Lyons, Troy; Stern, Fred

Riding the wave of the future

Hydrolink

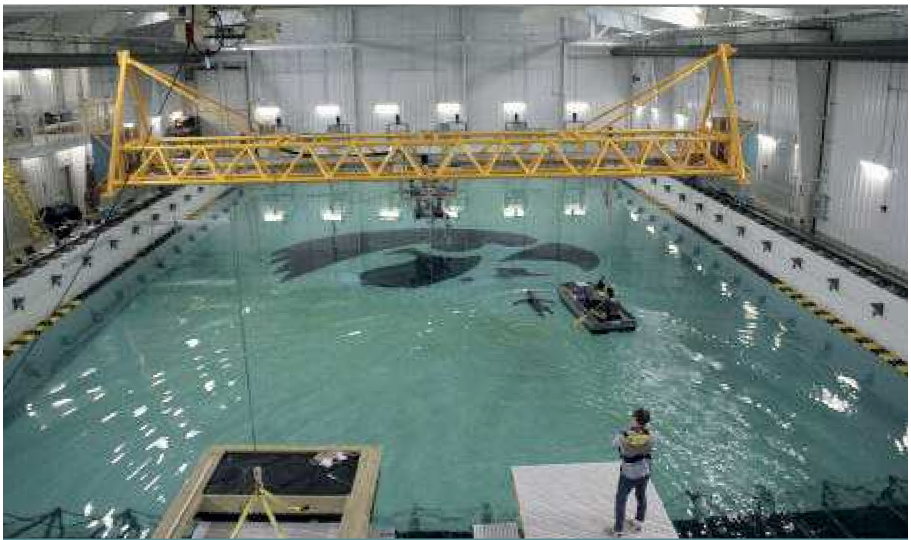
RIDING THE WAVE OF THE FUTURE

IIHR – HYDROSCIENCE & ENGINEERING: A DISTINGUISHED PAST, FOCUSED ON THE FUTURE

BY TROY LYONS & FRED STERN

IIHR – Hydroscience & Engineering (IIHR) has been a world leader in the field of hydraulic engineering and research for nearly a century. This world-renowned institute for hydraulic research and fluid mechanics is constantly evolving and expanding its scope to remain at the forefront of the field.

Based in the C. Maxwell Stanley Hydraulics Laboratory on the Iowa River, IIHR is a unit of the University of Iowa's College of Engineering. With remarkable computational capabilities and extensive experimental facilities—including a state-of-the-art wave basin, a new wind tunnel, and space for large models for fish passage studies and stormwater management structures—IIHR researchers are able to study fundamental processes and their ever-diversifying real-world applications.



CalWave is one of several organizations that tested wave energy technologies at the IIHR Wave Basin. The teams are competing for a U.S. Department of Energy prize; IIHR was selected as one of five sites nationwide to serve as a test facility

DOE Wave Energy Prize Comes to IIHR

In 2015, the U.S. Department of Energy (DOE) selected IIHR as a test facility for its prestigious Wave Energy Prize competition. Wave energy devices convert energy from ocean waves into electricity. The DOE launched the competition to stimulate development of innovative wave energy converter (WEC) technologies. Twenty teams competed for finalist status and the opportunity to test at the Naval Surface Warfare Centre's Maneuvering and Seakeeping basin. First, however, they had to pass proof-of-concept small-scale testing. Several did so at the IIHR Wave Basin.

The IIHR Wave Basin is a state-of-the-art facility completed in 2010 that accommodates free-running model testing in an open body of water. Researchers use the 40x20x3-meter wave basin to test captive or radio-controlled model-scale navy ships under a variety of real-life conditions, created by the basin's six wavemakers. The free-moving models can maneuver straight ahead, zigzag, full circle, and capsize.

