University of BRISTOL

# Pseudo-bistable morphing composites

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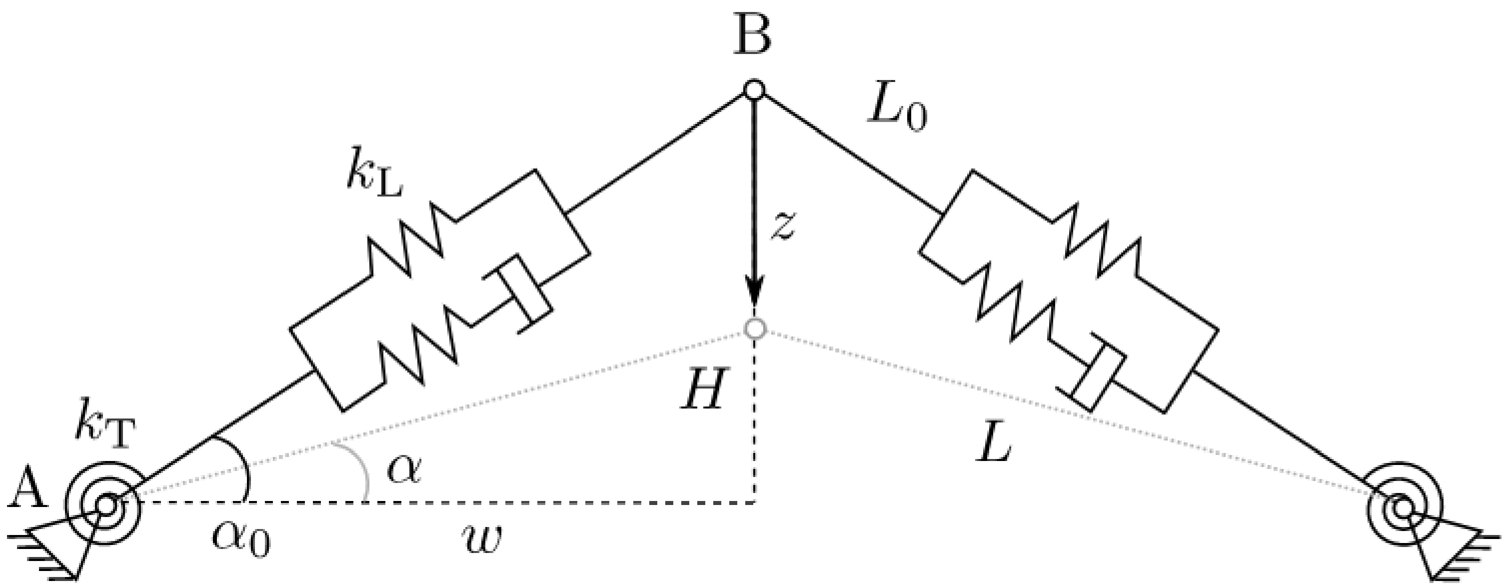
# Outline

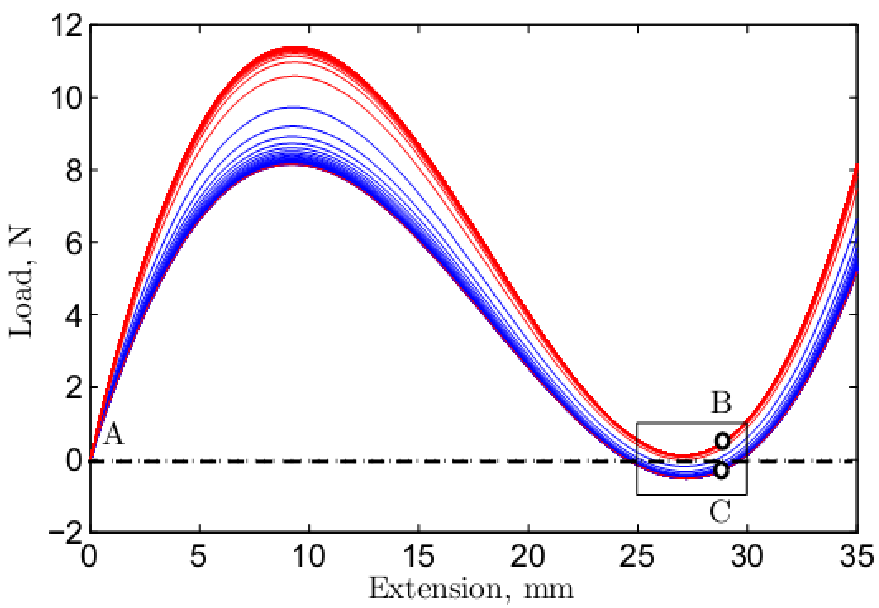
- Pseudo-bistability in a truss structure
- Isotropic pseudo-bistable behaviour
- Application to composites
  - Volume fraction limit
  - Influence of layup
- Future work

