Pseudo-bistable morphing composites

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Outline

• Pseudo-bistability in a truss structure
• Isotropic pseudo-bistable behaviour
• Application to composites
  – Volume fraction limit
  – Influence of layup
• Future work
A discrete model of pseudo-bistability

- Consider following truss structure to illustrate pseudo-bistability
- Linear and torsional viscoelastic springs with stiffnesses $k_L$ and $k_T$
  - $k_L =$ stretching stiffness
  - $k_T =$ bending stiffness
- Structure is **loaded** until buckling occurs and allowed to **relax**
- Finally strain is removed and structure freely **recovers**
During **loading**, structure follows **A-B** path
During **relaxation**, structure follows **B-C** path
  - Load-extension curves during relaxation are in **blue**
During **recovery**, inverse path **C-B** if extension is fixed
  - Load-extension curves during recovery are in **red**
At \( t = 8.6 \text{ s} \), \( P_{\text{min}} = 0 \), and the structure snaps back
Pseudo-bistability in a continuum structure

- The panel, initially flat, is pre-stressed by axial compression and rotation
- The panel is loaded by an indenter, allowed to relax, and the indenter is released
- The panel then snaps back after a period of time without further actuation

![Diagram](image)

**LOADING**

(a) $t = 0$ s

(b) $t = 0$ s

**RECOVERY**

(c) $t = 4.49$ s

(d) $t = 4.53$ s
Numerical validation
Experimental validation

load cell
indenter
support base
indenter
specimen
clamp
The geometrical parameter

**AXIAL COMPRESSION**

Recovery time $t_{\text{rec}}$, s

Compressive axial strain $x^*$

**ROTATION ANGLE**

Recovery time $t_{\text{rec}}$, s

End rotation, deg

**GEOMETRICAL PARAMETER**

$\lambda = f(x^*, \alpha)$

- **Mono-stability**
- **Pseudo-Bistability**
- **Bistability**

Increasing $\Lambda_\infty$, $\Delta \lambda$
Effects of volume fraction

• Increasing the volume fraction:
  – increases the maximum snap-through load (x7 for $V_E = 7\%$)
  – decreases the pseudo-bistable effect

• Pseudo-bistability disappears at $V_E = 7\%$

• This limit can be increased by choosing a material with a higher relaxation
Influence of layup

• Choosing an asymmetric layup causes the neutral axis and the position of the pseudo-bistable interval to shift:
  – Downwards for stiff layer on bottom
  – Upwards for stiff layer on top

• Bending and stretching effects become coupled
Future work

• Continue experimental work on composite panels
• Explore different materials & effect of layup orientation
• Investigate possible applications, e.g. flow control device on transonic airfoil.