Anisotropic Damping in MEMS Oscillator

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Abstract

Micro-machined structure, such as MEMS, work in a significantly different environment with respect to larger size machine. As a result MEMS devices are strongly affected by the surrounding air. The air presents a counter reactive force on the moving elements of such devices. According to Bao [1] the damping effect of enveloping air would be enforced if a plate was oscillating close to another plate, so that the air film was squeezed in between the two surfaces. For such sizes, the latter mechanism is what dominates the frequency response of the system, thus it needs to be investigated in order to optimize the system to achieve desired requirements.

The analyzed MEMS oscillator is composed by a spring (beam) supported mass (see Figure 1) that needs to vibrate with an high Q-factor in the horizontal plane. Nevertheless, the transverse motion needs to be highly damped (low Q-factor). Due to what has been said in section above, a simulation model has been built with particular attention in reproducing the mentioned physical phenomenon. The purpose of the work was to explore different system configuration to determine the most suitable one for the scope of the device. Different parameters were varied to sweep multiple scenarios, namely thin-film gap thickness, ambient pressure and surface texture.

The model made use of 3D Solid Mechanics physics interface of COMSOL Multiphysics® software; it solved the squeezed film air/structure interaction using the Thin-Film Damping extension within the former domain. The Thin-Film Damping is boundary physics, and not a domain one, due to the relative size with respect to the solid structure. Moreover, the model used the zero-pressure edge condition of the thin-film; hence edge pressure was always equal to ambient one. This was selected as boundary condition to better comply with existing researches; this led to a deeper understanding of the author on such constraint and a wider pool of results to compare the model with.

Reference

[1] M. Bao et al., Squeeze Film air damping in MEMS, Sensors and Actuators A, Vol. 163, p. 3 (2007)
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[5] S. Nigro et al., Evaluation of Squeeze-Film Damping Effects in MEMS Perforated Plates, New Aspects of Fluid Mechanics, Heat Transfer and Environment, ISBN: 978-960-474-215-8
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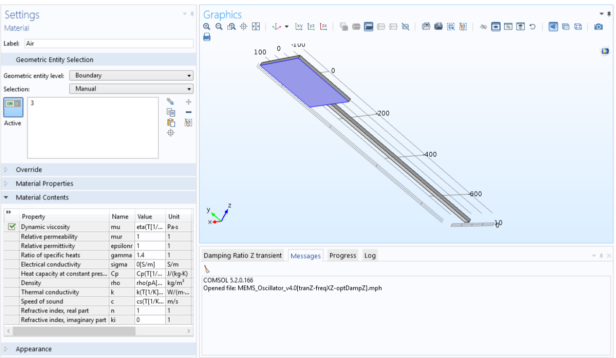
[8] https://www.comsol.it/optimization-module

Figures used in the abstract



Label: Air

Geometric entity level: Boundary

Selection: Manual

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	Property	Name	Value	Unit
☑	Dynamic viscosity	mu	eta(T[1/...	Pa·s
	Relative permeability	mur	1	1
	Relative permittivity	epsilonr	1	1
	Ratio of specific heats	gamma	1.4	1
	Electrical conductivity	sigma	0[S/m]	S/m
	Heat capacity at constant pres...	Cp	Cp(T[1/...	J/(kg·K)
	Density	rho	rho(pA[...	kg/m³
	Thermal conductivity	k	k(T[1/K]...	W/(m·...
	Speed of sound	c	cs(T[1/K...	m/s
	Refractive index, real part	n	1	1
	Refractive index, imaginary part	ki	0	1

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Figure 1: Air thin-film settings.

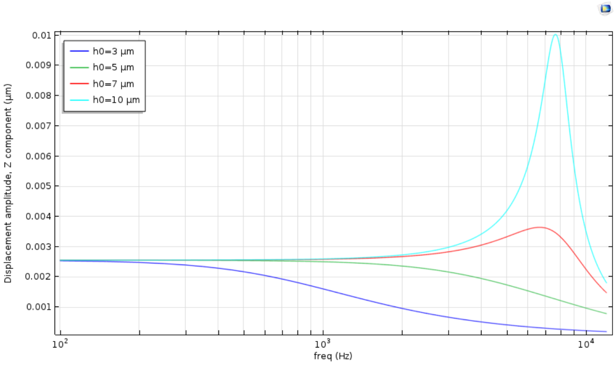

Figure 2: Frequency response along z axis.

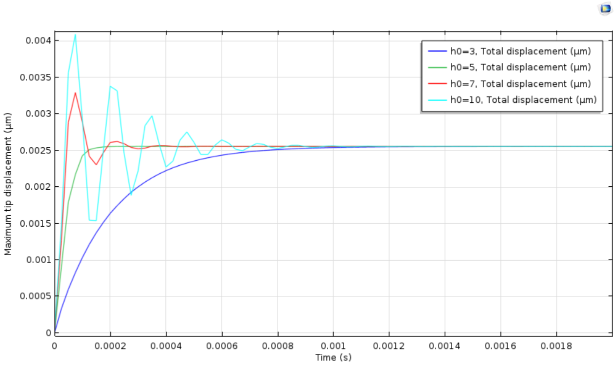

Figure 3: Tip dislacement (gap thickness sweep).

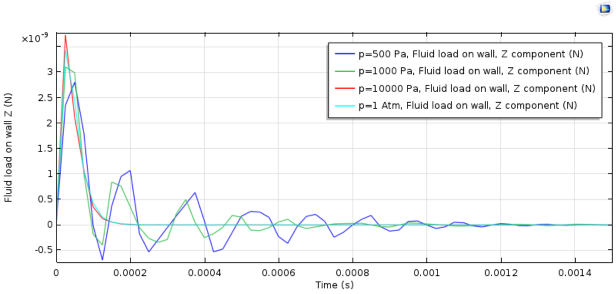

Figure 4: Fluid load on wall Z-component (pressure sweep).