Organization(s): **CFD Research Corporation ; Carnegie Mellon University; Georgia Tech; and University of Florida, Gainesville**

Title: Generation of Reduced Parametric Models of Microdevices from High Fidelity Tools

Duration of Effort: August 1997 - August 2000

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Objective

Develop, validate, and demonstrate Software Tools for Automated Generation of Compact/Reduced Models of Microdevices from High Fidelity 3D Simulations.

Progress/Results

- Compact models (Spice and Saber) of squeeze film damping, validated with CFD-ACE+3D simulations, and inserted into the NODAS MEMS-CAD system library at CMU.
- Compact model of lateral (shear) damping in MEMS, validated with CFD-ACE+ .
- Automatic generation of reduced thermal models (R-networks) for MEMS micro-heaters.
- Developed mixed-dimensional and compact fluidic models of microchannels, microvalves, micropumps, droplet generators, and synthetic jets, and procedures of their generation.
- Automatic generation of compact model (lumped capacitances) of comb-drive resonators, from high-fidelity 3D electrostatic simulations with CFDRC's FastBEM.
- At CMU: * The compact squeeze film model was compared with experimental data from a CMOS-MEMS bandpass filter. The NODAS simulation results with new model are in excellent agreement with the experimental measurements. * A first-order model for lateral damping within NODAS. * A new data format GBV (Geometry, Boundary and Volume conditions) for interchange of simulation data between Cadence and CFDRC simulators.
- At Georgia Tech: * Fabricated micromachined synthetic jets with integrated MEMS modulators, and measured with particle image velocimetry (PIV). * Measured characteristics of arrays of synthetic jets in local active control of microsystem temperature. * The data measured with infra-red (IR) camera will be compared with numerical simulations at CFDRC, including the use of reduced models in jet arrays.
- At UF: * Matrix reduction techniques for structure dynamics: Lanczos method, WYD Ritz algorithm. * Testing of the methods on the crab-leg flexure MEMS structure - about 300x acceleration has been achieved in comparison to full 3D FEM computation time. * Validation of the implementation of Lanczos algorithm through comparison with a MEMS structure from MIT. * Implementation of the WYD algorithm in the CFD-ACEUN code of CFDRC.

Status

- Developing a graphical user-interface for automated generation of reduced models from high-fidelity simulations in CFD-ACE+; testing the compact models in MEMS circuits.
- Working on interoperability with other design tools of Composite CAD program.
- Working on technology transfer to academic and industrial partners.

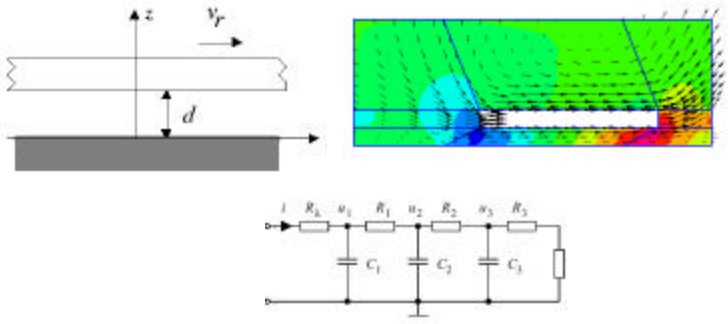


Fig. 1. A new compact/circuit model of lateral damping in MEMS was developed and validated with CFD numerical simulations.

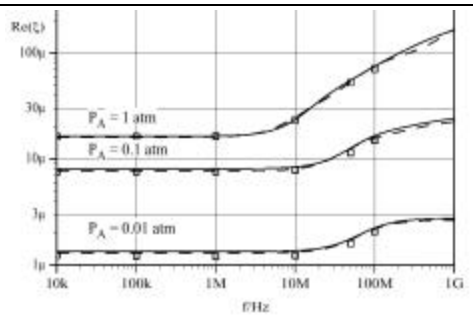
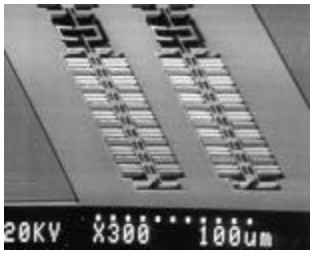
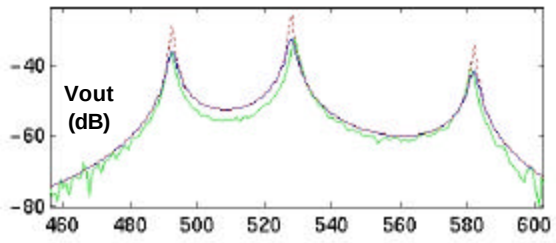


