequency.

Demonstrate Vibration Damping: Through experimental demonstrations, we intend to showcase the ability of the system to dampen vibrations effectively when resonance occurs. **This serves as the core proof of concept for the dynamic shock absorber.**

Frequency Tuning: Experiment with adjusting the natural frequencies of the masses and springs to fine-tune the resonance effect. This will allow us to control the system's responsiveness to different vibration frequencies.

Real-World Applications: Explore and discuss potential real-life applications of this technology, such as in the automotive industry for improved ride comfort, structural engineering for earthquake and wind load mitigation, and industrial machinery for reducing vibrations and enhancing safety.

Educational Outreach: Share the project's findings and insights with the academic and engineering community to promote a better understanding of vibration control principles and their practical applications.

By achieving these objectives, the Dynamic Shock Absorber Project aims to contribute to the understanding of vibration control mechanisms and potentially pave the way for practical implementations that can benefit various industries and enhance overall quality of life.

Methodology

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1. Conceptualization and Design: The project begins with a clear definition of its objectives and scope. A conceptual design for the 2-degree-of-freedom vibration control system is developed, detailing the masses, springs, and damping elements. Simulation software is used to model the expected system behaviour under various conditions.

2. Materials and Equipment Procurement: All necessary materials and equipment are procured, ensuring they meet project specifications and safety standards. This includes masses, springs, damping materials, a motor, sensors, and data acquisition equipment.

3. Laboratory Setup: A controlled laboratory environment is established, featuring a stable workbench and safety measures. The 2-degree-of-freedom system is assembled according to the design specifications.

4. Instrumentation and Sensors: Sensors such as accelerometers are installed to measure vibration levels and frequencies accurately. These sensors are connected to data acquisition equipment for real-time data collection.

5. Data Collection and Calibration: Sensors are calibrated to ensure precise measurements. Baseline tests are conducted to determine the system's natural frequencies and damping characteristics.

6. Frequency Variation Tests: Testing commences with the system subjected to varying frequencies through the motor. Data on mass vibrations is recorded, and their behavior is observed as the excitation frequency changes.

7. Resonance Identification: Instances of resonance, where natural frequencies match the excitation frequency, are identified. Data and observations during resonance are documented.

8. Vibration Damping Demonstration: The project demonstrates the dynamic shock absorber's ability by showing how one mass stops vibrating while the other continues during resonance. Video footage is recorded, and data is collected for analysis.

9. Data Analysis: Collected data is analyzed to quantify the system's response to different excitation frequencies. The effectiveness of vibration damping during resonance is determined.

10. Fine-Tuning and Optimization: The system's natural frequencies and damping characteristics are fine-tuned by adjusting masses, springs, and damping elements. Tests and data collection are repeated to assess changes in performance.

11. Documentation and Reporting: All aspects of the project, including design details, equipment, test procedures, and results, are comprehensively documented. A detailed report is prepared, summarizing the methodology, findings, and potential real-world applications of dynamic shock absorber technology.

12. Presentation and Knowledge Sharing: Project results are shared through presentations, seminars, or academic publications to contribute to the field of vibration control and educate others about the project's outcomes and implications.

Calculations:

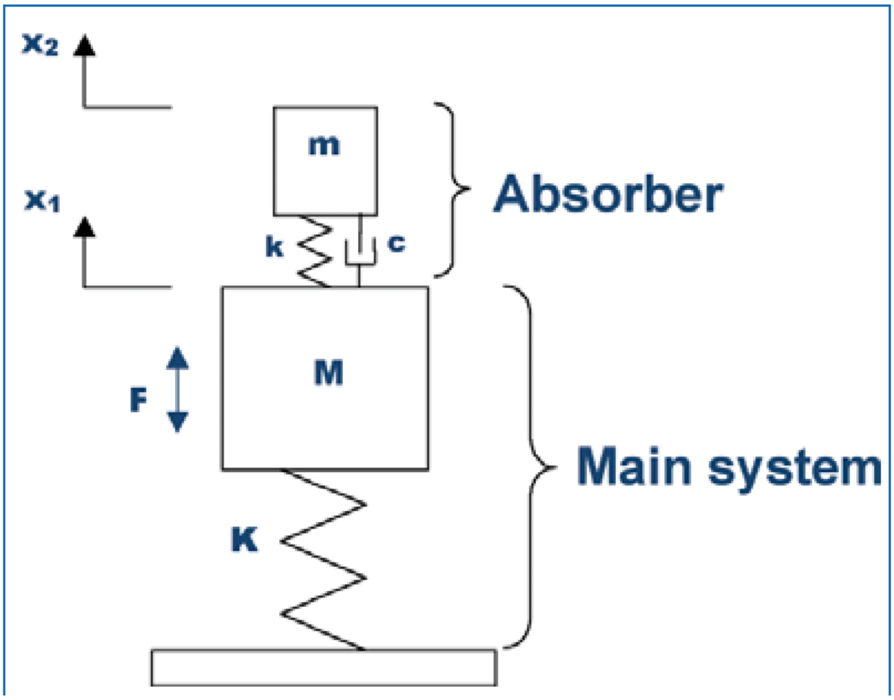
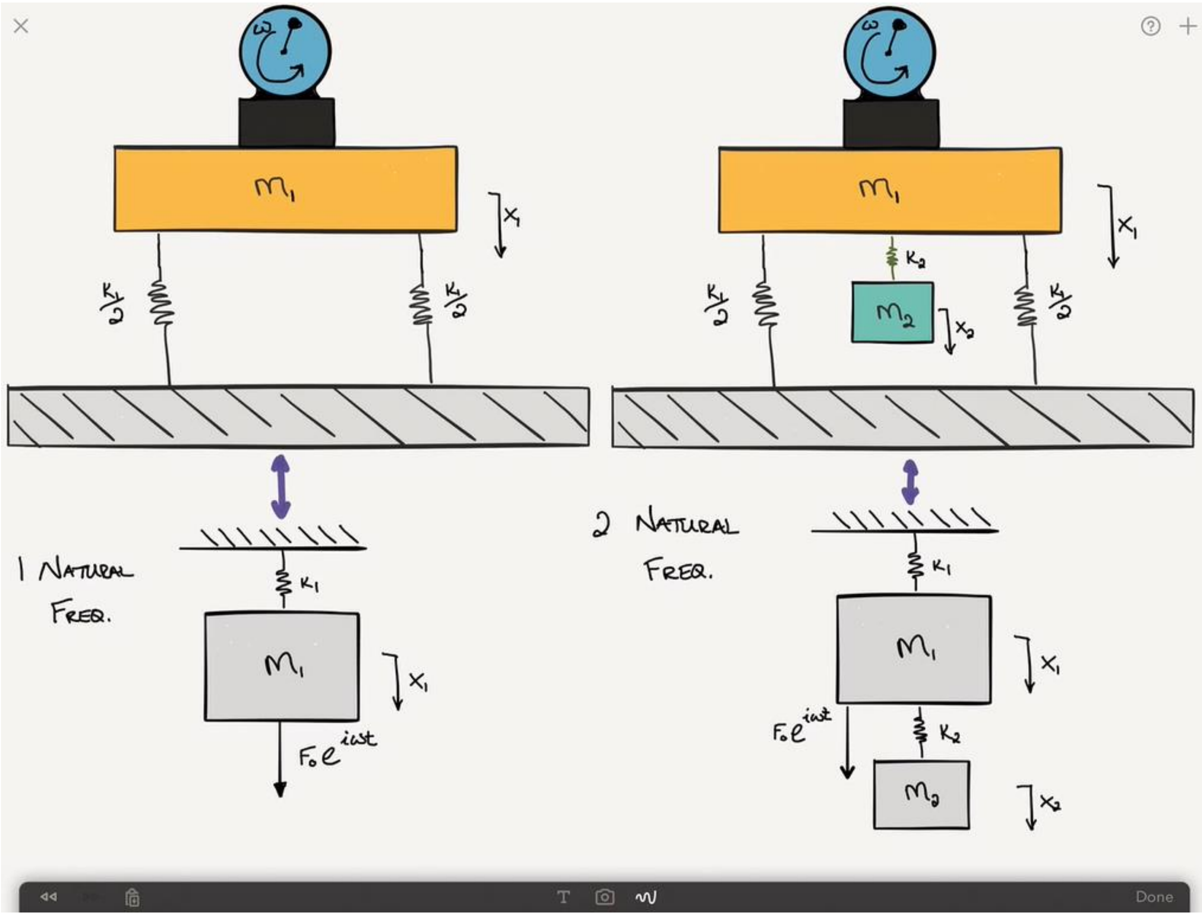