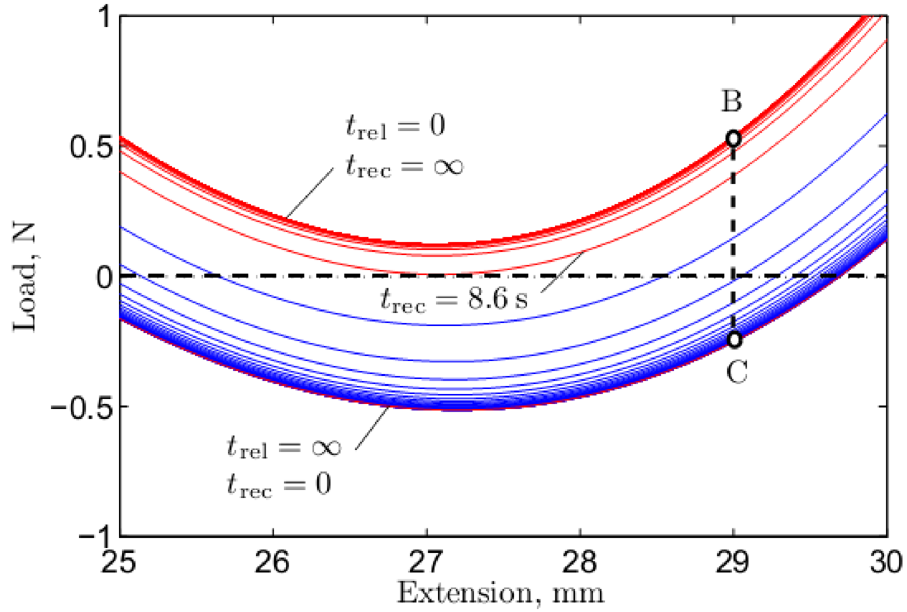
# A discrete model of pseudo-bistability

