Abstract

The aim of this Thesis is to develop topology and advanced shape optimization methodologies for application of multiphysics problems concerning acoustic-mechanical interactions and turbulent flow heat transfer systems. The overall research is motivated by the fact that the complexity of the coupled physics often prohibits design improvements using trial and error approaches.

Part I of the Thesis aims to develop a robust and versatile optimization procedure for vibroacoustic problems. Existing parameterization and design update methods utilized for acoustic-mechanical interaction problems are investigated with a comparative study to highlight individual strengths and weaknesses. Based on the findings, a level set based shape and topology optimization method is developed. In order to realize efficient and accurate modeling during optimization, the immersed boundary cut element method is extended to vibroacoustic problems to handle modeling of non-conforming boundaries on a fixed grid. The generality of the optimization problem is attained with the developed design parameterization allowing consistent utilization of gradient based optimizers for the design update.

The developed optimization procedure is first applied on simplified 2D models. Optimization of a bidirectional wave splitter, considered for two discrete frequencies, resulted in remarkable directivity of the emitted acoustic waves. The framework is also applied on optimization of simplified 2D model of a hearing instrument. 2D optimization cases demonstrated significant improvements on the system behavior, however exhibited strong dependency on the initial design.

The extension to 3D and the applicability of the developed optimization procedure to complex and large scale problems are demonstrated on an industrial scale hearing aid device. In order to minimize sound pressure on the microphone surface, the outer sections of the tube and the suspension structures are optimized. It is demonstrated that the developed optimization procedure is capable to provide performance improvements on complex 3D problems with interior and exterior acoustic domains.

Part II of the Thesis aims to develop an efficient topology optimization framework for the design of large scale multiphysics problems involving turbulent flows with the focus of obtaining exact sensitivities without resorting to any simplifying assumptions. To achieve this, a methodology is proposed for efficient utilization of automatic differentiation tools in the discrete adjoint process. The fluid flow is modeled with Reynolds-averaged Navier–Stokes equations and a turbulence closure model. The developed framework is applied on several 2D and 3D optimization problems. The importance of including turbulence modeling in the optimization process is demonstrated. Coupling to additional physics is further demonstrated on a topology optimization example dealing with design of a heat sink with turbulent forced convection. The study highlights the importance of realistic 3D designs over optimization of simplified 2D models and demonstrates that, for fast flows, better performing heat sink designs can be obtained with including turbulence modeling in the design process.