DYNAMIC INTERFACE SIMULATION USING A COUPLED VORTEX-BASED SHIP AIRWAKE AND ROTOR WAKE MODEL

R. McKillip, Jr., A. Boschitsch, T. Quackenbush, J. Keller, and D. Wachspress
Continuum Dynamics, Inc.
Ewing, NJ 08618

Abstract

Recent work in Dynamic Interface simulation is described whereby a real-time free wake module was coupled to a lower-order ship airwake model. A novel physics-based computational method of representing the unsteady airwake of Navy ships is modeled using vortex doublet elements shed from sharp edges of the ship superstructure, and the approaching rotorcraft is described by a panel-based fuselage model and freely distorting wake analysis. The airwake model representation provides an appropriately detailed level of fidelity to capture handling qualities features of importance to shipboard rotary-wing aircraft operations, while maintaining high (and eventually real-time) computation throughput. This approach promises to revolutionize "dynamic interface" simulation by combining physics-based models of helicopter flight dynamics, rotorcraft free wake representations, unsteady ship airwake generation, and, optionally, ship motion dynamics. The resulting simulation environment, when eventually run in real-time, may be used to quantify operational shipboard approach envelopes without the considerable time and expense of at-sea testing.

INTRODUCTION

The work described here represents the first stages of developments that could potentially revolutionize the manned flight simulation of helicopter and other VTOL aircraft operating from ships by directly calculating the unsteady aerodynamic environment that exists in the landing zone of the ship in real time. This direct computation of the ship "airwake" using a novel hybrid scheme, would represent an extension of fast vortex-based flow modeling that has recently allowed the coupling of a helicopter free-wake calculation with a real-time flight simulation model. This new model would be implemented in a framework that could accommodate not only this revolutionary real time capability, but also an array of existing and projected non-real-time airwake models, ranging from empirically based treatments through wind tunnel data table lookup approaches, to CFD methods capturing complex viscous flow effects. To truly appreciate the significance of this capability in supporting Navy operations and missions, it is necessary to understand the methods that are currently used for qualifying the use of each VTOL aircraft from a given ship.

Dynamic Interface Testing Challenges

Perhaps the most difficult piloting task presented to an aviator is the challenge of landing a helicopter onto the flight deck of a moving ship in high sea-states at night with gusty wind conditions. The goal of safely landing the aircraft onto what is often a minimalist platform, located on the aft deck of what is referred to as a "non-aviation" ship, is compounded by the highly unsteady wake produced by the ship superstructure immediately ahead of the landing zone. This ship airwake is generated from the bluff-body aerodynamic interaction of the ship towers, hangars, exhaust stacks, and other components with the oncoming wind over deck and ship-motion induced flows. Because this environment places such a stress on both man and machine, the U.S. Navy (and its counterparts in other nations) requires an extensive series of tests to be performed prior to qualifying the use of a particular helicopter or V/STOL aircraft from a given ship. This process, called "dynamic interface" (DI) testing, is expensive, resource-constrained, and time consuming. Proper qualification of aircraft/ship combinations requires that the two assets are available during the testing period (along with the pilots and test crews), and that sufficiently variable winds and sea-state conditions exist to properly cover the range of operation anticipated for fleet use. The results from these tests are summarized in ship compatibility documents, which include operational envelopes that indicate allowable wind over deck (WOD) conditions for operations, given a particular bound on sea-state and day/night operations. A typical example of an operational envelope is shown in Figure 1.

One potential alternative to the cost, resource and time requirements of traditional at-sea DI testing is the use of simulation.[1] An obvious benefit from using simulators is the availability of any sea state, wind condition, aircraft and surface ship, provided one has appropriately detailed mathematical models that characterize their respective influence on the DI landing and take-off task. Computer simulation of the DI

Presented at the American Helicopter Society 58th Annual Forum, Montreal, Canada, June 11-13, 2002.