Fig.2. Frequency response of the compact model and the results from numerical simulations

- **CMOS-MEMS 3-resonator filter [Jing et. al. MEMS'00] fabricated at CMU, its characteristics, and NODAS model:**





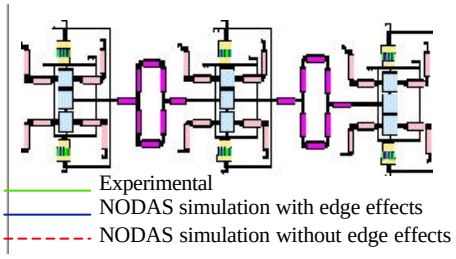
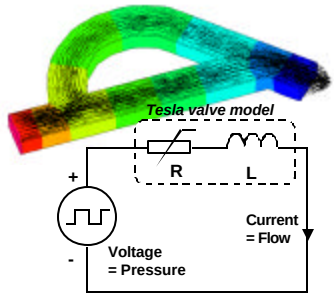


Fig. 3. Squeeze-film damping behavioral model from CFDRC was enhanced at CMU with edge effects and inserted into NODAS CAD system, where it was compared with experimental data. Error in Q was reduced from 20% to 2%.

Nonlinear Circuit Models for Microfluidics, from CFD Simulations



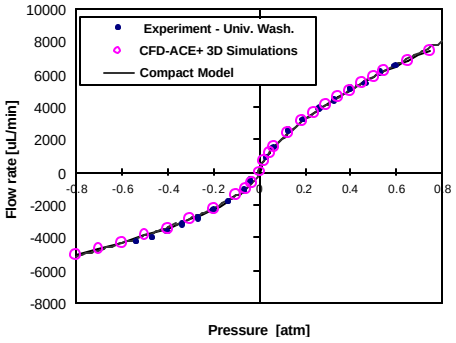


Fig. 4. Tesla Valve: 3D Simulations, Circuit Model, and comparison of characteristics

Synthetic Jets in Temperature Control System

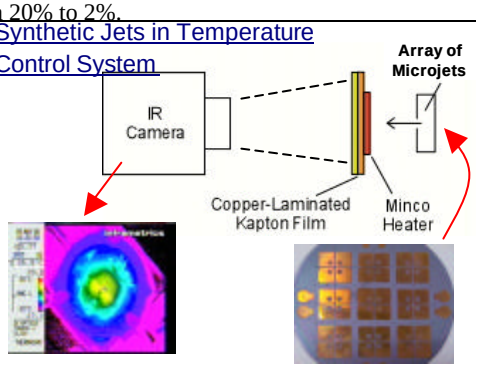
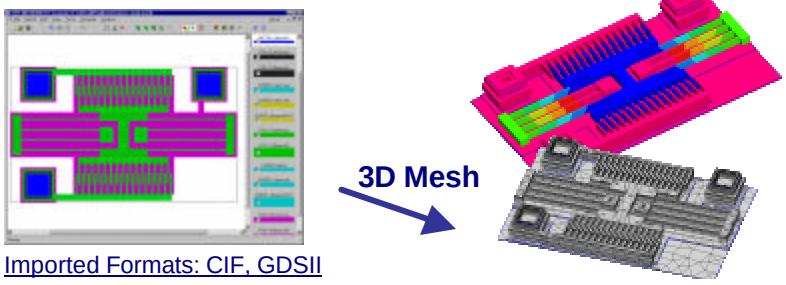


Fig. 5. Georgia Tech experiments are used for CFDRC's reduced models validation.

CFD-Micromesh: **EDA Layouts ➔ Solid Model**



Imported Formats: CIF, GDSII

New: DXF, SIPPs (process description)

Fig 6. Fast, automatic generation of 3D model and mesh from EDA layouts; integrated interface from Cadence

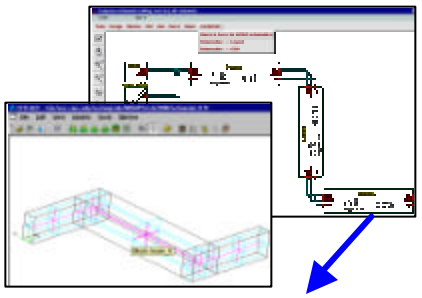


Fig. 7. CMU: Direct model building from CADMEMS Schematic to 3D Mesh (DTF)