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"Flourish and Nurturing Sustainable Innovation for a Prosperous Nation"

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Editorial Board

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Preface

In the name of Allah, the Almighty who gives us the enlightenment, the truth, the knowledge and with regards to Prophet Muhammad (peace be upon him) for guiding us to the straight path. We thank to Allah for giving us guidance and strength to write this e-book.

This e-book compiles the extended abstracts that submitted to Johor International Innovation Invention Competition and Symposium 2024 (JIIICaS2024), where JIIICaS2024 is a virtual platform for all creative minds to share and present their invention and innovation. Each abstract gives a brief background on the innovation or project.

We hope that this e-book will help the readers to get to know the innovation done by the students and get some ideas to develop future innovation products.

Foreword Rector

Assalamualaikum warahmatullahi Wabarakatuh, Salam Sejahtera, Salam Malaysia MADANI and Salam UiTM Dihatiku.

In the name of Allah, the Most Gracious, the Most Merciful.

It is a great honor to welcome you to the Johor International Innovation, Invention, Competition, and Symposium 2024 (JIIICaS 2024). This event connects various disciplines, focusing on education and engaging educators, students, researchers, and innovators from all walks of life.

Innovation is not just about ideas; it demands perseverance, creativity, and determination to turn those ideas into reality. The remarkable projects showcased today highlight the dedication and spirit of all participants. Initiatives like this not only explore new technologies but also cultivate skills and leadership among our youth. At Universiti Teknologi MARA (UiTM) Johor Branch, we are fully committed to fostering a dynamic culture of innovation, promoting the commercialization of new products, and encouraging meaningful collaborations with industry and society.

As we celebrate this event, I would like to extend my heartfelt gratitude to all sponsors, judges, the College of Computing, Informatics and Mathematics, UiTM Pasir Gudang Campus as the event organizer, as well as to the researchers and participants for their hard work in making this event a success. Let us continue striving for innovation and excellence. May the ideas presented today inspire us and lay the groundwork for future achievements.

Thank you.

Associate Professor Dr. Saunah Zainon
Rector
Universiti Teknologi MARA (UiTM)
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(A-ST154) ENHANCING VIBRATION ATTENUATION THROUGH MATERIAL OPTIMIZATION IN DYNAMIC VIBRATION ABSORBERS

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ABSTRACT

This research presents an innovative methodology for enhancing vibration attenuation in fixed-fixed beam systems through the application of dynamic vibration absorbers (DVAs) fabricated from various materials. Employing an advanced Experimental Modal Analysis (EMA), our study meticulously identifies the natural frequencies, mode shapes, and Frequency Response Functions (FRFs) of the system to precisely tune the DVAs. We investigate the vibrational performance of aluminium, stainless steel, brass, and titanium DVAs at motor speeds of 14.8 Hz, 35 Hz, and 46.5 Hz. Our findings reveal that these materials exhibit unique vibration attenuation properties, with aluminium demonstrating superior effectiveness at higher frequencies. This significant improvement in vibration reduction highlights the critical role of material selection in DVA design. This study provides valuable insights for optimizing vibration-sensitive systems, offering a robust framework for enhancing stability and performance across various industrial applications.

Keywords: Dynamic Vibration Absorbers (DVA), Vibration Attenuation, Fixed-Fixed Beam Systems, Experimental Modal Analysis (EMA), Structural Dynamics

1.0 INTRODUCTION

Dynamic Vibration Absorbers (DVAs) are critical in managing and mitigating unwanted vibrations in mechanical systems. The choice of material for DVAs significantly influences their performance. This study explores the efficacy of DVAs made from aluminium, stainless steel, brass, and titanium across different motor speeds, highlighting the innovation of using aluminium for superior vibration attenuation.

2.0 OBJECTIVE

To develop and evaluate dynamic vibration absorbers (DVAs) made from different materials to optimize vibration attenuation in fixed-fixed beam systems across varying motor speeds, thereby enhancing the performance and reliability of vibration-sensitive industrial applications.

3.0 METHODOLOGY

3.1 Experimental Modal Analysis (EMA)

The primary goal of the Experimental Modal Analysis (EMA) conducted in this research was to determine the natural frequencies, modal shapes, and Frequency Response

Functions (FRFs) of the unbalanced motor-beam structure. This analysis ensures that the Tuned Dynamic Vibration Absorber (TDVA) is tuned to the target mode most affected by the motor's unbalance. Solving this eigenvalue problem provides insights into the vibrational characteristics and dynamic behavior of structural systems, essential for optimizing design and mitigating undesired vibrations.

3.2 Instrumentation and Measurement Setup

An accelerometer (Kistler type 8776A) was attached to the motor-beam assembly to measure the output acceleration in the Z-axis direction. An Impact Hammer (Kistler type 9724A5000) was used to impart a precise input force to the structure at 22 designated points along the beam's length to ensure comprehensive modal excitation. Both the accelerometer and the impact hammer were interfaced with the LMS SCADAS Data Acquisition (DAQ) system to capture and transmit the data with high fidelity.

3.3 Data Collection Procedure

After setting up and calibrating the measurement system, a series of impacts were administered using the impact hammer. Each impact point was struck multiple times, and the data was averaged to reduce variability and enhance reliability. The accelerometer continuously recorded the structure's response to the excitation forces. The DAQ system facilitated the synchronous recording of the input and output signals, essential for analyzing the system's dynamic characteristics.

3.4 Analysis of the Measured Data

The acquired signals were imported into the LMS Test.Lab software for analysis. The first step was identifying and isolating the natural frequencies of the beam by examining the peaks in the FRFs. The corresponding mode shapes were then calculated, revealing the deformation patterns of the beam at different frequencies. The FRFs were extracted to understand the resonance phenomena of the unbalanced motor, encapsulating the relationship between the input force and output vibration across a range of frequencies.