- 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**



# A discrete model of pseudo-bistability

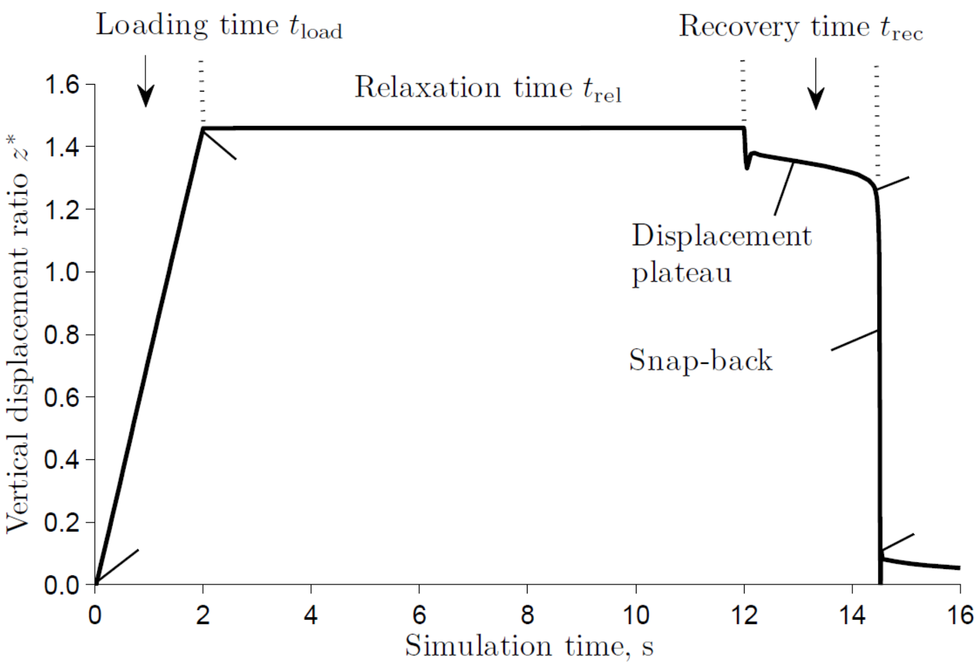


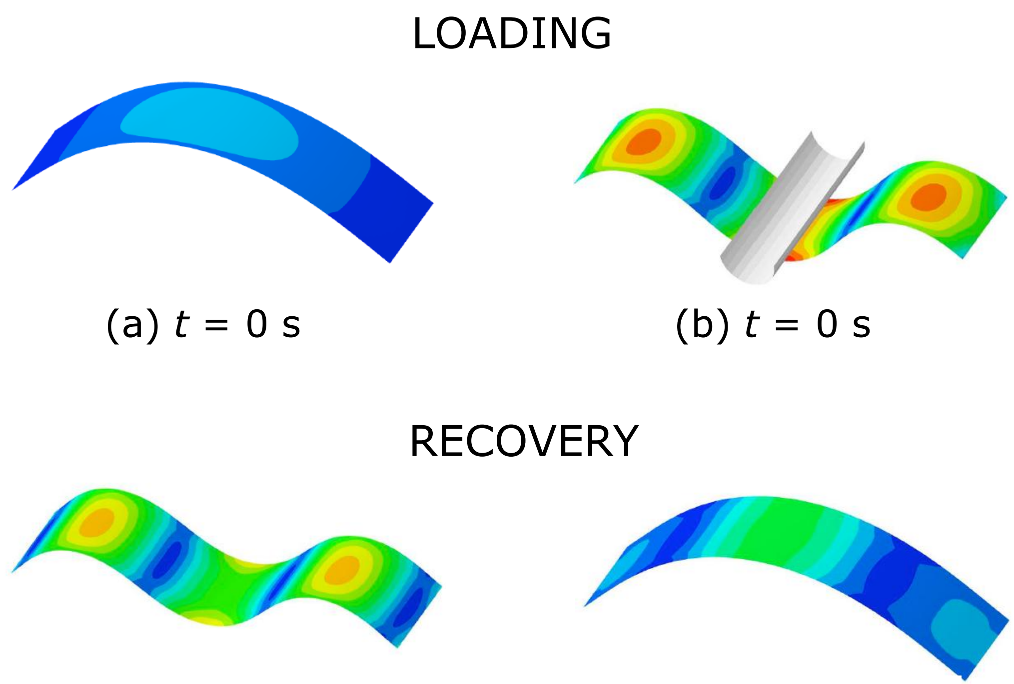




- During **loading**, structure follows **A-B** path
- During **relaxation**, structure follows **B-C** path
  - Load-extension curves during relaxation are in blue
- During **recovery**, inverse path **C-B** if extension is fixed
  - Load-extension curves during recovery are in red
- At t = 8.6 s, $P_{min}$ = 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

