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Wire rope vibration isolator for precision equipment in UAVs - A Review

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Abstract - *This Vibration control is a critical aspect of ensuring the performance and stability of precision equipment mounted on Unmanned Aerial Vehicles (UAVs). In this project, a Wire Rope Vibration Isolator (WRVI) is designed and developed to mitigate the adverse effects of vibrations, specifically focusing on its impact on a camera mounted beneath the isolator. A key concern in aerial imaging applications is the Jello effect, a distortion that occurs due to high-frequency vibrations transmitted to the camera sensor. To evaluate the effectiveness of the WRVI, simulated vibration conditions replicating those experienced by UAVs in real flight scenarios are used. The isolator's ability to dampen vibrations and reduce the Jello effect is analysed through experimental testing and simulation studies. By optimizing the isolator's design and material properties, the project aims to improve stabilization for drone-mounted precision equipment. The findings from this study contribute to enhancing UAV-based imaging systems, making them more reliable and effective for applications such as aerial surveying, surveillance, and remote sensing. The results can also be extended to other sensitive payloads, broadening the scope of vibration isolation techniques in UAVs beyond just camera stabilization.*

Key Words: Wire Rope Vibration Isolator (WRVI), Unmanned Aerial Vehicles (UAVs), Vibration Isolation, Jello Effect, Camera Stabilization, Precision Equipment, Drone-Mounted Systems Vibration Simulation, Structural Damping, Aerial Imaging

1.INTRODUCTION *(Size 11, Times New roman)*

Unmanned Aerial Vehicles (UAVs) are widely used in various applications, including surveillance, aerial photography, mapping, and industrial inspections. However, during flight, UAVs are subjected to various types of vibrations due to factors such as propeller motion, air turbulence, motor operations, and sudden maneuvering. These vibrations can negatively impact the performance of onboard precision equipment such as cameras, sensors, and measurement devices. One of the most common issues faced by UAV-mounted cameras is the Jello effect, a distortion in video footage caused by high-frequency vibrations affecting rolling shutter cameras. This problem makes it crucial to implement effective vibration isolation techniques to maintain the accuracy and reliability of onboard equipment.

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1.1 Importance of vibration isolation for precision equipment

Unmanned Aerial Vehicles (UAVs) are widely used in various applications, including surveillance, aerial photography, mapping, and industrial inspections. However, during flight, UAVs are subjected to various types of vibrations due to factors such as propeller motion, air turbulence, motor operations, and sudden maneuvering. These vibrations can negatively impact the performance of onboard precision equipment such as cameras, sensors, and measurement devices. One of the most common issues faced by UAV-mounted cameras is the Jello effect, a distortion in video footage caused by high-frequency vibrations affecting rolling shutter cameras. This problem makes it crucial to implement effective vibration isolation techniques to maintain the accuracy and reliability of onboard equipment.

1.2 Role of Wire Rope Vibration Isolators (WRVI)

Wire Rope Vibration Isolators (WRVI) are one of the most effective solutions for mitigating vibrations in UAV applications. These isolators are composed of interwoven metal cables arranged in loops between two mounting points, allowing for controlled flexibility and damping. They work by absorbing and dissipating vibrational energy before it reaches sensitive components. The key advantages of WRVIs in UAVs include high vibration damping, as the interwoven wire structure provides multi-axis vibration isolation, making it ideal for dynamic environments. WRVIs are also known for their durability and reliability, as they are resistant to harsh environmental conditions, such as temperature variations, moisture, and corrosion, ensuring long-term performance. Additionally, WRVIs feature a lightweight and compact design, which makes them ideal for UAV applications, unlike traditional dampers that may add excessive weight. Their low maintenance requirements make them a cost-effective solution, as they do not require frequent replacements or lubrication.

In this paper, a WRVI is designed and developed to evaluate its effectiveness in reducing vibrations affecting a camera mounted on a UAV. By simulating drone-induced vibrations, the study aims to analyse how well the WRVI minimizes the Jello effect and improves image stability, contributing to enhanced UAV performance in precision applications.

