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Short Communication

Comparison of Linear Vortex Lattice Method and Higher Order Panel Method with CFD and Wind Tunnel Data

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Abstract

In order to evaluate the applicability and efficacy of two distinct induced drag computational techniques based upon linearized, attached potential flow theory, a generic trapezoidal wing is analyzed. These two techniques are extensively utilized in academia and aerospace industry and are founded upon vortex lattice method and higher order panel method respectively. An extended VLM-based technique approximates the three dimensional wing and fuselage into a co-planar geometry. Moreover suction parameter that is calculated analytically, is given as an input to capture three dimensional leading edge thrust and vortex lift effects. On the contrary, the higher order panel method, models the complete geometry. It varies the wake orientation with angle of attack, to better predict the effects of downwash. Both techniques incorporate compressibility effects and therefore are more apt to analyze, both subsonic and supersonic regimes. Due to its wide spread applications in conceptual design and optimization of aircraft geometry, these two methods is compared for accuracy, set-up time and input controllability. The small UAV presents many advantages in size, cost, and portability. Because of this it is often desired to design many UAVs, one for each task, and often in a competitive environment. The designer needs a set of validated conceptual design tools that allow for rapid prediction of flight characteristics. The validation study will be conducted on the Ultra Stick 120 using a comparison of a Vortex Lattice method and Digital DATCOM to wind tunnel data. These computational tools are provided as a part of the CEASIOM software suite. This thesis uses two different methods to analyze wings in supersonic flows with a focus on preliminary design. The primary goals of this study are to compare the Euler equations finite volume method and supersonic vortex lattice method in predicting surface pressure on wings, and to develop a low-order supersonic vortex lattice method as a baseline tool that can be extended for further wing design and analysis. The supersonic vortex lattice method uses vortical sources to model the flow on the boundary, which replicates the aerodynamic shape of interest, in an inviscid and irrotational flow field and obtain solutions. The Euler equations of flow can be discretized using finite volume methods and can be integrated over the volume of interest and solutions can be obtained over the surface. These mathematically similar methods have a lot of differences in their numerical formulations, which can be critical in the design and analysis of wings. Hence, it is important to understand the key differences of these in order to develop a reliable baseline low-order design tool. To compare these two methods, a flat plate subsonic leading-edge delta wing with a leading-edge factor (cot(LE)) of 0.6 will be modeled at the same conditions. The lattice method will be coded using MATLAB and the Euler equations will be solved using ANSYS® Fluent. The differential pressure at the camber, aerodynamic coefficients, time to solve, effort to discretize, and other mathematical considerations for both methods are iii compared. As expected, pressure results shown good congruency between both methods. The lift coefficient and moment coefficient show around a 10% difference, while the drag shows the most difference at 30%. Convergence for the supersonic vortex lattice method happens immediately, on-the-order of seconds, while ANSYS® Fluent takes significantly longer, on-the-order of hours. Several programs exist today for calculating aerodynamic coefficients that with some simplifications provide fast approximations of the values for a real aircraft. Four different programs were analyzed for this report: Tornado, AVL, PANAIR and a handbook-type preliminary method. The accuracy of the results showed that the validity of the software depends on the planform of the aircraft, as well as the simulation parameters Mach number and Reynolds number. The jet thrust can then be vectored by use of the trailing edge curvature since the jet flow tends to remain attached by the "Coanda Effect". Wind tunnel and flight-testing have shown USB aircraft to be capable of producing maximum lift coefficients near 10. They have the additional benefit of shielding the engine noise above the wing and away from the ground. Given the potential gains from USB aircraft, one would expect that conceptual design methods exist for their development. This is not the case however. While relatively complex solutions are available, there is currently no adequate low-fidelity methodology for the conceptual and preliminary design of USB or USB/distributed propulsion aircraft. The focus of the current work is to provide such a methodology for conceptual design of USB aircraft. Based on limited experimental data, the new methodology is shown to compare well with wind tunnel data. In this thesis we have described the new approach, correlated it with available 2-D data, and presented comparisons of our predictions with published USB data and an existing non-linear vortex lattice method. The current approach has been shown to produce good results over a broad range of propulsion system parameters, wing geometries, and flap deflections. In addition, the semi-analytical nature of the methodology will lend itself well to aircraft design programs/optimizers such as ACSYNT. These factors make the current method a useful tool for the design of USB and USB/distributed propulsion aircraft.

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