Hydromechanics Laboratory

Professor David L. Kriebel, P.E.
Director

The Hydromechanics Laboratory supports midshipmen education, as well as midshipmen, faculty and staff research, in the areas of naval architecture and ocean engineering. The laboratory facilities include a large towing tank (380-ft long, 26-ft wide, and 16-ft deep), a small towing tank (120-ft long, 8-ft wide, and 5-ft deep), a coastal engineering wave basin (52-ft long, 48-ft wide, and 2-ft deep), a circulating water channel, and a stability and ballasting tank. All facilities are linked by a local network to a host computer system which is used to both operate the facilities and to acquire and analyze data.

The laboratory facilities are used on a weekly basis by midshipmen in the Naval Architecture and Ocean Engineering majors, and are used each semester by midshipmen in the Mechanical Engineering, Electrical Engineering, Systems Engineering, Physics, and Oceanography majors. In addition, the laboratory is used by more than 600 midshipmen each year in EN200, a core engineering course taken by all midshipmen in science or humanities majors. As a result, nearly all midshipmen use the Hydromechanics Laboratory facilities at some point during their four years at the Naval Academy.

In addition to classroom support, the laboratory facilities are used for both fundamental and applied research by midshipmen, faculty and staff supporting, other naval laboratories and government agencies. During the past year, research programs conducted by the laboratory have included:

- Zero and low speed seakeeping tests of a 2200-ton HYSWAS design. (Sponsor: Applied Maritime Physics Corporation)
- Shallow water wave measurements for a series 60 model (Sponsor: Naval Facilities Engineering Services Center)
- Measurements of ship-generated waves in deep water (Sponsor: Naval Facilities Engineering Service Center)
- Performance of ship protection barriers in waves (Sponsor: Naval Facilities Engineering Service Center)
- Characteristics of non-linear breaking waves (Sponsor: Office of Naval Research)
- Laboratory projects in naval architecture and ocean engineering – phase II (Sponsor: Academic Dean Curriculum Development Project)
- Upright resistance tests for existing and proposed U.S. Naval Academy 44-foot sloops. (Sponsor: Hydromechanics Laboratory)
- Measurement of the effects of surface roughness on the drag of a flat plate. (Sponsor: Hydromechanics Laboratory)
- Laser measurements of flow characteristics in the Hydromechanics Laboratory's circulating water channel. (Sponsor: Hydromechanics Laboratory)
- Evolution of non-linear effects in long runs of regular waves in the 120-foot Towing Tank (Sponsor: Hydromechanics Laboratory)
- Performance testing of historic sailing warships (Sponsor: Hydromechanics Laboratory)

The Hydomechanics Laboratory is operated and maintained by a multi-talented staff, which includes four engineers/naval architects, three engineering technicians, and an office manager/secretary. Supporting laboratory efforts are the shop and model-making facilities in the Technical Support Department. The laboratory is further supported by a Memorandum of Understanding (MOU) with the Naval Station-Annapolis, providing support of diving operations in the laboratory.

The results of laboratory research efforts are reflected in journal articles written by faculty and laboratory staff members and in presentations at technical symposia. The laboratory is actively represented on two of the technical committees of the International Towing Tank Conference (ITTC) and staff members are active participants in the Society of Naval Architects and Marine Engineers (SNAME), the American Society of Naval Engineers (ASNE), the American Towing Tank Conference (ATTC), and the American Society of Civil Engineers (ASCE). The diverse interests of these organizations reflect the broad nature of the Hydromechanics Laboratory's activities.

Sponsored Research

Evolution of Wave Grouping and Breaking for JONSWAP Spectra in the 120-foot Towing Tank

Researchers: Professor Thomas H. Dawson and Ms. Louise A. Wallendorf, P.E. (Hydro Lab)
Sponsor: Office of Naval Research (ONR)

As part of an ongoing research project on wave grouping and its relationship to wave breaking, long multiple time histories of two Joint North Sea Wave Project (JONSWAP) wave spectra were generated in the 120-foot wave tank in order to observe and measure the wave trains as they traveled down the tank. Wave time histories were measured at five locations down the tank, and analyzed for wave and crest height and period, and their probability distributions. The characteristics of the wave-maker drive signal was identical for the two spectra, except that the significant wave height of one spectrum was 1.5 times that of the other. This way the effect of wave steepness and linearity on the observed wave grouping and breaking could be evaluated. Results for both sea states were then compared to Markov theory.

