FREE WAKE CALCULATION OF ROTOR

FLOW FIELDS FOR INTERACTIONAL AERODYNAMICS

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Abstract

The principal objective of this work was to explore the applicability of recent innovations in the analysis of vortex dynamics to problems of interest in rotorcraft interactional aerodynamics. Using a novel, full-span rotor wake representation constructed of curved vortex elements, accurate qualitative and quantitative predictions of wake velocity data were achieved for rotors in both low- and high-speed forward flight. The flow field predictions also illustrated the radical changes that take place in the wake velocity field as speed increases and demonstrated the success of this new approach in capturing these variations. In addition, new methods for analyzing close interactions between vortices and fixed surfaces have been developed. The basis of this new approach is the inclusion of a special treatment of the vortex velocity field for close interactions with paneled surfaces which obviates the need for high local panel density. Model problems were solved featuring vortices in close proximity to surfaces that illustrate the accuracy and efficiency of the new method. The results of this preliminary effort indicated that several additional features must be added to the current analyses to produce a generally applicable interaction analysis. However, the primary conclusion of this research is that the new techniques described herein can form the foundation of such an analysis.

Introduction

Background

Historically, most of the analytical and computational work in rotorcraft wake modeling has focused on prediction of isolated rotor performance and loads (Refs. 1-3). Substantial progress in this area has been made, including recent advances in the prediction of rotor loads and wake geometry using novel free wake models, (Refs. 4 and 5). However, treatment of main rotor wake effects on other components of the helicopter (e.g., the tail rotor, empennage, and fuselage) is much less advanced. Thus, a significant opportunity exists to exploit current and anticipated developments in rotor wake modeling to advance the current understanding of interactional aerodynamics.

The importance of having a reliable tool to predict such loads is amply illustrated in many experimental studies in the literature, e.g. Refs. 6-9. The development history of the McDonnell Douglas AH-64 Apache in particular provides several examples of the potential importance of main rotor/tail rotor/empennage interaction. As Ref. 10 describes, the early versions of the AH-64 encountered significant trim excursions in forward flight and climb due to the unexpectedly large downwash of the main rotor wake on the T-tail horizontal stabilizer (Figure 1). Further complicating analysis and understanding of this phenomenon was the asymmetry of the downwash on the tail downstream of the main rotor (Figure 2). Lacking the tools to predict and analyze such wake-generated phenomena, extensive flight tests were required to diagnose and fix these problems. The AH-64 also encountered significant problems with unstable Dutch Roll motions due to the coupling of pitch motion with sideslip at high forward speed. Figure 3 illustrates the measured flowfield in the vicinity of the empennage showing the asymmetrical downwash that leads to the pitch/sideslip coupling in forward flight. Clearly, to capture inflow patterns like this accurately, an advanced wake model will be required.

The examples cited above are only a sample of the many interactional aerodynamic issues that are of interest for rotorcraft applications. Others include the determination of steady and unsteady loads on bluff structures like typical helicopter fuselages, and special effects due to the proximity of the ground. The problems discussed, though, emphasize the interaction of the main rotor wake with the tail rotor and lifting tail surfaces and are judged to be significant issues that may be addressed with technology that is currently available or may be developed from current analytical tools.

The problem as implied in this discussion is to calculate the steady and unsteady loads induced by the main rotor wake on fixed or rotating lifting surfaces downstream of the rotor. Several previous computational efforts have been

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