Design of Piezoelectric Energy Harvesting Devices based on Nonlinear Vibration

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Academic Disciplines:
ME, MSE

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RESEARCH OBJECTIVE

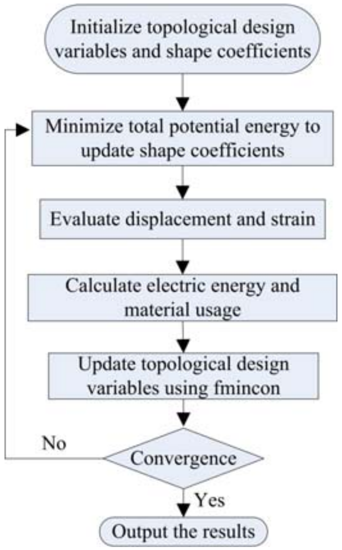
To achieve the low resonant frequencies and broadband energy harvesting performance of micro energy harvesting devices, in this study, the numerical modeling and experiment validation of the nonlinear vibration of a multi-buckled beam will be investigated. Moreover, structural topology optimization methods are explored to find the optimal piezoelectric material layout of a bistable nonlinear energy harvestor.

Energy harvesting devices based on nonlinear vibration

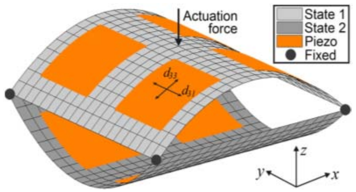
- **Multistable structure**
- **Bistable laminate**

DESIGN & OPTIMIZATION

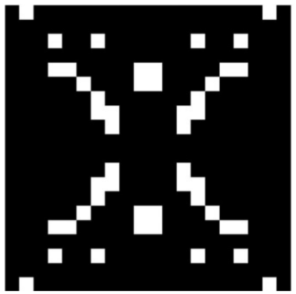
- Preliminary topological design of piezoelectric material on bistable laminates to maximize electrical energy output.
- Simplified analytical modeling for predicting the shape of laminates considering thermal, mechanical, and voltage loads.



Design flowchart



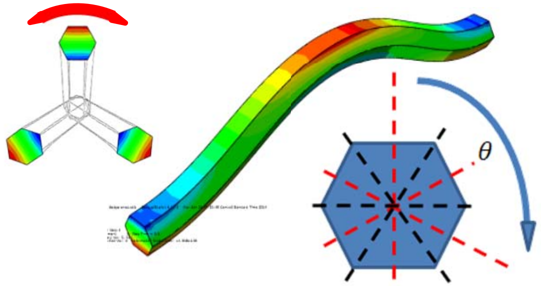
Piezoelectric patches (orange) on bistable laminates

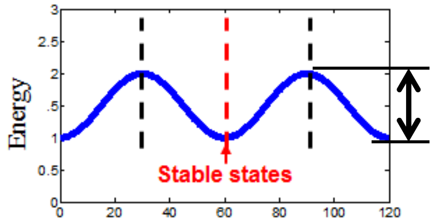


Optimal Design

Modeling & Simultion

- FE models of the multistable structure are created in Abaqus. The global omni-oscillation is observed near the natural frequency of the intrawell oscillation.
- Governing equations for the beam with hexagonal cross-section is developed





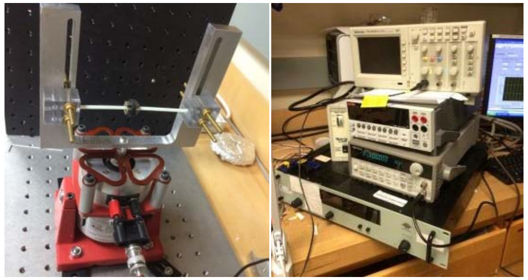
Lower energy barrier of the transition between adjacent stable states

Governing Equations:

$$\rho\left(\frac{\partial\theta}{\partial t}\right)^2\cdot w-\rho\frac{\partial^2 w}{\partial t^2}-EI(\theta)\frac{\partial^4 w}{\partial x^4}=0$$

$$-\frac{1}{2}E\left(\frac{\partial^2 w}{\partial x^2}\right)^2\cdot\frac{\partial I(\theta)}{\partial\theta}-\rho\frac{\partial^2\theta}{\partial t^2}=0$$

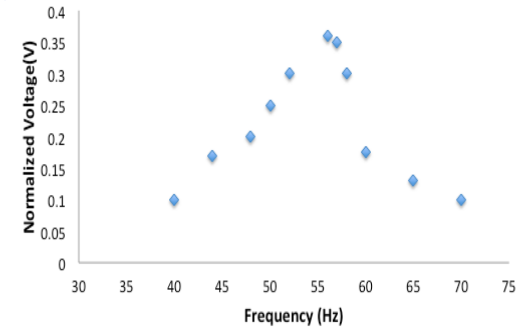
Experiments



- **Experimental setup** (sample with U shape Aluminum holder, shaker as vibrational source, and signal acceptor)
- **Pre-buckled sample preparation:**

1. supported cubic (Hardest material)
2. Hexagon beam, 2.95mm outer diameter, 100mm long, (No. 2&3 material) & Cylindrical disc (rubber-like material)
3. 6 tungsten rods around the beam

- The multi-stable design is realized in experiments. The resonant frequency of the structure is 56Hz for No. 2 hardest material.
- Piezoelectric film is attached to the surface of the beam. The mechanical/electrical converting efficiency can be measured



Normalized measured voltage of PZT films reaches maximum at 56Hz