Fig. 1: Project Diagram



EQUATIONS OF MOTION:

$$m_1\ddot{x}_1 + k_1 x_1 + k_2(x_1 - x_2) = F_0 e^{i\omega t} \quad ①$$

$$m_2\ddot{x}_2 + k_2(x_2 - x_1) = 0 \quad ②$$

$$x_j = X_j e^{i\omega t} \quad ③ \qquad j = 1,2$$

③ → ①

$$-\omega^2 m_1 X_1 + k_1 X_1 + k_2(X_1 - X_2) = F_0 \quad ④$$

③ → ②

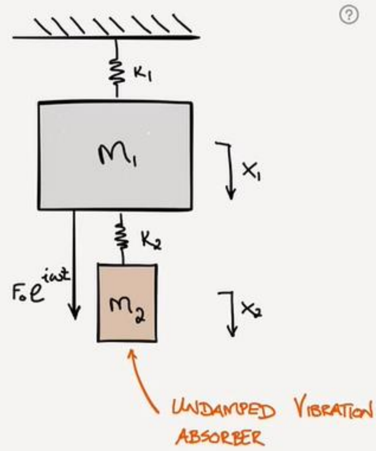
$$-\omega^2 m_2 X_2 + k_2(X_2 - X_1) = 0 \quad ⑤$$

$$\Rightarrow \begin{bmatrix} (k_1 + k_2 - \omega^2 m_1) & -k_2 \\ -k_2 & (k_2 - \omega^2 m_2) \end{bmatrix} \begin{Bmatrix} X_1 \\ X_2 \end{Bmatrix} = \begin{Bmatrix} F_0 \\ 0 \end{Bmatrix} \quad ⑥$$

$[Z]$ = IMPEDANCE MATRIX

$$[Z]\cdot\vec{X} = \vec{F}$$

$$X = [Z]^{-1}\cdot F$$



$$[Z_1] = \begin{bmatrix} (K_1+K_2-\omega^2 m_1) & -K_2 \\ -K_2 & (K_2-\omega^2 m_2) \end{bmatrix}$$

$$\vec{X} = [Z]^{-1}\vec{F} \quad (8)$$

$$\begin{Bmatrix} X_1 \\ X_2 \end{Bmatrix} = \frac{1}{|Z|} \cdot \begin{Bmatrix} Z_{22}\cdot F_0 \\ -Z_{21}\cdot F_0 \end{Bmatrix} \quad (9)$$

$$X_1 = \frac{(K_2-\omega^2 m_2)F_0}{(K_1+K_2-\omega^2 m_1)(K_2-\omega^2 m_2)-K_2^2} \quad (10)$$

$$X_2 = \frac{K_2\cdot F_0}{(K_1+K_2-\omega^2 m_1)(K_2-\omega^2 m_2)-K_2^2} \quad (11)$$

$$\Delta_{ST} = \frac{F_0}{K_1} \quad (12) \qquad \omega_1 = \sqrt{\frac{K_1}{m_1}} \quad (13) \qquad \omega_2 = \sqrt{\frac{K_2}{m_2}} \quad (14)$$

$$\omega \approx \omega_1$$

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$$[Z] = \begin{bmatrix} Z_{11} & Z_{21} \\ Z_{21} & Z_{22} \end{bmatrix} \quad (9) \qquad (Z_{21} = Z_{12})$$

$$[Z]^{-1} = \frac{1}{|Z|} \cdot \begin{bmatrix} Z_{22} & -Z_{21} \\ -Z_{21} & Z_{11} \end{bmatrix} \quad (10)$$