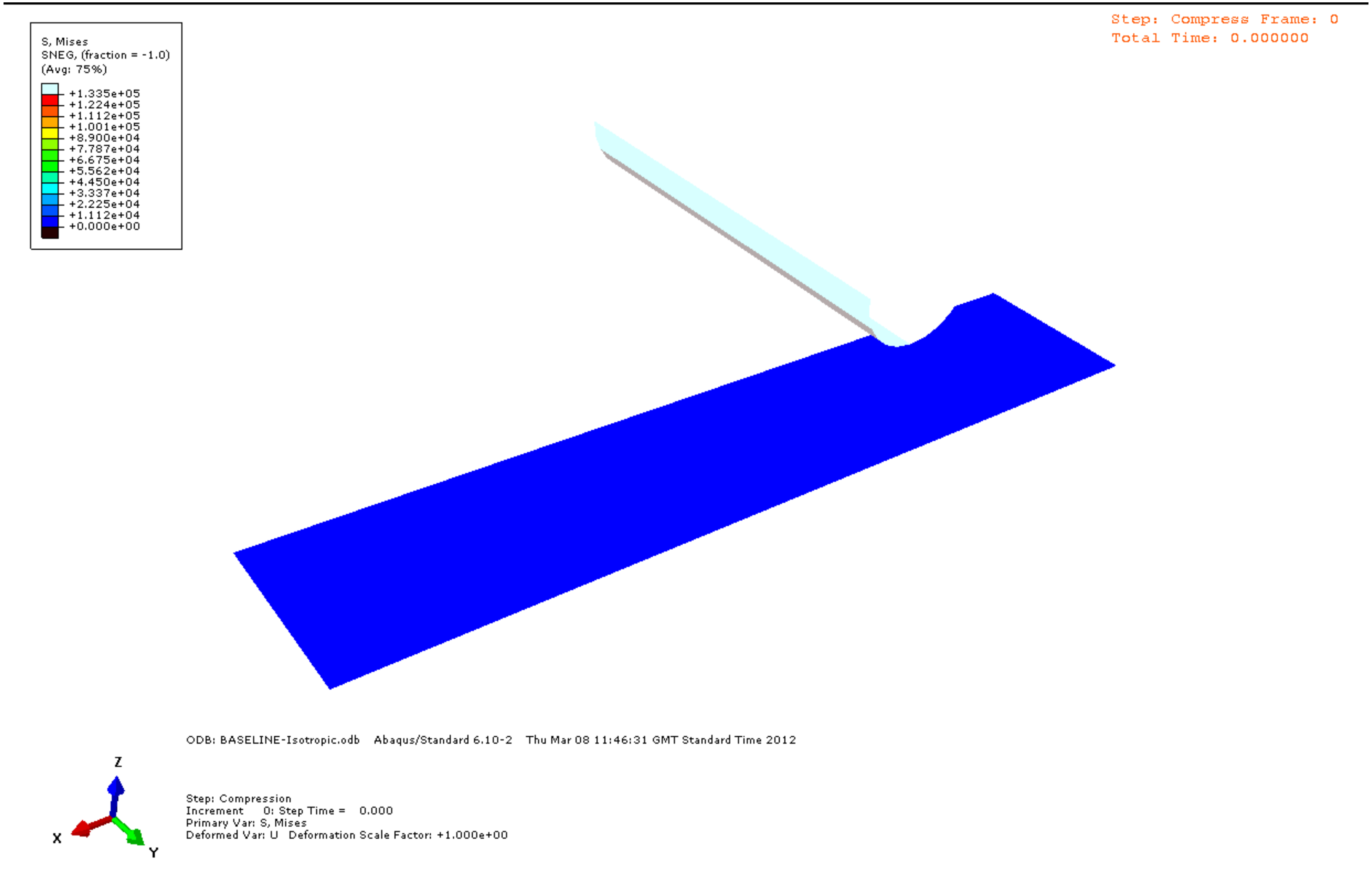


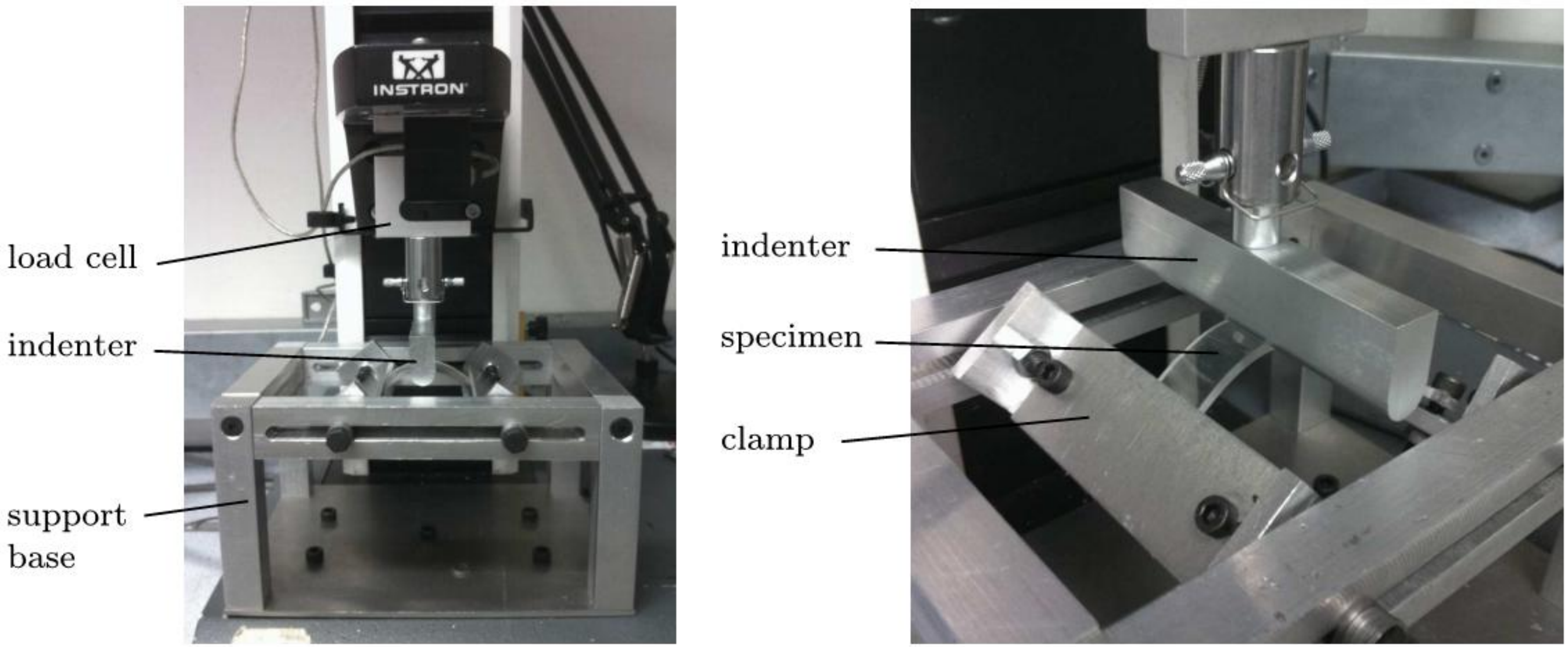

(a) $t$ = 0 s (b) $t$ = 0 s

(c) $t$ = 4.49 s (d) $t$ = 4.53 s

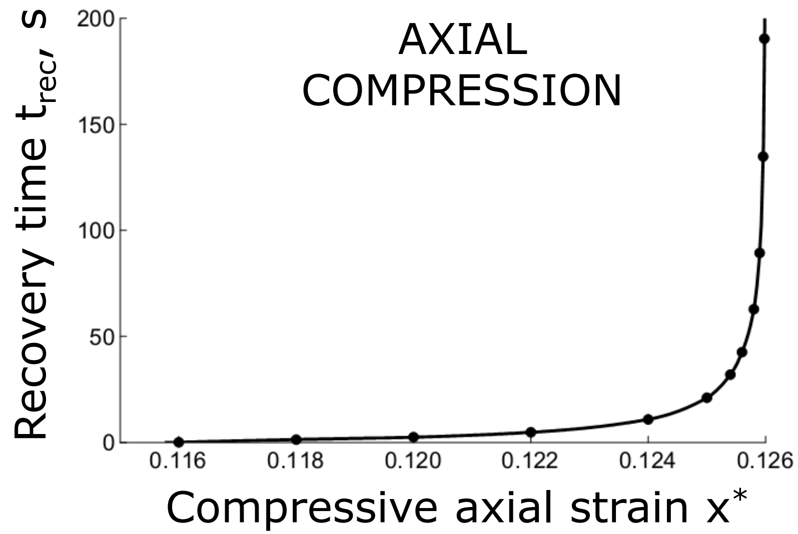
