CFD-based Simulation and Experiment in Helicopter Aeromechanics
R.E. Brown and S.S. Houston

Simulation of the flight dynamic performance of rotorcraft still poses significant difficulties to the analyst. The key to accurate prediction of the performance, handling qualities, fuselage dynamics and vibration of any given vehicle is accurate prediction of the geometry and the strength of the wakes generated by its rotors. These wakes have important structure on length scales ranging from the blade chord to the rotor diameter and are strongly time-dependent. In multiple-rotor configurations, the wakes introduce strong aerodynamic coupling between geometrically well-separated parts of the system. Wake-wake and wake-rotor interactions often dominate the aerodynamic environment of any rotorcraft and must also be modelled properly if the vehicle's aeromechanical behaviour is to be predicted with any confidence.

Up until recently, the traditional approach in flight mechanics simulations to modelling the effects of the wake has used unsteady potential theory to track the evolution of a finite (but arbitrarily large) set of rotor inflow-modes. Although simple to implement and capable of near real-time simulation, this approach has been shown over the years to have serious limitations when compared against flight test data. Indeed, the approach is invalid in certain flight conditions of operational interest. This has led us to explore the possibility of supplanting this approach to modelling the effects of the rotor wake by using a CFD-type technique. This technique is potentially capable of representing the flow physics to a much higher degree of accuracy than is possible with the traditional inflow-mode based approaches.

In this paper we describe the development of this model, and illustrate its use in a range of circumstances. Some results for the calibration of the model against some extremely well-prepared experimental studies are presented to illustrate the inherent validity of the approach. The difficulties in the calibration of such a model against flight test data are illustrated, though, by comparing model predictions with data from tests on a full-scale Puma aircraft conducted at DERA Bedford in the late 1980s and from more recent tests on gyroplanes. The reasons for the rather serious discrepancies in the model predictions of the full-scale systems are discussed, and some pointers towards the future of rotorcraft flight dynamic modelling are put forward.