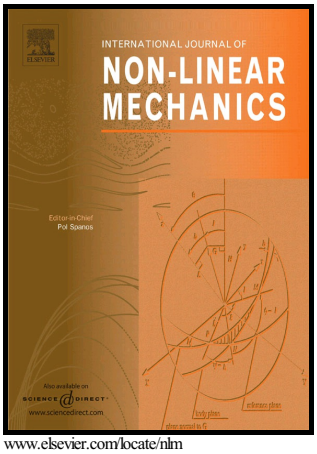

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Abstract

An analytical method is proposed to accurately estimate the pull-in parameters of a micro- or nano-cantilever beam elastically constrained by a rotational spring at one end. The system is actuated by electrostatic force and subject to Casimir or van der Waals forces according to the beam size. The deflection of the beam is described by a fourth-order nonlinear boundary value problem, or equivalently in terms of a nonlinear integral equation. New a priori analytical estimates on the solution from both sides are first derived and then lower and upper bounds for the pull-in parameters are obtained, with no need of solving the nonlinear boundary value problem. The lower and upper bounds turn out to be very close each other and in excellent agreement with the numerical results provided by the shooting method. The approach also provides accurate predictions for the pull-in parameters of a freestanding nanoactuator.

Keywords: Pull-in instability, Electrostatic actuation, MEMS, NEMS, Nanocantilever, Intermolecular surface attractions, Flexible support.

1. Introduction

The fundamental components of many MEMS and NEMS devices is a micro- or nanocantilever beam electrode suspended above a conductive substrate and actuated by a voltage difference which exploits the switching of the flexible electrode between two stable positions. This scheme has been employed in memory devices, manipulators, tweezers, resonators, sensors and other micro- and nanoscale devices [1, 2, 3]. Under the action of the electrostatic and intermolecular surface forces the flexible electrode deflects toward to the substrate. As the beam deflects, the separation distance reduces and correspondingly the magnitude of the attractive forces increases. Then, at a critical voltage, named pull-in voltage, the cantilever tip pulls-in onto the substrate, thus causing a sharp rise in the current through the device in the absence of an intermediate dielectric layer between the electrodes. In general,