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FOREWORD

In 1991, a symposium entitled *Multidisciplinary Applications of Computational Fluid Dynamics* was organized. Its bound volume (ASME FED-Vol. 129, O. Baysal, editor) included a few papers reporting on the utilization of CFD in a design environment. Since then, there has been a delightful increase in the interest in this topic for a clearly justified reason: CFD can be useful beyond just analyzing a fluid flow and be utilized for the purpose of design and optimization in order to cut down the turnaround time for a new product design.

This, however, may be a prohibitive proposition for the computational and human resources if, as is often the case, a large matrix of candidate designs or design variables are involved. Therefore, the motivation for the present Forum was to provide a medium for the beyond-the-cut-and-try approaches, where CFD is a module of an automated methodology seeking the improved designs.

As may be evidenced by the quality of the papers in this volume, some of the best in the field of CFD have investigated various approaches for this purpose. Today, there are government-funded initiatives to make even the multidisciplinary design optimization a reality, in which CFD plays one of the pivotal roles. Better yet, such efforts are not being perceived as just academic or esoteric exercises, but major corporations are investing in this exciting endeavor. (The engineering and the scientific communities wish that these corporations would also expedite the public release of their findings.)

Even a cursory glance through the emerging publications on the subject matter of the present volume should reveal the attempts and successes in the topics which include: pre- and post-optimization sensitivity analyses, discrete and variational sensitivity methods, gradient-based and non-gradient-based numerical optimization methods, adjoint methods, stochastic and genetic algorithms, shape optimization, direct and inverse methods, trade-off identification studies, multipoint designs, and artificial-intelligence-based methods. It is the intention of ASME's Fluids Engineering Division to repeat this Forum in the not-so-distant future in its attempt to disseminate the further advances and applications of these topics.

Finally, the editor acknowledges all the individuals who have contributed to this Forum and its bound volume. Among them are the authors, The Coordinating Group on CFD of ASME's Fluids Engineering Division, and the meetings and publications staff of ASME.

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Wing-Section Optimization for Supersonic Viscous Flow

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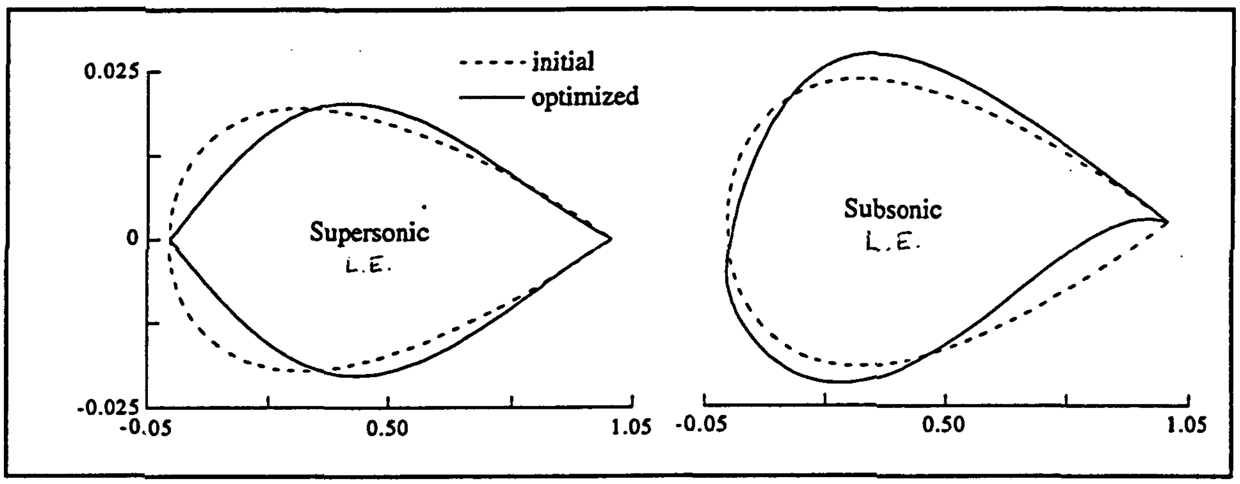

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WING-SECTION OPTIMIZATION FOR SUPERSONIC VISCOUS FLOW

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ABSTRACT

To improve the shape of a supersonic wing, an automated method that also includes higher fidelity to the flow physics is desirable. With this impetus, an aerodynamic optimization methodology incorporating thin-layer Navier-Stokes equations and sensitivity analysis had been previously developed. Prior to embarking upon the wing design task, the present investigation concentrated on testing the feasibility of the methodology, and the identification of adequate problem formulations, by defining two-dimensional, cost-effective test cases. Starting with two distinctly different initial airfoils, two independent shape optimizations resulted in shapes with similar features: slightly cambered, parabolic profiles with sharp leading- and trailing-edges. Secondly, the normal section to the subsonic portion of the leading edge, which had a high normal angle-of attack, was considered. The optimization resulted in a shape with twist and camber which eliminated the adverse pressure gradient, hence, exploiting the leading-edge thrust. The wing section shapes obtained in all the test cases had the features predicted by previous studies. Therefore, it was concluded that the flowfield analyses and sensitivity coefficients were computed and fed to the present gradient-based optimizer correctly. Also, as a result of the present two-dimensional study, suggestions were made for the problem formulations which should contribute to an effective wing shape optimization.

INTRODUCTION

Studies initiated by NASA has identified a growing long-range transport market for a new supersonic airliner. This recent interest in a High Speed Civil Transport (HSCT) has led to renewed research studies for enhanced supersonic configurations. Improving the cruise efficiency of such an aircraft, which can be enhanced by optimizing its wing-sections, is vital for its economical viability and environmental acceptability. In the past, several methods have been implemented to obtain the most suitable supersonic profiles. While linearized theory was used to develop the basic concepts, other advanced theories were studied to introduce the non-linear effects. Today, the challenge is the introduction of the viscous nature of the flow to the supersonic wing design and performing the design process in an automated manner.

Examining the designs with linear theory (Drougge, 1965), or second-order theory (Miele and Lusty, 1965), or optimizations with shock-expansion theory (Dutt and Sreekanth, 1979), the following may be concluded: (1) when a thickness constraint is imposed, the optimum shape is a double-wedge profile, whereas using an area constraint leads to a parabolic profile; (2) linear theory results give symmetric profiles with respect to mid-chord; (3) non-linear effects lead to a slight shift in the maximum thickness location in the flow direction; (4) for all the cases, the maximum thickness location is around the mid-chord and the leading- and trailing-edges are sharp.

The next step in the wing section optimization has been the introduction of the three-dimensional effects of the flow. Among the significant studies are the conical-full potential approach of Pittman (1987) and the modified linearized theory of Mann and Carlson (1994). Recently, three-dimensional inviscid optimizations were performed by Reuther et al. (1992), and Burgreen and Baysal (1994). Currently, viscous wing shape optimizations are under investigation.

It can be deduced from this brief survey that as increasingly higher fidelity flowfield equations were used in