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# A study on the applications of the acoustic design sensitivity analysis of vibrating bodies

A.S. Sarıgül *, A. Seçgin

*Department of Mechanical Engineering, Dokuz Eylül University, Bornova, İzmir, Turkey*

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**Abstract**

The determination of the sensitivity of the acoustical characteristics of vibrating systems with respect to the variation of the design parameters predicting these characteristics is a necessary and important step of the acoustic design and optimization process. Acoustic design sensitivity analysis includes the computation and evaluation of the sensitivity information required for this procedure. In this study, a boundary element code performing the sensitivity analysis of the acoustic pressure by using the matrix sensitivities with respect to different design variables has been developed. The effect of the precision of boundary element discretization on the acoustic pressure sensitivity is examined via this code. The formulation is applied to a multi-source system and the dimension sensitivity analysis of near field pressures of two-dilating-spherical source is performed. The last application is devoted to a real sound source: a washing machine sitting on the floor. Sensitivity of the field pressures to the machine's dimensions (size), surface velocity and frequency is examined on the bases of the boundary element model of the machine and half-space condition. The impacts of these variables are compared; and a limiting speed for the machine responding both the acoustical and operational requirements is determined.


*Keywords:* Helmholtz integral equation; Boundary element method; Acoustic sensitivity; Dilating sphere; Washing machine

* Corresponding author. Fax: +90-232-388-7864.
*E-mail addresses:* saide.sarigul@deu.edu.tr (A.S. Sarıgül), abdullah.secgin@deu.edu.tr (A. Seçgin).

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## 1. Introduction

It is one of the most important tasks in engineering to reduce the noise caused by vibrating bodies for designing comfortable and select products. The designer should investigate the optimum design parameters without reducing the operation performance. Design sensitivity analysis is the first and the most important step in the optimization problems, because it yields the information about the increment or the decrement tendency of the design objective function with respect to the design parameter. Therefore, acoustic sensitivity analysis plays an important role in determining which parameter of the vibrating body should be modified for effective improvement.

Design analysis generally requires definition of the design objective function. The sensitivity of a design objective function with respect to a design variable is the partial derivative of the function with respect to a characteristic value of the design parameter. In acoustic design sensitivity analysis, design objective function may be the acoustic pressure or acoustic power. The changeable structural or acoustical parameters such as dimension, velocity and frequency may be chosen as the design variable.

The researchers have concentrated on the acoustic design sensitivity analysis particularly in recent years. Most of these studies have been performed by using the boundary element method and concerned with the "shape sensitivity" analysis [1–5]. However in the applications of these studies regular dimensional changes have been considered. Ding [6] has presented a literature survey for structural optimization problems and explained the "shape sensitivity" as irregular dimensional changes computed by using "master nodes which control the shape of a subregion or a design element". Therefore, the "dimension sensitivity" terminology is used instead of "shape sensitivity" in this paper to examine the effect of a single dimension where the change is regular and established by controlling only one dimension.

Bernhard and Smith [1] have developed a sensitivity analysis procedure based on the boundary element implementation of the Helmholtz integral equation, which utilizes the sensitivity of the boundary element matrices to different design variables. They have used the finite difference method to compute the matrix sensitivities; and illustrated the usefulness of the sensitivity information by obtaining sensitivity results of an engine valve cover. Kane et al. [2] have presented an acoustic shape design sensitivity formulation based upon the implicit differentiation of the discretized Helmholtz integral equation. Smith and Bernhard [3] have compared their method of design sensitivity analysis with an alternative method referred to as "recomputation (iteration)" method, for a spherical source. Koo [4] has presented analytical expressions for design sensitivity of acoustic problems obtained by differentiating the conventional boundary integral equation. Koo et al. [5] have presented another study based on their previous formulations with some new examples. Wang and Lee [7] have developed a sensitivity algorithm (GASA, global acoustic design sensitivity analyser) performing "global acoustic design sensitivity of exterior noise with respect to structural sizing design variables". The calculation is based on the multiplication of acoustic sensitivity with respect to the normal velocity of the vibrating structure and structural sensitivity of the velocity with respect to the structural design variable,