A custom eight-ton overhead carriage tracks the radio-controlled ships using indoor global positioning and two-camera vision, shadowing the vessels to within +/-100 mm. A 3D particle image velocimetry system measures fluid velocities around the ships, facilitating the collection of detailed flow data. IIHR's wave basin is the first to include local flow measurement capabilities, critical for continued development of simulation-based design tools. Unlike towing tanks using captive ship models, which typically allow only straight line movement with very limited side to side motion, the wave basin facility with its local flow measurement instruments can test ships under many different real-world conditions, measuring the water flow and wave patterns around the ship, including breaking waves, bubbly ship wake flows, unsteady hull surface pressure, and more.

The wavemaker system consists of six wedge-shaped plungers aligned end-to-end with minimal clearance between ends. Each plunger is 1.2 meters high, 3.3 meters wide, and 0.8 meters thick and submerged 0.7 meters in calm water. The plunger stroke is adjustable up to 250 mm for plunger frequencies less than 0.62 Hz, where the maximum stroke is restricted to 77.5 mm at the maximum plunger frequency of 2.0 Hz. The wavemaker system has two operational modes. The first mode generates regular waves by using pre-set and fixed plunger amplitude and frequency values. The waves are generated in this mode with all six plungers moving simultaneously with the same amplitude and frequency and the same initial phase. The second mode generates irregular waves, where a train of analogue voltage signals of arbitrary wave form are input to each plunger. The wavemakers are calibrated to meet the International Maritime Organization (IMO) requirements (Bottiglieri et al., 2015).

IIHR's wave basin is also well-equipped to test wave energy converters under real-world conditions, making it a valuable tool in assessing whether the WEC devices will be able to prove their worth on the open ocean. Devices were tested under specified regular and irregular wave conditions designed to replicate sea conditions. Measurements included ultrasonic measurements of wave elevations, pressure fluctuations below the WEC, six-degrees-of-freedom (6DOF) motion capture of the WEC body, mooring forces, and resistance and displacement of the power take-off devices used to calculate power. In addition, underwater video was recorded for selected cases. Typical tests included 120 seconds of synchronized data collection. Judges chose the finalists based on their potential to double the energy produced by current WEC technologies. IIHR received funding from global engineering firm Ricardo PLC to conduct the testing of WEC devices entered in the DOE prize competition. The University of Iowa was one of five test sites for the small-scale WEC models. The testing process enabled IIHR to expand the capabilities of its advanced wave basin facility by matching specific wave frequencies and durations while controlling different conditions.

Private industry companies Teams Sea Potential, CalWave, and Waveswing America conducted WEC testing at the IIHR Wave Basin. All three companies are now among the nine finalists and two alternates announced in March 2016. The highest-ranked team after the 1:20 scale testing at the U.S. Naval Surface Warfare Center will receive a total prize purse totaling more than $2 million. The second-place team will receive $500K and third place $250K.

The WEC testing process was a collaborative team effort that included IIHR researchers, shop staff, and others—particularly researchers Yugo Sanada, Hyunse Yoon, Lyons, and Alan McCarville.