WHERE $|Z| = Z_{11}\cdot Z_{22} - Z_{21}^2$

$$[Z]^{-1} \cdot \begin{Bmatrix} F_0 \\ 0 \end{Bmatrix} = \frac{1}{|Z|} \cdot \begin{Bmatrix} Z_{22}\cdot F_0 \\ -Z_{21}\cdot F_0 \end{Bmatrix} \quad (11)$$

USE (12), (13) & (14) TO RE-WRITE (10) & (11) AS:

$$\frac{X_1}{\Delta_{ST}} = \frac{1-(\omega/\omega_2)^2}{\left[1+\frac{K_2}{K_1}-(\omega/\omega_1)^2\right]\left[1-(\omega/\omega_2)^2\right]-\frac{K_2}{K_1}} \quad (15)$$

$$\frac{X_2}{\Delta_{ST}} = \frac{1}{\left[1+\frac{K_2}{K_1}-(\omega/\omega_1)^2\right]\left[1-(\omega/\omega_2)^2\right]-\frac{K_2}{K_1}} \quad (16)$$

If $\omega = \omega_2 = \omega_1$ (17)

$$\Rightarrow \frac{X_1}{\Delta_{ST}} = 0 \quad (18)$$

$$\omega = \omega_1 = \omega_2 = \sqrt{\frac{K_1}{m_1}} = \sqrt{\frac{K_2}{m_2}}$$

$$\frac{K_2}{m_2} = \frac{K_1}{m} \quad (19)$$

Results

The results of the Dynamic Shock Absorber Project demonstrated the successful achievement of its objectives:

1. Resonance Behaviour: The project confirmed the occurrence of resonance when the natural frequencies of the two masses matched the excitation frequency. During resonance, one mass remained stationary while the other absorbed all vibrations, validating the fundamental concept of dynamic shock absorption.

2. Vibration Damping Efficacy: The system exhibited remarkable vibration damping capabilities, effectively reducing vibrations at the resonance frequency. This showcased the potential of the 2-degree-of-freedom setup as a practical solution for controlling vibrations in various applications.

3. Fine-Tuning and Optimization: Through systematic adjustments to mass, spring, and damping parameters, the project demonstrated the ability to fine-tune the system's natural frequencies and damping characteristics, offering versatility for different real-world scenarios.

4. Real-World Applications: The results underscored the project's relevance to industries such as automotive, structural engineering, and manufacturing, where controlling vibrations is crucial for safety, comfort, and efficiency.

These results provide valuable insights into the principles of vibration control and the potential of dynamic shock absorber technology to address real-world challenges.

Conclusion

In conclusion, the Dynamic Shock Absorber Project has proven to be a successful endeavour in understanding and applying fundamental principles of vibration control. The project's systematic approach, from design and construction to testing and fine-tuning, has yielded valuable insights and tangible results.

The demonstration of resonance behaviour, wherein one mass effectively absorbs vibrations while the other remains stationary, highlights the practical applicability of this technology. It showcases the potential to enhance ride comfort in vehicles, improve structural resilience in construction, and increase machinery efficiency in industrial settings.

Furthermore, the project's ability to fine-tune and optimize the system's characteristics underscores its adaptability to diverse real-world scenarios. This adaptability is a key asset in addressing challenges related to vibration control across various industries.

In essence, the Dynamic Shock Absorber Project serves as a foundation for further research and development, offering innovative solutions to mitigate vibrations and improve overall performance and safety in a wide range of applications. Its findings open doors to exciting possibilities in engineering, contributing to a more comfortable, resilient, and efficient future.