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Topology optimization of composite material plate with respect to sound radiation

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ABSTRACT

In this paper, topology optimization of composite material plate with respect to minimization of the sound power radiation has been studied. A new low noise design method based on topology optimization is proposed, which provides great guidance for acoustic designers. The structural vibrations are excited by external harmonic mechanical load with prescribed frequency and amplitude. The sound power is calculated using boundary element method. An extended solid isotropic material with penalization (SIMP) model is introduced for acoustic design sensitivity analysis in topology optimization, where the same penalization is applied for the stiffness and mass of the structural volume elements. Volumetric densities of stiffer material are chosen as design variables. Finally, taking a simple supported thin plate as a simulation example, the sound power radiation from structures subjected to forced vibration can be considerably reduced, leading to a reduction of 20 dB. It is shown that the optimal topology is easy to manufacture at low frequency, while as the loading frequency increases, the optimal topology shows a more and more complicated periodicity which makes it difficult to manufacture.

1. Introduction

Noise control is becoming more and more important for engineering design [1,2] while the sound radiation of thin plate is always one of the key points. Although active vibration control could be used to decrease structural noise [3], Low noise design is the most reliable means of reducing radiated noise. It is noted that the reduction of low frequency noise is of particular interest, not only because of comfort-related issues, but also because this is usually the most difficult range to deal with. In the passive approach, sizes and shapes of the structural components and composite material tailoring are candidates for optimization [4–6].

"Designing for noise control" was presented at the 37th "INTER-NOISE 1978" about more than 30 years ago. Richard [1], the professor of Massachusetts Institute of Technology, made a brilliant exposition on the conference. Koopmann and Constans [7,8] performed further research on low noise design of structures. The optimization about acoustic radiation properties was considered with the objective of minimizing the total sound power radiated from the vibrating shell surface into a surrounding acoustic medium using simulated annealing algorithm. In addition, a wine glass is tuned optimally to move the first four eigenvalues into harmonic relationships by Koopmann and Belegundu [7]. The design variables were small masses that were added to the upper surface of the wine glass. The conversion of mode shapes of a vibrating shell into weak radiator was accomplished through the introduction of point masses and the calculation of their optimum distributions by Constans and Koopmann [8]. The IUTAM Symposium on "Designing for Quietness" [9] pointed out that "Designing for Quietness" was an important aspect in engineering acoustics and technology acoustics. The noise of the structure should be the basic design index in the technical design stage so as to predict the noise level and make the noise controlled.

Based on the acoustic radiation modes [10] and further study about acoustic radiation, acoustic design sensitivity (ADS) analysis [11,12] was presented to guide low noise design. Weak radiator could be acquired by ADS analysis which was important to engineering design.

ADS analysis presents structural changes in the sound radiation characteristics which can predict the structures with the minimization of sound radiation power. Weak radiator could be obtained by ADS analysis which was important to engineering design.

Up till now, when studying ADS analysis about acoustic radiation, sound pressure is often adopted for design objective [13], and the

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