Semi-analytical Magnetic-Structural coupling with contact analysis for MEMS/NEMS

Phuong Pham Quang, Benoît Delinchant, Jean-Louis Coulomb, Bertrand Du Peloux

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P. Pham Quang[1,2], B. Delinchant[1], J.L. Coulomb[1] , B. du Peloux[2]
[1]Grenoble Electrical Engineering Laboratory, G2ELab, F-38402 St Martin d'Hères Cedex, France
[2]Cedrat SA, 15, Chemin de Malacher, F-38246 Meylan Cedex, France
pham-quang@g2elab.grenoble-inp.fr

Abstract - This paper presents a methodology and a tool for the coupled magnetic-structural with semi-analytical models. For this coupling, the magnetic model is available; we developed the structural-contact model for the cantilever beam and validate it by finite element simulation. This coupling is dedicated to the optimization process of MEMS/NEMS in general and to magnetic nano switch in particular.

I. Introduction

The magnetic MEMS/NEMS have received much attention in recent years. This one gives a large actuation distance and requires a low voltage action compared with electrostatic MEMS/NEMS. Contact quality depends on surface and contact force, but their modelings are often strongly approximated [1] [2]. This modeling need a deformation analysis with evolving boundary conditions, as it will be detailed in the full paper.

II. Magnetic model

Magnetic fields radiated by permanent magnets and conductors are computed through Coulombian equivalent surface charge approach and Biot-Savart law. Forces and magnetic torques applied on the beam (in magnet) are computed by surface and volume numerical integrations [1].

III. Structural-contact model

We developed a semi-analytical model structure-contact to compute the deformation of the cantilever beam in the presence of contact. Model inputs are geometry, mechanical properties of materials (Young's modulus), punctual forces, and punctual torques applied to the beam. Model outputs are deformation of the beam, length of contact and contact force.

The model is based on three hypotheses that will be detailed in the full paper: 1) small displacement (Bernoulli hypothesis) which allows reducing the cantilever beam 3D (basic geometry of MEMS / NEMS) to 1D, 2) linear and isotropic materials, 3) neglecting the secondary deformations.

Once the cantilever beam is reduced to 1D, the equation used to compute the deformation is: $EI\partial^2 u / \partial x^2 = M$, where E is the Young's modulus, I is the second moment of area, M is the bending moment, with adequate boundary conditions and connection conditions.

In the model, the principle of superposition is used due to elastic linear deformations. Total deformation is equal to the sum of the deformations created by each forces and torques. Contact analysis is realized by several state decompositions, which can be superposed.

Model of contact is inherently coupled with the structural model by replacing the contact by a distribution of force on contact. As this force distribution is not known, an iterative method is used.

The contact force is computed by $F_{contact}=F_{total}-F_{reaction}$, where F_{total} is the total force applied on the beam; $F_{reaction}$ is the reaction force on fixed side of the beam.

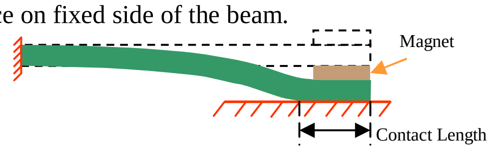

Fig. 1. Geometry in 2D of magnetic nano switch

No known tool can manage the magnetic-structural simulation with contact analysis. However, our contact analysis can be validated separately with constant forces by ANSYS software. Fig 2. shows the variation of the contact length and contact force as function of forces applied on the beam. The results obtained by our model are closed from the results of finite element simulation.

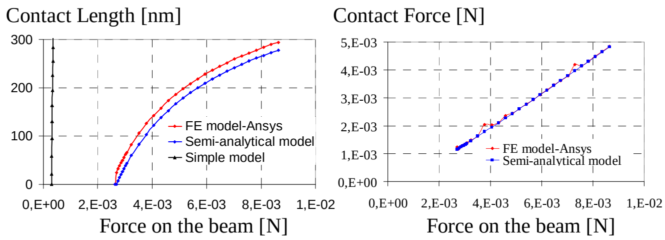

Fig. 2. Results of validation of structural-contact model

IV. Coupling tool

A tool following as [3] is developed, which generates automatically equations to describe the sequential magnetic-structural coupling. The interaction is accomplished via the load vectors of forces, torques and positions. The magnetic model requires position to compute forces and torques. These forces and torques are used in the structural-contact model to compute positions.

V. Conclusions

This work is supported by national project (ANR Monaco) in order to simulate forces exerted on nanometric bodies. Our tool gives the user the ability to add equations, which is very useful to add complementary forces from van der Waals or Casimir effects.

VI. References

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