3.5 Vibration and Transmissibility Measurement

The aim of the Vibration and Transmissibility Measurement was to establish the input-output vibrational relationship within the unbalanced motor-beam assembly, quantifying the beam's dynamic response to vibrational forces originating from the unbalanced motor.

3.6 Instrumentation and Setup

Tri-axial accelerometers (Kistler type 8776A) were mounted on the beam to capture the most pertinent dynamics. One accelerometer was affixed at point 19, closest to the unbalanced motor, to record the vibrational input. Additional accelerometers were placed at select points along the beam to measure the propagated vibrational responses. The Italvibras M3/4 Micro 240V Rotary Vibrator motor was used to generate controlled vibrating forces. The motor specifications, including a single-phase power supply at 240 volts and an adjustable frequency of 50/60 Hz, allowed for precise application of vibrational energy to the beam.

3.7 Data Collection and Operational Modal Analysis

The LMS SCADAS system captured vibration data from the physical structure without artificial stimulation, replicating real-life circumstances. The system was configured for frequency domain analysis using Fast Fourier Transform (FFT) data, with a frequency resolution of 0.195313 Hz over a range of 0 to 200 Hz, and a sampling rate of 400 Hz. Signal smoothing and averaging techniques were employed to reduce the impact of random noise and enhance data reliability.

3.8 Data Analysis and Interpretation

The vibrational data was analyzed to elucidate the transmissibility of the unbalanced motor's vibration through the beam, focusing on the magnitude and frequency content of the vibrations under different operational conditions. The FRFs provided a detailed map of the vibrational energy transmission pathways and nodal points of the beam structure.

3.9 Validation and Reliability

The acquired vibrational data was statistically analyzed to ensure repeatability and low variance. The consistency of observed natural frequencies and mode shapes across repeated trials validated the measurement protocol's robustness. The empirical data was compared to theoretical predictions and previous empirical findings to reinforce the validity of the results.

3.10 Application of TDVA to an Unbalanced Motor-Beam System

The previous EMA identified resonant frequencies crucial for the current investigation. Accurate measurements of the motor-beam system's response at specified speeds were essential for assessing the TDVA's efficacy in reducing excessive vibrations.

3.11 Impact Testing of TDVA Mass's Beam

Impact testing, a non-destructive method, was used to identify resonant frequencies by observing the system's response to a sudden transient force as in Figure 2. The testing was conducted across four different Dynamic Vibration Absorber (DVA) mass's beam configurations made from distinct materials, offering variations in damping and stiffness properties.

Figure 2: Impact testing to a mass’s beam.

3.12 Adjustment of TDVA Mass Positions

The TDVA features a beam with adjustable brass masses. Based on impact testing results, the optimal positions of the brass masses were determined to fine-tune the TDVA to the identified resonant frequencies for each operational speed of the motor.

3.13 Interchangeable Beam Materials for Comparative Analysis

The TDVA involved interchanging the beam with alternatives made from stainless steel, aluminium, brass, and titanium. The vibrational characteristics of each material were analyzed to determine their effectiveness in reducing vibrations.

3.14 Vibration Measurement with TDVA Implementation

The TDVA was mounted on a fixed support at the beam's midpoint to optimize vibration attenuation as show in Figure 3. The vibration measurement procedure was repeated under identical test conditions to ensure the reliability and comparability of the results.

Figure 2: The TDVA attachment of the unbalanced motor-beam system.

3.15 Analysis of Vibration Attenuation Performance

The vibrational response of each beam material configuration was analyzed to quantify the reduction in vibration amplitude at resonant frequencies compared to the system without the TDVA. The results were used to validate theoretical predictions and assess the TDVA's effectiveness.

The findings were compiled into a comprehensive report discussing each material's performance under various conditions, with practical recommendations for implementing TDVA in industrial settings and suggestions for future research.

4.0 RESULTS

The summarized results are presented in Table 1.

Table 1: Summary of Attenuation at 14.8Hz, 35Hz, and 46.5Hz Motor Speeds.

Material	Motor Speed (Hz)	Peak Acceleration (m/s^2)	Percentage Attenuation
Aluminium	46.5	1.50	93.18%
Stainless Steel	46.5	1.72	92.19%
Titanium	46.5	2.27	89.68%
Brass	14.8	0.24	78.57%
Brass	46.5	7.77	64.70%
Titanium	35	1.52	65%
Aluminium	35	3.14	28%
Stainless Steel	14.8	0.86	23.21%
Stainless Steel	35	4.21	3%
Aluminium	14.8	1.24	-10.71%
Titanium	14.8	1.21	-8.04%

This comparative analysis highlights several key findings regarding the performance of various materials used in dynamic vibration absorbers. Aluminium exhibits the highest percentage attenuation, achieving 93.18% at 46.5Hz, making it particularly suitable for high-frequency applications due to its lightweight nature and excellent damping properties. Both stainless steel and titanium demonstrate consistent performance across varying frequencies, with titanium slightly outperforming stainless steel overall. Brass, while highly effective at lower frequencies with a 78.57% attenuation at 14.8Hz, proves less effective at higher frequencies.

5.0 CONCLUSION

The findings from this study underscore the importance of material selection in the design and implementation of DVAs. Aluminium emerges as a superior material for high-frequency applications, while brass is more suitable for low-frequency scenarios. Stainless steel and titanium provide balanced performance across a broad range of frequencies. This innovation in using aluminium for enhanced vibration attenuation can significantly impact the design of vibration-sensitive systems, offering a path to optimized performance.

Further research should explore the long-term durability and cost-effectiveness of these materials in real-world applications. Additionally, investigating composite materials and advanced manufacturing techniques could yield further improvements in DVA performance.