Defence Seminar

Seminar Title	: Design and Development of a Metastructure with Nonlinear Stiffness Behavior for Vibration Control Applications
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Venue	: Mechanical Seminar Hall
Date and Time	: 28 May 2024 (11.00 AM)

Abstract :

The demand for small-scale precision instruments requires effective vibration control to isolate low-frequency excitations. While active isolators are effective, cost constraints lead to widespread use of passive isolators. However, the frequency range over which a linear passive vibration isolator is effective is often limited by the static stiffness required to support a load. This study enhances vibration isolation in low-frequency ranges by introducing nonlinearity, specifically quasi-zero-stiffness (QZS) characteristics. QZS operates on the high static and low dynamic stiffness (HSLDS) mechanism, enabling low-natural frequencies with large static deflection. To achieve QZS behavior, mechanical metamaterials are used with tailored property of negative stiffness.

Two design techniques are proposed in this work to obtain the unit cell: first, by combining negative and positive stiffness elements separately, and secondly, by designing single-element-based metamaterial. Four designs are proposed, including combinations of bistable inclined beams, cosine beam systems, and semicircular arches. Designs are fabricated using 3D printing, with deformable elements printed using Thermoplastic Polyurethane (TPU) and stiffer walls using Polylactic Acid (PLA). Analytical, numerical, and experimental methods validate static studies. Dynamic behavior is analyzed using the Harmonic Balance Method (HBM), confirming nonlinear characteristics. Dynamic experiments using an electrodynamic shaker setup validate low transmissibility, low resonance frequency, and wide isolation range for QZS payloads compared to linear payloads. Finally, a comparative study evaluates isolation effectiveness for all proposed metastructures.

This research presented a proof of concept where the mass can be customized by varying the geometrical parameters to obtain the QZS characteristic based on the payload requirement to isolate vibration at low-frequency ranges.