MAXIMIZATION OF PULL-IN VOLTAGE OF MICRO-ELECTROMECHANICAL STRUCTURES USING TOPOLOGY OPTIMIZATION

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The electrostatic actuation devices used in MEMS are generally based on capacitive systems with one mobile and one fixed electrodes. Applying voltage between the electrodes generates an electrostatic force, which tends to reduce the gap between the electrodes. Due to the non-linearity of the electrostatic force in function of the distance between electrodes, there exists a limit voltage from which there is no equilibrium between the electrostatic and mechanical forces and this leads to the pull-in phenomenon. In some applications, the pull-in instability is undesirable and maximizing pull-in voltage is searched. Microbeam is the simplest example of electrostatic actuated MEMS exhibiting pull-in and consequently it is suited to serve as test to develop topology optimization of similar devices.

The pull-in involves the interaction of both mechanical and electrostatic phenomena. Therefore the computation of the pull-in voltage for a given system requires strongly coupled multiphysics finite element simulations [1]. In order to find efficiently the pull-in voltage, the multiphysics finite elements method is combined with a normal flow algorithm [2]. The normal flow 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 design problem consists in maximizing the pull-in voltage using topology optimization method, which is formulated as an optimal material distribution [3]. In addition to the classical volume constraint, different structural constraints could be taken into consideration. Sensitivity analysis is one of the key issues of the optimization process and is performed with the formulation of eigenvalue topology optimization problems [2]. Here the paper investigates topology optimization of strongly coupled electromechanical systems. To avoid important modifications of the electric field by the optimization process, this first study considers a non design electrode and use topology optimization to design an optimal suspension structure.

Solution procedure of the optimization problem is based on CONLIN optimizer using a sequential convex programming. This method that has proved its efficiency in many structural problems (sizing, shape) is here tailored to strongly coupled multiphysics design problems under consideration. The choice of appropriate explicit convex approximations schemes for multiphysic problems is investigated.

The proposed method is illustrated and validated on microbeam optimization applications.

References

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