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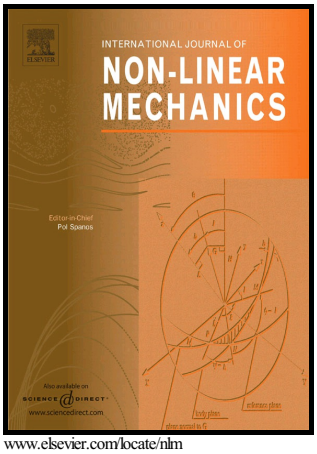


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# Dynamic analysis and design of electrically actuated viscoelastic microbeams considering the scale effect

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**Abstract**

Viscoelastic phenomena widely exist in MEMS materials, which may have certain effects on quasi-static behaviors and transition mechanism of nonlinear jumping phenomena. The static and dynamic behaviors of a doubly clamped viscoelastic microbeam actuated by one sided electrode are investigated in detail, based on a modified couple stress theory. The governing equation of motion is introduced here, which is essentially nonlinear due to its midplane stretching effect and electrostatic force. Through quasi-static analysis, the equilibrium position, pull-in voltage and pull-in location of the system are obtained with differential quadrature method and finite element method. The equivalent geometric nonlinear parameter is presented to explain the influence of the scale effect on the pull-in location. Different from elastic material, there are two kinds of pull-in voltages called as instantaneous pull-in voltage and the durable pull-in voltage in viscoelastic system. Then, Galerkin discretization and the method of multiple scales are applied to determine the response and stability of the system for small vibration amplitude. A new perturbation method to deal with viscoelastic term is presented. Theoretical expressions about the parameter spaces of linear-like vibration, hardening-type vibration and softening-type vibration are then deduced. The influence of viscoelasticity and scale effect on nonlinear dynamic behavior is studied. Results show that the viscoelasticity can reduce the effective elastic modulus and make the system tend to softening-type vibration; the scale effect can increase effective elastic modulus and make the system tend to hardening-type vibration. And most of all, simulation results of case studies are used to realize parameter optimization. Then parameter conditions of linear-like vibration, which is desired for many applications, are obtained. In this paper, the results of multi-physical field coupling simulation are used to verify the theoretical analysis.

**Keywords:** MEMS, Viscoelasticity, Modified couple stress, Multi-scale

## 1. Introduction

Electrostatically actuated microbeams, due to their geometric simplicity, broad applicability, and easy to implement characteristic, have become major components in many