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Nash Games and Evolutionary Algorithms for solving CFD design optimization problems: Applications to the drag reduction of a Natural Laminar Airfoil using a Control Bump Active device at transonic shocked flow regimes.

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Abstract

In order to improve the performances of a civil aircraft operating at transonic regimes , new computational optimization methods reducing friction drag have to be investigated. Natural Laminar Flow (NLF) airfoil/wing design belongs to the class of efficient methods to reduce the turbulence skin friction. However, the existence of wide range of favorable pressure gradient on a laminar flow airfoil/wing surface generates strong shock waves occurring at the neighborhood of the trailing edge of the airfoil/wing. Therefore, the reduction of the friction drag due to the extension of the laminar flow region of the airfoil is balanced with an increase of the shock wave induced drag.

In this lecture, an Evolutionary Algorithm (EAs) hybridized with different games strategies (Pareto, Nash and Stackelberg) is coupled with a RANS turbulent flow analysis solver from which an inner boundary layer information can provide the position of the transition point. This approach optimizes the airfoil shape with a larger laminar flow range (maximization by delay transition) and weakens simultaneously the shock wave drag due to an active Shock Control Bump (SCB) device position (minimizing wave drag).

Numerical experiments show that different games coupled to the EAs optimizer can easily capture a Pareto Front (PF), a Nash Equilibrium (NE) and a Stackelberg Equilibrium (SE) of the two-objective Airfoil-Bump shape optimization problem. From a comparative analysis of 2-D results it is concluded that a variety of laminar flow airfoils with greener aerodynamic performances can be significantly improved with optimal SCB active devices.

In conclusion this study illustrates the potential of games strategies coupled to EAs to solve challenging CFD shape design problems such as the optimization of NLF wings in industrial design environments and paves the way to their use in other disciplines such as minimizing the constrained weight of frames in Structural Engineering applications.

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