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Dissipation in MEMS in the near-vacuum regime

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ABSTRACT

Several mechanisms contribute to damping on microelectromechanical structures. The dominant damping mechanism is dependent on the pressure of the gas surrounding the structure. The size of damping, and therefore the size of the quality factor, is therefore pressure-dependent, as illustrated in figure 1.

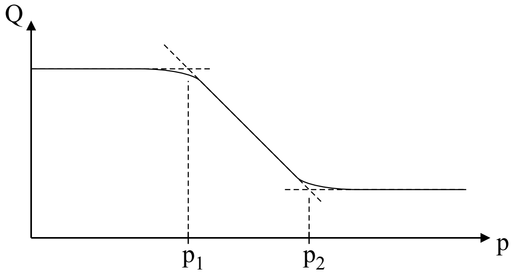

Figure 1: The dependence of the Q-factor on the air pressure [1]

For pressures above p_2 viscous damping mechanisms are dominant. Viscous damping mechanisms are commonly described by drag force damping or squeeze-film damping. These mechanisms can be simulated in a range of simulation tools.

Damping mechanisms for pressures below p_2 are less well characterised. This work concentrates on the mathematical derivation of models for these mechanisms and the implementation of the resulting expressions in simulation tools.

When environmental pressure or MEMS typical dimensions decrease below a certain threshold the flow enters the transition regime, where rare air damping plays an important role. This is the case in the region between pressures p_1 and p_2. Simulations concerning damping in this region will be presented.

If the pressure further decreases, the effects of thermo-elastic damping, electronic damping and anchor damping become important. In this work the modelling of thermo-elastic damping is presented. This results from thermal diffusion caused by inhomologenous deformation, such as flexure and torsion. The equations governing the thermoelastic behaviour of the slender structures in MEMS devices therefore describe the coupling between the strain field and the temperature field. A modelling strategy that facilitates the inclusion of these effects is the Cosserat theory. Based on this theory third order nonlinear models of beams used in MEMS devices, describing their mechanical behaviour, were developed in previous work. Results of the simulations of these beam models implemented in ordinary differential form, together with rigid body models and anchor point models, were presented in [2]. The ordinary differential equations were here achieved using a kinematic assumption of the shapes of deformation of the beam. In [3] partial differential equation based beam models were presented.

As the “kinematic assumptions” are only known for the mechanical deformation and not for the thermal diffusion, the thermoelastic beam model described here is based on partial differential equations. The dependence of Helmholtz free energy on both strain and temperature plays a key role in its derivation.

In the final paper, the models derived for both targeted damping regions will will be presented. In addition, measurement results will be presented for both damping regions.

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