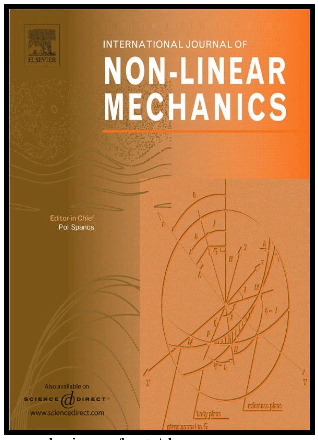

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On the geometric conditions for multiple stable equilibria in clamped arches

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Abstract

Curved structures, such as beams, arches, and panels are capable of exhibiting snap-through buckling behavior when loaded laterally, that is they can exhibit multiple stable equilibria, sometimes after any external loading is removed. This is a consequence of highly nonlinear force-deflection relations with perhaps multiple crossings of the zero-force axis for typical equilibrium paths. However, the propensity to maintain a stable snapped-through equilibrium position (in addition to the nominally unloaded equilibrium configuration) after the load is removed depends on certain geometric properties. A number of clamped arches are used to illustrate the relation between geometry (essentially the shape) and corresponding equilibrium configuration(s), and especially those conditions for which the initial equilibrium configuration is the only stable shape possible. Furthermore, related results are obtained when a change in the thermal environment may cause a system to exhibit a stable snapped-through equilibrium even when the system at ambient thermal conditions does not. Some representative examples are produced using a 3D printer for verification purposes.

Keywords: Snap-through, displacement control, arch, multiple equilibria

1. Introduction

Given a *pin-ended* elastic arch or buckled beam, pushing the system laterally will typically result in the system snapping to its inverted or symmetrically opposed equilibrium position, provided a sufficiently large force or disturbance is applied [1–7]. In the presence of a small geometric imperfection, the symmetry may be broken, but nevertheless it is usually possible to perturb from the initial stable equilibrium to a remote one given a sufficiently large applied force, loading history, or disturbance, and this of course persists after any applied force is removed.

However, when the initial configuration has *clamped* ends, the situation is more ambiguous [8–10]. Although for a zero end angle (for example a clamped buckled beam) we would again expect multiple stable

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