Computational Fluid Dynamics in Rotor Design

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Rotorcraft are important because they can hover, and the efficiency of this hover is fundamental to helicopter productivity. It is surprising, therefore, that our ability to predict hover efficiency (and thereby to design optimum rotors) is limited. This is because the rotor flow field is so sensitive to the rotor wake that there are large analytical errors. This same wake sensitivity also causes large experimental errors. (If a perfect prediction capability existed, there would be no way to know it, because of experimental error.) Therefore, the attainment of greater rotor analysis capability is a twofold problem of improving both computational and experimental accuracy. This effort is directed at the computational part of the problem.

The classic problem with the methods of computational fluid dynamics (CFD) is that numerical dissipation severely degrades the wake prediction. The method of vorticity-embedding is unique in that it is the only CFD method that totally obviates this dissipation. This unique ability enables the use of small grids and permits practical computation of the

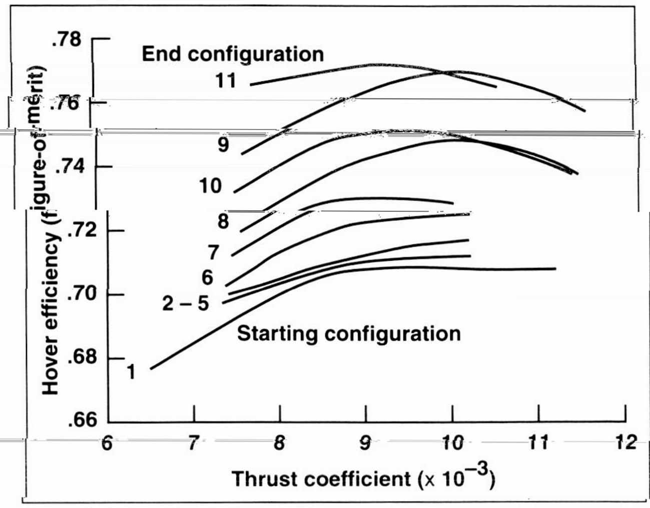
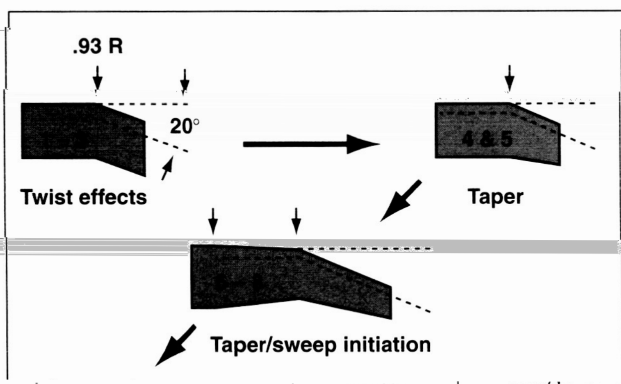
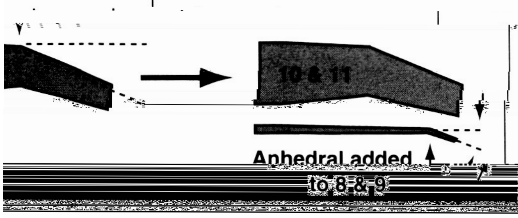


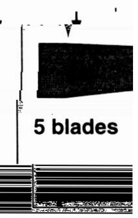
Fig. 2. Graphs of computed rotor efficiency computations performed using vorticity-embedded CFD. These efficiency plots correspond to the configurations shown in the first figure.

compressible, free-wake rotor flow. This method is now being applied to the analysis of specific rotor configurations in an effort to maximize the hover efficiency that can be attained with currently used fabrication technology.

The first figure shows one of several configurational development paths that are now being studied. This configurational evolution path includes the combined effects of sweep, taper, twist, and anhedral. The second figure shows the range of performance improvements obtained through this range of configurations. In this particular case the starting rotor is an AH-64A rotor and the resulting efficiency increases are sufficient to increase payload by about 1000 pounds.







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he tip sections of some rotors under study a path of rotor configuration variations to an enhanced hover efficiency.

Fig. 1. T showing leading