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

by

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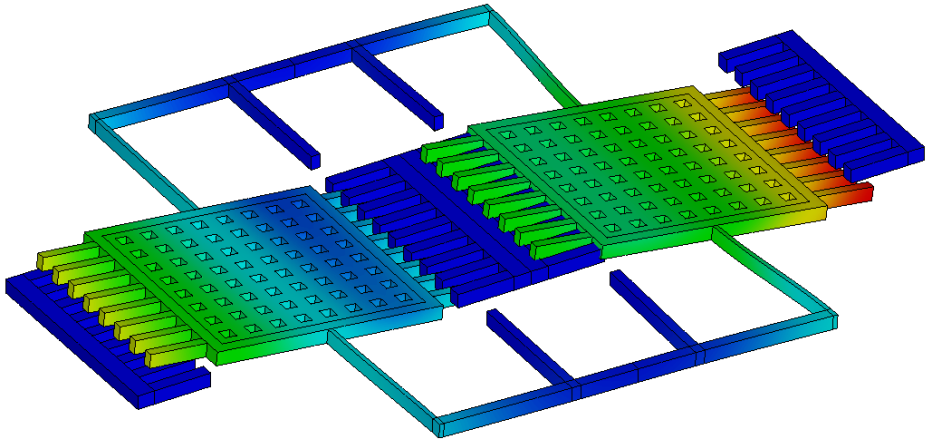
EMWORKS

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



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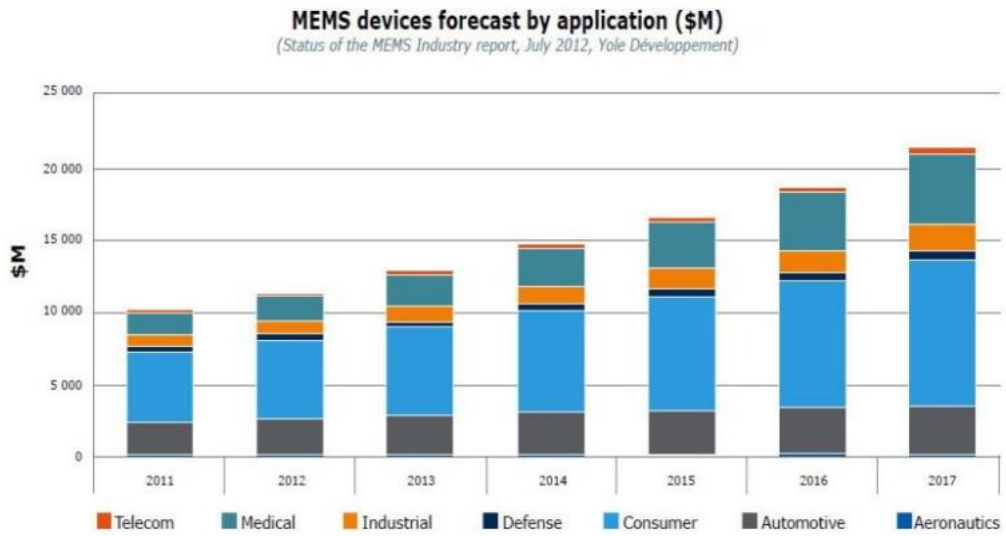

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MEMS Applications: Challenges versus solutions

EMS for SOLIDWORKS

Challenges	Solutions
Geometrical modeling	SOLIDWORKS
Materials modeling	Isotropic, anistropic, temperature dependent,etc
Ohmic losses, electric and magnetic forces	Electric and magnetic modules (static, harmonic and transient)
Capacitance, inductance, resistance, etc	
Multi-physics	Thermal and structural coupling
Design iterations	Parameterization (geometrical and simulation variables)/ SW multi-configurations

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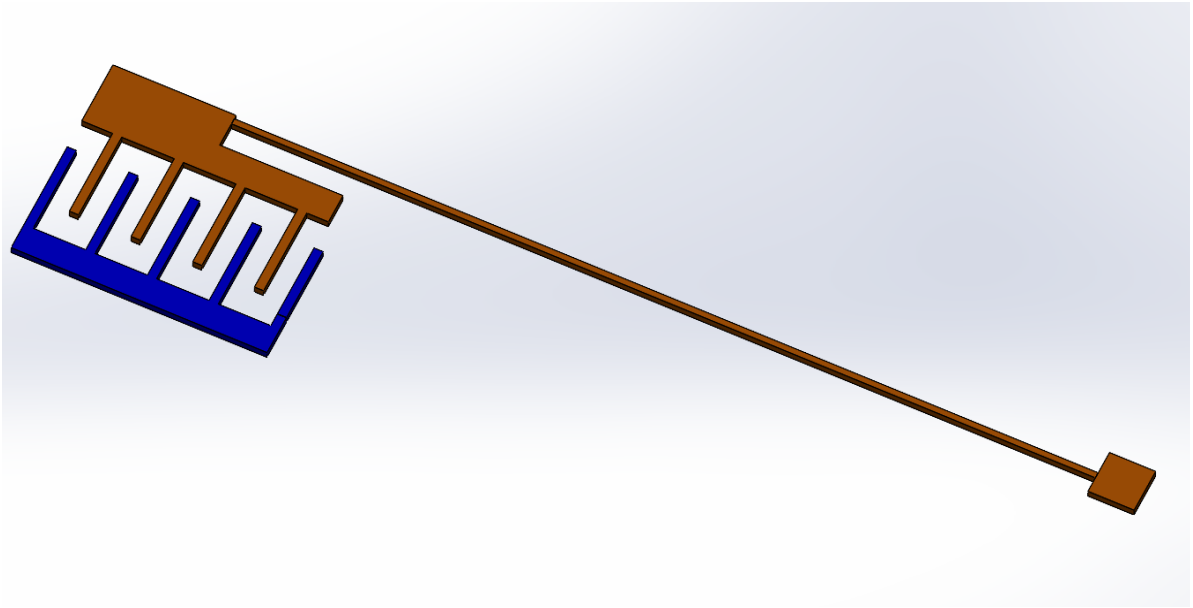
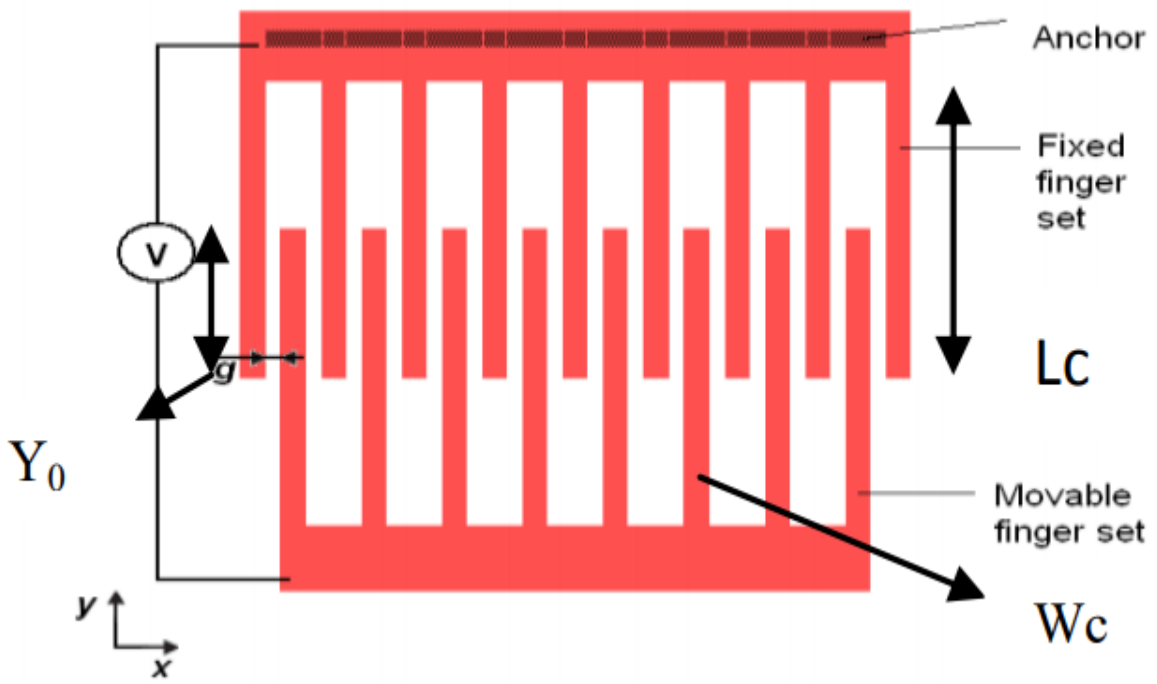
Example 1- Comb drive actuator





$$C = \frac{2n\varepsilon_0 t(y_0 + y)}{g}$$

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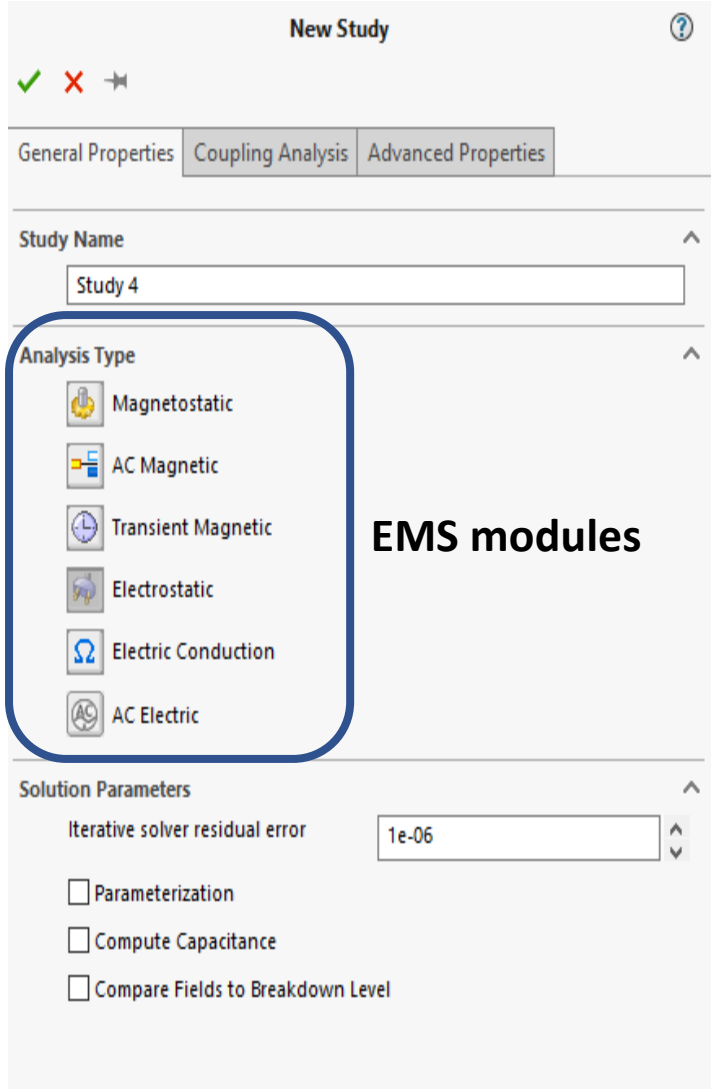
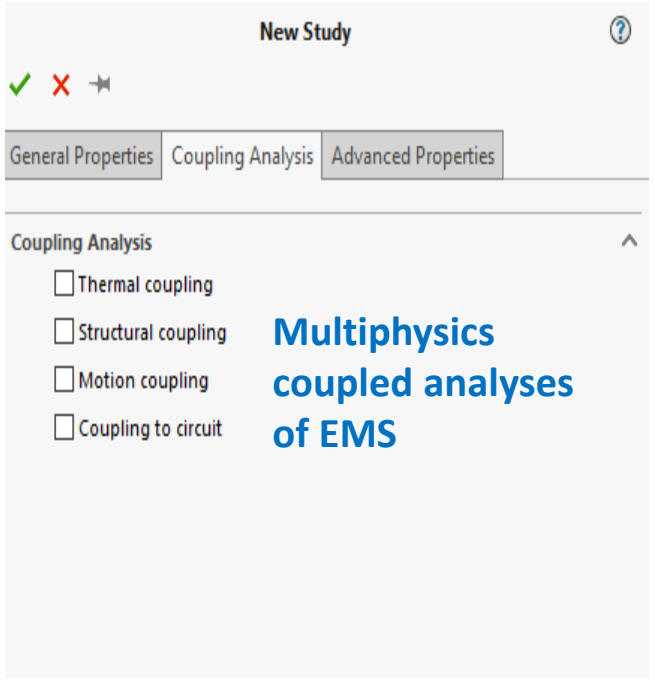
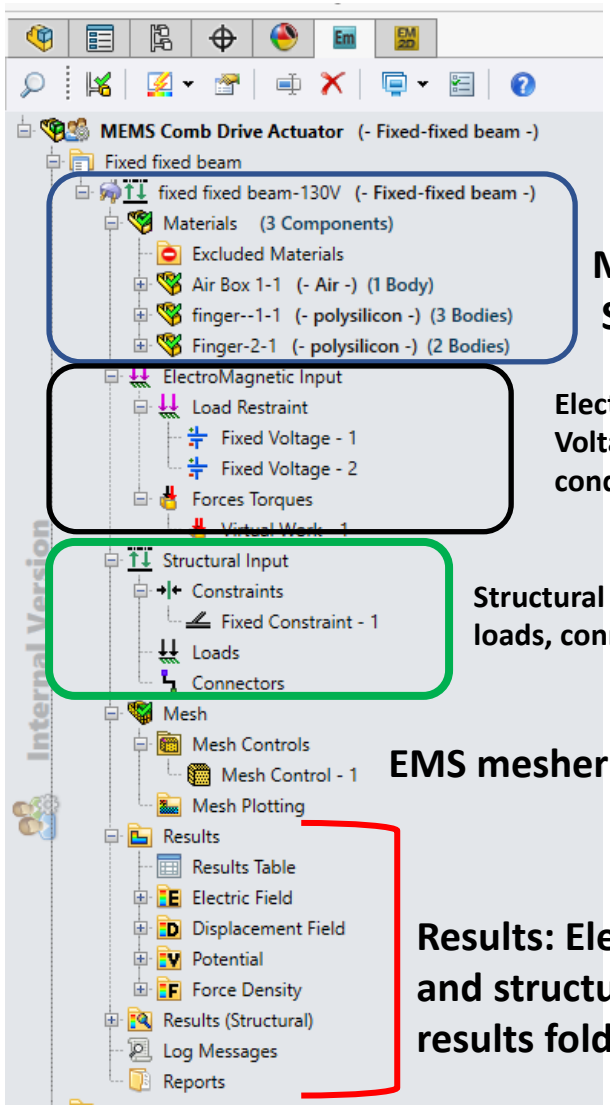


