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OPTIMIZATION OF A MAGNETIC DEFORMABLE NANO SWITCH BASED ON SEMI-ANALYTICAL MODEL

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Abstract. This paper is about the optimization of magnetic nano switch. A tool based on semi analytical model is presented. It allows realizing the magnetic structural coupling considering contact analysis. The optimization methodology using a direct method and successive response surfaces is discussed.

Keywords: Contact analysis, magnetic nano switch, magnetic structural coupling, reponse surface.

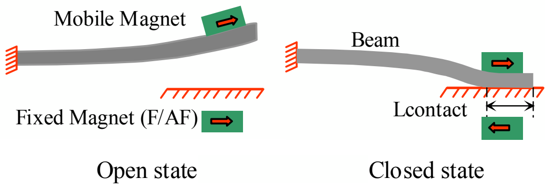
I. INTRODUCTION

Magnetic nano switches have many applications as power switches, nanomechanical memory ... Their working principle is based on the deflection of a beam with magnet under the influence of the field created by a ferromagnetic/antiferromagnetic (F/A) association, which is able to create more than 2T fields without power supply [4] [5]. The switching is achieved by reversing the magnetization of the F/A using conductors.

In this paper, the virtual design of a magnetic nano switch -and especially its preliminary sizing- is addressed, using two non-commercial software realized in our laboratory. As no known tool can manage the magnetic-structural simulation with contact analysis, we developed in our Macmmems software [2] a dedicated semi-analytical model for this coupling. FGOT software [3] is then used for the optimization using direct or successive response surface method.

II. MODELLING

II.1 Modelling software



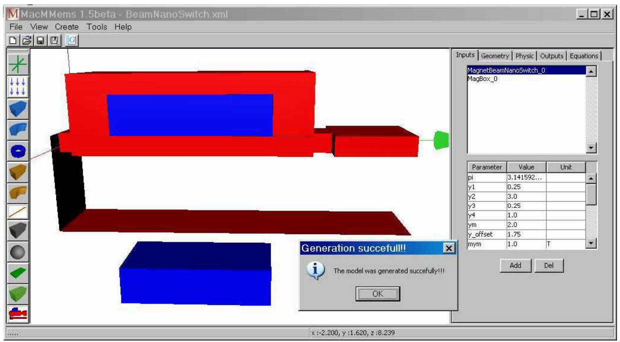


Figure 1. Magnetic nano switch: Operating principle (left) and modelling in MacMMems (right)

II.2 Semi-analytical modelling

II.2.1 Magnetic modelling

Thanks to basic geometries, magnetic fields radiated by permanent magnets and conductors are computed by using pure algebraic equations through Coulombian equivalent surface charge approach and Biot-Savart law. Surface and volume numerical integrations are used to compute magnetic forces and torques applied on the beam (in magnet) [2].

II.2.2 Structural-contact modelling

We developed and validated a semi-analytical model structure-contact to compute the deflection of the cantilever beam in the presence of contact [1]. The model is based on three hypotheses: 1) small displacement (Bernoulli hypothesis) which allows reducing the 3D cantilever beam to 1D, 2) linear and isotropic materials, 3) neglecting the secondary deformations.

The principle of superposition is used due to elastic linear deflection. Total deflection is equal to the sum of the deflection 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 forces. As this forces distribution is unknown, an iterative method is used.

II.2.3 Magnetic – structural coupling

A add-on in [2] has been 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.

III. OPTIMIZATION SPECIFICATIONS

Two magnetization structures of the magnetic nano switch are proposed: Horizontal magnetization or vertical magnetization of magnets.

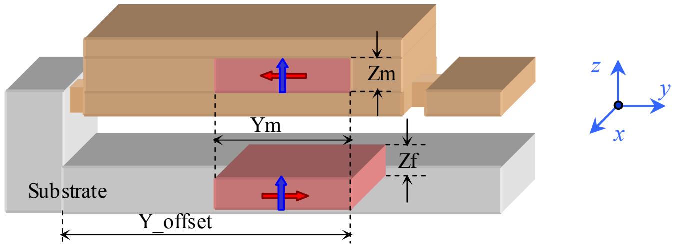


Figure 2. Two magnetization structures of magnetic nano switch and parameters to be optimized

The optimization aims to determine the dimensions of both fixed and mobile magnets and their positions on beam, to minimize the volume of magnets, while respecting constraints such as length of contact and contact force (to ensure the quality of contact or contact resistances below a desired value).

Inputs	**Comments**	**Type of constraint**	**Units**
Ym	Width magnets (mobile and fixed)	[100 ; 800]	nm
Zm	Mobile magnet height	[50 ; 500]	nm
Zf	Fixed magnet height	[50 ; 500]	nm
Y_offset	Positions of magnets (mobile and fixed)	[2500 ; 3500]	nm
Outputs			
L_contact	Contact's length	≥ 300	nm
F_contact	Contact's force	≥ 1.0E-8	N
V_magnet	Volume of magnets	Objective function (to be minimized)	nm^3

Table 1. Optimization specifications

IV. OPTIMIZATION RESULTS AND CONCLUSIONS

Considering direct optimization, a standard genetic algorithm is used, with a population of 1000 individuals, and during 5000 generations, corresponding to 20 hours computing and about 120000 model evaluations.

Our second approach uses a response surface, based on polynomial approximation using a latin hypercube sampling. Then a combination of a gradient based algorithm (SQP) and a standard genetic algorithm are used to optimize on the response surface. The space is also reduced and centred arround the solution, repeating iteratively this process. Ten iterations were done, leading to 308 evaluations of the model in about 3 minutes.

	Initial values	**Optimized values**			
		Horizotal magnetization (My)		Vertical magnetization (Mz)	
		Direct	Response surface	Direct	Response surface
Ym	500	230	228	203	204
Zm	200	212	219	146	143
Zf	200	222	219	142	145
Y_offset	3200	3500	3500	3500	3500
L_contact (constraint)		310,86	311,13	311,07	311,45
F_contact (constraint)		1,0001E-8	1,0009E-8	1,0009E-8	1,0056E-8
V_magnet (objective)	1,0E8	4,991E7	4,9932E7	2,9232E7	2,9376E7

Table 2. Optimized results

In conclusions, the direct method with genetic algorithm can find a good result but with a long time. The indirect method with successive response surfaces is faster, and leads to the same solution which is accurate enough for preliminary sizing. The structure comparison shows that structure with vertical magnetization is better than horizontal one.

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