FULL VEHICLE FLIGHT SIMULATION WITH REAL TIME FREE WAKE METHODS

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ABSTRACT

The development of fast, high-fidelity models of rotorcraft flight mechanics is a crucial requirement for streamlining the design and testing of new rotorcraft. Efficiently capturing the complex aerodynamics and dynamics of the rotor/fuselage system is a central challenge in meeting this requirement. This paper describes an effort to bring the most advanced current free wake aeromechanical models to bear on this class of problems via the development of a spectrum of innovative techniques for greatly accelerating free vortex wake and fast panel calculations. The new Real Time Free Wake (RTFW) methods described have provided dramatically accelerated embodiments of validated free wake models for flight dynamics and simulation applications. By embedding RTFW methods in the stand-alone CDI CHARM (Comprehensive Hierarchical Aeromechanics Rotorcraft Model) code, high fidelity treatments of rotor/wake and rotor/airframe interaction have been produced while yielding real time performance on both current workstations and desktop/laptop PCs. In addition, a real time free wake module was also produced and coupled to both in-house simulation tools as well as the Sikorsky GenHel code to demonstrate and validate a fast, comprehensive free flight simulation.

Nomenclature

a	lift curve slope, rad^{-1}
c	mean blade chord, ft
C_T	thrust coefficient
k	order of multipole expansion
L	number of levels in an octree mesh
N	number of vortices
N_b	number of blades
N_ψ	number of steps in a blade revolution
q	pitch rate, rad/sec
r	radial distance along rotor blade, ft.
r_b	radius encompassing box b of the octree
R	rotor radius, ft.
T	rotor thrust, lbs.
w	downwash velocity at rotor disk, fps
v_0	mean downwash velocity at rotor disk, fps
v_c	cosine component of rotor downwash, fps
x	nondimensional radial distance r/R
α_S	shaft angle of attack, deg.
ε_{SC}	scaling factor for size of near field region
μ	advance ratio, $U/\Omega R$
ρ	air density, $slugs/ft^3$
σ	rotor solidity,
ψ	blade azimuth angle, deg.
Ω	rotor rotation rate, rad/sec
O( )	order of magnitude

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Overview

One of the key technical problems in the area of flight simulation modeling is the challenge of representing rotor wake effects in an accurate, robust, and computationally fast manner and transitioning such a model to use in practical analysis tools. A range of problems from crew training to control system design would be greatly improved by the availability of a fast-turnaround, high fidelity free wake model suitable for these applications, a model that could also support vehicle preliminary design work. Such an analysis would also bypass the simplifications of the current generation of analyses used in rotorcraft free flight simulations, eliminating the tradeoff in fidelity and computational speed that has limited their reliability.

The particular technical approach taken here was to develop a dramatically accelerated, reduced order embodiment of a validated free wake model, thus providing a high fidelity treatment of rotor/wake/body interaction for flight dynamics and simulation activities. A specific aim was to demonstrate that a Real Time Free Wake (RTFW) model was in hand, with supporting goals of effecting a coupling with an industry-standard flight simulation and validating the resulting coupled model. This goal was achieved, demonstrating that the reduced order approach yields dramatically increased computational speed, permitting real time operation on conventional workstations and PCs.