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***Abstract*—This work focuses on the modeling of mechanical contact applied to Nano-Electro-Mechanical-Systems (NEMS). A magneto-elastic formulation associated to the definition of unilateral contact in static case is presented. This model is discretised by finite element method and a numerical study of a magnetic nano switch is performed.**

I. Introduction

The magnetic MEMS and NEMS have received much attention in recent years, enabling new types of devices related to magnetism. This is given by low voltage and power consumption with large actuation distance which provides a number of advantages compared to electrostatic NEMS [1]. In NEMS technology, magnetic nano switches have many applications as nanomechanical memory, power switches,... Their working principle is based on the deflection of a beam submitted to the influence of a magnetic field. The mechanical contact between beam and substrate depends on surface and contact force. Contact quality is an important parameter, nevertheless its modeling are often strongly approximated [2]. In this work, a magneto-elastic model including unilateral contact formulation and its discretisation by the finite element method is proposed. The modelisation is applied to a magnetic nano switch.

II. Magneto-Mechanical Modeling

The problem under consideration involves the contact of an elastic body, submitted to magnetic forces, with a rigid (or elastic) body in static case. In the framework of linear elasticity, the mechanical problem is defined by:

$$\begin{cases} \nabla \cdot \boldsymbol{\sigma} + \boldsymbol{f} = 0 & \text{in } \Omega_m \\ \boldsymbol{\sigma} = \boldsymbol{C} : \boldsymbol{s} & \text{in } \Omega_m \\ \boldsymbol{\sigma}(\boldsymbol{u}) \cdot \boldsymbol{n} = \boldsymbol{t} & \text{on } \Gamma_\sigma \\ \boldsymbol{u} = \boldsymbol{u}_0 & \text{on } \Gamma_u \end{cases} \quad (1)$$

where $\boldsymbol{s}$ is the strain tensor defined in the assumption of small displacement and $\boldsymbol{\sigma}$ the stress tensor linked to $\boldsymbol{s}$ by the stiffness tensor $\boldsymbol{C}$. $\boldsymbol{f}$, $\boldsymbol{t}$, $\boldsymbol{u}_0$ and $\boldsymbol{n}$ are, respectively, the body forces, the prescribed tractions, the imposed displacements and the outward unit normal vector.

For a frictionless contact, the unilateral contact conditions on the contact boundaries Γ_c, which implies that no boundary point of the first body may penetrate the other, are defined by:

$$\begin{cases} g_n = (\boldsymbol{u}_2 - \boldsymbol{u}_1) \cdot \boldsymbol{n} \geq 0 \\ \sigma_n = \sigma_{n_1} = -\sigma_{n_2} \leq 0 \\ \sigma_n \cdot g_n = 0 \end{cases} \quad (2)$$

with g_n the signed normal distance and σ_n the normal component of the tractions vectors. The first condition states that no penetration may occur. Hence, this is the form in which the impenetrability constraint is cast. Using this, the normal traction can be characterised. The second condition states that the contact normal traction should be compressive. Finally, the third condition states a complementarity condition. If there is no contact, then no compressive tractions can occur. Alternatively, if there are no compressive stresses, then the distance must be positive.

In the static case, the formulation of the magneto-elastic contact problem according to variational principles, gives the following magnetic and mechanical formulations associated to arbitrary variations $\boldsymbol{\delta a}$ and $\boldsymbol{\delta u}$:

$$\int_\Omega \nabla \times \boldsymbol{\delta_a} \, \boldsymbol{\nu} \, \nabla \times \boldsymbol{a} \, d\Omega + \int_{\Gamma_h} \boldsymbol{\delta_a} \cdot (\boldsymbol{h} \times \boldsymbol{n}) \, d\Gamma = \int_\Omega \boldsymbol{\delta_a} \cdot \boldsymbol{j} \, d\Omega \quad (3)$$

$$\int_{\Omega_m} s(\boldsymbol{\delta u}) \boldsymbol{C} \boldsymbol{s} - \boldsymbol{\delta u} \cdot \boldsymbol{f} d\Omega - \int_{\Gamma_\sigma} \boldsymbol{\delta u} \cdot \boldsymbol{t} d\Gamma - \boldsymbol{\delta u} \left(W(\boldsymbol{b}, \boldsymbol{0}) \right) \geq 0 \quad (4)$$

with $\boldsymbol{a}$ the magnetic vector potential and $\boldsymbol{j}$ the current density. The inequality (4) is due to the contact definition and resolution are realizing by a penalty method, the Lagrange multiplier method or an augmented lagrangian method [3].

III. Application

Modeling is applied to a magnetic NEMS, constituted of a ferromagnetic beam fixed at one end, and a permanent magnet. Under the action of magnetic forces, the beam undergoes a bending which leads it brought into contact with the substrate (Fig. 1).

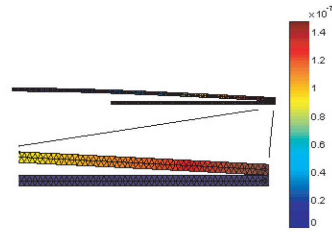

Fig. 1. Deformation of the beam in contact with the substrat

IV. Conclusion

In this paper, the formulation of a magneto-mechanical contact problem for a finite element analysis has been presented. In the full paper, this model will be developed and particularly the finite element discretisation, the numerical resolution thanks to regularization methods and the procedure to improve the contact management.

References

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