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APPLICATION OF GENETIC ALGORITHMS TO HIGH SPEED AIR INTAKE DESIGN

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Abstract Recent advances in methodologies for flow simulation and optimization have enabled automated design optimization of high speed air intakes (inlets). The flow simulation techniques are typically hybrid empirical/inviscid codes which incorporate either experimental data or a theoretical model for the total pressure losses in the terminal shock system. Reynolds-averaged Navier-Stokes (RANS) codes are employed to verify the designs, but are not commonly used in the design optimization process. Optimization methods include both local (gradient-based) and global (stochastic) methods. The paper presents a summary of high speed air intake design studies performed at the Center for Computational Design at Rutgers University in collaboration with Aérospatiale Matra Missiles and United Technologies Research Center.

1. INTRODUCTION

High speed (*i.e.*, supersonic) intakes are essential elements of air breathing propulsion systems. Their function is to provide a specified mass flow to the engine (*e.g.*, compressor face in the case of a turbojet) at high total pressure and minimal flow distortion.

Two major technology trends have enabled *automated* optimal design of high speed intakes. First, computer processor performance is doubling every 18 to 24 months[1] with a concomitant reduction in the cputime per simulation. This trend permits the use of more advanced simulation methods for analysis of intakes (*e.g.*, 3-D Euler equations) in an automated design environment wherein hundreds to thousands of flow simulations are performed. Second, local (*e.g.*, gradient-based) and global (*e.g.*, stochastic) optimization algorithms (also known as search algorithms or search engines) have improved significantly in applicability, efficiency, and robustness.

This paper reviews recent research in automated optimal design of high speed intakes at the Center for Computational of Rutgers University in collaboration with Aérospatiale Matra Missiles and United Technologies Research Center. A complete list of participants is provided in the Acknowledgments section.

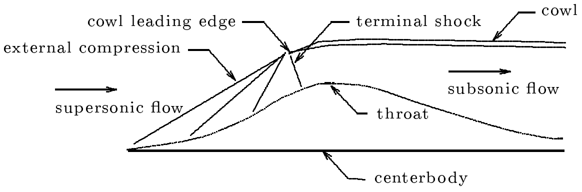

Fig. 1 External compression intake

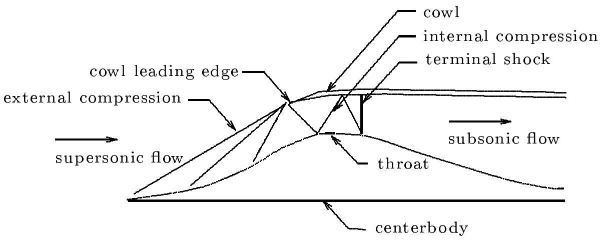

Fig. 2 Mixed compression intake

2. INTAKE AERODYNAMICS

The function of a conventional (*i.e.*, non-scramjet) supersonic intake is to provide a specified mass flow rate at a given subsonic speed to the engine (*e.g.*, compressor in the case of a turbojet, or combustor in the case of a ramjet) with minimal loss of total pressure and flow distortion. There are two types of supersonic intakes, namely, external compression and mixed compression as illustrated in Figs. 1 and 2, respectively. In an external compression intake, the flow deceleration from supersonic to subsonic speeds occurs upstream of the cowl leading edge (the intake entrance) through a series of oblique shocks (or, possibly, an isentropic compression) followed by an approximately normal shock (the terminal shock). The flow is further decelerated in the diverging portion of the intake (the subsonic diffuser). In a mixed compression intake, the flow deceleration from supersonic to subsonic speeds occurs both upstream and downstream of the cowl leading edge. The terminal shock is located in the diverging section of the intake to achieve stability in the presence of small disturbances[2]. Supersonic intakes are common on aircraft and missiles (*e.g.*, the F-14 shown in Fig. 3 and the Aérospatiale Matra