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Elaso-plastic behavior of micro strings loaded by distributed electrostatic force

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Abstract

The behavior of a micro string (one-dimensional membrane) made of nonlinear inelastic material and subjected to electrostatic force is analyzed. The present work introduces the coupling between material nonlinearity and the commonly considered geometric and electrostatic nonlinearities. The effects of the material softening behavior on the string response and pull-in instability are studied analytically and numerically. Moreover, the accumulation of irreversible stretching and the residual state of the string after unloading are examined. It is suggested that the residual string elongation can be exploited for various applications, including cold forming and residual stress tuning. Analytical and numerical results show that inelastic irreversible deformation can be achieved in strings of realistic dimensions actuated by feasible voltages.

Keywords: Material softening, Plasticity, Pull-in, Residual stress tailoring, Electrostatic cold forming, Thin membrane

1. Introduction

Electrostatically actuated devices are the most widely used in micro- and nanoelectromechanical systems (MEMS/NEMS) due to relative simplicity of their fabrication, high efficiency of electrostatic forces on the micro and nano scale, low power consumption, quick response and possibility of integration with electronic circuits environments [1, 2]. The behavior of structural elements incorporated in such devices is inherently nonlinear. This