A FEM/BEM based topology optimization of submerged bi-material shell structures under harmonic excitations

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Abstract

A topology optimization approach is proposed for the optimal design of bi-material distribution on underwater shell structures considering the complete interaction between the structural domain and acoustic domain. The finite element method (FEM) is used to model the structures and the boundary element method (BEM) is used to model the exterior acoustic domain. The Burton-Miller formulation is used to overcome the fictitious eigen-frequency problem when using a single Helmholtz boundary integral equation for exterior acoustic problems. The design variables are volumetric density of design material in a bi-material model constructed by the solid isotropic material with penalization (SIMP) method, and the minimization of sound power level (SWL) is chosen to be the design objective. In this study, the adjoint operator is employed to calculate the sensitivity of the objective function with respect to the design variables. Based on the sensitivity information, the gradient-based optimization solver is finally applied for updating the design variables during the optimization iteration process. Numerical examples are provided to illustrate the accuracy of the sensitivity analysis approach and the validity of the proposed optimization procedure. Results show that the heavy fluid feedback has a big impact on the final design, and thus it's necessary to conduct a strong coupling scheme between the fluid and structures. In addition, the optimal design is strongly frequency dependent, and performing an optimization in a frequency band is generally needed.

Keywords: Topology optimization, Boundary element method, Finite element method, SIMP