IIHR Ship Hydrodynamics

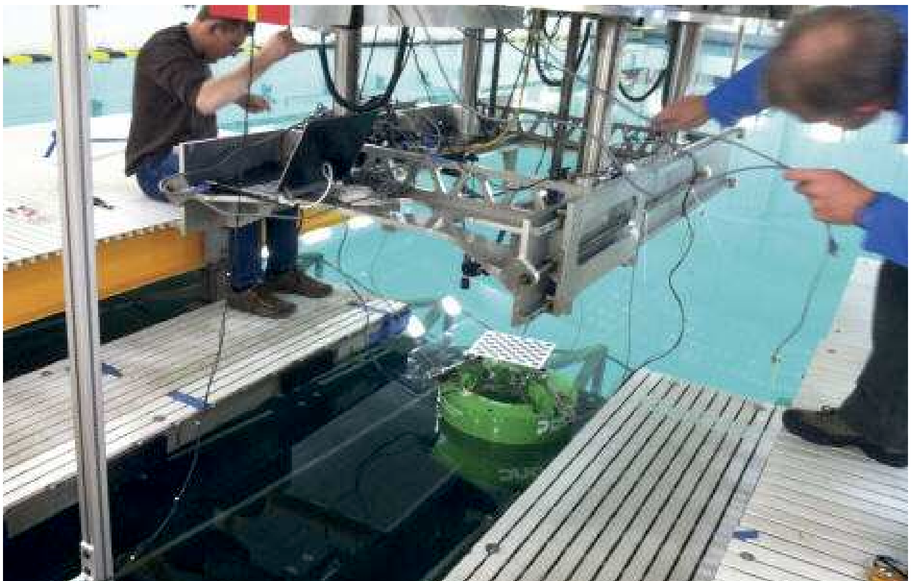
IIHR has played a major role in the evolution of fundamental ship hydrodynamics for decades. Since its founding, the Office of Naval Research (ONR) has continuously funded IIHR's ship hydrodynamics research. IIHR's work with the U.S. Navy began during World War II, focusing on resistance, turbulence, cavitation, and developing hydraulics into a rigorous engineering discipline firmly based on fundamental fluid mechanics.

Today, IIHR's advanced facilities and expertise continue to support the U.S. Navy, while new enhanced capabilities in wave generation promise exciting new avenues of research. The IIHR ship hydrodynamics program is a leader in the area of simulation-based design (SBD), which is revolutionizing naval ship hydrodynamics. Computer simulations guide model-scale physical experiments conducted in the IIHR Wave Basin and towing tank.

The towing tank is 100 m long, 3 m wide, and 3 m deep, equipped with a drive carriage, a planar motion mechanism (PMM), and wall-side wave dampeners and wave-dampening end-beach. The drive carriage is instrumented with data-acquisition computers, a speed circuit, and signal conditions. The drive carriage pulls the PMM carriage, which is used as a contact point of attachment for certain models. The wave-dampeners and the end-beach enable 12-minute intervals between carriage runs. This combination of computer simulations and experiments, in conjunction with sophisticated uncertainty analysis and optimization, puts IIHR at the cutting edge of research in ship hydrodynamics.

Over the next decade, IIHR hopes to build on the strength of the current program, emphasizing international collaborations and focusing on second-generation SBD tools, supported by physical experiments in IIHR's towing tank, flumes, and wave basin.

IIHR's unique combination of resources, facilities, and people promise an ongoing role for IIHR at the front lines of naval ship design. ■



Team Sea Potential prepares its WEC device prior to testing

IIHR Director of Engineering Services *Troy Lyons* joined the institute in 2001 as a staff engineer, after earning BS and MS degrees in civil engineering from the University of Iowa. His role at IIHR has evolved and grown, and today he bridges the gap among clients, engineers, researchers, and shop staff. His research spans several areas, including:

- **Hydraulic structures and dropshafts**
- **Hydropower and fish passage**
- **River hydraulics**
- **Laboratory measurement methodology**
- **Field measurement systems**

Lyons has been instrumental in the success of many multimillion-dollar proposals and collaborative efforts at IIHR.

***Fred Stern* earned BS, MS, and PhD degrees in naval architecture and marine engineering from the University of Michigan. He joined IIHR–Hydroscience & Engineering (IIHR) is 1983, bringing expertise in propellers, free surface effects, and numerical methods for viscous flows. Today, Stern heads up the ship hydrodynamics program at IIHR. Under his leadership, researchers at IIHR have successfully integrated experimental fluid dynamics, computational fluid dynamics, and uncertainty analysis to create simulation-based design. IIHR researchers also developed a groundbreaking computer code, CFDShip-Iowa, the most advanced in the world for ship hydrodynamics. Stern is also the first George Ashton Professor in Hydroscience and Engineering at the University of Iowa.**