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Location: Ames 234

Speaker: Dr. S. M. Scorpio
Applied Physics Laboratory, Johns Hopkins University

Title: **“Hydrodynamic Wakes of Surface Penetrating Structures”**

Abstract

Naval submarine operations in the littoral often require mast penetrations for extended periods. Such exposures can lead to detection by observation not only of the mast itself but also the hydrodynamic wake. In addition, wakes of obstacles in the coastal ocean or rivers can provide sites for enhanced biological activity and the wakes of bridge and pier supports can affect their structural integrity. While substantial research has gone into the study of flow around ships relatively little effort has gone into understanding the surface wake processes.

In this study the wakes of cylindrical and streamlined shapes have been measured in a large, salt water tow tank facility (200 m x 20 m). The evolution and decay of the WWW, which is the bubble pattern generated by the entrained air, was observed in detail. Correlations of the white-water wake (WWW) area and other wake characteristics were made with the relevant dimensional parameters, the Reynolds number that is indicative of the degree of turbulence/air entrainment, and the Froude number that determines the nature of the surface wave pattern.

Several simultaneous processes contribute to the WWW due to the flow past a surface penetrating structure. These include: the turbulent drag wake around the body (the boundary layer and the near field recirculation zone), air entrained beneath the surface at the leading edge that resurfaces behind the object, leading edge water run up and splash down, and breaking surface waves generated by the flow around the structure. Evidence of each of these mechanisms has been found, however it is often difficult to separate them.

Optical imagery was used to evaluate wake properties such as total white water area; regions of wave breaking, breaking wave angle and breaking intensity. At high Reynolds numbers, where turbulence effects dominate the white water patterns, the total white water area scales as Re^3. At lower speeds, wave breaking is the dominant contributor to the white water area. The breaking wave white water exhibited a local maximum at Froude number ~ 1.4.

A numerical flow code is used to provide additional insight into the white water patterns observed behind the bodies. The code is an unsteady 3D potential flow model with nonlinear free surface boundary conditions. The code was used to estimate regions of breaking waves and breaking intensity in the wake. Using a breaking wave Reynolds number defined as $\mathrm{Re}_w = c\lambda/\upsilon = \sqrt{\frac{g}{2\pi}}\frac{\lambda^{3/2}}{\upsilon}$,it is proposed here that breaking intensity can be estimated from the model results as $B_i = C\lambda^{3/2}a_L$,where a_L is the vertical acceleration at the wave crest, is the breaking wavelength and is an empirically determined constant. The constant is determined such that predicted breaking intensity correlates with turbulent plume length as measured from the optical imagery.