Density and gradient based topology optimization of acoustic-mechanical interaction using equivalent structural loads and acoustic sources from interpolated coupling matrices

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ABSTRACT

Coupled problems, such as acoustic-mechanical interaction, are a challenge when it comes to designing topology optimization schemes. Inherent full design freedom with a priori unknown material distribution is a major strength in a conceptual design phase, but conflicts with most computational schemes for analyzing the coupling between structural vibrations and acoustic pressure in cavities and external domains due to the unknown location of boundaries.

Several methods have been proposed to alleviate the problems and facilitate a topology optimization design procedure. A mixed-FEM formulation was proposed in [1] based on the splitting of stresses into a volumetric (pressure) part and a deviatoric part allowing for a simple interpolation between a structural and acoustic domain without explicit boundary representation. A level method was developed in [2] using explicit interface representation to create a natural separation of structural and acoustic domains. Simplified formulations with restricted design freedom that avoids the need to interchange structural and acoustic domains has also appeared in recent works [3-4].

The present work proposes an alternative computational scheme to analyze coupled acoustic-mechanical problems which is directly applicable to topology optimization. Separate structural and acoustic FE problems are assembled on the entire domain. These are based on a design description using an element-wise continuous density combined with interpolated acoustic and structural properties with artificial acoustic parameters assigned to structural parts and artificial structural parameters assigned to acoustic parts. Interpolated coupling matrices are assembled on the entire domain resulting in equivalent structural loads from the acoustic pressure and equivalent acoustic sources from the vibrating structure.

The computational method has been explored for various test problems and results compare well to standard computational methods implemented in a commercial software (COMSOL). Based on the new analysis method small topology optimization problems for acoustic-mechanical interaction are examined.

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