Modelling a helicopter rotor's response to wake encounters

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ABSTRACT

In recent years, various strategies for the concurrent operation of fixed- and rotary-wing aircraft have been proposed as a means of increasing airport capacity. Some of these strategies will increase the likelihood of encounters with the wakes of aircraft operating nearby. Several studies now exist where numerical simulations have been used to assess the impact of encounters with the wakes of large transport aircraft on the safety of helicopter operations under such conditions. This paper contrasts the predictions of several commonly-used numerical simulation techniques when each is used to model the dynamics of a helicopter rotor during the same idealised wake encounter. In most previous studies the mutually-induced distortion of the wakes of the rotor and the interacting aircraft has been neglected, yielding the so-called 'frozen vortex' assumption. This assumption is shown to be valid only when the helicopter encounters the aircraft wake at high forward speed. At the low forward speeds most relevant to near-airfield operations, however, injudicious use of the frozen vortex assumption may lead to significant errors in predicting the severity of a helicopter's response to a wake encounter.

NOMENCLATURE

a	aerofoil lift-curve slope
A	rotor disc area πR^2
c	blade chord scaled by R
C_L	blade section lift coefficient
C_T	rotor thrust, scaled by $\rho A(\Omega R)^2$
I_β	blade flapping inertia, scaled by ρAR^3
L	distance from the vortex core to the rotor hub
N	number of rotor blades
r	radial coordinate, scaled by R
r_c	vortex core radius, scaled by R
R	rotor radius
S	vorticity source, scaled by $\Omega^2 R^2$
t	time, scaled by $1/\Omega$
v	velocity of flow surrounding rotor, scaled by ΩR
v_c	velocity at periphery of vortex core, scaled by ΩR
v_i	velocity normal to rotor disc, scaled by ΩR
v_P	velocity parallel to blade section, scaled by ΩR
v_T	velocity normal to blade section, scaled by ΩR
v_{vortex}	vortex-induced velocity field, scaled by ΩR
v_{wake}	wake-induced velocity field, scaled by ΩR
α	blade section angle-of-attack
β	blade flapping angle
β_0	rotor coning angle
β_{1s}	rotor lateral tilt angle
β_{1c}	rotor longitudinal tilt angle
γ_β	rotor Lock number $ac/\pi I_\beta$
θ	blade feathering angle
θ_0	collective pitch control angle
θ_{1s}	longitudinal cyclic pitch control angle
θ_{1c}	lateral cyclic pitch control angle
μ	rotor forward speed, scaled by ΩR
σ	rotor solidity Nc/π
ψ	blade azimuth
ω	vorticity of flow surrounding rotor, scaled by ΩR^2
ω	blade flapping frequency, scaled by Ω
Ω	rotor rotational speed

1.0 INTRODUCTION

Innovative exploitation of the runway-independent nature of helicopter operations has been proposed as a means of maximizing the use of ground- and air-space at airfields[1] and thus of increasing

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