# Numerical validation

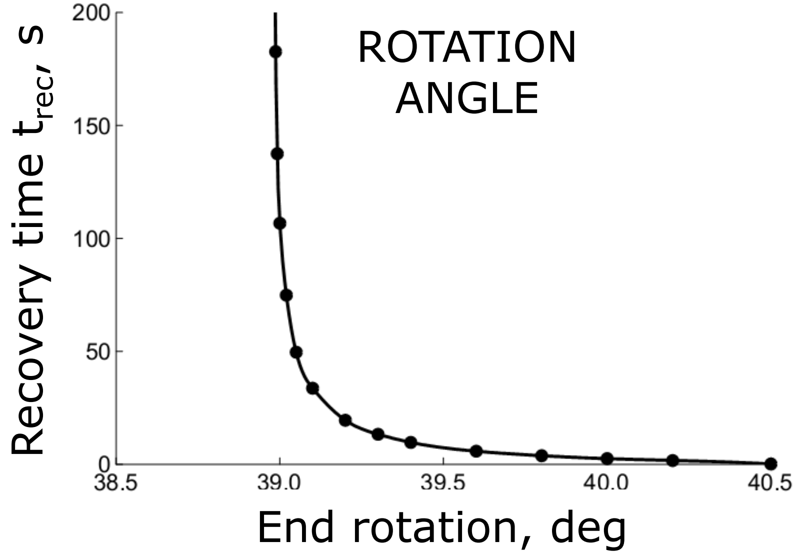


# Experimental validation

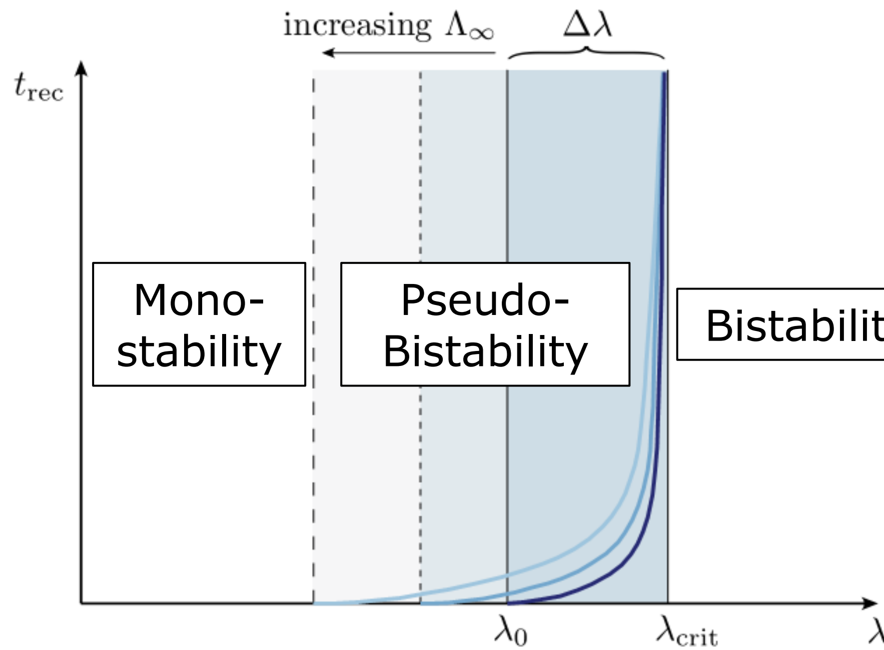


# The geometrical parameter



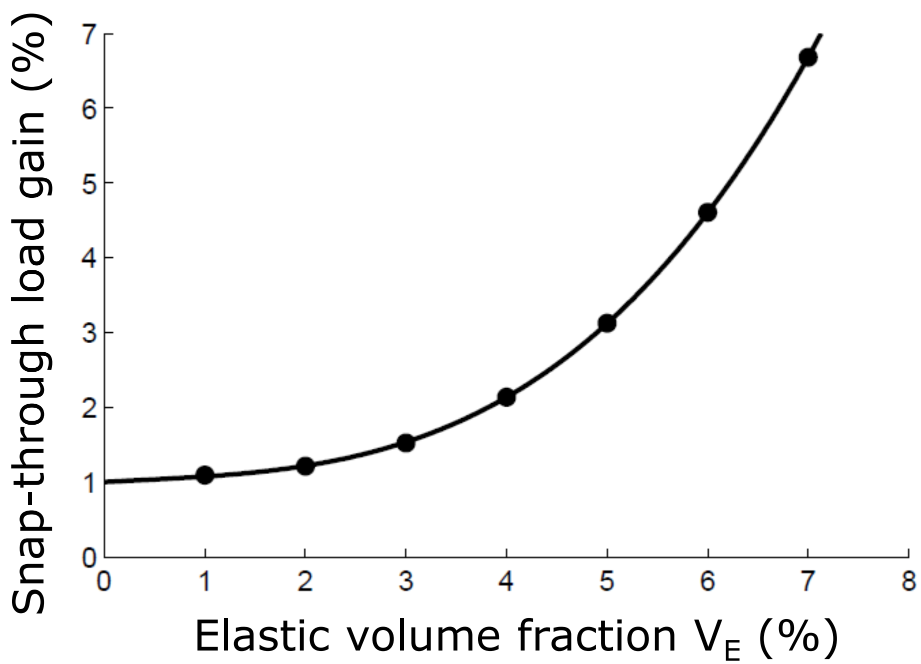

GEOMETRICAL PARAMETER