EMS modules



Multiphysics coupled analyses of EMS



EMS Tree

Materials Section

Electromagnetic inputs: Voltage, charge, floating conductors/ force definition

Structural inputs: constraints, loads, connectors…

EMS mesher

Results: Electric and structural results folders

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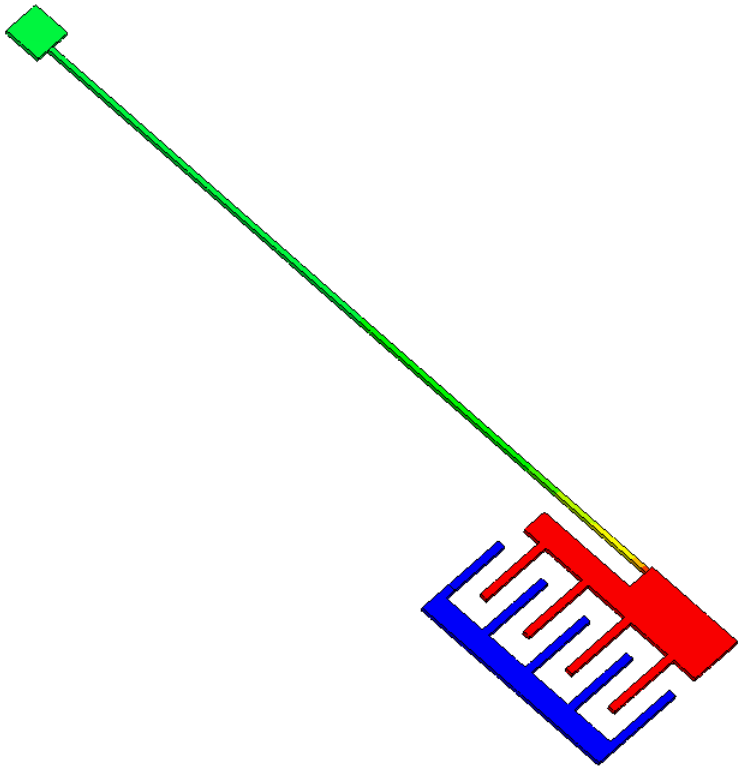
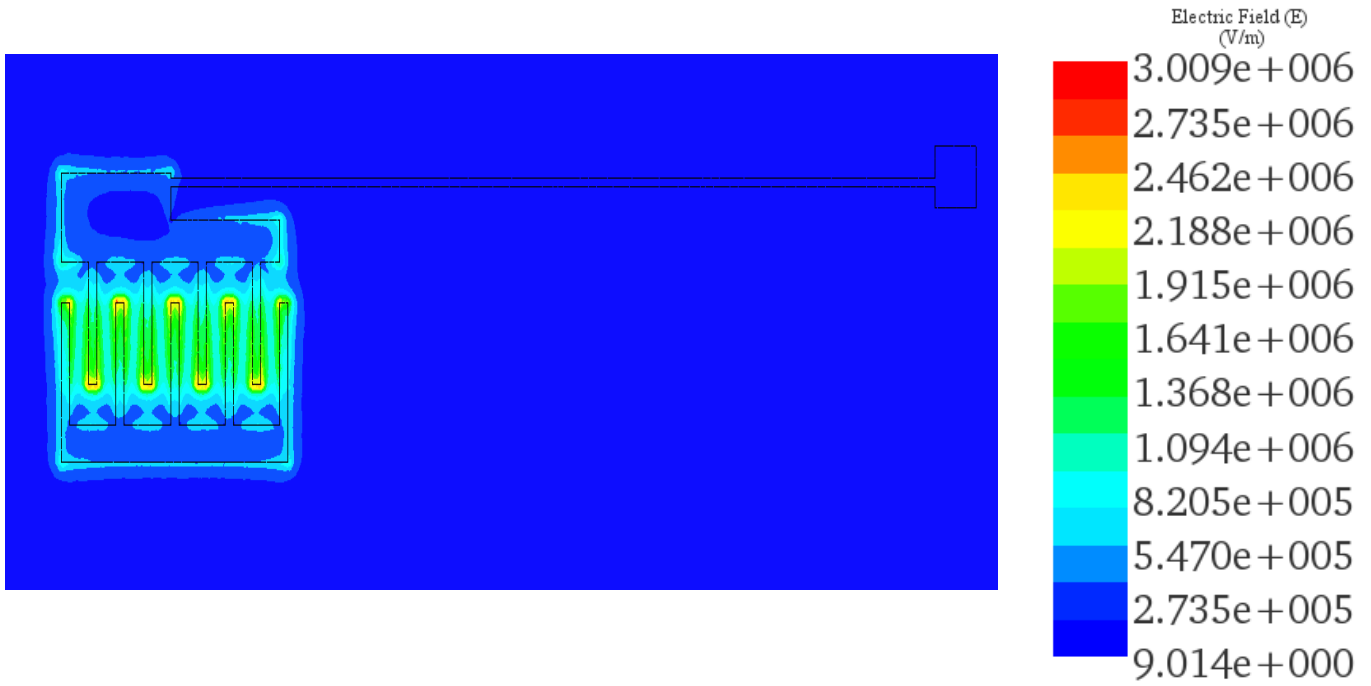


Voltage Results



Electric Field Results

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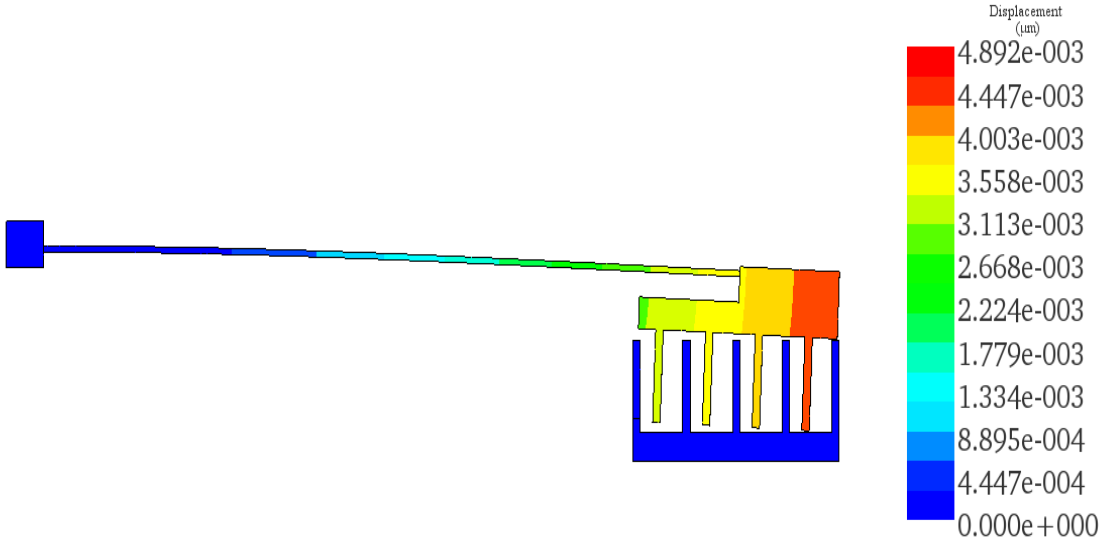
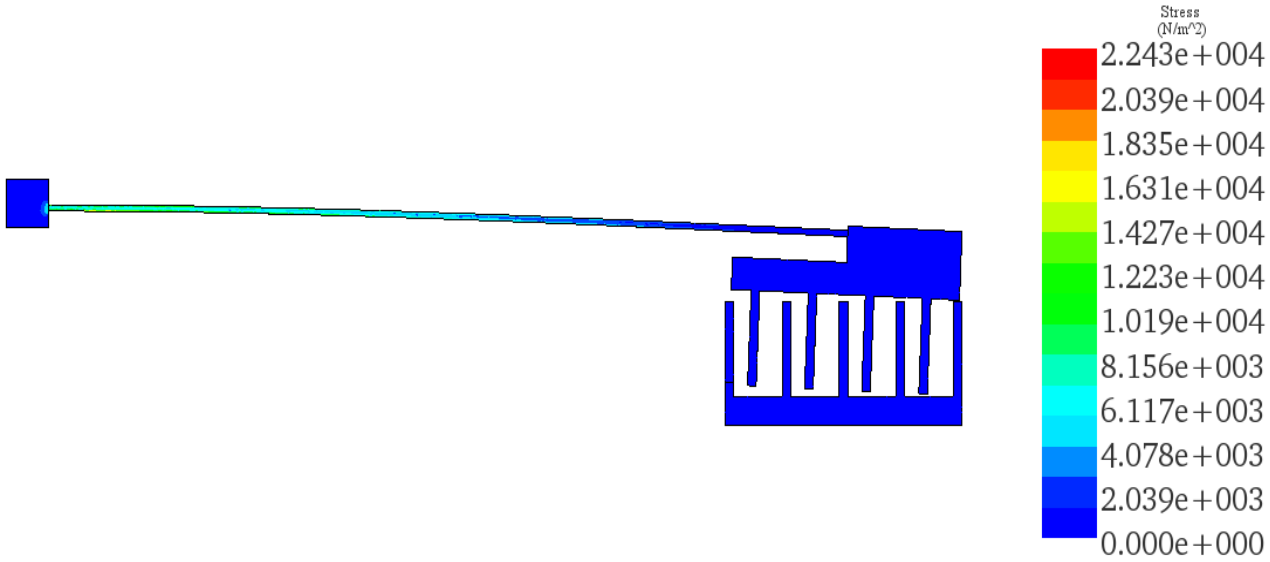


Mechanical Displacement Results



Von Mises Stress Results

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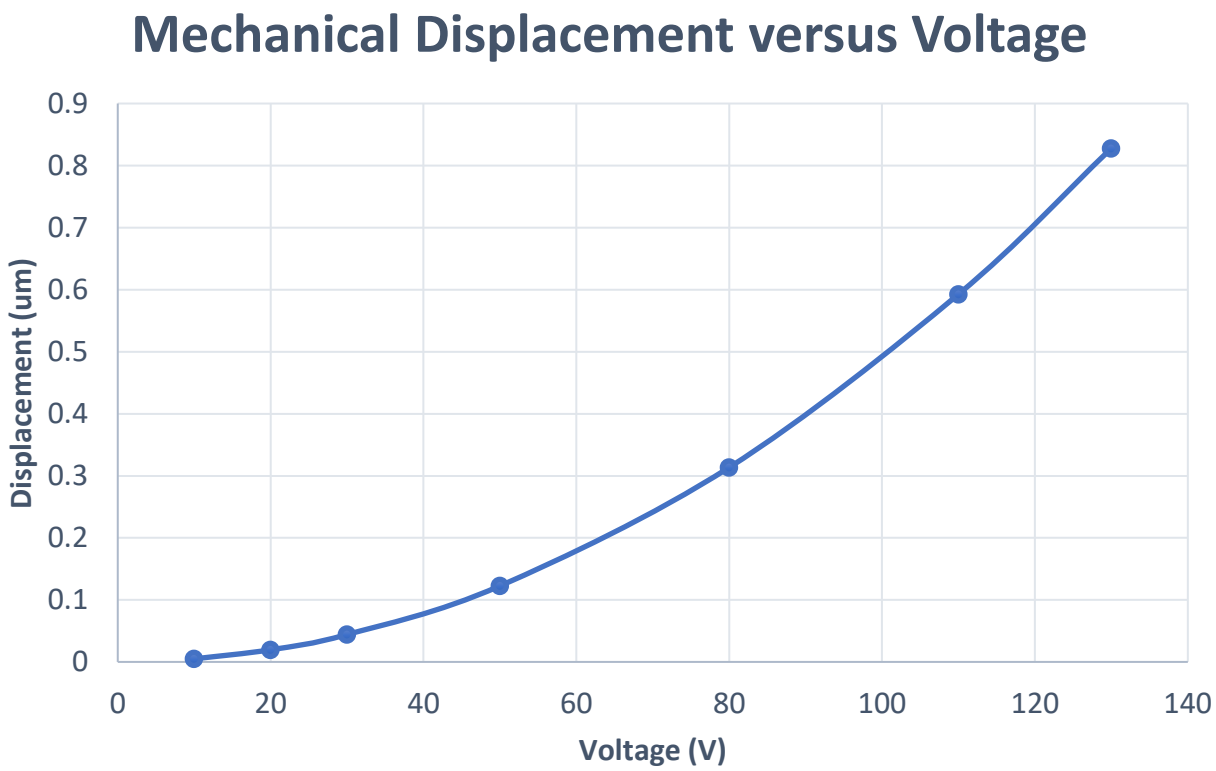

