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An airfoil shape optimization technique coupling PARSEC parameterization and evolutionary algorithm

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ABSTRACT

In this work an innovative optimization process for airfoil geometry design is introduced. This procedure is based on the coupling of a PARSEC parameterization for airfoil shape and a genetic algorithms (GA) optimization method to find Nash equilibria (NE). While the PARSEC airfoil parameterization method has the capability to faithfully describe an airfoil geometry using typical engineering parameters, on the other hand the Nash game theoretical approach allows each player to decide, with a more physical correspondence between geometric parameters and objective function, in which direction the airfoil shape should be modified. As a matter of fact the optimization under NE solutions would be more attractive to use when a well posed distinction between players variables exists.

0. Introduction

Airfoil shape optimization is today a common practice used in aerospace and mechanical engineering field. As outlined in Song and Keane [27], the airfoil aerodynamic design can be divided into two main approaches: Inverse Design (ID) and Direct Numerical Optimization (DNO). The first method relates to search an airfoil shape able to satisfy a fluid dynamic characteristic (such as the pressure or the skin friction distribution). On the other hand, DNO methods couple a geometry definition and aerodynamic analysis code in an iterative process to produce optimum design subject to various constraints. However both the approaches share the need to modify airfoil geometry to achieve the goal. Depending on whether the goal is achieved through a small local airfoil modification or a completely new design, different methods of shape parameterization must be employed. Local airfoil shape modifications are usually obtained by smooth perturbations of the original airfoil coordinates through analytical function, such as Legendre, Chebyschev or Bernstein polynomials [14,22,15]. These methods have the advantage of smooth local modifications, although they have no direct relation to geometry and this could lead to undulating curves [15]. The design of a new concept airfoil needs a parameterization method able to accommodate a wider range of new shapes. In the literature several airfoil shape parameterizations can be found. A survey on parameterization method can be seen in Samareh [23]. B-splines and Bezier curves have been widely used to fit airfoil shapes via interpolation methods [8,11]. These methods are very useful to reconstruct and optimize an airfoil (using several artifices on geometry curvatures) but they give some problems due to the difficulties to manage the control points' relative position. Analytical functions have also been derived to represent families of airfoils, as reported in the work of Hicks and Henne [13]. Although this method results very powerful to represent several families of airfoil, it cannot be useful in a radical new concept design. More physically intuitive method enables the use typical airfoil parameters to define the airfoil shape such as leading edge radius, airfoil thickness or trailing edge angle. A methodology of this type is presented by Sobieczky [25,26] and it is called PARSEC. This method uses 11 parameters to represent an airfoil. These parameters are directly linked to the airfoil geometry (thickness, curvature, maximum thickness abscissa, etc.) and they give to a designer the real concept of what will be the design. The geometry definition must be subsequently coupled with an optimization technique which must properly takes into account of the airfoil parameterization. In this work an innovative optimization process for airfoil geometry is introduced. This procedure is based on the coupling of a PARSEC parameterization for geometries and a genetic algorithms (GA) optimization method to find a Nash equilibrium solution. Then the results are compared with the classical Pareto front ones. Many of the past and current optimization processes extensively adopt PARSEC parameterization [25,26] procedure within evolutionary or gradient-based optimization to find the Pareto's front [15,16,20], while Bezier or Hicks–Henne parameterizations are employed with evolutionary or gradient-based

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