ROTORCRAFT INTERACTIONAL AERODYNAMICS WITH FAST VORTEX/FAST PANEL METHODS

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ABSTRACT

A Comprehensive Hierarchical Aeromechanics Rotorcraft Model, (CHARM), incorporating fast vortex and fast panel methods for modeling complete rotorcraft has been developed and applied to the problems of rotor/wake/body interaction, wind tunnel wall interference, and ground effect. Sample calculations are presented to demonstrate the capabilities of the fast methods in these modeling applications. Correlations with test data are described that illustrate the performance of the analysis in capturing measured values of average rotor performance, rotor-induced fuselage loading, and wake geometry associated with interactional aerodynamics phenomena. Results suggest that these fast methods can provide good accuracy for a wide variety of key interactional aerodynamics problems at computation times far less than finite volume/finite difference (FV/FD) CFD analyses.

INTRODUCTION

The accurate prediction of rotor/wake/fuselage interactions is a perennially challenging and significant issue in rotorcraft design, especially so today in light of the wide variety of rotorcraft (e.g., single-rotor, tandem, intermeshing, tiltrotor) currently in service or under study. Interactional phenomena affect rotorcraft performance, vibration and handling qualities in several ways, particularly (1) alteration of main rotor inflow due to the presence of the fuselage, (and for tiltrotors, the wing), (2) unsteady fuselage pressures due to the influence of the main rotor and main rotor wake, and (3) the influence of the main rotor wake on other lifting surfaces such as the tail rotor, the empennage (rear lifting surfaces and stabilizers), and for tiltrotors the main wing. Interactive phenomena are also by definition important in testing or operational situations where wind tunnel wall interference or ground effect are present.

The need for a computationally efficient tool to address these problems and analyze complex, full-aircraft configurations has long been evident, and the model development and validation activity described here has been directed at meeting this need. This effort built on previous work at Continuum Dynamics, Inc., (CDI), which saw the coupling of a full-span, free wake model to a non-lifting panel analysis for the purpose of analyzing rotor/wake/fuselage interactions (Ref. 1). This prior analysis has been extended to include provision for lifting surfaces, flow through closed and open section wind tunnel sections, and through the incorporation of fast panel and fast vortex methods that greatly reduce CPU and memory requirements to allow full-aircraft simulations while maintaining high-fidelity representations of the rotors, wake, and fuselage.

In the late 70's, Sheridan and others (Refs. 2-4) brought attention to interactional aerodynamics (IA) problems associated with rotorcraft. This attention resulted in numerous experimental (e.g., Refs. 5-9) and analytical (Refs. 1, 10-19) efforts directed toward developing a data base on rotorcraft IA, as well as computational tools for modeling the interaction of rotor wakes with fixed surfaces. The analytical efforts cited above all involved using potential flow methods coupling either prescribed or free vortex wake models with panel singularity representations of the fuselage.

Despite the important role of viscosity in wake/fuselage interactions, the choice to use potential flow methods has often been made because Euler and Navier-Stokes (NS) methods require enormous amounts of computation time and memory and face significant difficulties combining rotating and fixed frames and in avoiding numerical dissipation of vorticity. The latter is a particularly daunting handicap when studying vortex/surface interactions which may occur far downstream of the main rotor. However, with the continuing high rate of increase in speed and memory capabilities of computers as well as algorithmic advances, Euler and NS codes have begun to be applied to interactional aerodynamics problems more effectively, first for the isolated fuselage, (Refs. 20-22) then with implicit or actuator disk modeling of the rotor (Refs. 23, 24) and finally modeling the full rotor/wake/fuselage configuration, (Refs. 25-28).

Still, potential flow analyses continue to be popular tools among rotorcraft manufacturers and can (as will be seen) provide a great deal of useful information regarding rotor/rotor-wake/fuselage interactions. For this class of

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