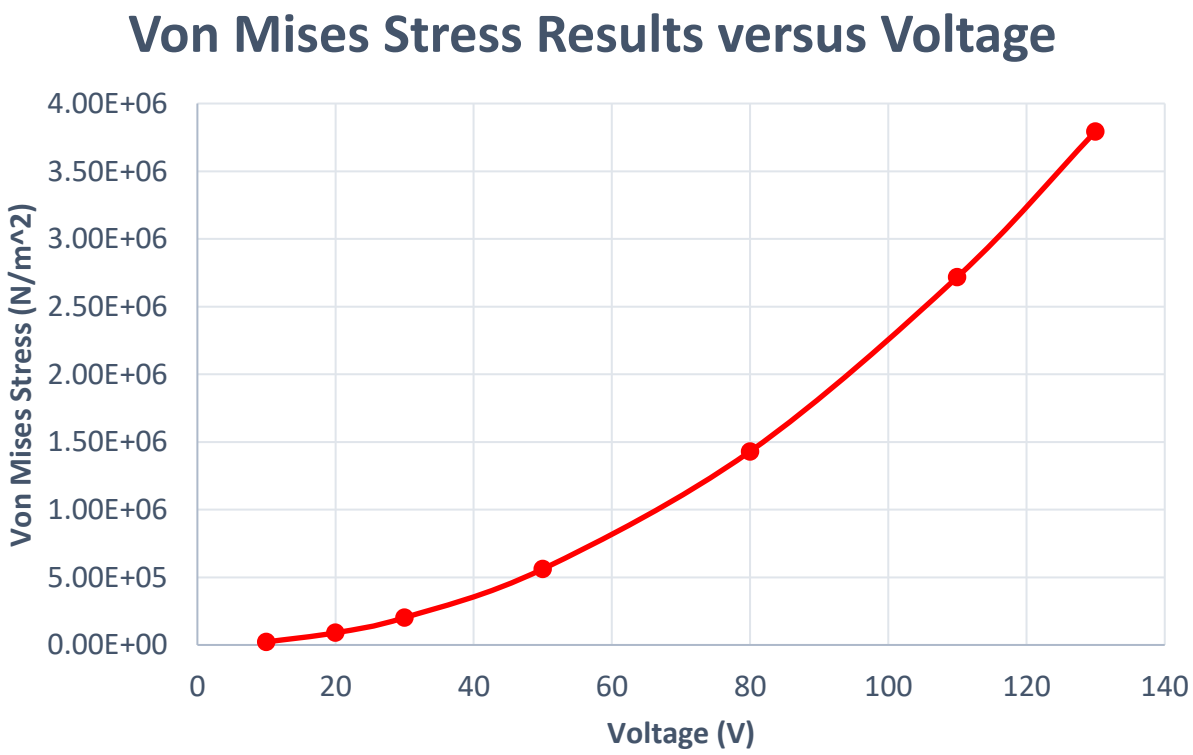

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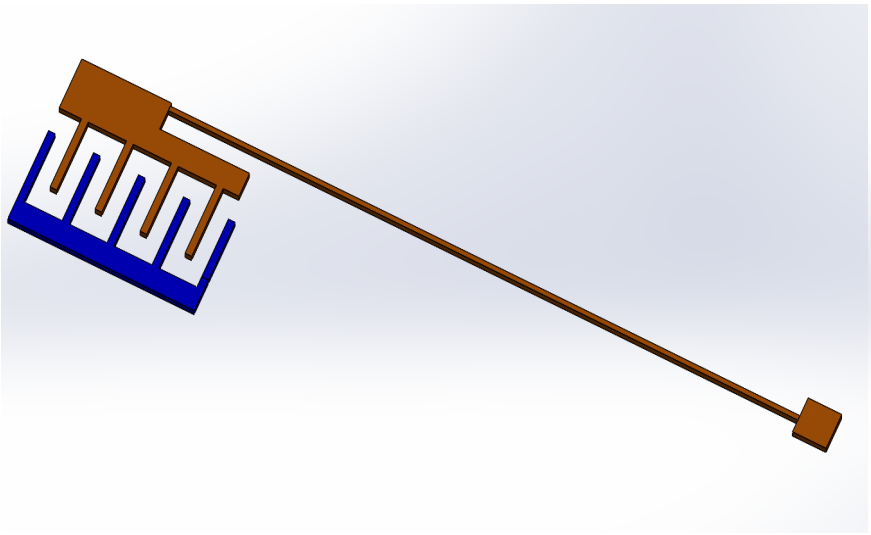
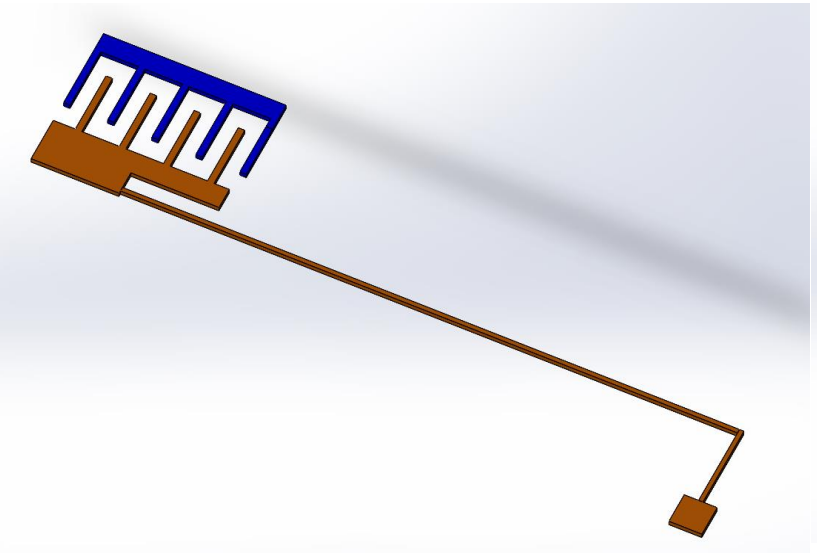
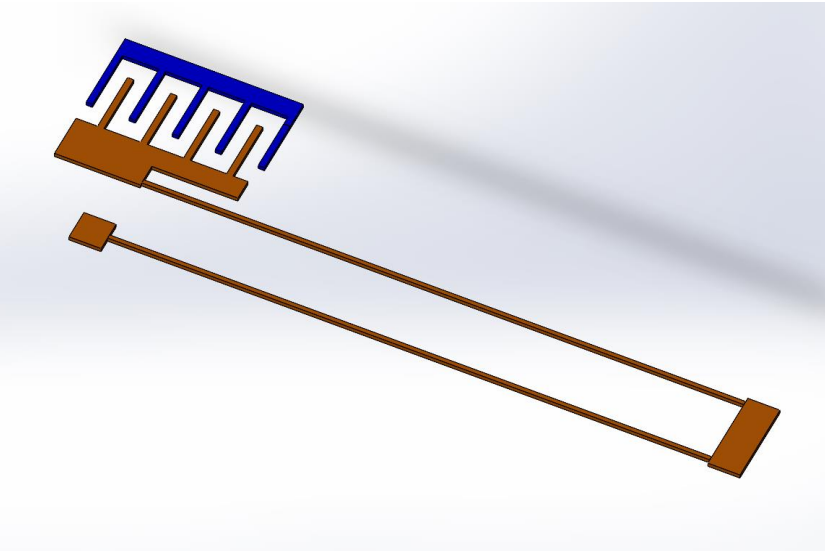


Fixed-fixed beam



Crab leg flexure beam



Folded flexure beam

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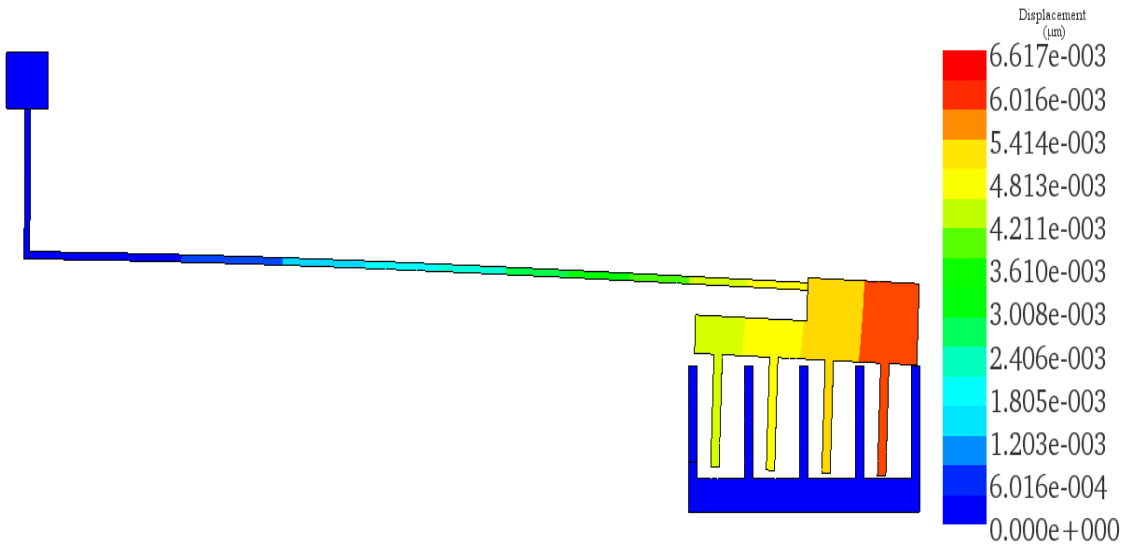
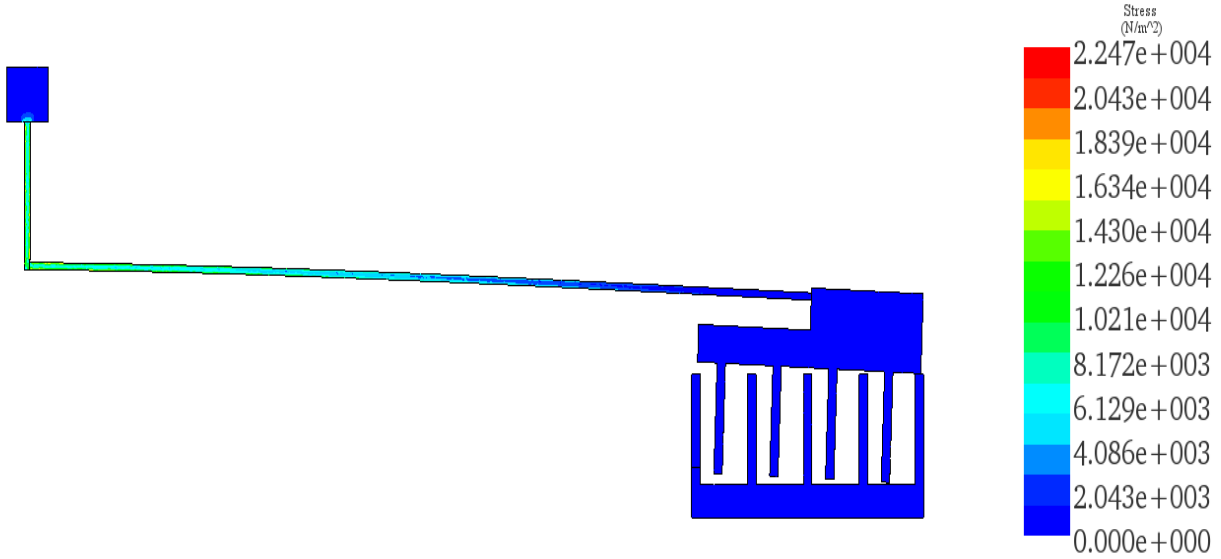


Mechanical Displacement Results



Von Mises Stress Results

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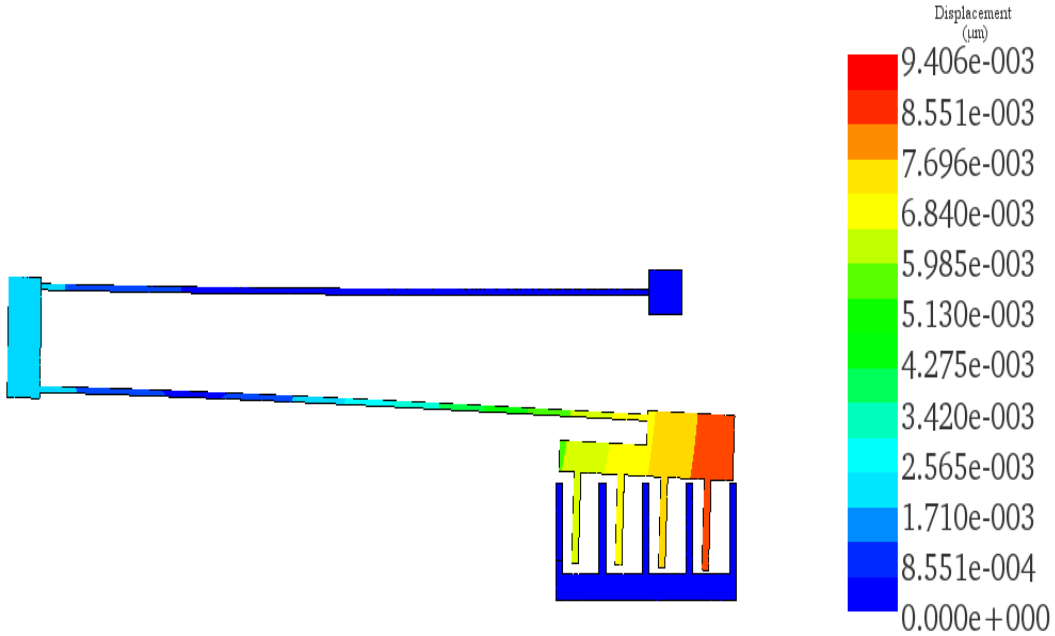

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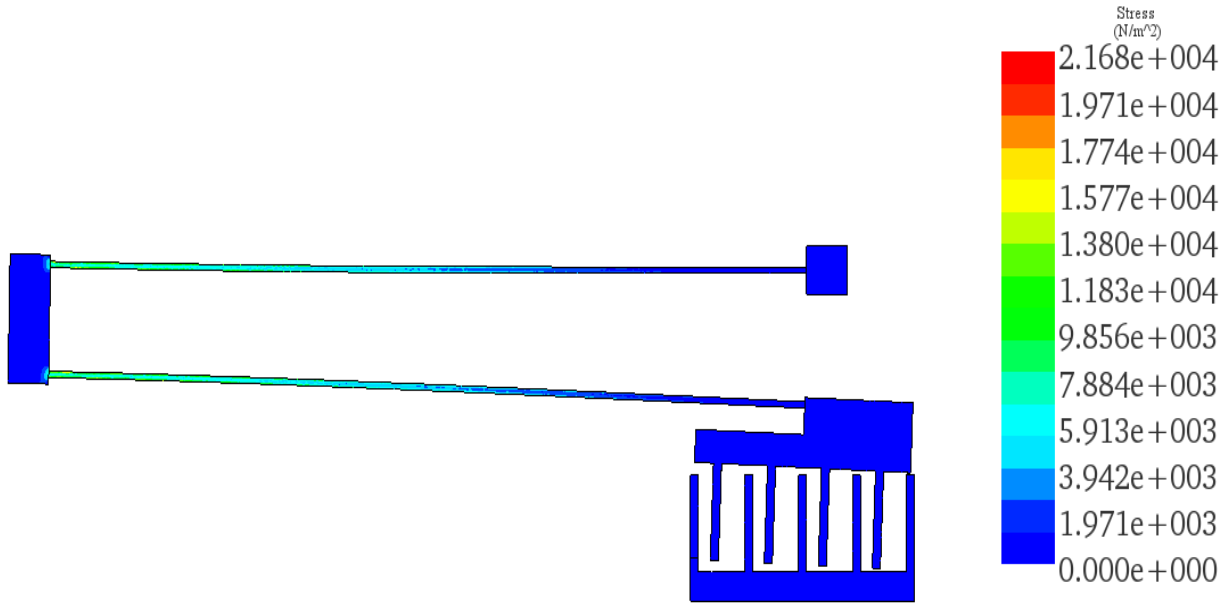

