Vibration Isolator Incorporating a Composite Bistable Plate

Alexander Shaw, Prof. David Wagg, Dr. Simon Neild, Prof. Paul Weaver
Introduction

- High Static Low Dynamic Stiffness vibration isolator
  - Theory and benefits
- Bistable Plates
  - What they are and how they work
- Quasi-static response
  - Numerical Results and Empirical formula
  - Possible path dependency and hysteresis
  - Experimental results
- Dynamic response
  - Initial tap test results
  - Modelling
- Ongoing/Future work

Vibration Isolator Incorporating a Composite Bistable Plate
• A soft mount has a low resonant frequency – and therefore a wider isolation region
• However, low linear stiffness implies a poor weight bearing capacity
• HSLDS mount seeks to reduce stiffness at the equilibrium point whilst maintaining overall stiffness
• Profile achieved through combination of linear springs and negative stiffness elements
Bistable plates

- Plates with 2 stable curved positions
- Created flat in the autoclave
- Curvature driven by asymmetric layup and thermal contraction on cooling from cure
- Gaussian curvature change drives change from saddle shape to twin singly-curved stable shapes
- Applications to morphing structures e.g. morphing aerofoils
Bistable plate as negative spring

- Force/Displacement Curve produced in ABAQUS using nonlinear shell elements
- Empirical formula fits curve very well:
  \[ F(x) = Ax - B \tan^{-1}(Cx) \]
- Need to avoid \( \frac{1}{2} \) snap shapes

Force through plot of bistable plate from FEA – showing smooth response

Excessively curved bistable plates form \( \frac{1}{2} \) snap states during force through giving non-smooth response
Improved design – hybrid steel/CF plate*

- 110mm $[0^\circ_{CF\ 3\ 3}, 0^\circ_{steel}, 90^\circ_{CF\ 3\ 3}]$ plate
- Steel has high $E_a$ – creating large thermal contraction forces on cool, which couples with the asymmetric stiffness to create far greater bistable effect
- More compact
- ‘Half snap’ shapes are not stable with this lay up/geometry – so no hysteresis
- Good agreement with ATAN model

Hybrid steel/CF plate experimental results

- Good match with ATAN model for displacement
- Stiffness plot shows quality of agreement better
- Ideal for implementation in HSLDS

Force / displacement (left) and stiffness / displacement (right) graphs of hybrid bistable plate.

Vibration Isolator Incorporating a Composite Bistable Plate
HSLDS Demonstrator

Vibration Isolator Incorporating a Composite Bistable Plate
HSLDS – Tap Test Results

- Good match with theory - reducing linearised stiffness reduces natural frequency and increases peak response to forcing

FRF result from tap test on mount showing natural frequency reduction. (Blue line to red)
• Normal Forms used to model response
• Higher order polynomial allowing different stiffness polynomials
• Established useful performance limits of mount

Prediction for 5\textsuperscript{th} order polynomial HSDLS with forced excitation. $h_3$ and $h_5$ are 3\textsuperscript{rd} and 5\textsuperscript{th} harmonics. Markers show numerical simulation results.
Future work

- Extend dynamic experimentation to more realistic excitation
- Modelling of plate phenomena (force through response and ½ snaps)
- Consider different types of bistable plate to achieve more consistent response, easier manufacturing and elimination of external springs from the mount
The End

Thank you

Any Questions?