USS Constitution Grand Parade of Sail, Tall Ships 2000

Researchers: Mrs. Nancy A. Harris, Naval Architect (Hydro Lab)
and Mr. Stephen W. Enzinger, Naval Architect Technician
Sponsor: Naval Sea Systems Command (NAVSEA) Hydrodynamics Division

The USS Constitution was the lead ship in the Grand Parade of Sail during the Tall Ships 2000 stop in Boston, Massachusetts in July 2000. The ship was towed out to the start of the parade, turned around, and, while undertow, hoisted some of its fore and aft sails. The Naval Academy Hydromechanics Laboratory (NAHL) was asked to participate in the event by instrumenting the ship to monitor the apparent wind speed, apparent wind heading, ship speed, ship heading, tow force in the towline, pitch, and roll.

Even though the Constitution is towed out into Boston Harbor a few times each year to perform the turn-around cruise, this tow was to be different because some of the sails were going to be set and instead of towing just from the hip, the ship would also be towed from a towing bridle at the bow. Naval Sea Systems Command (NAVSEA) was interested in instrumenting the ship in order to obtain information on the ship's pitch and roll motions, the ship's speed and heading, the apparent wind speed and heading, and the towing force. The purpose of obtaining this information was two-fold: to provide the ship's captain with real-time performance values, and to add to the database of information regarding the Constitution. The Hydromechanics Laboratory's role was to acquire the equipment needed, set up the data acquisition, install the equipment on the ship, gather the data during the sail, report it to the captain in real-time, and post-process the data after the event was over.

Performance of a Port Security Barrier in Waves

Researchers: Professor David L. Kriebel, P.E. and Ms. Louise A. Wallendorf, P.E. (Hydro Lab)
Sponsor: Naval Facilities Engineering Services Center (NFESC)

This project involved small-scale physical model testing for a proposed Port Security Barrier (PSB) to establish its response properties in a seaway. The PSB, designed to prevent unauthorized small boat penetration into naval ports, consists of a horizontal beam and netting supported on flotation pontoons. The main goal of this project is to test the PSB in waves to determine its motions in heave and roll, and to establish the adequacy of the pontoon design to prevent capsizing.

Measurements of Ship Generated Waves in Deep Water

Researcher: Ms. Louise A. Wallendorf, Ocean Engineer, P.E. (Hydro Lab)
Sponsor: Naval Facilities Engineering Service Center (NFESC)

When ships operate in harbors, their wake has been known to cause significant damage to moored vessels and structures in the harbor. The Naval Facilities Engineering Service Center (NFESC) has been investigating the wake produced by different ships by obtaining model test data for various hulls, in order to develop a reasonable set of guidelines for setting maximum allowable ship speeds in enclosed waterways. In support of this program, the Naval Academy Hydromechanics Laboratory developed a technique for measuring the waves generated by a passing ship or "wave cut", using wave gages designed and built by the lab staff.

Model tests were performed on a Series 60 model operating in deep water conditions in the 380-foot wave tank. The model was towed at full-scale speeds of 2.5 to 7.0 knots, at three different displacements. The ship waves were measured at five distances from the model sailing line along with the ship's rise and trim. The maximum wave height and its associated period at each gage location were obtained from analysis. This data was taken as a deep-water baseline for this hull shape to compare with further tests in shallow water.

Shallow Water Wave Measurements for a Series 60 Model

Researcher: Mr. John J. Zseleczky, Naval Architect, P.E. (Hydro Lab)
Sponsor: Naval Facilities Engineering Service Center (NFESC)

The Naval Facilities Engineering Service Center (NFESC) has been investigating the wake produced by different types of ships in order to develop a reasonable set of guidelines for setting maximum allowable ship speeds in shallow water enclosed waterways. In support of this program, the Naval Academy Hydromechanics Laboratory (NAHL) conducted a series of ship model towing tank experiments in which the wake of the model was measured at two fixed locations in the tank as the model passed by at different speeds. Trim and rise of the model were also measured.

An important feature of this test program was that the tests were conducted in shallow water, with a ship draft-to-depth ratio of 0.58. Sources of shallow water model test data are extremely limited so this set of data was of great interest to NFESC. The expense of the program was minimized, by running the tests immediately after the completion of a Naval Academy midshipman laboratory class, in which a Series 60 model was tested in shallow water.

Independent Research

Evolution of Non-linear Runs of Long Waves in the 120-foot Towing Tank

Researchers: CDR Sung Youn Boo, KN, and Ms. Louise A. Wallendorf, P.E. (Hydro Lab)

Long time histories of regular waves were generated in the 120-foot wave tank in order to observe and measure the wave trains as they traveled down the tank. Wave time histories were measured at five locations down the tank, and analyzed for height, period and frequency content. Sample videos of the water's surface were obtained. Wave time histories were evaluated for the existence of "parasitic" waves.