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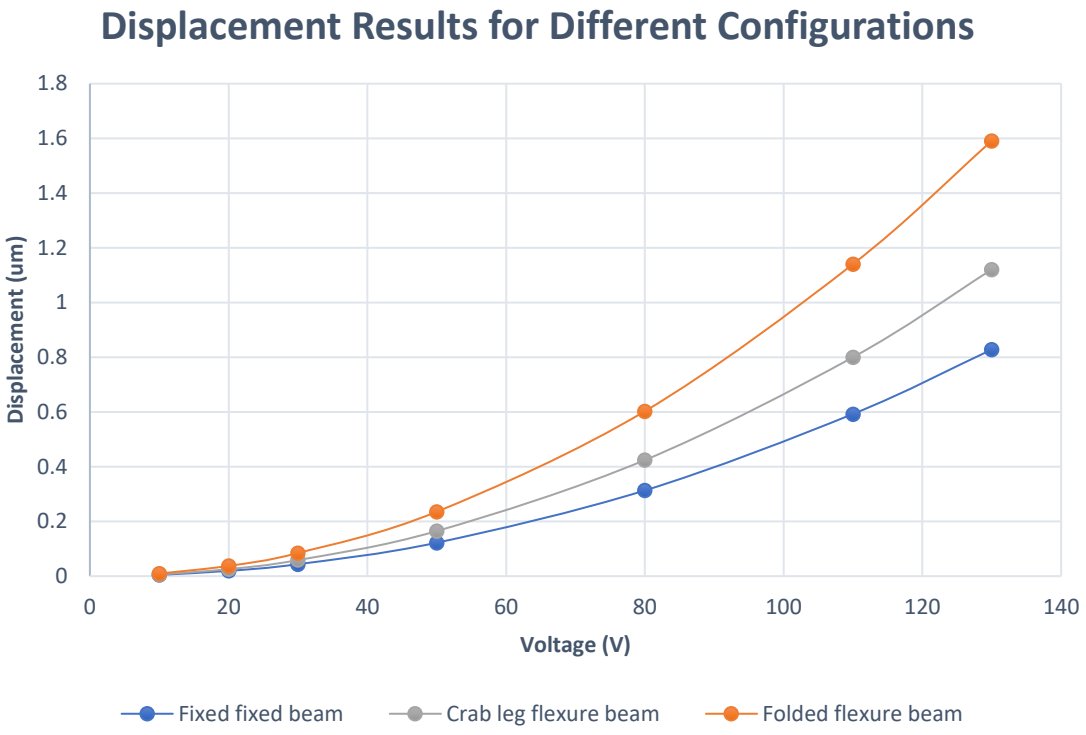

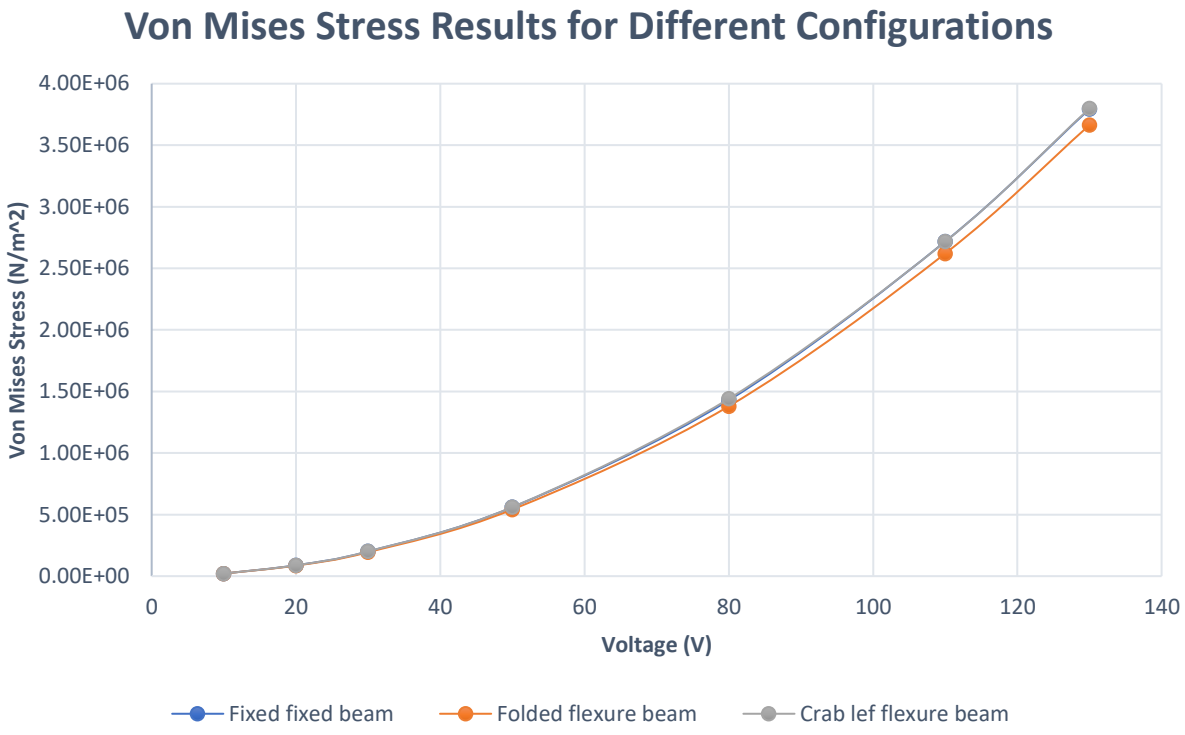

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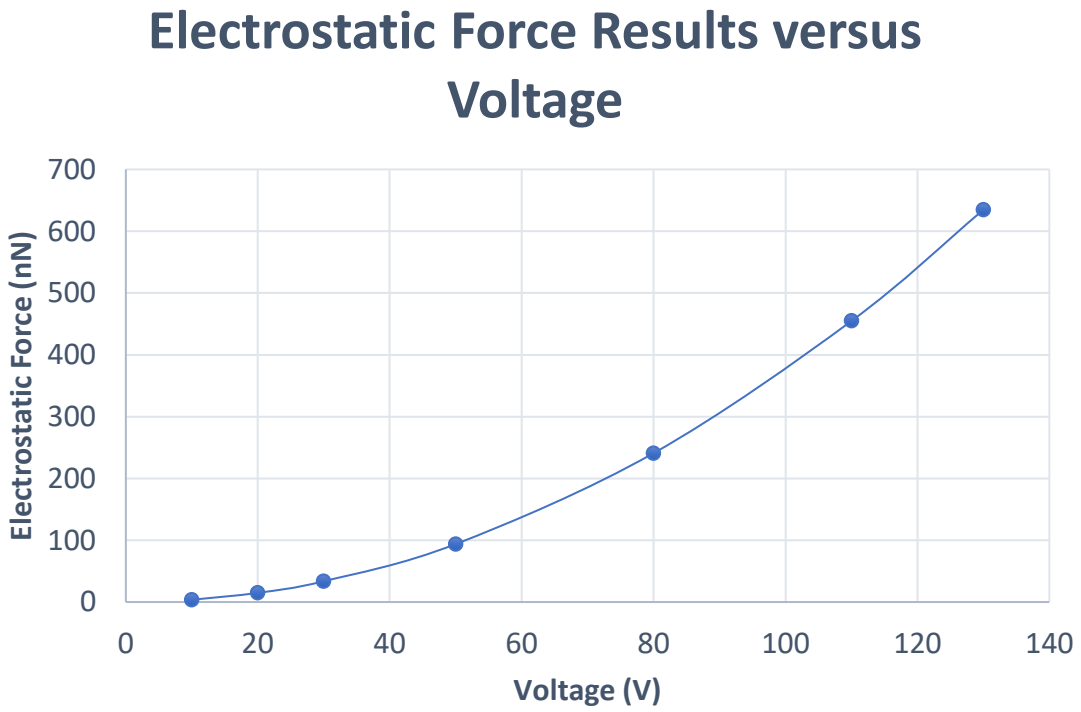
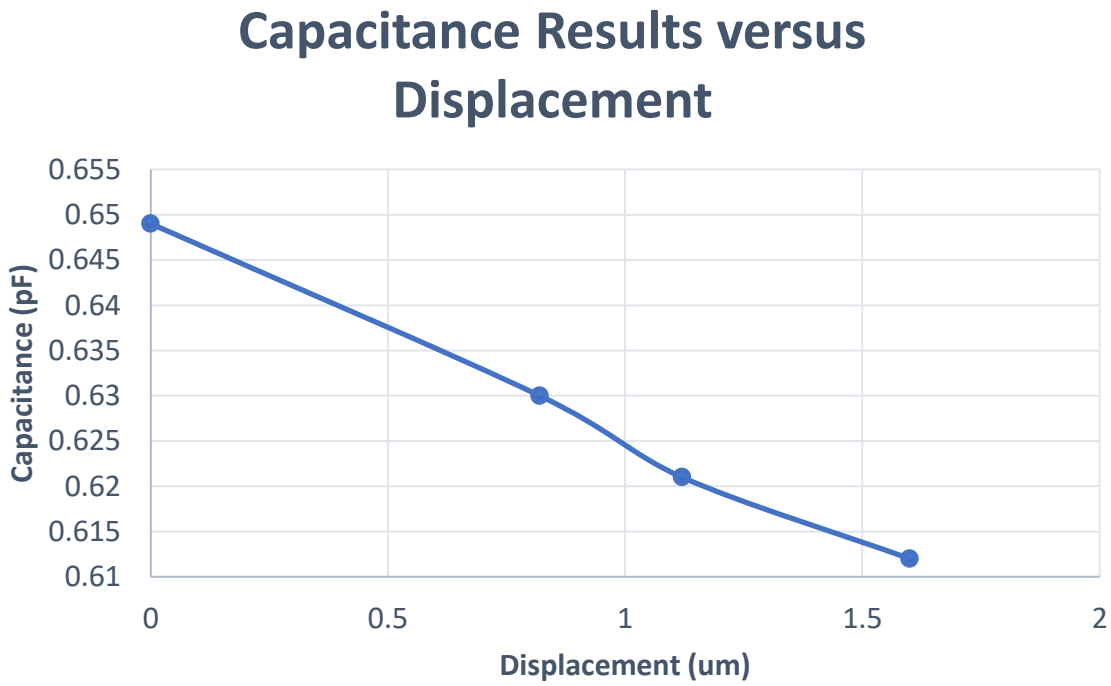
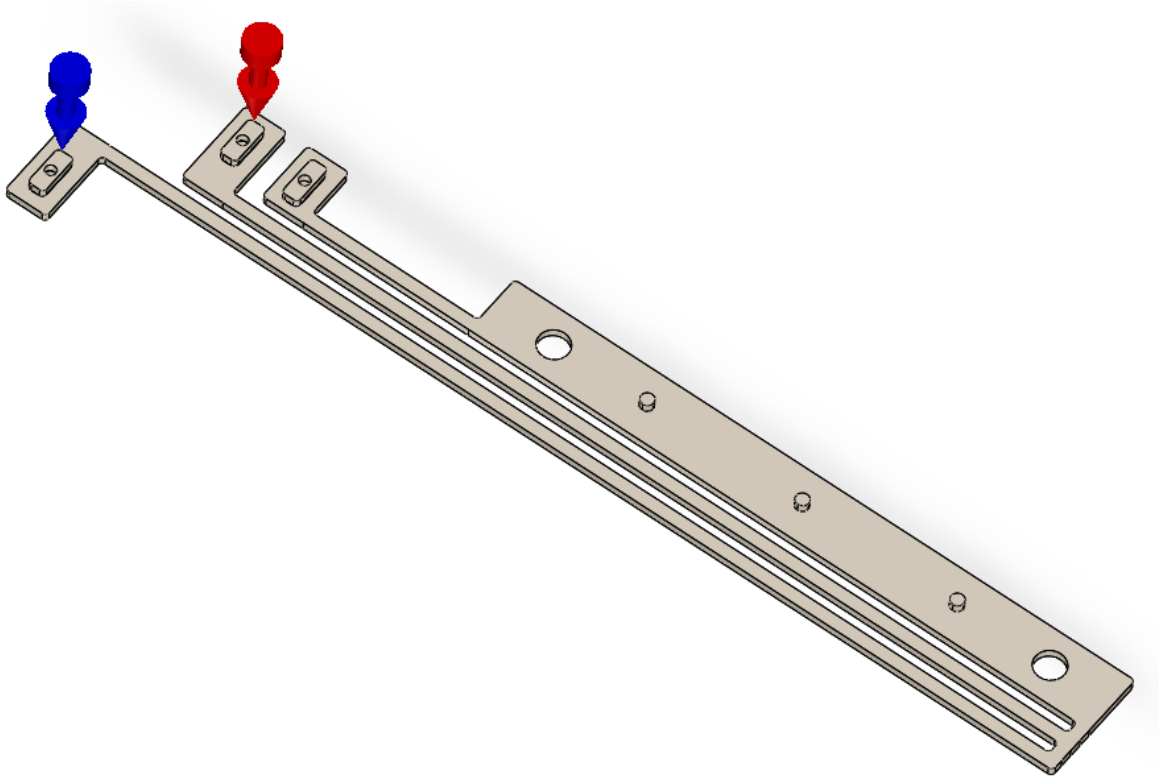




Example 2- Micro-thermal actuator (Joule heating)



