# Reliability-Based Optimization of the Coupled Structural-Acoustic System with Random Parameters

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Structural noise is an important factor that endangers aircraft fatigue life and flight safety. It also has a negative effect on aircraft stealth performance and noise navigability. An optimal design of a structure-acoustic coupled system is an effective way to reduce noise and vibration. Due to the uncertainties that exist in the structural and acoustical parameters, the traditional deterministic optimization method may be unfeasible when the parameters are subject to fluctuations. This means that when the parameters are uncertain, the results obtained from the deterministic optimization method may be beyond their constraints. This paper proposes to apply the stochastic reliability-based optimization method to the design optimization of the coupled structural-acoustic system with random parameters. A comparison between the results of the stochastic reliability-based method, the safety factor-based method, and the deterministic method show that the first two methods can effectively consider the dispersion of the parameters.

## 1. INTRODUCTION

Due to the modern industry's rapid development, traffic, city construction, and noise pollution have all attracted attention because they are harmful to structural performance and the general populace's health. Aircraft noise affects both the comfort and work efficacy of the pilot as well as the normal use of instruments inside the aircraft. Uncertainty widely exists in the objective world: it is inevitably subjected to the impact of the uncertainty of a load, structural size, material properties, the influence of various sudden external factors in production, design and use of aircrafts, spacecrafts, etc. These will all have an effect on the working characteristics and normal use of structures and could even lead to failure.

Since the 1970's, some scholars have begun to pay close attention to uncertain structure vibrations and acoustic radiation and have obtained some research results. Shuku and Ishihara[1] investigated the analysis of the acoustic field in irregularly-shaped rooms using the finite element method. Craggs[2] proposed an acoustic finite element approach for studying boundary flexibility and sound transmission between irregular enclosures. Chen and Chertock[3,4] computed sound radiation by using the boundary element method. Marburg[5] studied an optimization problem of the acoustic radiation of finite element beam structures, and analyzed the influence of variables on the objective function where the variables were density, thickness, and young's modulus. Bös[6] studied the optimization problem of three-dimensional structural acoustic performance. Mullen and Muhanna[7] considered the static structure problem with uncertain structural loads based on the fuzzy set theory and interval analysis. Zheng-Dong Ma[8–11] studied the sensitivity of response sound pressure, eigenvalue, and eigenvector to structural parameters based on the modal method, the iterative method, and the direct method. Papadopoulos[12] constructed a finite element model of a room sound field and improved the sound quality of a room by redistributing the low frequency sound modal. Denli[13] studied the structural vibration and acoustic radiation optimization by optimizing the boundary condition. Christensen[14,15] studied the coupled structural-acoustic sensitivity analysis and optimization problem.

The Stochastic reliability-based optimization method is a rather classical approach in the field of optimization, but it has never been used for acoustic optimization. Besides, the previous optimization of the coupled structural-acoustic system were still limited to the deterministic method, and did not take the system parameter uncertainties into account. Deterministic structural optimization design often fails to consider the influence on structural performance by the randomness of material parameters, geometric dimensions, and loading. The optimal solution is usually located at the boundary of the constraint condition because if the randomness of the parameters is considered, the optimal solution may be in violation of the constraint condition and lead to an optimization failure.

The contribution of this paper is to overcome the shortcomings of the structural-acoustic deterministic optimization method by using two different methods: the interference theory of stress- intensity[16–18] and the stochastic reliability-based optimization method, which are both applied to the coupled structural-acoustic system with established random parameters.

## 2. THE FINITE ELEMENT METHOD OF COUPLED STRUCTURAL-ACOUSTICSYSTEM

### 2.1. The Finite Element Equation of the Coupled Structural-Acoustic System

The finite element equation of the coupled structural-acoustic system under frequency domain is as follows:

$$-\omega^2\mathbf{MU} + j\omega\mathbf{CU} + \mathbf{KU} = \mathbf{F}; \qquad (1)$$