Coventor MEMS+ Application for Simulation Rotational Motion Microsensor

Jacek Nazdrowicz

Lodz University of Technology
jnazdrowicz@dmcs.pl

INTRODUCTION

Creating output MEMS sensor for manufacturing requires preparation in dedicated software environment like well-known Cadence. However, before that, many simulations must be performed to get satisfied responses from such system. In case of micromechanical systems one can use Coventor MEMS+ because it is more convenient for designing and it has interface to Cadence environment to perform simulation and prepare final structure for fabrication. On the other side this software has excellent interface to Matlab/SIMULINK environment which allows to create model including dedicated MEMS+ object (for example gyroscope).

PHYSICAL MODEL OF MEMS GYROSCOPE AND RESULTS OF SIMULATIONS

Model of MEMS Gyroscope which was chosen is presented in fig.1. It vibrates in x direction and measures rotation of object around y axis (Coriolis force is along z direction). It consists of four beams anchored at the ends and have four Box Beams springs included. Box Beam springs application gives better motion stability in z-direction and also takes much less space in compared to serpentine spring.

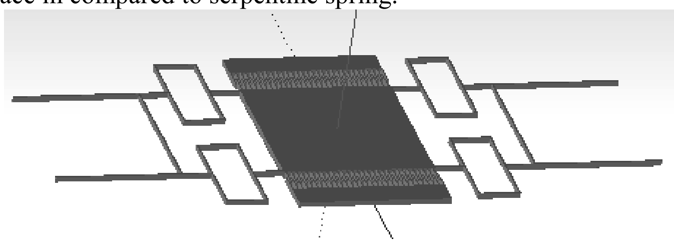

Fig. 1 Gyroscope model used in simulations.

In fig. 2 there are results of modal analysis presented. For this gyroscope first two modes should be considered only and their eigenfrequencies (table 1). Tuning gyroscope to get appropriate frequencies causes getting maximum displacement along sense direction. Next modes are ineffective and they are not used during optimization.

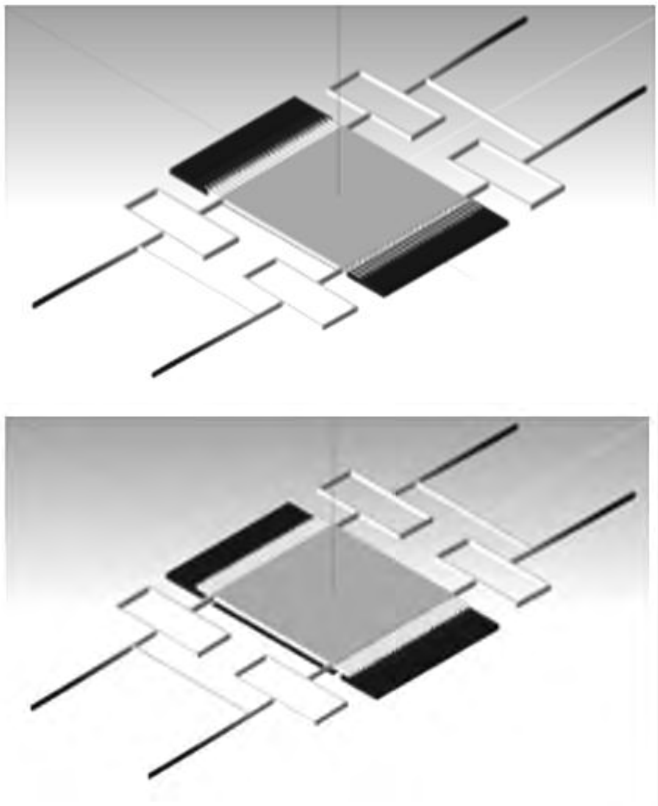

Fig. 2 Modal analysis results for first and second modes.

TABLE 1

MODAL ANALYSIS RESULTS

#	Mode Frequency (Hz)	Pole (real, imag)	Q factor	Maximum Translation
1	9685.13	(-18.5158,60853.5)	1643.28	Mass_x
2	14460.3	(-41.1875,90856.6)	1102.96	Mass_z
3	24730.3	(-120.444,155385)	645.05	M61_z
4	44825.2	(-396.565,281645)	355.106	M63_z
5	48570.5	(-466.433,305177)	327.14	Mass_y

Results presented in table 1 (for five first modes) show that maximum translation for y direction can be achieved for 48570Hz frequency applied, therefore the optimal solution is to choose x direction for actuation and z direction for sensing (lower frequencies).

