Shape optimization of electromechanical microsystems for prescribed "capacitance-voltage" curve

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The electrostatically actuated devices used in MEMS are generally based on capacitive systems in which one electrode is mobile and the other one is fixed. Applying voltage between the electrodes generates an electrostatic force which tends to reduce the gap between the electrodes. Once the equilibrium reached, quantity of electrical loads accumulated on each electrode determines capacitance of the device. This physical quantity is a very important functional parameter of the structure since it conditions the energy stored between the two electrodes. In some applications, it can be interesting to associate the capacitance obtained for several voltages to various desired values. A simple way to obtain such capacity, named variable capacity, is to work on the geometry of the device.
In the same time, the existence of an electrostatic force between the two electrodes introduces a limit voltage from which no equilibrium between electrostatic and mechanical forces can be found and leads to the pull-in phenomenon. This pull-in instability is undesirable in variable capacities and it becomes obvious to include a restriction on the pull-in voltage in the design process.
Technically, the capacitance and pull-in behaviors involve both mechanical and electrostatic effects. Furthermore, these two contributions are strongly coupled, so that multiphysics finite element simulation is necessary [1]. A Newton-Raphson algorithm is sufficient to obtain the capacitance value but the computation of the pull-in voltage requires the determination of a point of instability. In order to find efficiently this point, the Riks-Crisfield method is combined with a regula falsi algorithm [2]. The Riks-Crisfield algorithm is used to compute the equilibrium position for a given voltage. The successive voltages are computed according to a regula falsi algorithm to lead to the pull-in voltage.
The work presents 2D shape optimization applications of the microbeam mobile electrode. The considered design problem consists in fitting a prescribed "capacitance-voltage" curve with a constraint on the pull-in voltage and a classical volume constraint. The capacitance and pull-in sensitivities will be both computed in a semi-analytical formulation as in ref [2,3]. Solution procedure of the optimization problem is based on CONLIN optimizer using a sequential convex linear programming.

References

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