Abstract

Simulation and Synthesis of MicroElectroMechanical Systems

by

Ningning Zhou

Doctor of Philosophy in Mechanical Engineering

University of California at Berkeley

Professor Alice M. Agogino and Professor Kristofer S. J. Pister, Chair

This thesis presents a MEMS simulation method based on modified nodal analysis(MNA) and a synthesis method for MEMS devices using evolutionary techniques.

Modified nodal analysis (MNA) is demonstrated to be successfully applied to MEMS simulation in multi-energy domains. Nodal equations of coupled linear and nonlinear ordinary differential equations in mechanical and electrical domains are formed and solved. Physical models that fit into MNA framework are derived for anchors, two dimensional(2D) linear and nonlinear beams, three dimensional(3D) linear beams, 2D electrostatic gaps with contact models, 2D comb drives, 2D rigid plates. Algorithms for static(DC), steady state and modal frequency analysis are developed. The modified nodal analysis framework together with analysis routines and physical models are implemented as a simulation tool called SUGAR in Matlab. The accuracy of the program is compared with analytical solutions, experimental data, finite element method(FEM) simulations. The verification shows

that this MNA approach could lead to an accurate, fast, higher level simulation package in multi-energy domains for MEMS.

The second part of the thesis incorporates this simulation method into an evolutionary algorithm loop to automatically synthesize MEMS designs. Given a higher-level description of the device's desired behavior, both the topology and sizing of the devices are generated using a Multi-Objective Genetic Algorithm (MOGA). An initial population of candidate designs is generated randomly from a number of available components such as anchors, beams, electrostatic gaps, combs and springs. Each design is checked for geometrical validity and its performance is evaluated by SUGAR. MOGA is then applied to the initial population to iteratively search for functional designs that meet constraints and optimize performance. Variations of design coding schemes, random design generation, selection, crossover, elitism and immigration are implemented to test their effectiveness in producing superior designs in the MOGA implementation. The obtained results on a 2D spring design, gap-closing actuator design and resonator design demonstrated the feasibility of this approach to MEMS functional structure synthesis.

Professor Alice M. Agogino and Professor Kristofer S. J. Pister
Dissertation Committee Chair