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"Measurement of the Velocity Field of a Cylinder in the Wake of a Rotor in Forward Flight".

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ABSTRACT

The problem of predicting the flowfield around a rotorcraft in low-speed forward flight is studied using a potential-flow code, whose results are compared with surface pressure measurements and flow velocity measurements. The test case used is a 2-bladed teetering rotor above a hemisphere-cylinder airframe in a wind tunnel. The dominant features of this problem are modeled by a lifting line/lifting surface rotor model with a free wake distorting in the presence of the airframe. The airframe flowfield is modeled using a source/doublet panel method. The instantaneous flowfield is computed at specified intervals of rotor azimuth, with the effects of blade motion added to the formulation. Modeling the energy addition at the rotor using actuator segments leads to successful prediction of the time-averaged pressure field. The periodic velocity variations along the spine of the airframe are predicted successfully. When a fully unsteady potential formulation is used, however, large differences appear between measured and computed periodic velocity at the sides of the airframe. These are attributed to the inadequate understanding of interaction of the rotor tip vortices with the airframe surface, as well as to inadequate modeling of the flowfield around the rotor hub.

NOMENCLATURE

Cp_u	Difference between instantaneous and local mean static pressures, normalized by the tunnel dynamic pressure.
R	Rotor radius.
u	Velocity component along the tunnel axis. Positive going downstream.
Uoo	Tunnel freestream velocity.
v	Vertical velocity component. Positive down.
X	Longitudinal distance from rotor hub center.
Xb	Longitudinal distance from the airframe nose.
Yb	Lateral distance from the cylinder axis.
Zb	Vertical distance from the cylinder axis. Positive upwards.
Z'	Vertical distance from the top surface.
Ψ	Azimuthal location of the 1/4-chord line of the reference rotor blade. Zero at the trailing edge of the rotor disc.
θ	Azimuth angle going around the periphery of the cylinder. Zero at the top.
μ	Ratio of freestream velocity to rotor tip speed.

INTRODUCTION

The flowfield around a rotorcraft poses a strong challenge to aerodynamicists. The wake and the proximity of the rotor blades cause large effects on the airframe and other components of the rotorcraft, which in turn modify the operating characteristics of the rotor system. This strongly interactive flowfield is inherently unsteady, and contains steep property gradients, strong vortices, large amplitudes of fluctuation, and unsteady flow reversal. The resulting complexities strain the current capabilities of both computational and experimental techniques.