In the design of mechanical components, numerical simulations and experimental methods are commonly used for design creation (or modification) and design optimization. However, a major challenge of using simulation and experimental methods is that they are time-consuming and often cost-prohibitive for the designer. In addition, the simultaneous interactions between aerodynamic, thermodynamic and mechanical integrity objectives for a particular component or set of components are difficult to accurately characterize, even with the existing simulation tools and experimental methods. The current research and practice of using numerical simulations and experimental methods do little to address the simultaneous “satisficing” of multiple and often conflicting design objectives that influence the performance and geometry of a component. This is particularly the case for gas turbine systems that involve a large number of complex components with complicated geometries.

Numerous experimental and numerical studies have demonstrated success in generating effective designs for mechanical components; however, their focus has been primarily on optimizing a single design objective based on a limited set of design variables and associated values. In this research, a multiobjective design optimization framework to solve a set of user-specified design objective functions for mechanical components is proposed. The framework integrates a numerical simulation and a nature-inspired optimization procedure that iteratively perturbs a set of design variables eventually converging to a set of tradeoff design solutions. In this research, a gas turbine engine system is used as the test application for the proposed framework. More specifically, the optimization of the gas turbine blade internal cooling channel configuration is performed. This test application is quite relevant as gas turbine engines serve a critical role in the design of the next-generation power generation facilities around the world. Furthermore, turbine blades require better cooling techniques to increase their cooling effectiveness to cope with the increase in engine operating temperatures extending the useful life of the blades.

The performance of the proposed framework is evaluated via a computational study, where a set of common, real-world design objectives and a set of design variables that directly influence the set of objectives are considered. Specifically, three objectives are considered in this study: (1) cooling channel heat transfer coefficient, which measures the rate of heat transfer and the goal is to maximize this value; (2) cooling channel air pressure drop, where the goal is to minimize this value; and (3) cooling channel geometry, specifically the cooling channel cavity area, where the goal is to maximize this value. These objectives, which are conflicting, directly influence the cooling effectiveness of a gas turbine blade and the material usage in its design. The computational results show the proposed optimization framework is able to generate, evaluate and identify thousands of competitive tradeoff designs in a fraction of the time that it would take designers using the traditional simulation tools and experimental methods commonly used for mechanical component design generation. This is a significant step beyond the current research and applications of design optimization to gas turbine blades, specifically, and to mechanical components, in general.

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