Efficient Computational Fluid Dynamics for Rotorcraft Analysis

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Airflows over rotorcraft are far more complex and more difficult to predict than those that occur on fixed-wing aircraft. The inability to predict many of these flows is a direct or indirect contributor to the cost, duration, and risk of the rotorcraft development process. For this reason, the application of computational fluid dynamics (CFD) is an important and growing part of the rotorcraft research process. However, rotorcraft aerodynamics is difficult for CFD because the limiting physical problems of rotorcraft differ from those of fixed-wing aircraft for which CFD was originally developed. An example of such a flow is the wake that is shed by the rotor. Such wakes are also generated by conventional aircraft and are made visible in the contrails of high-altitude airliners. The primary difference with rotorcraft is that because of its rotary motion, a rotor never gets far from its shed wake. This adjacent wake strongly determines the performance and acoustics of a rotor. The ability to predict this wake with the required accuracy has been shown to require far greater computational resources (with conventional methods) than is practical for engineering analysis. The objective of this work is to develop new CFD wake-computation methods that are accurate and practical for everyday use.

A new class of CFD methods, specifically designed for engineering analysis, has been developed. The method is a modification of the potential solvers that were an early focus of CFD development. The approach, called "vortex embedding," consists of a means of inserting a freely convecting vortical wake —a capability that such solvers originally lacked. This approach permits the prediction of this wake with a grid system that is orders-of-magnitude smaller (and hence more efficient) than present methods. Until this year, the approach lacked the ability to predict the viscous flow on the rotor surface. This shortcoming has been removed with the development of an overset/hybrid solver that combines the embedding method in the wake region and a Navier-Stokes viscous-flow solver adjacent to the blade surface.

The prediction of tilt-rotor flows is ideal for this method because the high lift of these rotors results in blade-root stall. Recent computations are demonstrating the ability to predict the performance of the XV-15 tilt-rotor performance. The accompanying figure shows experimental and computed figures of merit (a measure of rotor power) for this rotor. It is shown that the figures of merit at higher thrust levels (characteristic of actual operating conditions) is well predicted. The inset in this figure is a visualization of the computed wake that is shed by this rotor.

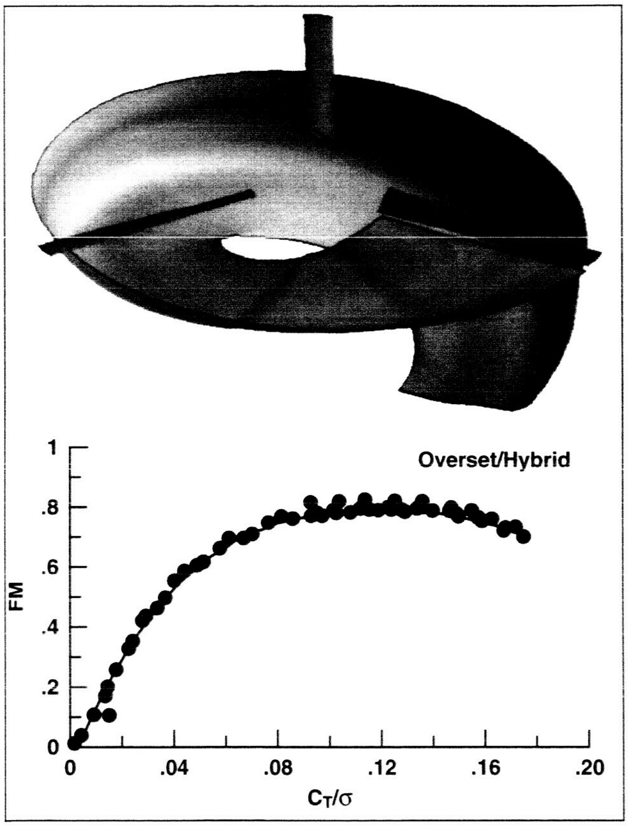

Fig 1. Hybrid overset/imbedded computation of XV-15 hover performance.

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