Electrostatic coupling of MEMs structures: transient simulations and dynamic pull-in.

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MEMS are very small devices in which electric as well as mechanical dynamics phenomena appear. Because of the microscopic scale, some strong coupling effects between the different physical fields appear, and some forces, which are negligible at macroscopic scales, have to be taken into account. In order to make a good design of these micro-systems, it is important to analyse the coupling between the electrical and mechanical fields. This paper concerns the modelling of the strong electromechanical coupling appearing in micro-electro-mechanical systems (MEMS). The finite element method (FEM) is used to perform transient analysis taking into account large mesh displacements.

The state of the art currently consists in using staggered procedures to compute quasi-static configurations based on the iteration between a structural model loaded by electrostatic forces and an electrostatic model defined on a domain following the deformation of the structure. Staggered iteration then leads to a static equilibrium position. In our work, we have developed a fully coupled electro-mechanical formulation that allows to find static equilibrium positions in a non-staggered way and which provides fully consistent tangent stiffness matrices for transient analysis. A interest of the coupled tangent matrix is the computation of the dynamical behaviour of the coupled problem when we apply suddenly a voltage to the electrodes. Even under the pull-in voltage, the overshoot of the dynamical response may reduce the distance between the plate so that the electric force becomes dominant and the plates stick together. This phenomenon can be considered as a dynamical pull-in.

We will summarize the new formulation developed for simulating strong electrostatic coupling in Microsystems and show simulation examples illustrating the dynamic behavior of MEMs, including dynamic pull-in.