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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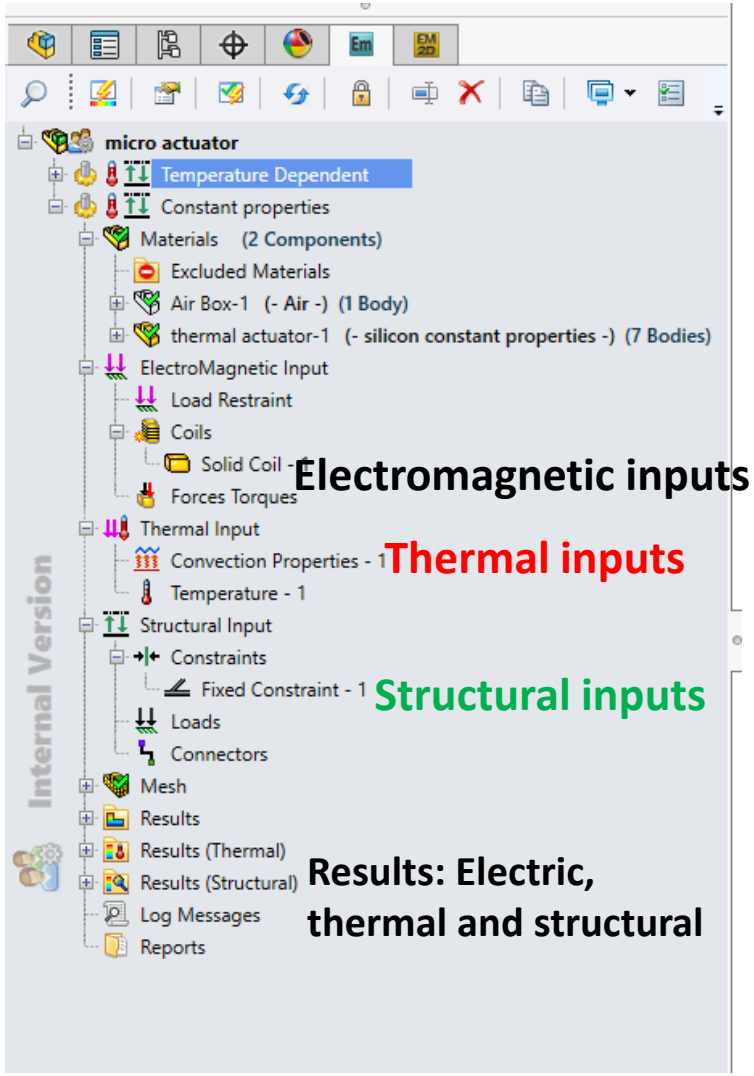
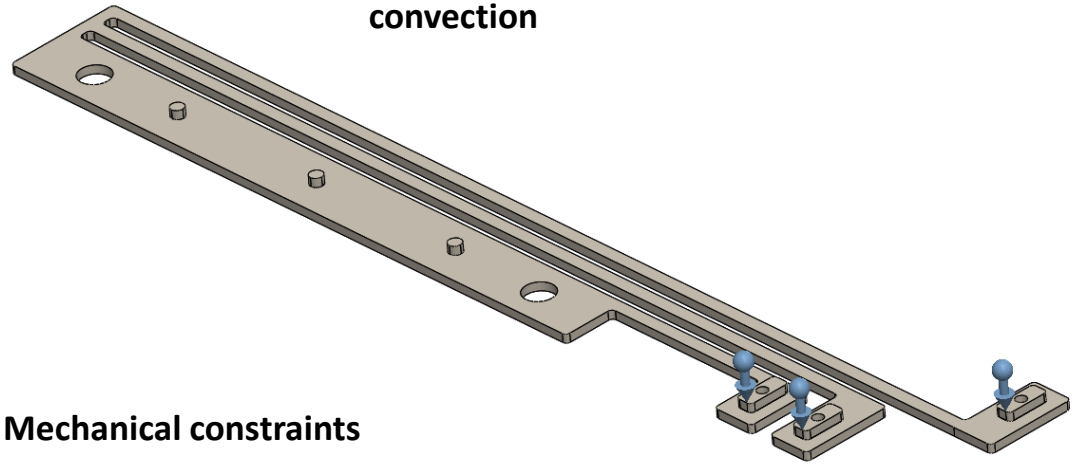
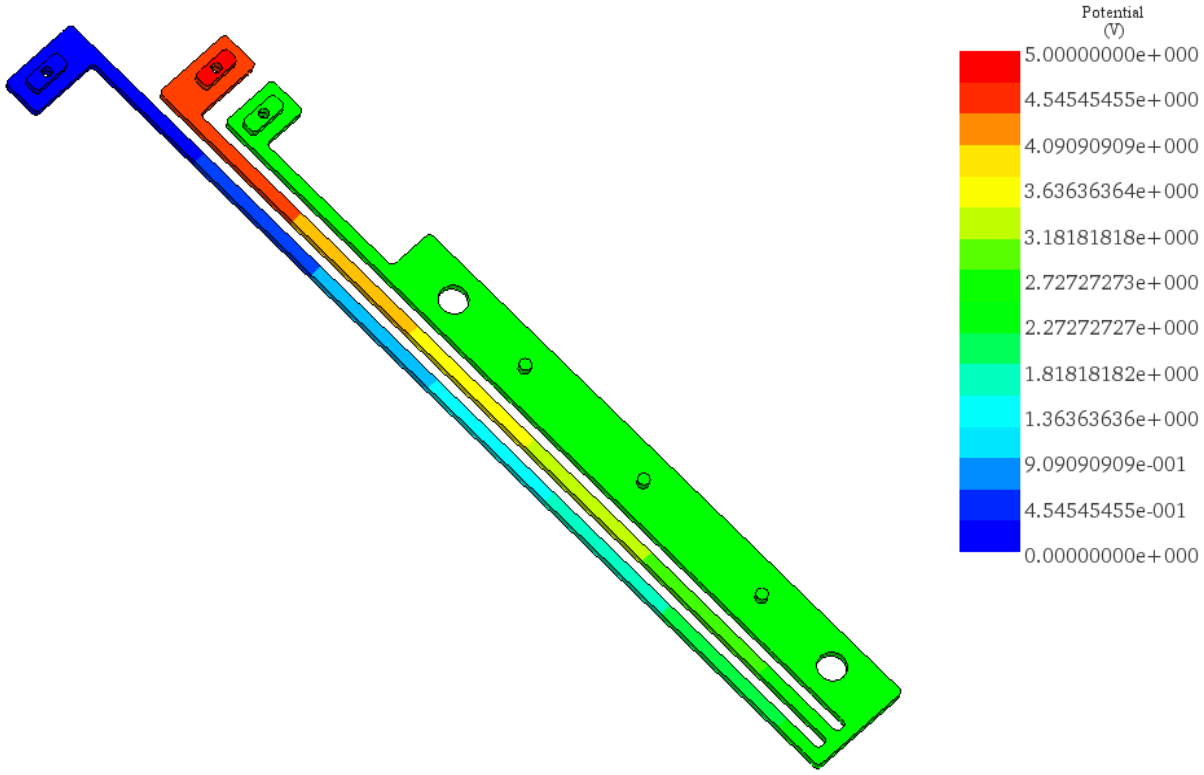


Thermal loads: temperature and convection

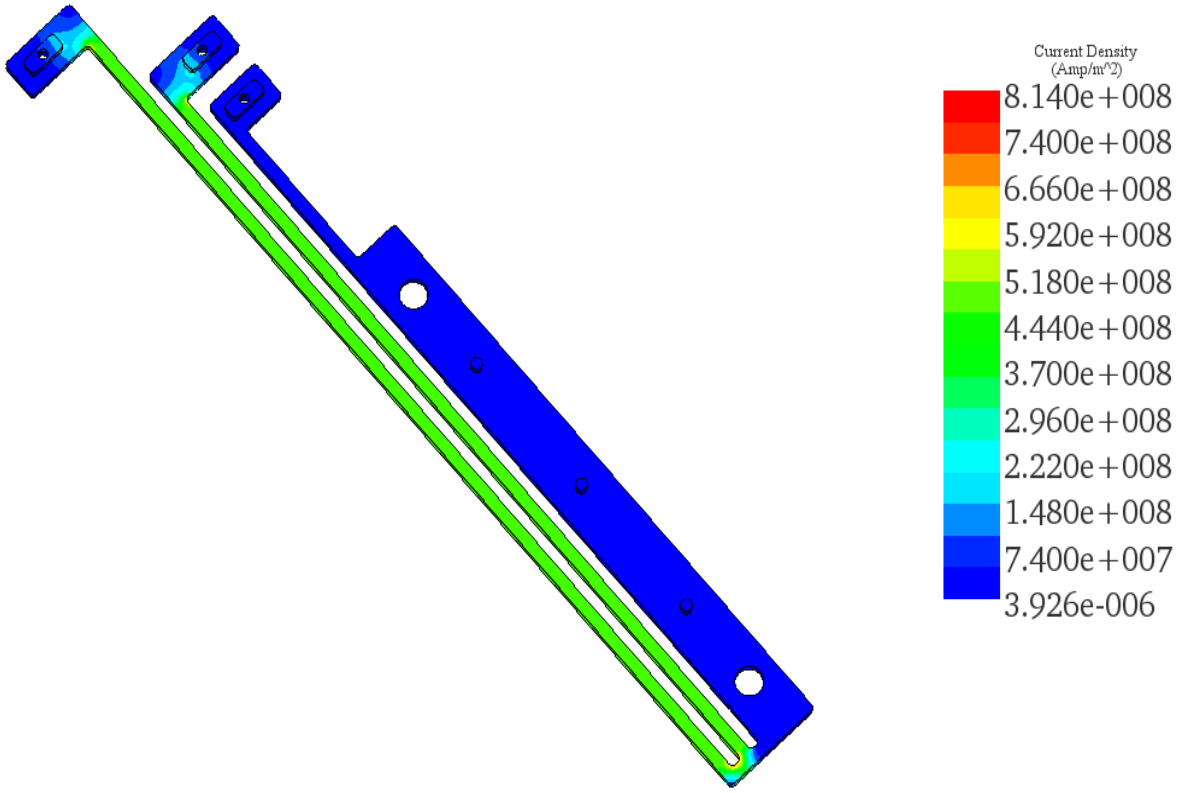


Mechanical constraints

Example 2- Micro-thermal actuator (Joule heating)



Voltage Results



Current Density Results

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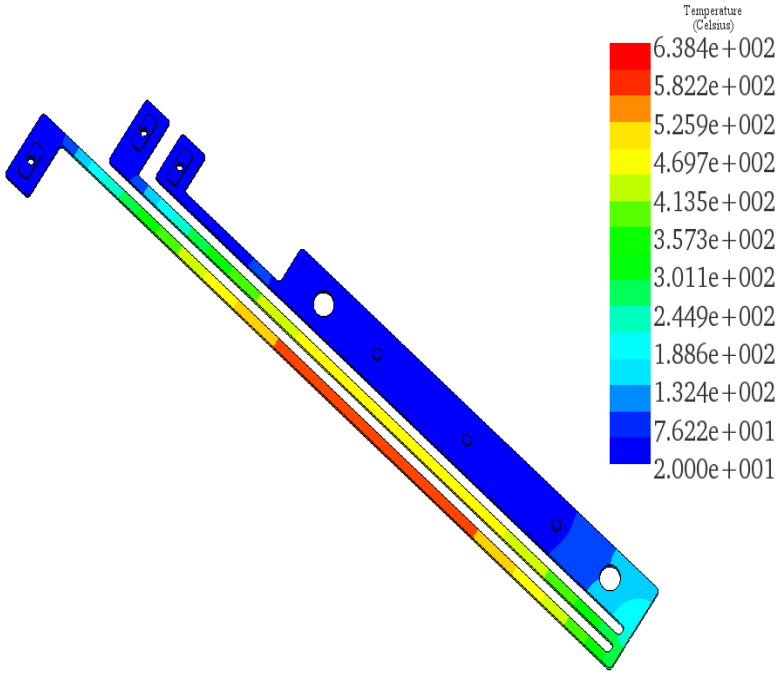
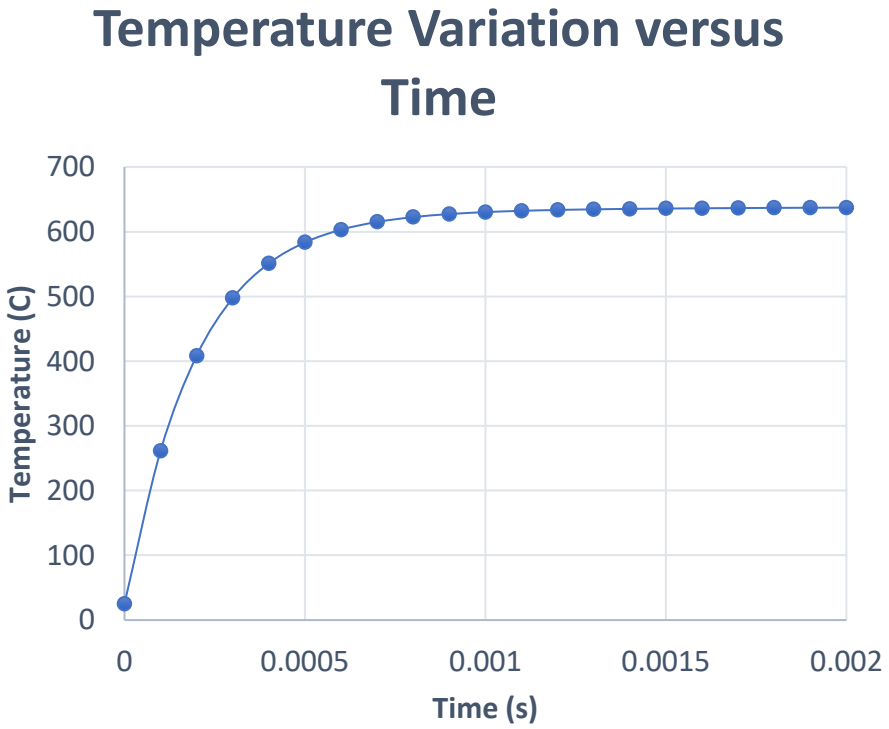
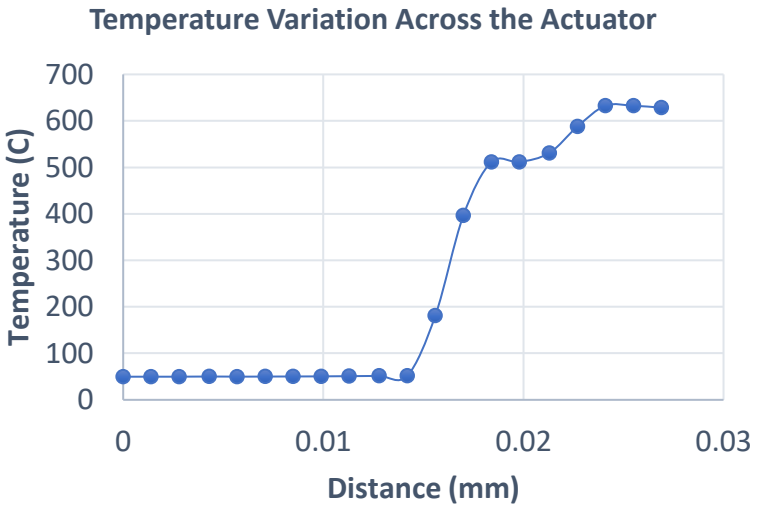
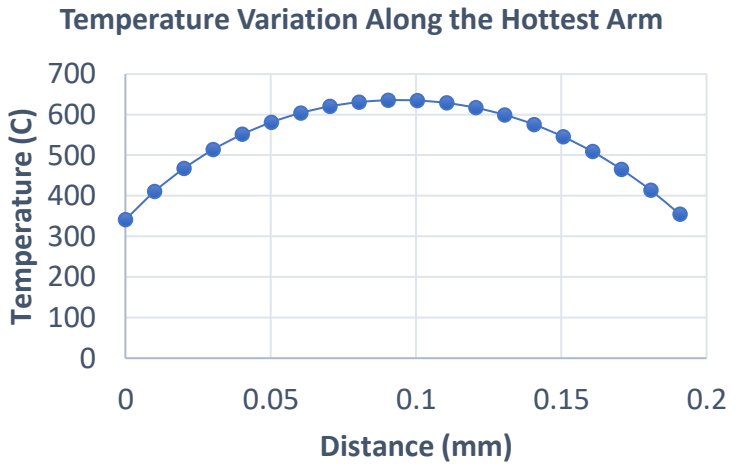