Upright Resistance Test For Both The Existing and Proposed U.S. Naval Academy's 44-foot Sloop

Researcher: Assistant Professor Paul H. Miller

The developmental testing of a new design for the Navy 44 sail training sloop started as a faculty support effort for the Naval Station's project to replace the aging current fleet of forty-four foot sloops. Adopted by 1/C Midshipmen for their capstone naval architecture class, the students developed a set of electronic lines for both the current as well as an alternate design. The

two 52-inch models (1/10 scale) were built by the Technical Support Department (TSD) Model Shop and tested for upright and heeled resistance in the Hydromechanics Laboratory 120-ft tank. Based on the initial testing, a new, lower-drag keel was developed for the new design.

HYSWAS Calm Water Testing Techniques

Researchers: ENS Peter C. Mitalas, USN
and Mrs. Nancy A. Harris, Naval Architect (Hydro Lab)

A scaled model of an 850-ton Hydrofoil Small Waterplane Area Ship (HYSWAS), based on a design by Maritime Applied Physics Corporation (MAPC), was built in the Model Shop and tested in the Hydromechanics Laboratory at the U.S. Naval Academy. This effort supported a midshipman research project during the Spring Semester 2001; it is also intended to be used for future midshipman projects, as well as labs in the Advanced Marine Vehicle class offered in the Fall Semester of 2001. Various HYSWAS testing techniques were investigated. The goals of this initial testing included: (1) determining the angles of attack of both foils that resulted in the correct amount of lift and a cancellation of the moments, (2) determining the drag of the model, and (3) isolating the lift and drag characteristics of the foil shape.

The model was tested in calm water, fixed at the flying waterline in the following conditions: (1) bare hull, (2) with the main foils only, and (3) with both the main foils and the aft foils. The foil angles were not actively controlled but were adjustable between runs. Flow visualization tests were performed to determine the angle of the flow going into the foils. Scale effects were investigated, and predictions based on theory and results of tests of foils at higher Reynolds numbers were made and compared to the results.

The Effect of Surface Quality on the Frictional Resistance of Sailboat Hull Finishes

Researcher: Assistant Professor Michael P. Schultz

Racing sailors are continually looking for competitive advantage over their opposition. This has led many to become obsessive about maintaining a smooth hull in order to reduce frictional resistance. However, the question as to the point at which sanding with very fine grit sandpaper and polishing leads to a vanishing reduction in drag remains. The goal of this experimental investigation was to better quantify the effect that surface preparation has on skin-friction drag. To accomplish this, the frictional drag on a flat plate painted with hull coatings ranging from an as-sprayed epoxy primer, to a polished finish, was measured in the Naval Academy Hydromechanics Laboratory (NAHL) 380-ft towing tank. The surface roughness was documented with a laser profilometer. The relationship between the surface texture and the hydrodynamic roughness function was examined. These lab-scale results will next be scaled up to a planar surface at yacht-scale using a similarity law analysis.

Investigation of the Flow Uniformity and Free-steam Turbulence Intensity in the Hydromechanics Laboratory Recirculating Water Tunnel

Researcher: Assistant Professor Michael P. Schultz

A study is presently underway to document the flow uniformity and free-stream turbulence intensity in the recirculating water channel at the Naval Academy Hydromechanics Laboratory (NAHL). A single component, fiber-optic, laser Doppler velocimeter (LDV) is being used to measure the flow field in the 0.40-meter by 0.40 meter by 1.0-meter test section of the water channel. A computer-controlled traverse moves the LDV probe through a grid of 49 transverse sampling locations at three streamwise stations. Measurements are being made throughout the operating velocity range of the tunnel (3-ft per second – 18-ft per second). It is expected that, from this study, deficiencies in the flow quality and tunnel operating characteristics can be identified and changes for their improvement offered. The present results will also serve as baseline performance data for the water tunnel facility.

Performance Testing of Historic Sailing Warships

Researcher: Professor Gregory J. White

The United States Naval Academy's Class of 1951 Gallery of Ships contains a collection of British Dockyard Models of 16th through 19th century naval vessels. These models, built by dockyard craftsmen contemporaneously with their full-scale counterparts, are considered by experts to be accurate reproductions of the ships they represent. This permits the models to be used for research on the evolution of warship design during this period when most of the technical developments in sailing warships occurred. However, due to the low range of speeds at which these historic ships of sail operated (under 12 knots), the size of the tow tank model became an issue. There are no existing guidelines as to the size of the scale model, the speed range at which reliable data could be obtained, or the proper turbulent stimulation to achieve reliable data for these historic hull forms. In order to develop a baseline of knowledge for future testing these historic ships, a systematic series of resistance tests were performed on an existing 8-ft model of the USS Constitution (1/25th scale). The Constitution (1797) falls almost in the middle of the time period covered by the Dockyard Model collection and represented a change in the historic design of frigates. As such, it makes an interesting starting point in the overall project of ship performance comparison.

Presentations

HARRIS, Nancy A., Naval Architect, "FastShip 5 Training Session for the Junior Class at Webb Institute of Naval Architecture," Webb Institute of Naval Architecture, Glen Cove, New York, 16 March 2001.