CAV2027
13th International Symposium on Cavitation
June 6-10, 2027, Austin, Texas, USA

PREDICTION OF DEVELOPED TIP VORTEX CAVITATION VIA A LOW ORDER PANEL METHOD

[1]Seungnam Kim and [1]Spyros A. Kinnas

[1]Ocean Engineering Group,
Dept. of Civil, Architectural and Environmental Engineering,
The University of Texas at Austin, Austin, TX 78712, U.S.
Email: naoestar@utexas.edu; kinnas@mail.utexas.edu

Abstract: In the past, the main focus of propeller design was on the effective control on decreasing cavity volume for a range of operating conditions. Cavities arising on the blade surface and near the blade tip are destructive due to its intrinsic growth and collapse mechanism. Excessive pressures during the collapse stage, for example, cause pitting on the blade, which in turn accelerates surface erosion. Sheet cavitation near the blade tip often evolves to developed tip vortex cavitation, and they both are known to be associated with the underwater acoustic noise in all frequencies, as well as the propeller-induced pressure fluctuations on the ship hull. Recent demand for high speed vehicle under high loading condition, however, has altered such stream of designing philosophy to practically tolerate cavity volume. Instead, such stream allows high-speed cavitating propellers in ocean vehicles, making the accurate prediction of sheet and developed tip vortex cavitation more essential in the assessment of propeller performance, its induced vibrations on the hull, and underwater noise radiated from cavitating propellers.

Figure 1. A cavitating propeller with developed tip vortex cavities and a hub-vortex cavity originating from the blade tip and the hub. With permission granted by Professor Spyros A. Kinnas.

In this paper, the central focus is laid on a better understanding of the hydrodynamic

characteristics of developed tip vortex cavitation and its effect on the propeller performance. A low order potential-based boundary element method is applied for the numerical modeling of unsteady developed tip vortex cavitation on hydrofoils and marine propellers. A finite tip vortex core is placed at the tip of fully aligned wake after aligning the trailing wake to the local flow in order to satisfy the force free condition. The boundary value problem on the developed tip vortex cavity is then solved for the cavity source strength, by initially assuming the cavity is a solid body of given radius. Then, an iterative scheme, using the Jacobian of the surface pressures with respect to the cavity shape parameters (in both the axial and radial direction), adjusts the overall shape of the developed tip vortex cavity, in time and space, by enforcing the surface pressures to match the vapor pressure. The method is first applied to a 3D hydrofoil subject to the uniform inflow with non-zero angle of attack and then a marine propeller under the non-axisymmetric effective inflow. Comparisons are made qualitatively and quantitatively on the predicted cavity patterns and the propeller performance with the experimental measurements. Grid independence studies are carried out on the computational parameters to show stability and accuracy of the presented method.

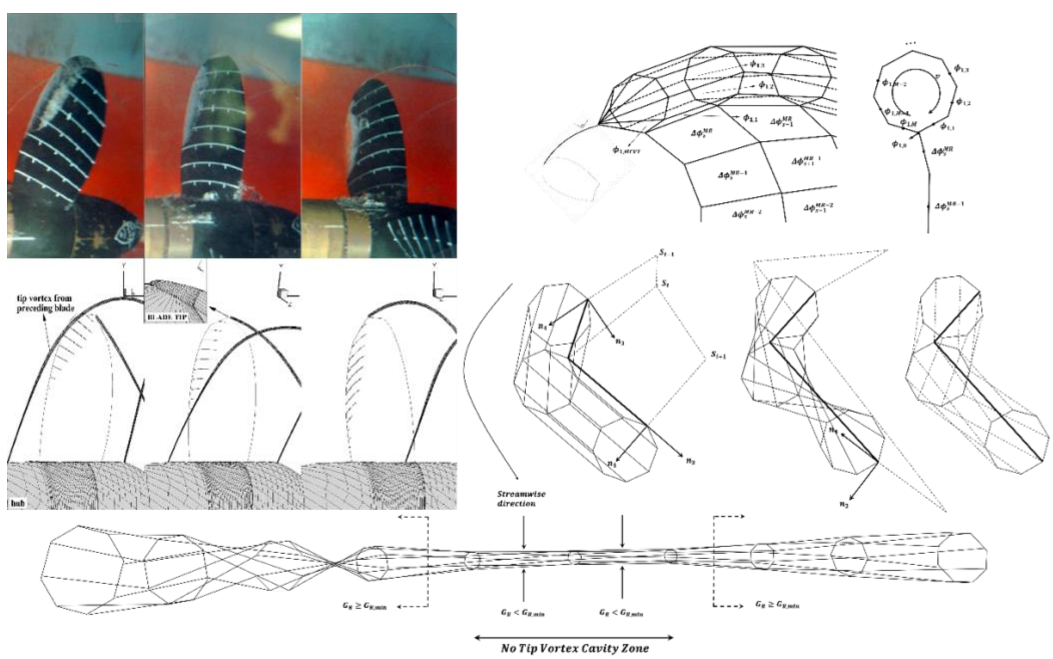

Figure 2. Panel arrangement on the developed tip vortex cavity (top right). Twisted tip vortex cavity before adjusting radii by boundary conditions (bottom) and treatment of the twisted panels along the streamwise direction (middle right). Application to N4148 propeller subject to non-axisymmetric inflow inside MIT's cavitation tunnel (left).

Keywords: Developed tip vortex cavitation, Sheet cavitation, Boundary element method, Unsteady wake alignment scheme,