Trusses of Nonlinear Morphing Elements

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Presentation Outline

- Concept
  - compliant mechanisms
  - morphing elements

- Results

- Conclusions

- Future work
Concept

**Multistable compliant mechanisms**

### Current mechanisms
- flexible members
- *monolithic compliance* – ability to transfer motion, force or energy through elastic deformations of the underlying components, rather than the mobility of joints.

### This work
- *morphing composite structures* as the flexible elements
- able to change shape and undergo large deformations
- maintain *load carrying capability* and *structural integrity*.

**BUT**
- design limited by strength considerations.

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Morphing Element

- Carbon fibre strips: pre-stress introduced by flattening curved strips.
- Double-helix architecture.
- Variable geometry: helix angle $\theta \in [0^\circ, 90^\circ]$.
- Tailorable nonlinear stiffness characteristics.
Assembly of the Mechanism

- Assembly of the double-helices in a truss-like configuration.
- Analysis using: (i) energy landscapes
  (ii) path-following method (modified-Riks).
Results – effect of composite lay-up

- Strain energy landscapes

- Double-helices of $L = 95$ mm, $R = 15$ mm, $R_i = 30$ mm, $W = 5$ mm, with composite strips of a $[\beta_2/0/\beta_2]$ lay-up with $\beta \in [0^\circ, 90^\circ]$.
- Points 1–4 denote stable equilibria, while points A–G identify positions of unstable equilibrium. Points I-IV denote stable boundary equilibria.
Results – effect of composite lay-up

- Strain energy landscapes

Red points indicate the equilibrium paths of the apex under an applied vertical load ($P_h = 0$).

- Load-displacement curves ($P_h = 0$)

Dashed lines represent areas of instability.
Results – effect of initial truss angle

- Strain energy landscapes

\[ \alpha_{0,1} = 35^\circ, \ [45_2/0/45_2], \ P_h = 0 \]

- shallow truss
- bistable

\[ \alpha_{0,1} = 70^\circ, \ [45_2/0/45_2], \ P_h = 0 \]

- steep truss
- quadristable

- Load-displacement curves (\(P_h=0\))

\[ \alpha_{0,1} = 35^\circ, \ [45_2/0/45_2], \ P_h = 0 \]

Normalized load, \(P/P_{crit}\)

\[ \alpha_{0,1} = 70^\circ, \ [45_2/0/45_2], \ P_h = 0 \]

Normalized load, \(P/P_{crit}\)
Conclusions & Future work

- The mechanism characteristics can be varied significantly by altering:
  - the composite strip lay-up, and/or
  - the initial truss geometry.

- The equilibrium paths bifurcate, enabling all internal equilibria to be traversed just by applying a vertical load.

- Explore reconfigurability of the mechanism.
- Manufacture and test a prototype.
Thank you!

...any questions?

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