Distributed Multi-Vehicle Simulation Including High-Order Airwake Representation

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Abstract

Attempts to simulate the dynamic interface (DI) environment of landing aircraft onto Navy ships typically incorporate extensive approximations in both the component aerodynamic models and their interaction. These lower fidelity models are employed in order to achieve real-time throughput speeds required in manned simulation, or may simply result from lack of data or sufficient analytical tools in the models themselves. A novel fully-coupled aerodynamic simulation that includes multiple aircraft simultaneously operating from a ship has been prototyped, and represents time-accurate couplings between aircraft wakes, ship superstructure, and ship airwake emanating from a moving platform. Various modeling simplifications for far wake decay and dissipation have been applied to this simulation and their effects evaluated in order to quantify the level of detail necessary to use this software as a DI testing predictive tool. Additional extensions to the model included the capability for full airframe wake modeling and an enhanced treatment of ship airwake effects. Favorable comparisons with a variety of datasets, and several simulation integration exercises, show the prototype model to be sufficiently general and robust to assure successful continued development to support a wide range of simulation applications.

BACKGROUND

Current Naval practice for DI test planning often does not permit any pre-test simulation, but must rely upon previous test results and experience using similar aircraft and ships. This shortfall has been recognized for some time, and various researchers have attempted to address this need using modern simulation tools and vehicle models[1,2,3]. Simulation of DI engagements would support pre-test planning by reducing testing requirements for new DI qualification trials, since flight activity could more directly focus on determining operational boundaries. Most previous work in DI simulation has involved a single aircraft operating from a ship with a pre-calculated ship airwake model (or one from a tabular look-up routine), often without any representation of ship motion effects in the airwake and/or semi-empirical representations of ground effects during close aircraft-ship encounters. Although multi-aircraft simulation is important in duplicating the operational environment typical of Naval aviation activity, few if any simulations of the DI environment have attempted it.

Adding multiple aircraft to an already highly complex DI simulation significantly complicates the modeling of the complete aerodynamic environment surrounding all the vehicles of interest. This is partly due to the "N-squared" growth of interaction as more vehicles are added to the simulation environment. Attempts to reduce this interaction typically start by assuming that the ship airwake may be modeled as an *additive element* in computing the flow field seen by the operating aircraft. This assumption thus enforces a one-way coupling of ship airwake to the aircraft, and hence implies that the airwake is not influenced by the wake from the aircraft downwash. This assumption will not always be correct, particularly in the context of multiple aircraft shipboard operations, as shown recently[4]. However, within current DI simulation environments there typically is no mechanism to modify the wake model if its source is from lookup tables or previously computed CFD results. Or put another way, there is typically *no other option available* for modeling the ship airwake effect on the flight vehicle.

Mutual interaction between aircraft is often simulated in a similar fashion, in that each vehicle is assumed to have a "rigid" wake whose orientation is specified by kinematic considerations of the aircraft motion and relative wind, with each aircraft contributing perturbation velocities to the local flow conditions experienced by the other's lifting surfaces. While this represents part of the aerodynamic interaction between the aircraft, it completely ignores any effect that these aircraft have on distorting the wakes of the other aircraft, which in turn would produce additional perturbations in local velocities (and hence loads) on both vehicles. This issue has recently been re-examined in the context of providing better understanding of potential wake hazards experienced by aircraft operating in the terminal area environment[5,6].

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