2. PROBLEM STATEMENT

Unmanned Aerial Vehicles (UAVs) have become an integral part of modern applications, including aerial surveillance, mapping, precision photography, remote sensing, and industrial inspections. These operations require UAVs to carry high-precision equipment, such as cameras, LiDAR sensors, and thermal imaging systems, to collect reliable data. However, UAVs are inherently subject to various sources of vibration, including propeller motion, motor vibrations, aerodynamic forces, and sudden maneuvering. These vibrations can negatively affect the performance of onboard equipment, leading to reduced accuracy, poor image quality, and compromised data collection.

3. LITRETURE REVIEW

1. **Passive Isolator Design and Vibration Damping of EO/IR Gimbal Used in UAVs**

Authors: Mehmet Taha Görmüş, Bilal Faruk Adın, Pasa Yayla

Published in: International Journal of Aviation Science and Technology, 2023

Summary: This study focuses on designing a passive vibration isolation system for a two-axis electro-optical gimbal used in mini-UAVs. The proposed system aims to mitigate vibrations transmitted from the UAV to the gimbal, enhancing image quality.

2. Performance Study of Wire Rope Isolators for Vibration Isolation

Authors: S. K. Sinha, A. K. Verma, P. K. Jain

Published in: ARPN Journal of Engineering and Applied Sciences, 2016

Summary: This paper investigates the effectiveness of wire rope isolators (WRIs) in attenuating vibrations. The study highlights WRIs' ability to provide isolation in multiple directions and their application in military and industrial settings.

3. Design and Experiment of a Passive Vibration Isolator for Small Drones

Authors: Jae-Hun Lee, Seung-Ho Han, Jong-Bae Park

Published in: Applied Sciences, 2024

Summary: This research presents the development of a passive vibration isolator tailored for small drones. The isolator aims to enhance the precision of optical equipment by mitigating vibrations specific to drone operations.

4. Quasi-Static Cyclic Behaviour of Wire Rope Isolators: Comprehensive Experimental and Numerical Study

Authors: A. M. Abdelrahman, M. A. Tawfik, M. A. Wahab

Published in: Heliyon, 2022

Summary: This study examines the quasi-static cyclic behaviours of wire rope isolators, emphasizing their application in military and aerospace industries for vibration and shock protection.

5. An Investigation on UAV Vibration Control Based on Negative Poisson's Ratio Structure

Authors: Y. Li, Z. Wang, J. Liu

Published in: Mechanical Systems and Signal Processing, 2025

Summary: This paper explores the use of structures with negative Poisson's ratio for vibration control in UAVs, proposing a novel isolation platform to reduce vibrations affecting UAV performance.

4. Comparative Analysis of Different Isolation Methods

Several vibration isolation methods have been investigated for UAV applications, including: A comparative study tested WRVIs, elastomeric mounts, and active isolators under UAV vibration conditions.

Isolation Method	Advantages	Disadvantages
Elastomeric Mounts	Lightweight, cost-effective, easy to integrate	Limited lifespan, degradation over time, temperature sensitivity
Wire Rope Isolators (WRVIs)	High durability, multi-directional damping, maintenance-free	Slightly heavier than elastomers, stiffness needs to be optimized for UAVs
Active Isolation Systems (Piezoelectric & Electromagnetic)	Real-time vibration control, adaptable	Expensive, power-consuming, complex integration

Hybrid Isolation (Combination of Passive & Active Systems)	Optimal vibration suppression, adaptable to different UAV loads	Higher cost, requires additional power source

Table -1: Comparative analysis of different isolation methods.

CONCLUSIONS

The isolation of unmanned aerial vehicle (UAV) can be effectively provided by the WRVI. The WRVI provides the damping of the external disturbance through its friction between the wire strands which also makes it effective in all three planes and directions. The present work was the study on the performance of the WRI.

One of the key strengths of this WRVI design is its simplicity and modularity. It can be scaled to accommodate different payload weights or customized to fit various drone chassis configurations without requiring significant redesign. Additionally, the system offers a low-cost and passive solution that does not require power, sensors, or control circuits, making it ideal for drones where weight, cost, and power consumption are tightly constrained. In conclusion, the WRVI prototype not only meets the initial design objectives but also lays a strong groundwork for future innovation in vibration isolation systems. Whether in commercial, industrial, or defence sectors, the integration of such isolators can significantly enhance UAV reliability, data accuracy, and component lifespan, contributing to safer and more effective drone operations.

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