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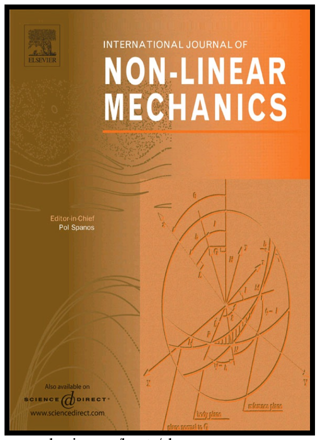

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P. Belardinelli, M.K. Ghatkesar, U. Staufer, F. Alijani

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Linear and non-linear vibrations of fluid-filled hollow microcantilevers interacting with small particles

P. Belardinelli[a], M.K. Ghatkesar[a], U. Staufer[a], F. Alijani[a,*]

[a]*Department of Precision and Microsystems Engineering, TU Delft, Netherlands*

Abstract

Linear and non-linear vibrations of a U-shaped hollow microcantilever beam filled with fluid and interacting with a small particle are investigated. The microfluidic device is assumed to be subjected to internal flowing fluid carrying a buoyant mass. The equations of motion are derived via extended Hamilton's principle and by using Euler-Bernoulli beam theory retaining geometric and inertial non-linearities. A reduced-order model is obtained applying Galerkin's method and solved by using a pseudo arc-length continuation and collocation scheme to perform bifurcation analysis and obtain frequency response curves. Direct time integration of the equations of motion has also been performed by using Adams-Moulton method to obtain time histories and analyze transient cantilever-particle interactions in depth. It is shown that exploiting near resonant non-linear behavior of the microcantilever could potentially yield enhanced sensor metrics. This is found to be due to the transitions that occur as a matter of particle movement near the saddle-node bifurcation points of the coupled system that lead to jumps between coexisting stable attractors.

Keywords: Non-linear vibrations, microbeam-particle interaction, transient response, microfluidics

1. Introduction

The characterization of cells and biological molecules in lab-on-a-chip devices is one of several goals reached by the Nano/Micro-Electro-Mechanical-Systems (NEMS/MEMS) technology in recent years. A wide and fast evolution, driven primarily by new advances in the fabrication processes, have led the sensors shrink in both size and mass, directing to new areas of investigations around previously unexplored experimental regimes [1, 2, 3].

Excellent dynamic characteristics of MEMS and NEMS resonators make them interesting tools for mass sensing and molecular interactions [4, 5]. Among different configurations, suspended cantilever resonators have shown superior qualities in terms of dynamic ranges and quality factors (QFs) comparing to doubly clamped beams [6]. The ability of these micro and nano tools for mass sensing is directly related to the fact that a decrease in the overall dimensions of the sensing device, corresponds to an increase in mass sensitivity, which is proportional to the resonant frequency of the cantilever and inversely proportional to its mass. Therefore, unprecedented sensitivity can be reached by inertial mass sensing [7] with Very High Frequency (VHF) nanobeams [8, 9]. Molecular mass measurements up to zeptogram [10] and attogram scale [11] have been achieved combining higher resonance frequencies and quality factors. The actual real limits of

*Corresponding author: Farbod Alijani, Department of Precision and Microsystems Engineering, 3ME, Mekelweg 2, (2628 CD) Delft, Netherlands. Tel.: +31 (0)15 27 86739. Email: f.alijani@tudelft.nl

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