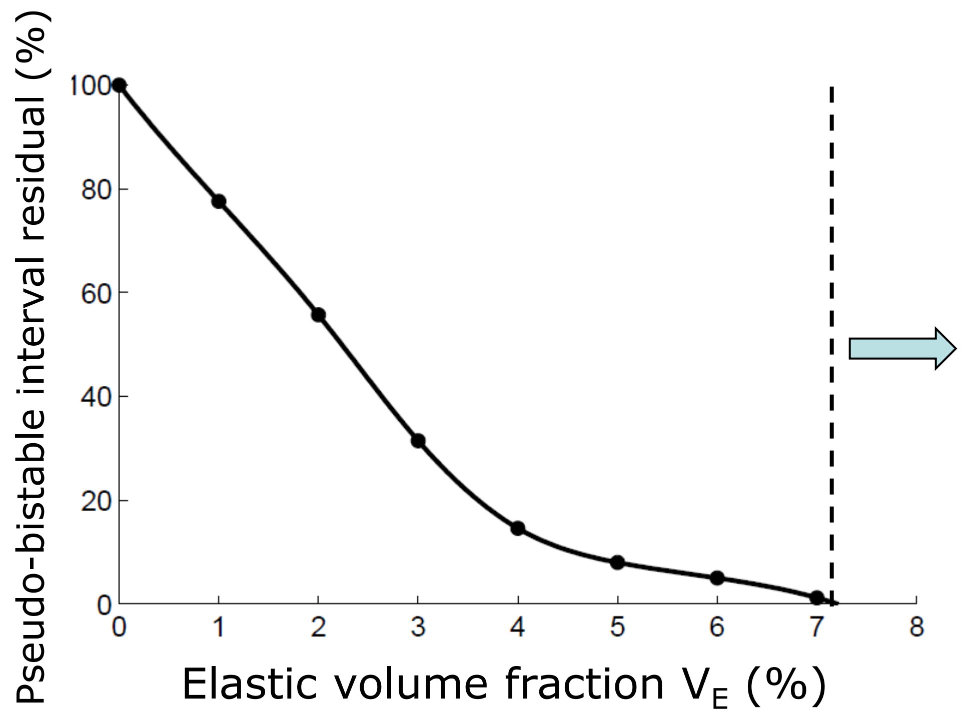



$$\lambda = f(x^*, \alpha)$$

# Effects of volume fraction

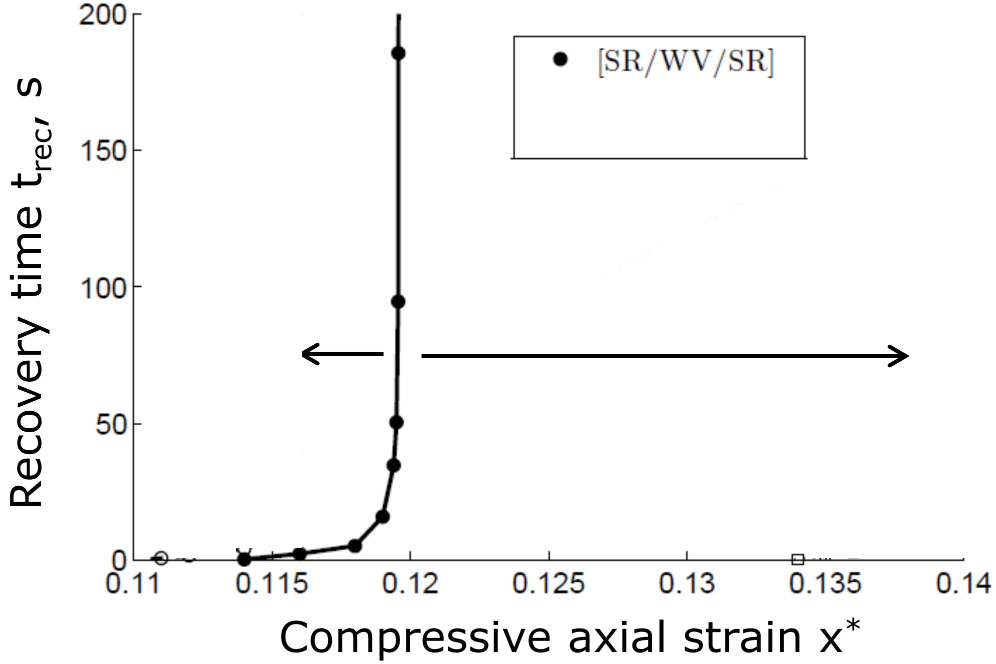
- Increasing the volume fraction:
  - increases the maximum snap-through load (x7 for $V_E$ = 7%)
  - decreases the pseudo-bistable effect
- Pseudo-bistability disappears at $V_E$ = 7%
- This limit can be increased by choosing a material with a higher relaxation

