Fifth International Conference on Advanced COmputational Methods in ENgineering (ACOMEN 2011)
Liège, Belgium, 14-17 November 2011

Topology optimization of electrostatic micro-actuators including electromechanical stability constraint

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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 works by Raulli and Maute in Ref. [1] and by Yoon and Sigmund in Ref. [2]. Raulli considers maximization of the actuator output displacement for given electric potential input locations. This very general method allows the optimizer modifying electrostatic pressure distribution. 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. This improvement simplifies greatly the modeling procedure.

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 since it can be impossible to separate the electrodes afterwards. Previous researches by the authors (see Ref. [3]) have considered the possibility to control pull-in voltage using topology optimization. In order to solve the difficulties one by one, these previous works only study pull-in voltage maximization using topology optimization.

The idea of the present study is to merge the compliant optimization problem with the pull-in voltage optimization problem. Therefore, in this new optimization problem, the pull-in voltage does not appear anymore in the objective function but in a constraint which prevents the pull-in voltage to decrease below a given minimal value $V_{pi,min}$. The objective of the new optimization problem is then to design a microdevice which provides maximum output displacement for a given input voltage $V_{input} < V_{pi,min}$.

The new optimization problem is compared to the basic one without pull-in voltage constraint on basis of numerical applications. The pull-in voltage constraint proved to be very useful since it prevents the pull-in voltage of the mechanism to drop below the driving voltage during the optimization process. Moreover, it has been shown that mechanisms design using topology optimization may lead to mechanisms that exhibit large displacements. Consequently, the effect of geometric non linearity modeling is also tested on numerical applications of our optimization procedure.

References

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