Adaptive relaxation based BEM-FEM coupling for estimating anchor losses in MEMS

A. Aimi[1], L. Desiderio[2,*], P. Fedeli[3]

[1]Department of Mathematical, Physical and Computer Sciences, University of Parma, Parma, Italy
[2]Department of Mathematical Sciences, Politecnico di Torino, Torino, Italy
[3]Department of Civil and Environmental Engineering, Politecnico di Milano, Milano, Italy
*Email: luca.desiderio@polito.it

Keywords: BEM-FEM coupling; relaxation; adaptivity; anchor losses; MEMS resonator.

In a resonating structure the quality factor is defined as $Q = 2\pi W/\Delta W$, where ΔW and W are the energy lost per cycle and the maximum value of energy stored in the resonator, respectively. The Q factor has a peculiar importance in micro-structures (MEMS) where energy issues become dominant. Among the sources of damping that affect their performance, the most relevant are: thermoelastic dissipation, air damping, intrinsic material losses, electrical loading due to electrode routing, anchor losses. The focus of the present contribution is set on anchor losses which become particularly meaningful for resonators working at pressure in the order of the microbar [1, 2]. Anchor losses are due to the scattering of elastic waves from the resonator into the substrate. Since the latter is typically much larger than the resonator itself, it is assumed that all the elastic energy entering the substrate through the anchors is eventually dissipated. In this work, the response of a resonating MEMS attached to a much larger substrate is computed by using a relaxed and an adaptive relaxation based versions of frequency-domain non-overlapping iterative BEM-FEM coupling, where the resonator is modeled by Finite Elements and the dissipation of radiated waves into the substrate by collocation Boundary Element Method. A similar technique for space-time wave propagation problem was formulated and implemented in [3, 4]. Even if its reduced dimensionality and high accuracy have made BEM particularity suitable for time-harmonic elastodynamics, solving one frequency-domain equation in 3D domain using classic BEM is computationally very costly. In order to simulate the response of MEMS micro-structures in a real time and highly accurate way, further acceleration is obtained considering H-matrix/vector product [5,6] in the BEM subdomain. This innovative numerical approach results in a modest elapsed computational time and it will therefore allow applications to real life engineering problems.

References

[1] A. Frangi, A. Bugada, M. Martello and P.T. Savadkoohi, Validation of PML-based models for the evaluation of anchor dissipation in MEMS resonators, *European Journal of Mechanics - A/Solids*, **37** (2013), pp. 256–265.

[2] A. Frangi, M. Cremonesi, A. Jaakkola and T. Pensala, Analysis of anchor and interface losses in piezoelectric MEMS resonators, *Sensors and Actuators A: Physical*, **190** (2013), pp. 127–135.

[3] A. Aimi, M. Diligenti, A. Frangi and C. Guardasoni, Energetic BEM-FEM coupling for wave propagation in 3D multidomains, *International Journal for Numerical Methods in Engineering* **97** (2014), pp. 377–394.

[4] S. Falletta and G. Monegato, An exact non reflecting boundary condition for 2D time-dependent wave equation problems, *Wave Motion* **25** (2014), pp. 168–192.

[5] S. Chaillat, L. Desiderio and P. Ciarlet Jr., Theory and implementation of $\mathcal{H}$-matrix based iterative and direct solvers for oscillatory kernels, *Journal of Computational Physics* **351** (2017), pp. 165–186.

[6] L. Desiderio, An $\mathcal{H}$-matrix based direct solver for the Boundary Element Method in 3D elastodynamics, *AIP Conference Proceedings* **1978** (2018), pp. 120005_1-120005_4.