Temperature Results







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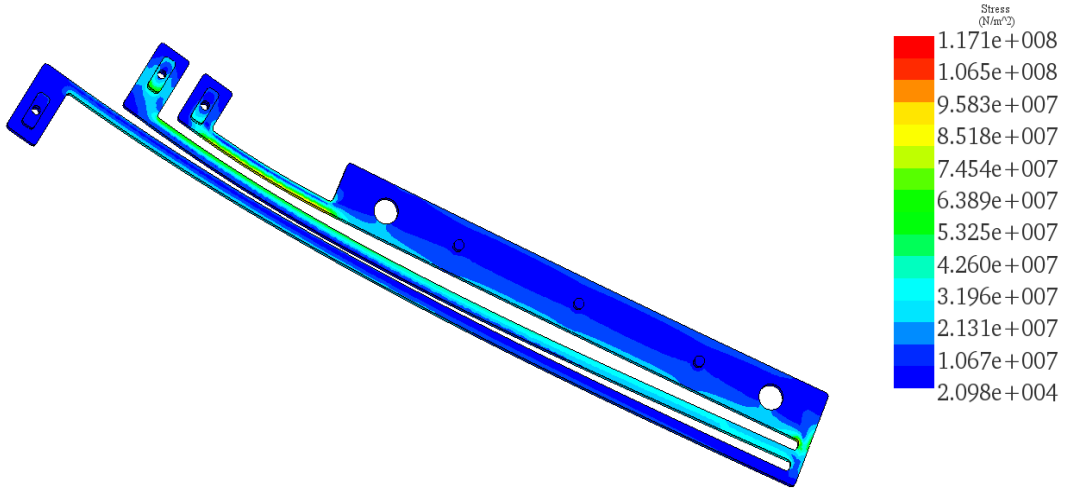
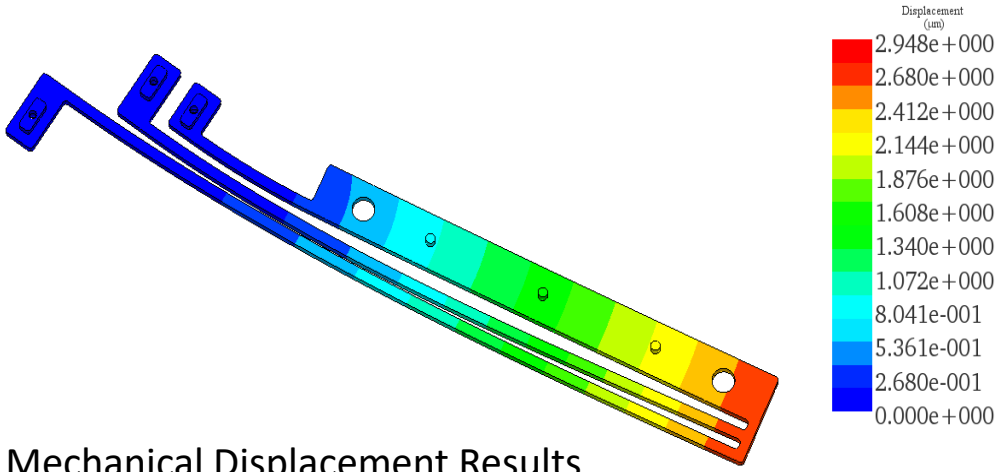
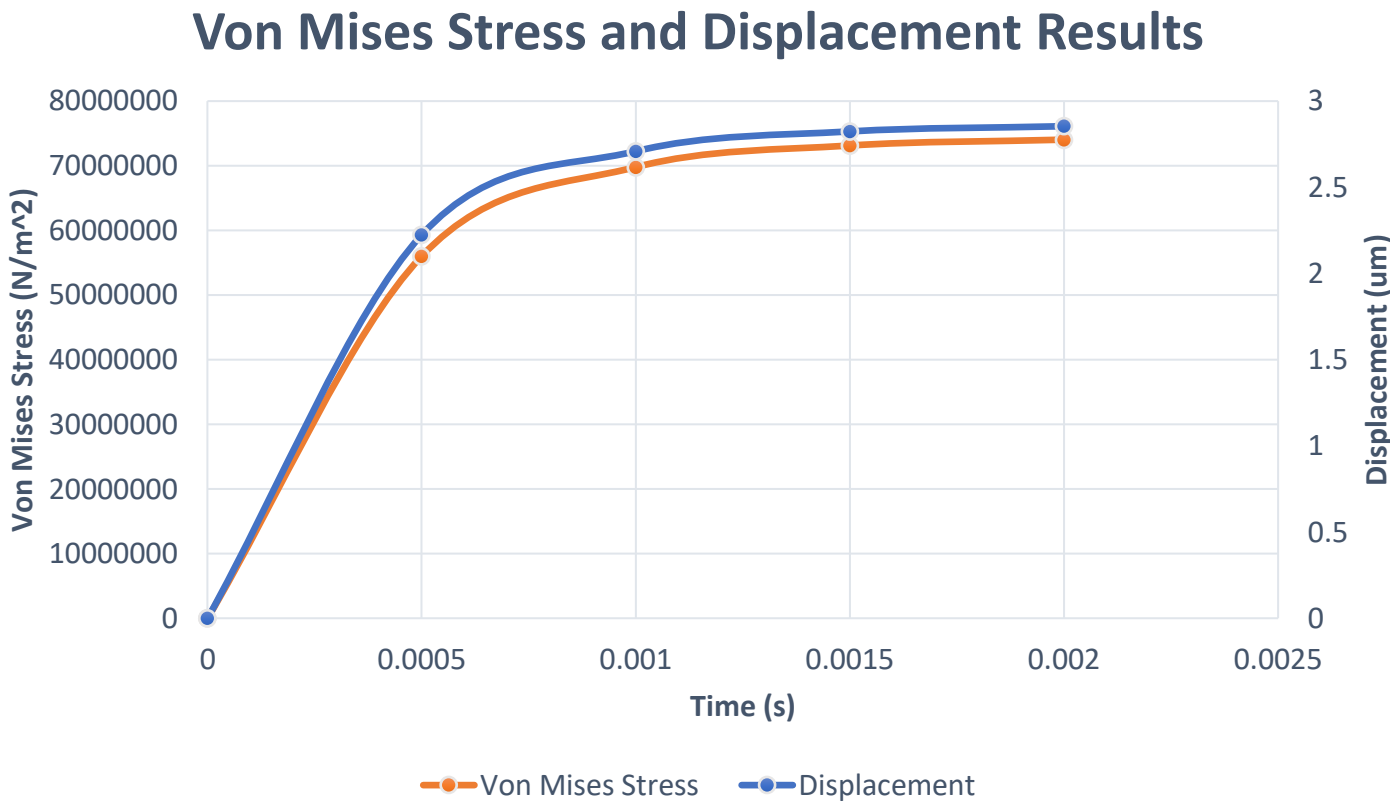


Von Mises Stress Results



Mechanical Displacement Results



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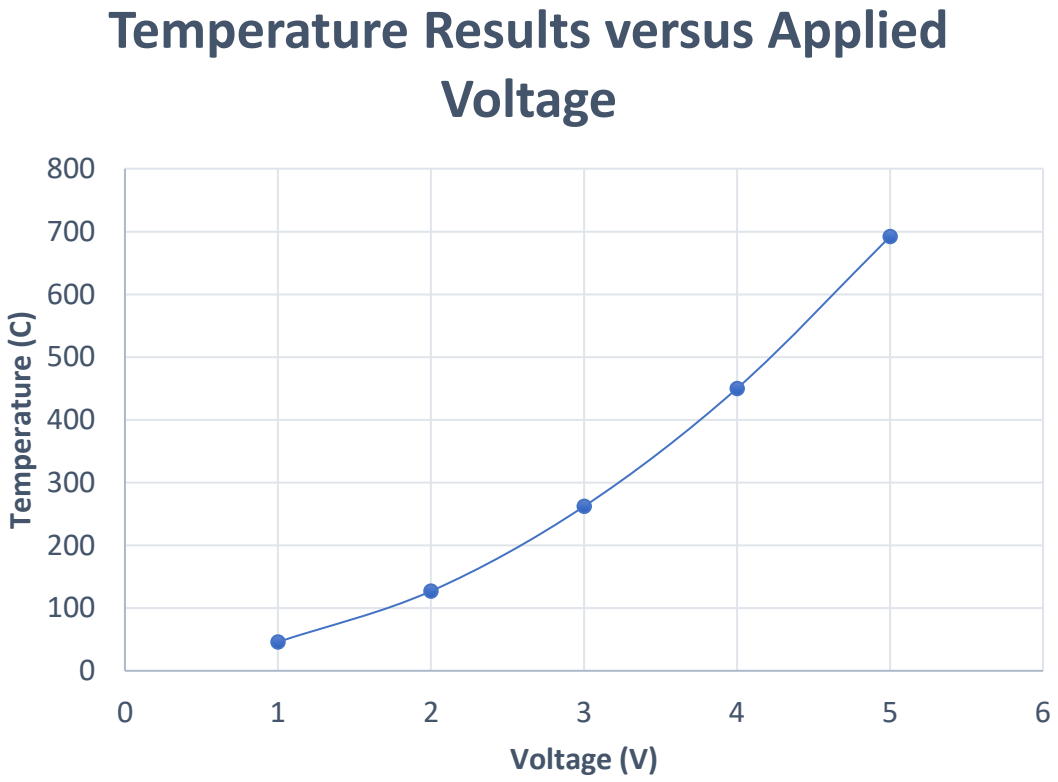

