Snap Buckling of a Constrained Photomechanical Switch Driven by Elastic Instability
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Introduction
Photomechanical materials convert the energy in light to mechanical work. This class of materials represents a unique opportunity for wireless actuation and morphing surface technology. Challenges for realizing functional devices with these materials include: producing controlled complex motion, low power output, and degradation in actuator behavior with use. A typical strategy for producing complex motion is to engineer materials with various material anisotropies \([1]\). Recently we reported on a strategy for producing fast actuation rates (\(< 10\) ms) and controlling positioning based in part on mechanical design concepts using snap-through of a photomechanical, buckled arch \([2]\). Herein we, propose that rational use of geometric contact points will lead to enhanced, controllable complex motion for a multi-position actuator.

Background
Photomechanical materials based on azobenzene convert light energy to mechanical work via cooperative microscopic motion.

Formulation and Computational Methods

Reference Configuration

Governing Equations

Inelastic Strains: Induced Photo-Strains

Constitutive Equation

Strain-Displacement Relationship

Simulation Details: Simulations were performed using the structural mechanics module of COMSOL Multiphysics. In this preliminary effort the material was modeled as a 2D, linearly elastic, solid with initial photo-induced strains. The BDF solver with the automatic Newton method was used to perform time dependent studies. Friction free contact surfaces were assigned between the bottom of the strip and the fixed pin. The ends were modeled as clamps with specified displacement allowed at the right end.

Parameter Definitions:
- \(L_0\) – original length of material strip
- \(a\) – thickness of strip
- \(X_c\) – focus point of collimated laser
- \(u_0\) – displacement of right end
- \(r\) – vertical position of fixed pin
- \(I_o\) – Light intensity
- \(\varepsilon\) – material coordinates
- \(u < u_o < \frac{d}{2}\)
- \(v = \frac{d}{2} < \frac{d}{2}\)
- \(F\) – deformation gradient
- \(\epsilon\) – Stiffness tensor
- \(S\) – 2nd Piola–Kirchhoff stress tensor
- \(\gamma_P\) – Photo Poisson-like ratio
- \(\beta\) – Photo-induced strain
- \(\rho\) – Material density
- \(d\) – attenuation length of light

Results

Critical Buckling vs. Pin Position

Critical Photo-Strain vs. Pin Position

Critical Photo-Strain vs. Laser Focus Point

Conclusions

Simulations predict a possible route to 3 and 4 position discrete actuators driven by light.
- The storage and rapid release or elastic energy results in potentially high power output actuators
- Preliminary qualitative trends in actuator behavior for variations in several design parameters were explored in order to hone future investigations

References:

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