11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

STATIC BEHAVIOUR OF FLEXTENSIONAL ACTUATORS WITH CONSTRICTED HINGES

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Key Words: *Actuator, Piezoelectricity, Nonlinear Problem, Statics, Prestressing.*

Mechanically amplified piezoelectric actuators having different forms, dimensions and geometries related to their industrial applications, are characterized by large deformation and large strokes both in static and dynamic conditions including resonance. The attributes of these actuators like compact structure, very precise movement, high force generation, quick response time with low energy consumption, make them appropriate for micro positioning, structure shaping, structural health monitoring, vibration control, cancellation and generation, fluid control functions in valves, dispensers and micropums, in various domains such as automotive, life and medical sciences, aviation, aerospace, optics and electronics applications [1].

The objective of this paper is to present the mathematical modelling and numerical testing of the static behaviour of flexure hinge actuators. The actuators are constructed of two beams mounted by stiff links with an offset to a piezoceramic rod or piezo stack. A hinge lever mechanism is applied by cutting constricted hinges at the links and/or the beams to generate and magnify the in-plane displacement created by the application of ~~a~~ voltage to the piezo member [2, 3]. Structures of this type have been commonly used since the manufacturing of its prototypes in the form of Moonie or cymbal actuators. A generalised non-linear analytical model of the actuator has been developed on the basis of stationary value of total potential energy principle. The Bernoulli-Euler beam theory has been applied together with von Karman strain-displacement relations. The electromechanically coupled constitutive equation, which accounts for the history of mechanical loading and electric field, has been used for the piezoelectric material. Actuators of different architecture with two and four pairs of hinges have been modelled and examined. Due to some manufacturers of flextensional actuators recommending its prestressing to avoid undesirable stretching of the piezoelectric stack, the internal preload has been taken into account. An uniform external transverse load applied to the actuator beams has completed the loading scheme of the transformer.

During the numerical analysis, the static deflection and internal axial force generated by the electric field application have been determined by changing the actuator properties such as the distance between the beams and the rod as well as the stiffness of the constricted hinges. Further computation has covered the participation of mechanical loads and the role of piezoelectric force in counterbalancing them or in cancellation of the beam deflection induced by external loading. The results concerning different types of actuators have been compared to select and indicate the one with the best performance. It has also been shown that for the flextensional actuators with a very high flexibility of constricted hinges, the generated transverse displacement is limited by the maximum electric field as the characteristic property for each piezoceramic material. The change of deflection as a result of applied loads for different actuators architecture has also been presented.

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