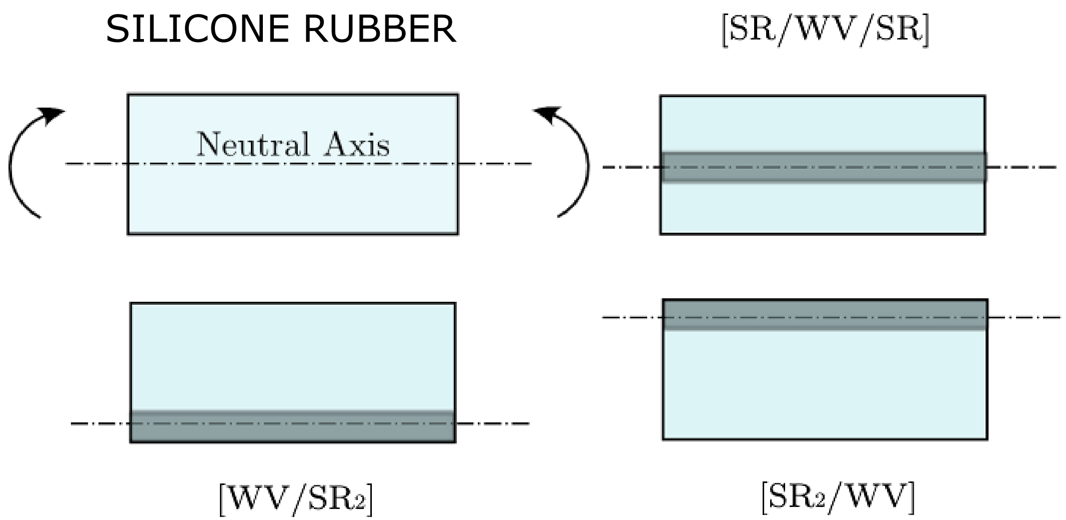


# Influence of layup

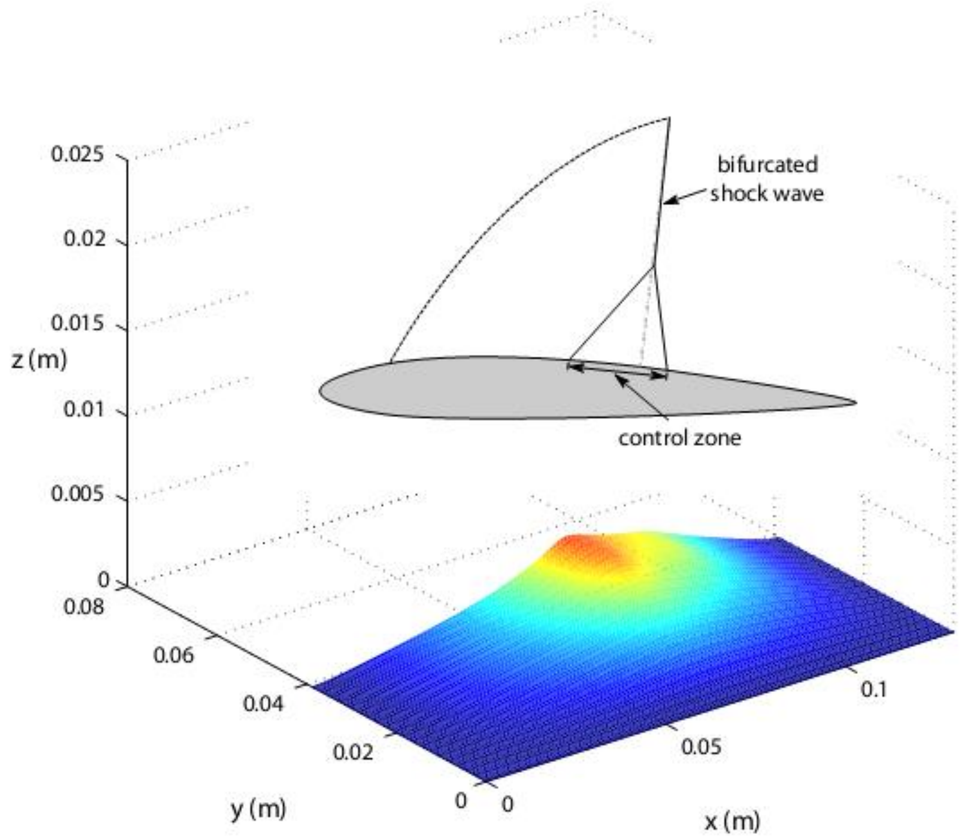
- Choosing an asymmetric layup causes the neutral axis and the position of the pseudo-bistable interval to shift:
  - Downwards for stiff layer on bottom
  - Upwards for stiff layer on top
- Bending and stretching effects become coupled



# 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.




Rhodes & Santer, 2011

# Questions