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AEROFOIL INVISCID DRAG MINIMIZATION BY CONSTRAINED GLOBAL OPTIMIZATION

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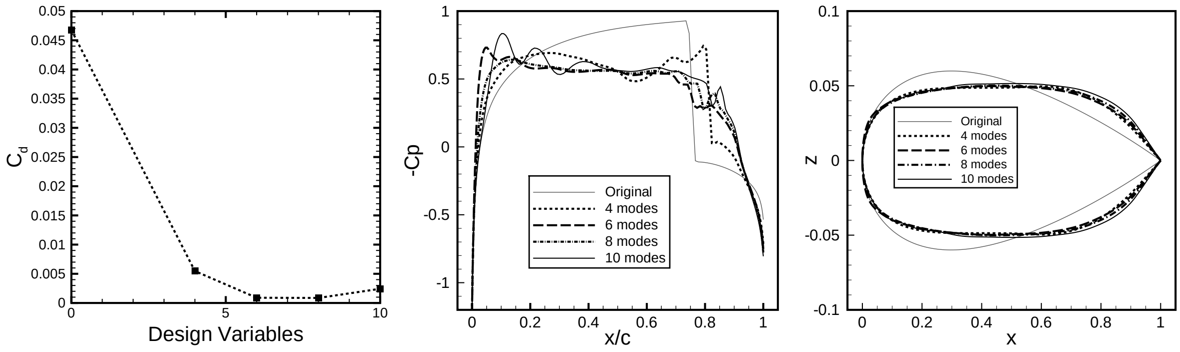
1 Introduction

Aerodynamic shape optimization (ASO) often uses volume-based computational fluid dynamics (CFD) methods to analyse the flow physics to obtain values for the objective function, constraints and sensitivities such that an optimization algorithm can construct a search process, and as such often represents an expensive process. Furthermore, the necessity for strict enforcement of constraints, such as lift and volume, makes selection of an optimization algorithm especially important. The objective of this paper is to investigate the effect that using a constrained global search algorithm has on ASO results and whether globally optimal feasible solutions can be obtained for a variety of aerofoil drag minimization cases. The issues of cost and convergence properties of a constrained global search algorithm are considered, as well as design space modality. This has implications on robustness and optimality, which are considered for several transonic aerofoil shape optimization cases.

2 Results

The gravitational search algorithm (GSA) [1] is a global search optimization algorithm that is based on Newtonian gravitational laws and mechanics, where a set of agents in the search space have a fictitious mass depending on their fitness, and gravitational attractive forces transfer data throughout the swarm. The algorithm, however, has no direct constrained handling mechanism so the approach taken here is to assign the objective function of the particles either the true objective function if they are feasible, or the constraint violation if they are infeasible. Surface and volume control is done by an efficient domain-element [2] approach, which decouples the design variables from the surface. The design variables used have been derived from a decomposition approach [3] to give a reduced set of aerofoil design variables. Inviscid, compressible CFD is used to analyse the objective function. Several different aerodynamic shape optimization test cases have been considered using various numbers of design variables. A result is presented below, demonstrating shock free solutions have been found resulting in up to 98% drag reduction.



(a) Dimensionality (b) Pressure distributions (c) Surface shapes

Figure 1: Dimensionality effect, surface shapes and pressure distributions for zero lift drag minimization of NACA0012 at $M = 0.85$, $\alpha = 0$ with a constraint on volume.

3 Concluding Remarks

This paper has considered the effect of using a constrained global optimizer on a set of aerodynamic shape optimization test cases. High drag reduction results were observed when considering transonic drag minimization of various aerofoils at various conditions, though the cost of using the global optimizer is higher than a gradient-based one. This high number of solutions was made possible due to the parallelisation of the optimizer, when each agent in the search system is assigned to a processor to evaluate its objective function.

Results to appear in the final paper include further cases tested, with further analysis of optimizer convergence and cost, dimensionality and modality.

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