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Eigenproblem formulation for electromechanical microsystem pull-in voltage optimization

Etienne Lemaire, Laurent Van Miegroet, Emmanuel Tromme, Lise Noël, Pierre Duysinx

Aerospace an Mechanical Engineering Departement, University of Liège, Belgium,
{E.Lemaire;L.VanMiegroet;Emmanuel.Tromme;Lise.Noel;P.Duysinx}@ulg.ac.be

Abstract

Electrostatic actuators are often used in MEMS since they are relatively easy to manufacture and provide a short response time. Previous studies have already considered topology optimization of such micro-actuators like the work by Raulli and Maute [1] and by Yoon and Sigmund [2]. Raulli considers maximization of the actuator output displacement for given electric potential input locations. The paper by Yoon *et al.* goes further by replacing the staggered modeling used by Raulli by a monolithic approach where both physical fields (electric and mechanical) are solved at once.

However, electrostatic micro-actuators possess a limit input voltage called the pull-in voltage, beyond which they become unstable. If a voltage greater than the pull-in voltage is applied to the device, elastic forces of the suspension system are not able to balance electrostatic forces and electrodes stick together. In some cases, the pull-in effect can damage the device. Previous researches by the authors [3] have considered the possibility to control pull-in voltage using topology optimization. In this first approach, pull-in voltage itself was included in the optimization problem and treated as objective function.

Nevertheless, in some applications, the developed pull-in voltage optimization procedure suffers from design oscillations that prevent from reaching solution. As illustrated in this paper, the issue is similar to the mode switching problem that arises in eigenvalue optimization problems. The classical solution to this issue consists in including several eigenvalues in a ‘max-min’ formulation. However as the classical pull-in voltage optimization problem is not formulated as an eigenproblem, direct application is not possible. Indeed, pull-in being a nonlinear instability phenomenon, strictly speaking, it is only possible to compute one instability mode and upcoming instability modes cannot be captured. Therefore, this paper is dedicated to the development of a linear eigenproblem approximation for the nonlinear stability problem after the work on nonlinear buckling by Lindgaard and Lund [4].

The proposed stability eigenproblem leads to an alternative optimization procedure aiming at maximizing pull-in voltage. The first eigenmode corresponds to the actual pull-in mode while higher order modes allow estimating upcoming instability modes. Using a multiobjective formulation to maximize the smallest eigenvalue of the stability problem, it is possible to circumvent oscillation issues met with pull-in voltage optimization. Moreover, numerical results show that even if the eigenproblem formulation is an approximation of the actual pull-in voltage optimization problem, eigenproblem formulation leads to significant improvement of pull-in voltage.

References

[1] M. Raulli and K. Maute, *Topology optimization of electrostatically actuated Microsystems*, Struct. & Mult. Opt., 30(5):342-359, November 2005.
[2] G.H. Yoon and O. Sigmund, *A monolithic approach for topology optimization of electrostatically actuated devices*, Comput. Methods Appl. Mech. Engrg., 194:4062-4075, 2008.
[3] E. Lemaire, V. Rochus, J.-C. Golinval, and P. Duysinx, *Microbeam pull-in voltage topology optimization including material deposition constraint*, Comput. Methods Appl. Mech. Engrg., 194:4040-4050, 2008.
[4] E. Lindgaard and E. Lund, *Nonlinear bucking optimization of composite structures*, Comput. Methods Appl. Mech. Engrg., 199:37-40, 2010.