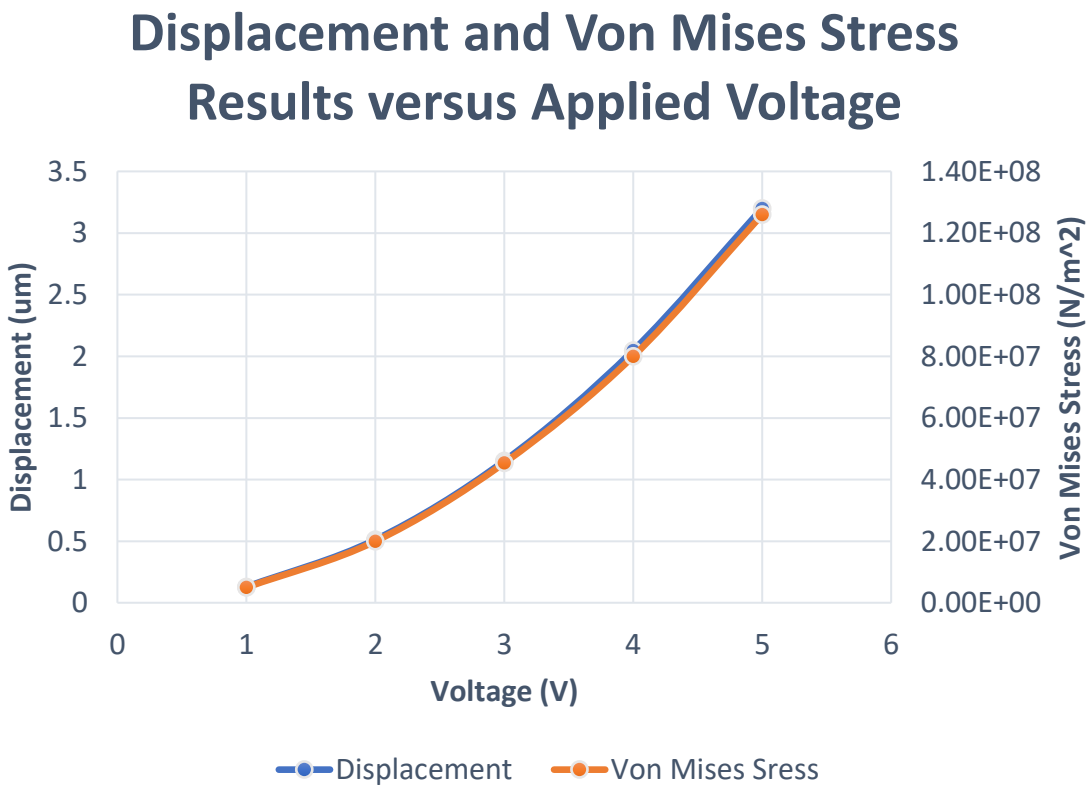

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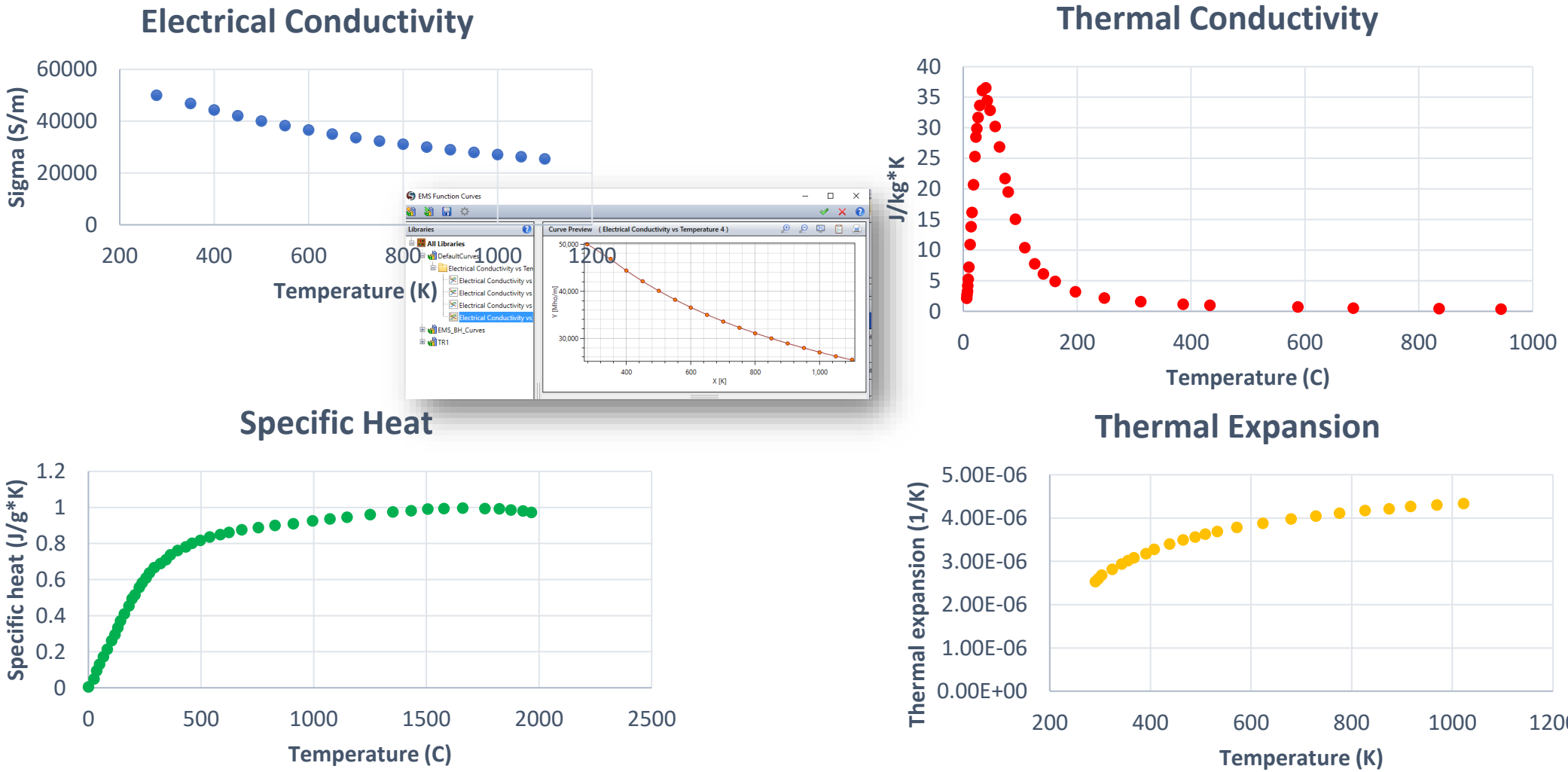

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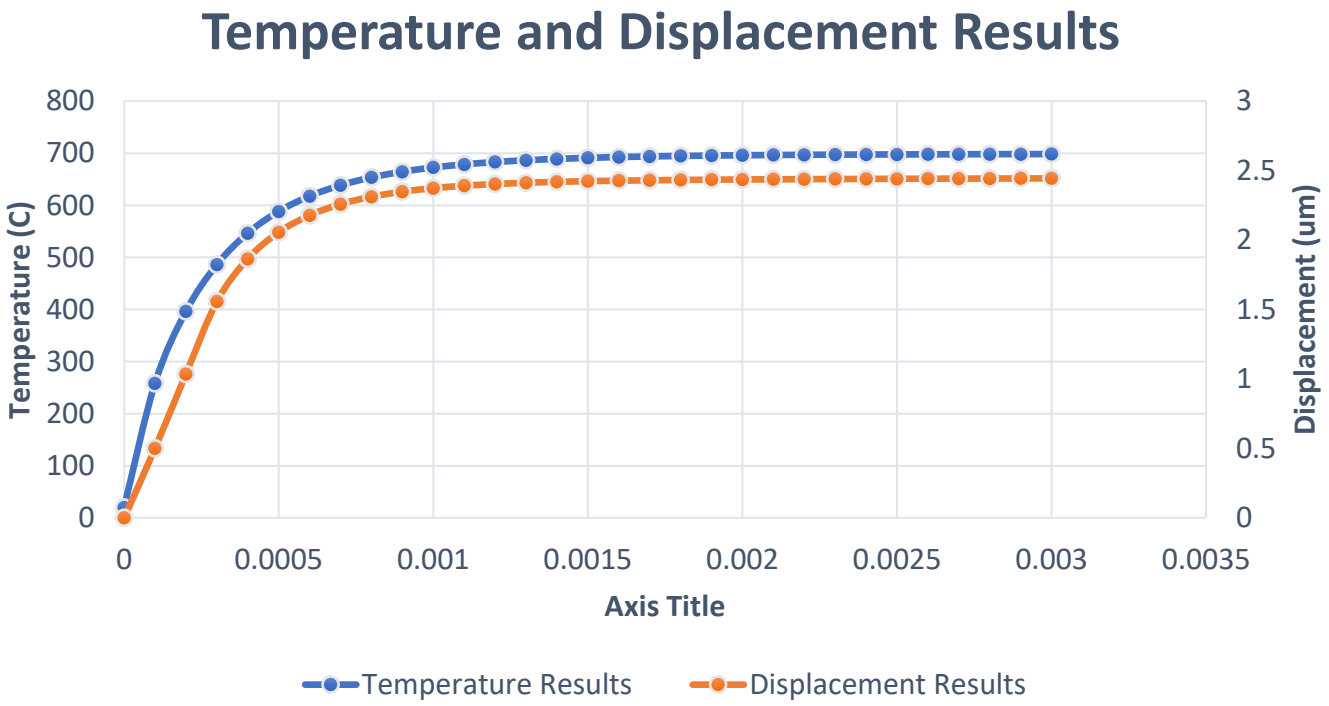
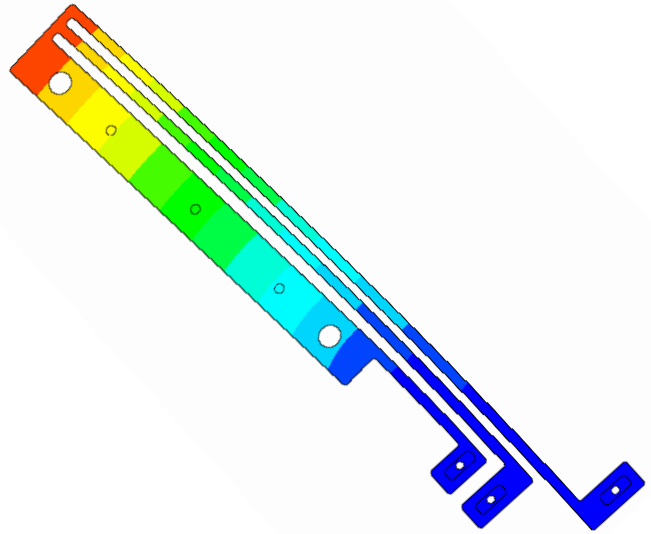


	Max temp.	Max disp.	Max stress
Constant properties	635	2.32	2e+8
Temperature dependent properties	700	2.48	2.15e+8
Error (%)	10%	6.8%	6.9%



Mechanical Displacement Results

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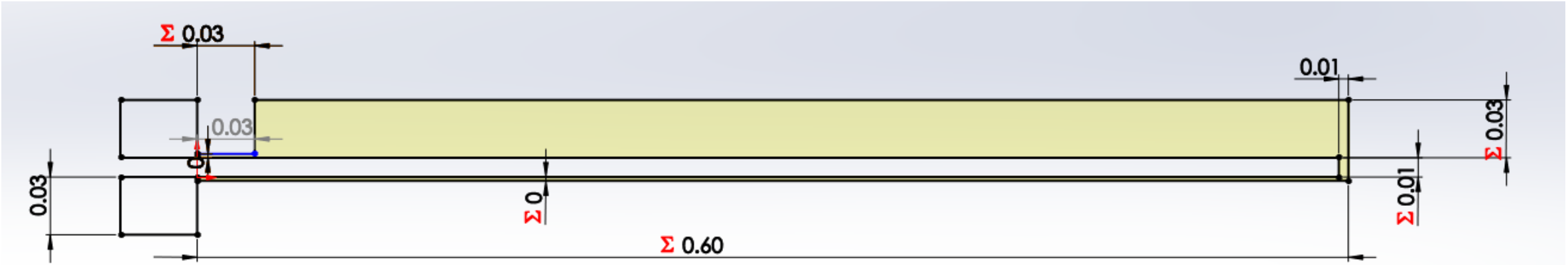

