The 8th European Congress on Computational Methods in Applied Sciences and Engineering
ECCOMAS Congress 2022
5 – 9 June 2022, Oslo, Norway

# Topology and shape optimization for transient vibroacoustic problems

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**Key Words:** *Topology optimization, transients, vibroacoustics, viscothermal losses.*

Controlling and tailoring the interaction between structural vibrations and pressure fluctuations in an acoustic medium is integral to the successful design of micro-acoustic-mechanical systems such as sensor, microphones, hearing systems and vibroacoustic metamaterials. For example, a strong vibroacoustic coupling is desired for applications such as microphones and speakers, whereas the effect should be controlled and minimized when designing the housing for hearing systems. However, the interaction arising from the coupled physics makes it hard to use engineering intuition, or trial-and-error design approaches, which motivates the use of systematic design tools such as topology optimization to ensure well-performing vibroacoustic devices [1].

An important requirement for micro-vibroacoustic devices is broad band frequency control. However, if the physics is analyzed in the frequency domain, the consequence is a high numerical cost in terms of the number of indefinite linear systems that must be be solved at every design cycle. To circumvent this potential numerical bottleneck, we propose to solve the state problem in the time domain using white noise as input [2]. By application of a fast Fourier transform, the temporal response is transformed into the frequency domain, in which the optimization problem is cast. The necessary sensitivities are obtained by a fully discrete adjoint analysis and demonstrative examples covering various vibroacoustic filters are included to show the potential of the proposed design methodology.

The vibroacoustic coupling is not the only effect that needs to be taken into account when designing micro-acoustic-mechanical devices. At the micro-scale, losses arising from viscous and thermal boundary layers have the potential to significantly alter the device performance. The inclusion of viscothermal losses can easily be incorporated using a boundary layer impedance condition [3], but such approximations does not capture overlapping boundary layers and can therefore lead to incorrect physical responses. One remedy for this issue is to include the viscothermal losses using a Kirchhoff decomposition [4] through a boundary element implementation. Examples demonstrating the effect of including viscothermal losses will be presented to illustrate the pros and cons of of both approaches.

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