The design and regulation of bistable structure based on dielectric elastomer actuator

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Introduction

The snap-through bistability of the Venus flytrap is one of the essential inspirations for bionic structure, which can be adopted to improve the shortcoming of dielectric elastomer actuators and develop a new actuation structure with low energy consumption, variable configuration, and multi-mode actuation. In this paper, the minimum energy structure of dielectric elastomer is taken as the research object, while the design method, performance influencing factors, and actuation mode conversion of the electroactive bistable actuator are investigated from the perspective of system energy. This study can provide theoretical guidance and practical experience for developing the design and application of dielectric elastomer actuators with multi-mode, high-performance, and long-life characteristics.

Methods

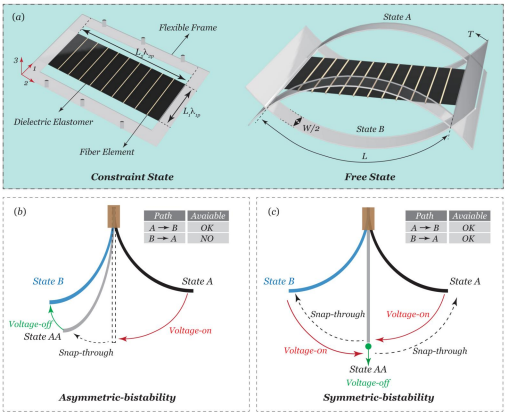

Figure 1 Electroactive bistable actuation design.

The energy of the flexible frame: $U_F = \alpha \frac{K\theta^2}{2}$

The energy of the dielectric elastomer actuation unit:

$$W_{DE} = L_1 L_2 H_0 \left[-\frac{\mu J_{lim}}{2} In\left(1 - \frac{\lambda_1^2 + \lambda_2^2 + \lambda_1^{-2}\lambda_2^{-2} - 3}{J_{lim}}\right) - \frac{\epsilon \Phi^2 \lambda_1^2 \lambda_2^2}{2H_0^2} \right]$$

The total system energy of the bistable actuator :

$$U_T = W_{DE} + U_F = L_1 L_2 H_0 \left[-\frac{\mu J_{lim}}{2} In\left(1 - \frac{\lambda_{1p}^2 + \lambda_2^2 + \lambda_{1p}^{-2}\lambda_2^{-2} - 3}{J_{lim}}\right) - \frac{\epsilon \Phi^2 \lambda_{1p}^2 \lambda_2^2}{2H_0^2} \right] + \alpha \frac{K\theta^2}{2}$$

The deformation λ_2 of the actuation unit is: $\lambda_2 = \frac{2Lsin(\theta/2)}{L_2\theta}$

Discussion/Results

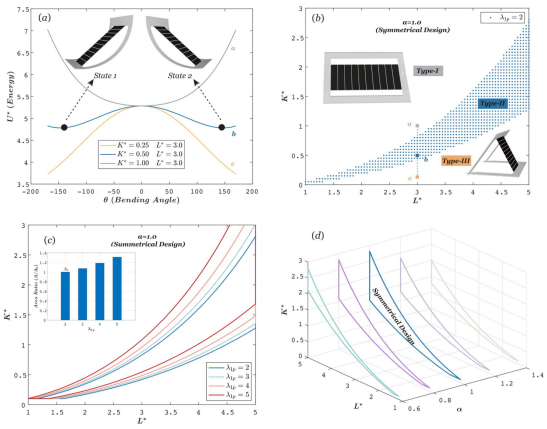

Figure 2 Effective parameter combinations of bistable design and their influence factors.

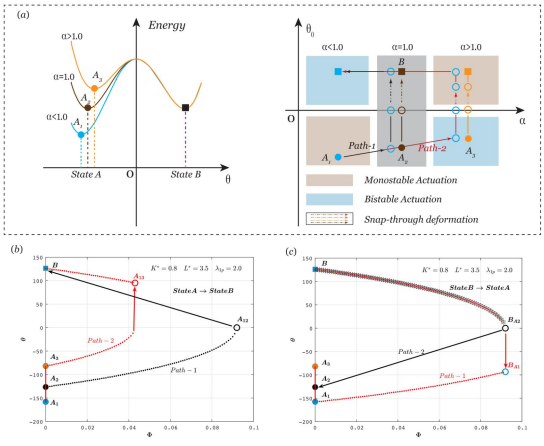

Figure 3 Regulation principle and method of electroactive bistable actuator.

Conclusions

In this paper, the influence of pre-stretching and symmetry factors on the actuator's trigger voltage, actuation stroke, and actuation charge was studied and analyzed. Furthermore, the comprehensive influence of pre-stretching and symmetry factors on the bistable actuation performance was obtained. Accordingly, it was proposed that bistable actuators in the monostable, bistable, symmetrical, and asymmetrical actuation can be achieved by cooperatively regulating the excitation voltage and symmetry factor.