Prediction of Propulsor-Induced Maneuvering Forces Using a Coupled Viscous/Potential-Flow Method for Integrated Propulsors

by

Christopher L. Warren

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Abstract

This thesis develops a method to analyze the maneuvering forces on surfaced and underwater vehicles with complex propulsors. The analysis method is developed for general propellers yet has unique applicability to model highly contracting stern flows associated with integrated propulsors. Integrated propulsors exhibit strong coupling of the various blade-rows and duct, if present, to the vehicle stern. The method developed herein provides a robust means to analyze propulsor-induced maneuvering forces including those arising from wake-adapted, multi-stage, ducted propulsors.

The heart of the maneuvering force prediction is a three-dimensional, unsteady lifting-surface method developed as the first part of this thesis. The new method is designated PUF-14 for Propeller Unsteady Forces. The lifting-surface method uses many advanced techniques. One significant advance is the use of a wake-adapted lattice to model the flow through the propulsor. In related research, a 2-D Kutta condition has been augmented using Lagrangian interpolation to dramatically reduce the required computational time to model a 2-D gust.

The second thrust of this thesis couples the unsteady lifting-surface method with a three-dimensional, time-average Reynolds-Averaged Navier-Stokes flow solver. Rotating a propeller through a spatially-varying flow field causes temporally-varying forces on the propeller. From the converged-coupled solution, the maneuvering and blade-rate forces can be estimated. This thesis explores the relationship of time-varying and time-average forces in the flow solver and potential-flow domains. Similarly, it explores the relationship of the effective inflow in the two domains. Finally, this thesis details the synergistic means to correctly couple the potential-flow method to a viscous solver.

Verification and validation of the method have been done on a variety of geometries and vehicles. Preliminary results show good correlation with experiment. The results strongly suggest this maneuvering force prediction method has great potential for the modern propulsor designer.

Thesis Supervisor: Justin E. Kerwin
Title: Professor of Naval Architecture