Multi-physics modeling of Micro-Electro-Mechanical-Systems using EMS for SOLIDWORKS

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Agenda

- Overview about MEMS applications
- Challenges versus solutions
- Examples
- Conclusion





MEMS- Micro-Electro-Mechanical-Systems



https://www.arrow.com/en/research-and-events/articles/mems-and-iot-applications







MEMS devices forecast by application (\$M) (Status of the MEMS Industry report, July 2012, Yole Development)



MEMS Applications: Challenges versus solutions **EMS for SOLIDWORKS** Em Challenges **Solutions** Geometrical modeling **SOLIDWORKS** Isotropic, anistropic, Materials modeling temperature dependent,etc Ohmic losses, electric and Electric and magnetic magnetic forces modules (static, harmonic Capacitance, inductance, and transient) resistance, etc Thermal and structural Multi-physics coupling

Design iterations

Parameterization (geometrical and simulation variables)/ SW multiconfigurations





 $C = \frac{2n\varepsilon_{0}t(y_{0}+y)}{g}$

Optimizing the Performance of MEMS Electrostatic Comb Drive Actuator with Different Flexure Springs. Shefali Gupta , Tanu Pahwa , Rakesh Narwal , B.Prasad , Dinesh Kumar



New Study			0	
✓ × +				
General Properties	Coupling Analysis	Advanced Properties		
Study Name			^	
Study 4				
Analysis Type			^	
🧄 Magnetos	static			
► AC Magnetic				
() Transient Magnetic		EMS mod	lules	
🙀 Electrosta	tic			
Ω Electric Co	onduction			
🛞 AC Electri	ι J			
Solution Parameters			^	
Iterative solver	residual error	1e-06	\$	
Parameteriz	ation			
Compute Ca	apacitance			
Compare Fi	elds to Breakdown L	evel		

	New Study					?
✓ ×	*					
General Pr	operties	Coupling A	Analysis	Advanced Properties		
Coupling	Analysis					^
T	hermal co	upling				
St.	tructural	coupling	Μι	ultiphysics		
Motion coupling coupled analyses						
□ c	oupling t	o circuit	of	EMS		











Mechanical Displacement Results

Von Mises Stress Results





Von Mises Stress Results versus Voltage





Fixed-fixed beam

Crab leg flexure beam

Folded flexure beam





Mechanical Displacement Results

Von Mises Stress Results





Mechanical Displacement Results



Von Mises Stress Results



Stress (N/m^2)

Displacement Results for Different Configurations 4.00E+06 1.8 1.6 3.50E+06 1.4 3.00E+06 2.50E+06 **Displacement (nm)** 1 0.8 0.6 Stress 2.00E+06 Mises 1.50E+06 **5** 1.00E+06 0.4 5.00E+05 0.2 0.00E+00 0 120 0 20 40 60 80 100 140 0 20 40 60 80 100 120 140 Voltage (V) Voltage (V) ——— Crab leg flexure beam — Fixed fixed beam ---- Crab lef flexure beam

Von Mises Stress Results for Different Configurations







0

Silicon Properties

Properties	Values	
Relative permittivity (ε_r)	4.5	
Electrical conductivity (σ)	45000 S/m	
Young modulus (E)	160*10^9 Pa	
Poisson ration (ν)	0.22	
Mass density	2320 kg/m^3	
Thermal expansion	2.6e-6 (1/K)	
Thermal conductivity	34 (W/m*K)	
Specific heat	678 (J/Kg*K)	



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600 **Temperature Variation versus** Temperature (Celsius) Temperature (C) 500 6.384e + 0025.822e + 002Time 400 5.259e + 002300 700 4.697e+002 200 4.135e + 002600 100 3.573e+002 0 3.011e+002 0 0.01 0.02 0.03 2.449e+002 0 1.886e + 002Distance (mm) 1.324e + 0027.622e+001 2.000e+001 **Temperature Variation Along the Hottest Arm** 700 100 600 Temperature (C) 500 0 400 0 0.0005 0.001 0.0015 0.002 300 Time (s) 200 100 **Temperature Results** 0 0.2 0.05 0.1 0.15 0 Distance (mm) WORKS

Temperature Variation Across the Actuator

700



Temperature Results versus Applied Voltage





---Displacement ---Von Mises Sress



Thermal Conductivity Electrical Conductivity 40 60000 35 Sigma (S/m) 2. 40000 30 **3** 25 **3** 20 **1** 15 20000 - 🗆 🗙 S EMS Function Curves 🗑 🗃 🖬 🌣 🗸 🗙 🙆 15 0 Curve Preview (Electrical Conductivity vs Temperature 4) 🗩 🗩 🖾 🚊 800 Mil Libraries 1200 10 200 400 600 Electrical C 5 Electrical Conductivity vs **Temperature (K)** 40.00 Electrical Conductivity Electrical Conductivity vs 0 GMS_BH_Curves 200 400 600 800 1000 0 🖮 🍓 TR1 30.00 600 1,000 **Temperature (C)** 400 800 X [K] **Specific Heat Thermal Expansion** 1.2 5.00E-06 Specific heat (J/g*K) Thermal expansion (1/K) 1 4.00E-06 0.8 3.00E-06 0.6 2.00E-06 0.4 1.00E-06 0.2 0 0.00E+00 2500 500 1000 1500 2000 0 200 400 600 800 1000 1200 **Temperature (C) Temperature (K)**





Temperature and Displacement Results

Temperature Results
Displacement Results

	Max temp.	Max disp.	Max stress
Constant properties	635	2.32	2e+8
Temperature dependent properties	700	2.48	2.15e+8
Error (%)	10%	6.8%	6.9%





Mechanical Displacement Results











Example 3- Valveless micro-pump







a) Picture of the fabricated micro-pump, b) and its schematic illustration

a) 3D isometric view of the micropump b) cross-sectional view of the micro- pump.

(b)



Example 3- Valveless micro-pump





Conclusion

- EMS was used to study different MEMS devices including electric and magnetic applications
- Electrostatic and magnetic forces were computed by EMS
- Ohmic losses and capacitance results were calculated by EMS
- Temperature variation and structural deformation were estimated versus different situations and scenarios
- EMS results were compared to experimental and analytical results