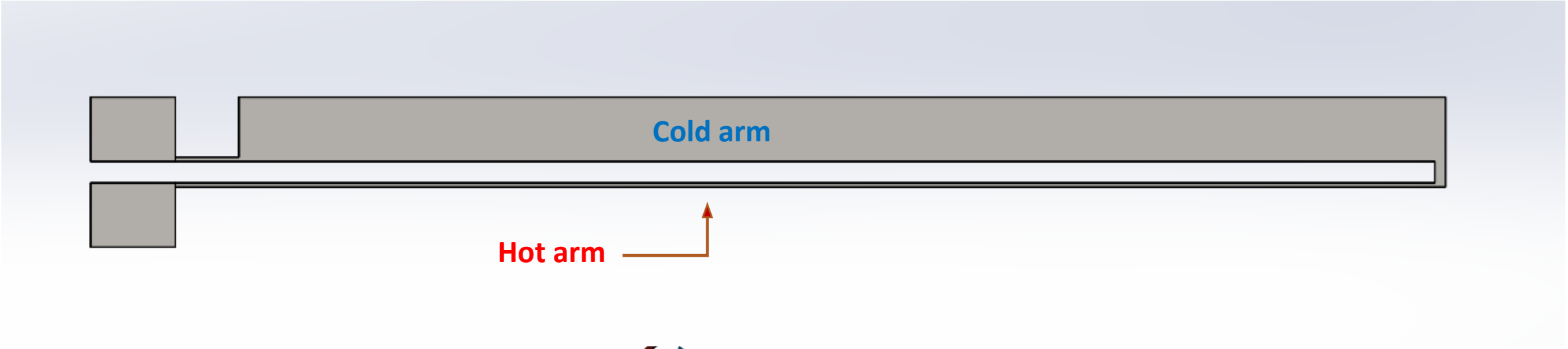

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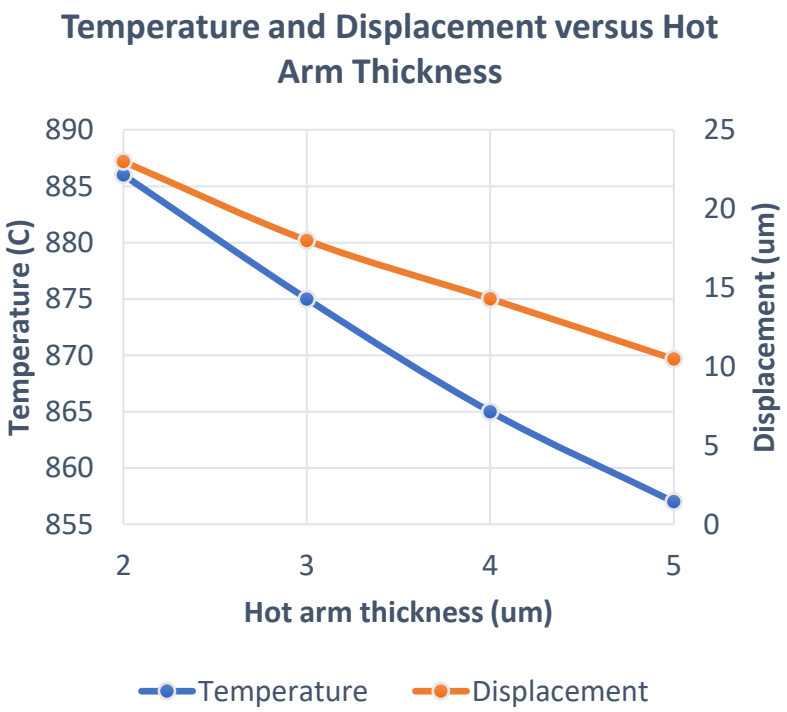
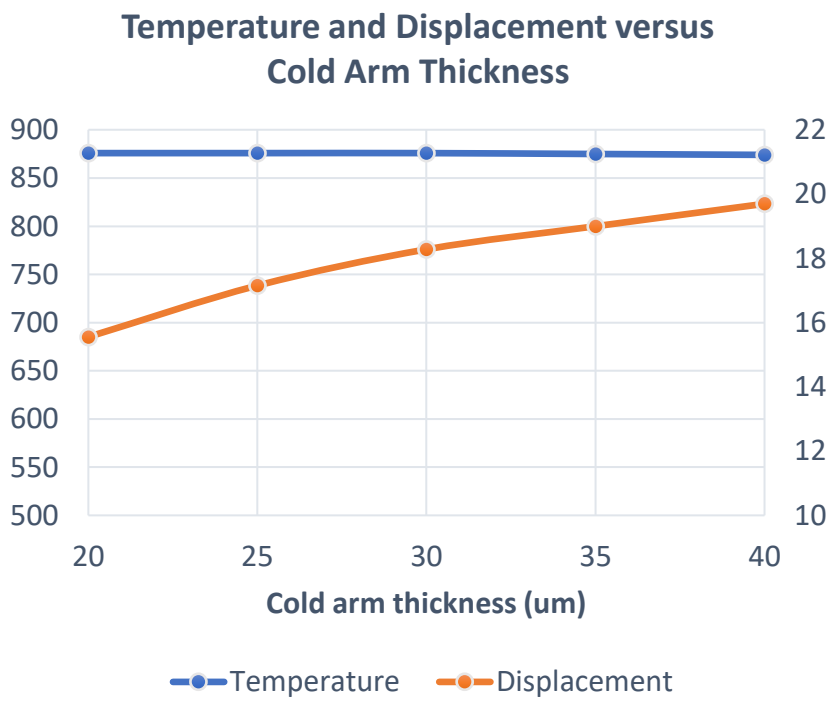
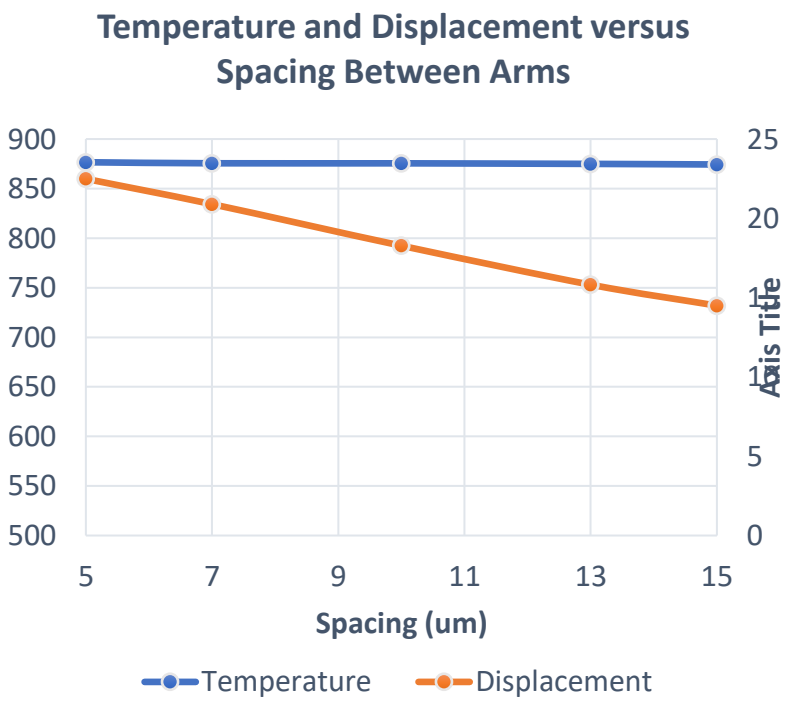
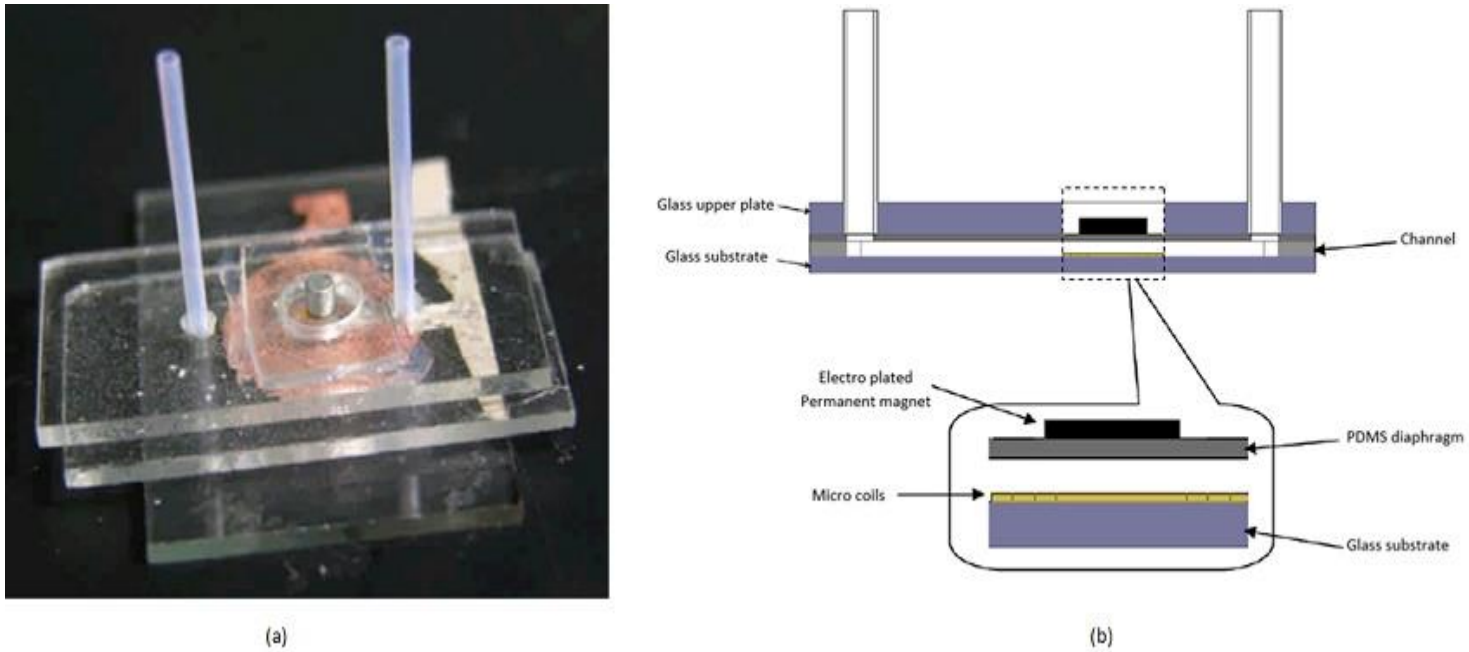


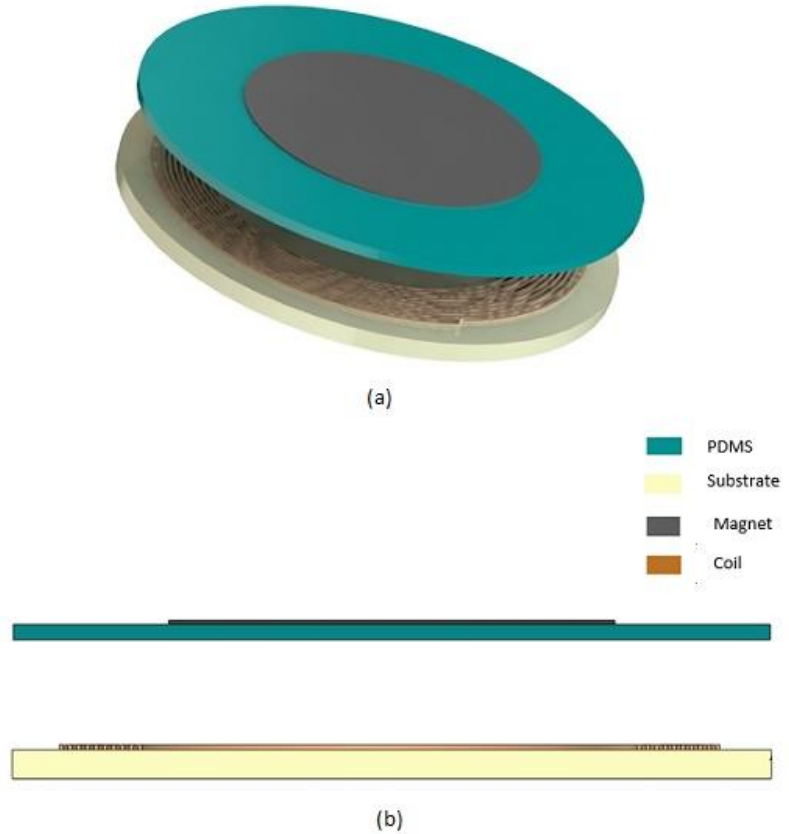




Example 3- Valveless micro-pump



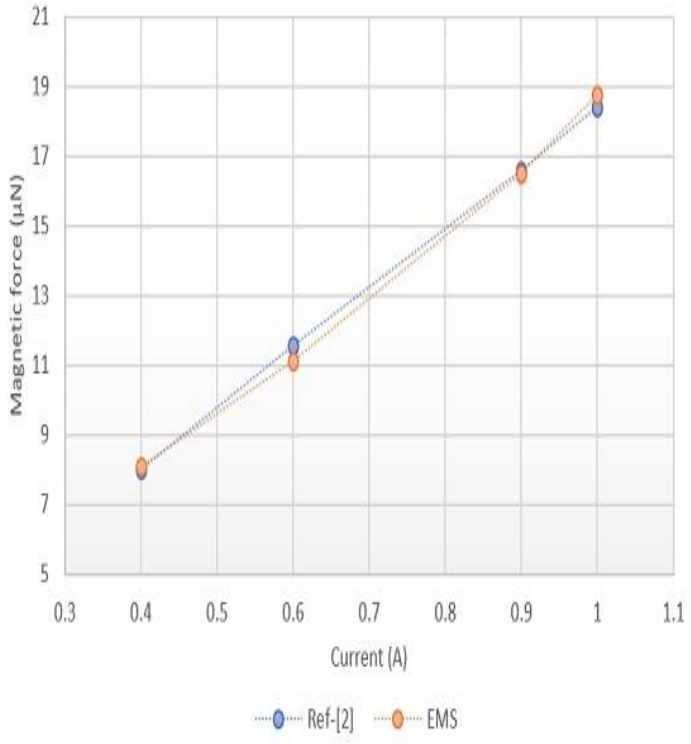
a) Picture of the fabricated micro-pump, b) and its schematic illustration



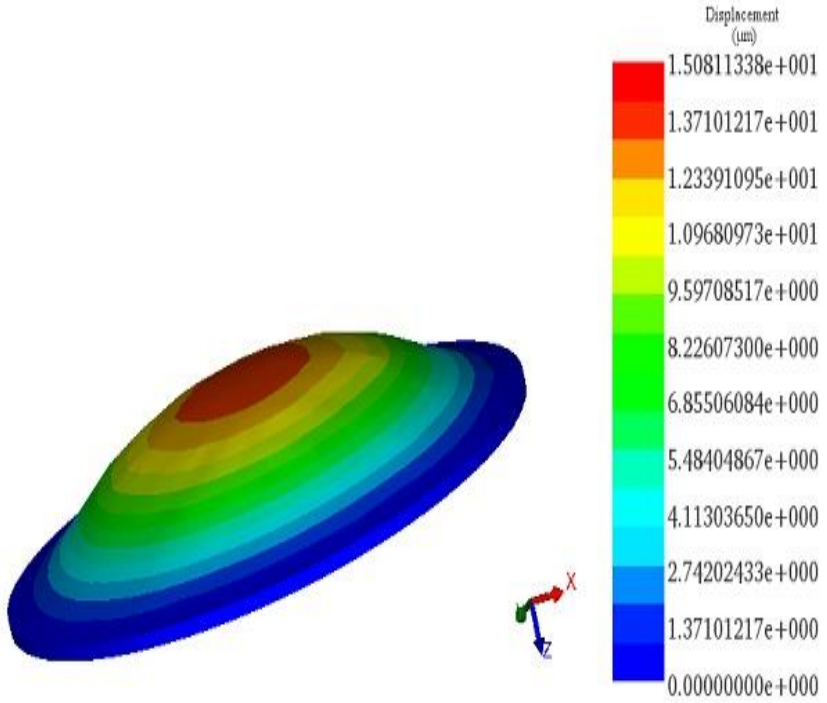
a) 3D isometric view of the micropump b) cross-sectional view of the micro- pump.

https://www.emworks.com/application/ems-structural-simulation-of-valveless-micro-pump-based-on-electromagnetic-actuation

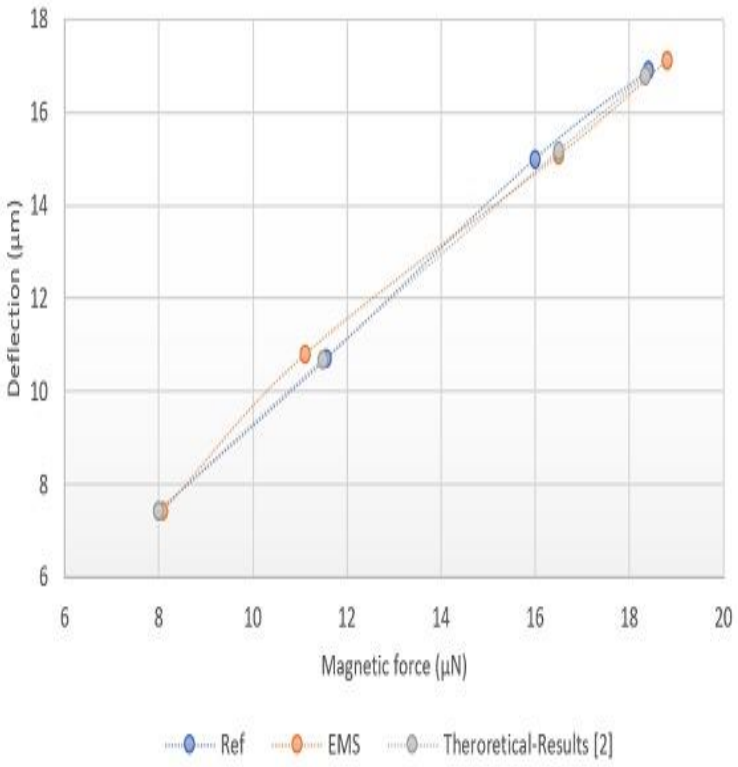
Example 3- Valveless micro-pump



Force Results versus Current



Displacement Results



Deflection versus Magnetic Force (0.9A)

Chang, Hsien-Tsung, et al. "Theoretical analysis and optimization of electromagnetic actuation in a valveless microimpedance pump." Microelectronics journal 38.6-7 (2007): 791-799.

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