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Level set-based topology optimization for the design of a wave motion converter in an acoustic-elastic interaction system

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Abstract

We propose a topology optimization method for the design of a wave motion converter consisting of an elastic medium and air, using a level set-based boundary expression and the Finite Element Method. In an acoustic-elastic coupled system, both acoustic and elastic waves are present. Although acoustic waves propagate only as longitudinal waves, elastic waves propagate as both longitudinal and transverse waves. The aim of a wave converter is to convert one wave type into another type, for example, converting longitudinal waves into transverse waves, or *vice versa*. A wave motion converter based on an optimum design will maximize either the longitudinal or the transverse components of displacement oscillations. To represent the acoustic-elastic coupled system, we introduce a unified multiphase (UMP) modeling technique using Biot's equations, governing equations originally proposed for poroelastic media [1]. In the conventional approach for acoustic-elastic coupled systems, an acoustic Helmholtz equation and an elastic equation are used, and coupling boundary conditions are imposed on the boundaries between the air and elastic medium regions. Due to these boundary conditions, a remeshing process is needed since the configuration will change in every step of the optimization process. In the research cited above, however, the expressions of the air and elastic medium regions are based on adjustment parameters used in the weak form of Biot's equations, so there is no need to remesh the design domain as the interface of the acoustic-elastic coupled system evolves during the optimization process. First, the level set-based topology optimization method is discussed [2]. The optimal design problem for a wave motion converter is formulated next and, based on this formulation, an optimization algorithm is then constructed. Finally, two-dimensional design examples are provided to demonstrate the validity of the proposed method.

References

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