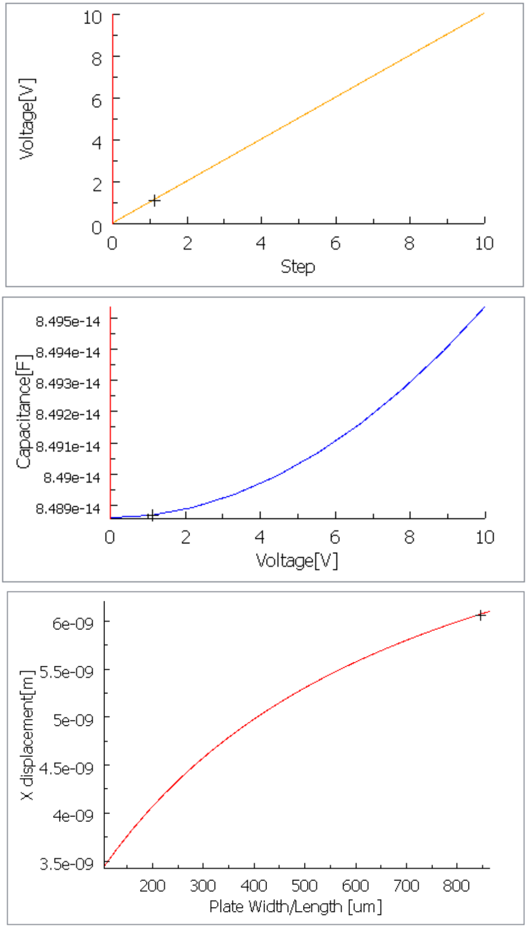

Fig. 3 Voltage steps, capacitance versus voltage,
x displacement versus on plate dimensions plots.

In fig. 3 (middle) there are outputs how capacitance changes for different voltage applied in actuator (0V is applied to mass). We see that this dependency is not linear - the best capacitance results are for higher electrodes voltage. Very interesting are results of displacement in all

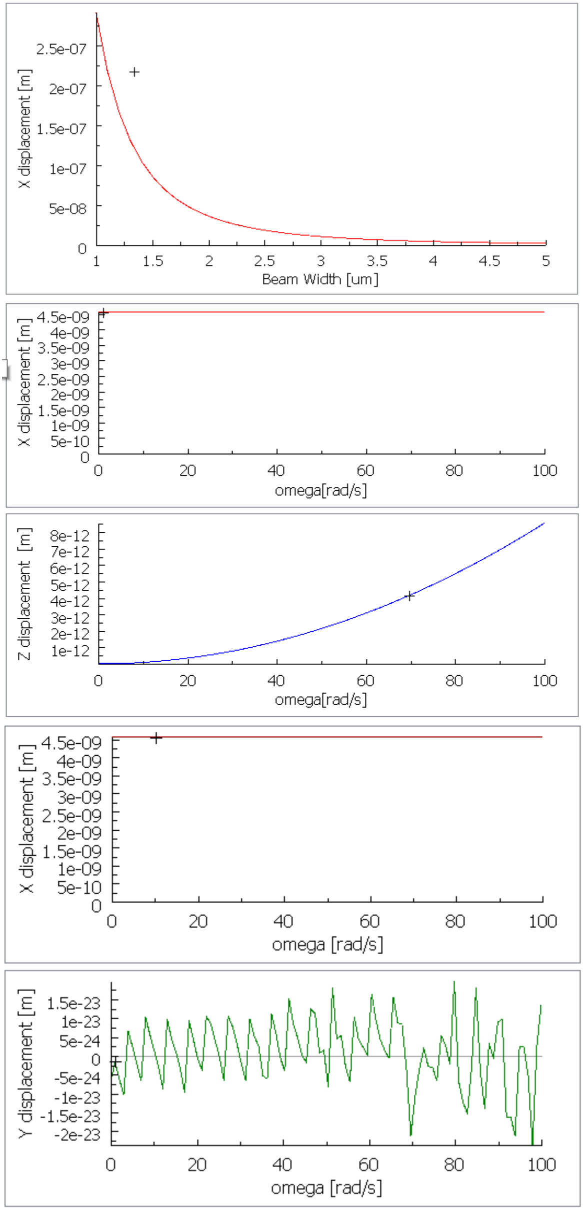

Fig. 4 X displacement versus beam width, x/z displacements versus rotational velocity, x/y displacements versus rotational velocity.

directions with various geometry details. We see in fig. 3 (right) that increase one dimension (width or length) causes nonlinear decrease amplitude in x direction (with the proviso that for small dimensions change is higher than for large dimensions).

In fig. 4a we see dependency x amplitude on beam width. It is obvious that increase this dimension will decrease amplitude in x direction (and y, z too), because of stiffness growth. However amplitude changes more meaningful for small width values.

Fig. 4 middle and 4 right presents output results for displacement dependent on rotational velocity for two cases. In fig. 4 (middle) rotation is on y axis, in fig. 4 (right) rotation is on z axis. As one can see better results are for first case. Note, that for case where rotation is around z axis, maximum displacements are of 10^{-12}m order (10^4 times less than for actuator). For second case this is 10^{-23}m order (10^{15} times less), moreover, this dependency extremally fluctuates.

CONCLUSIONS

Presented results initially show how important are modal and DC analysis. Thanks to them we can see what are maximum displacements, how behaves sensor and what need to be considered during sensor design. As we can see DC analysis showed us that sensor based on Coriolis phenomena have much smaller displacement along sense directions in compare to drive one. This causes that electrostatically based sensing method gives very small capacitance differences, what can cause errors and inaccuracies. Modal analysis allows us detect the optimal sense directions and eigenfrequencies which enable resonant what gives meaningfully better displacement results.

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