Aerospace Engineering Thesis Defense

Unique Design Discoveries for a Modern Mach 1.3 Airliner Including Anomalies in the Shock Wave Formation Along a Highly Swept Blunt Leading Edge Wing

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Abstract

The process of designing any real world blunt leading-edge wing is tedious and involves hundreds, if not thousands, of design iterations to narrow down a single design. Add in the complexities of supersonic flow and the challenge increases exponentially. One possible, and often common, pathway for this design is to jump straight into detailed volume grid CFD, in which the physics of supersonic flow are modeled directly but at a high computational cost and thus an incredibly long design process. Classical aerodynamics experts have published work describing a process which can be followed which might bypass the need for detailed CFD altogether. This work outlines how successfully a simple vortex lattice panel method CFD code can be used in the design process for a Mach 1.3 cruise speed airline wing concept. Specifically, the success of the wing design is measured in its ability to operate sub-critically (i.e. free of shock waves) even in a free stream flow which is faster than the speed of sound. By using a modified version of Simple Sweep Theory, design goals are described almost entirely based on defined critical pressure coefficients and critical Mach numbers. The marks of a well-designed wing are discussed in depth and how these traits will naturally lend themselves to a well-suited supersonic wing. Unfortunately, inconsistencies with the published work are revealed by detailed CFD validation runs to be extensive and large in magnitude. These inconsistencies likely have roots in several concepts related to supersonic compressible flow which are explored in detail. The conclusion is made that the theory referenced in this work by the classical aerodynamicists is incorrect and/or incomplete. The true explanation for the perplexing shock wave phenome observed certainly lies in some convolution of the factors discussed in this thesis. Much work can still be performed in the way of creating an empirical model for shock wave formation across a highly swept wing with blunt leading-edge airfoils.

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