Naval Architecture and Ocean Engineering Department

Professor Bruce C. Nehrling
Chair

The faculty and midshipmen associated with the two engineering disciplines taught by the Naval Architecture and Ocean Engineering Department actively pursued scholarly research and professional development during the 2000-2001 Academic Year. As they undertook both funded and unfunded research activities, significant use was made of the Academy's outstanding experimental, computational, and library facilities. The broad spectrum of research themes addressed reflects the varied specialties resident within the department's two areas of technical concentration.

Naval Architecture topics included the study and experimental testing of compressive loads on composite panels - including ultimate strength and failure characteristics, investigations into the durability of marine composites, and experiments to categorize the structural behavior of hull laminates. Research was also conducted into the modeling of vortex flow, on fouling within turbulent boundary layers, and in the design of an experimental channel for creating fully-developed turbulent flow. In addition, experiments for predicting the performance of unconventional hydrofoil hulls, parasitic submarine configurations, and historic sailing ships were conducted in the Hydromechanics Laboratory. Finally, performance studies were conducted on hull and cockpit configurations for the proposed new Navy 44 sail training vessel.

Ocean engineering topics included hydrodynamic experiments into the behavior of wave groups, characteristics of ship generated surface waves, performance attributes of a mobile offshore base module, response of a compliant tower to waves, and gravity based mooring systems. In materials and structures, research projects dealt with the analysis of adhesively bonded composite joints, fiber placement for lightweight composite structures, and the use of composite materials for fabricating pressure vessels. Other research projects investigated the thermal protection of divers - which resulted in a patent being issued, amphibian thermal suits for combat swimmers, and experiments on passively controlled rebreather apparatus. Finally, a multi year study continued on the technical, operational, and economic issues affecting the design and maintenance of navigable channels.

Research funding was made available from many sources including department operating funds and contracts and grants from the Office of Naval Research; the Naval Facilities Engineering Services Center; the U.S. Army Corps of Engineers Institute for Water Resources; the American Bureau of Shipping; the National Science Foundation; the Naval Surface Warfare Center, Coastal Systems Station; the Naval Surface Warfare Center, Carderock Division; and RADM Guy Schaffer, USN, Class of 1951. The faculty and midshipmen of this department appreciate the cooperation and support provided by these sponsoring agencies and organizations.

The department's faculty and midshipmen continue to participate actively in professional meetings and conferences, both nationally and internationally. They had fifteen manuscripts published in professional journals, nineteen articles in conference proceedings, and fourteen technical reports. More than forty presentations were made at numerous national and international symposia. An energized and up-to-date academic environment for both core and major courses is one beneficial outcome of this department's extensive and significant involvement in research.

Sponsored Research

Wave Groups and Wave Breaking in Random Seas

Researcher: Professor Thomas H. Dawson
Sponsor: Office of Naval Research (ONR)

Wave groups in random deep-water waves are being studied experimentally using the Naval Academy's 380 foot wave/towing tank. Results to date have been compared with theoretical work that accounts for nonlinear effects on crest amplitudes. Recent work has been concerned with investigation of wave-group statistics derived from Markov theory for wave runs and with the effects of breaking waves on group statistics. The work is continuing under ONR sponsorship. Recent publications include the papers: (a) Markov Theory for Runs of High Waves, *Proceedings International Offshore & Polar Engineering Conference*, Seattle, Vol. 3, pp. 20-24, 2000; and (b) Maximum Wave Crests in Heavy Seas, *Transactions ASME Journal of Offshore Mechanics and Arctic Engineering*, Vol.122, pp. 222 – 224, 2000.

Effects of Alterations to the LEX-Delta Wing Junction on the F/A-18 E/F

Researchers: Associate Professor Karen A. Flack (Mechanical Engineering Department)
and Assistant Professor Michael P. Schultz
Sponsor: Office of Naval Research (ONR)

The junction of the leading edge extension (LEX) and the delta wing on the F/A-18 E/F aircraft is a region of highly complex vortex flows interactions. The region is important not only to the performance and stability of the aircraft, but may affect cyclical loading of the tail due to vortex buffet. The geometry of the junction is also critical in the overall radar signature of the aircraft. The objective of the present research is to compare the aerodynamic forces on a model with different LEX-wing fillet configurations. Three fillet types were tested in this junction on a 1:28 scale F/A-18 E/F model in a low speed wind tunnel in the Aeronautics Laboratory at the United States Naval Academy. The fillets were found to have little effect on the aerodynamic forces on the model. This result is contrary to previous research on a flat plate model of a delta wing. Further tests are being performed on a flat plate model of the same planform with and without a centerbody to compare to previous research and to investigate the accuracy of using two-dimensional models to model three-dimensional vortex flows.

Air Gap Tests on a Mobile Offshore Base Module

Researchers: Professor David L. Kriebel and Ms. Louise Wallendorf, P.E. (Hydro Lab)
Sponsor: Office of Naval Research (ONR)

This project involved small-scale physical model testing of one semi-submersible module of the Mobile Offshore Base (MOB), a future-generation floating air base currently being investigated for its technical feasibility. The overall MOB platform would be about 5000 feet long, 400 feet wide, with a total height from keel to deck of about 250 feet. The structure would consist of five modules linked end-to-end. Each module would be a semi-submersible floating platform, 1000 feet long and 400 feet wide, with a draft of about 100 feet. The USNA research effort involved testing of this model in the large wave/towing tank located in the Naval Academy Hydromechanics Laboratory. The purpose of these tests was to evaluate the dynamic motions of the MOB module and to measure the wave amplitudes under the moving hull. These two sets of measurements are being used to determine the "air gap" or the open air space between the bottom of the deck and the water surface. Of particular interest are wave events that produce zero air gap or, in other words, wave slamming on the bottom of the deck. Results of these tests will be presented at the 10th International Offshore and Polar Engineering Conference in June 2001.

Ship Generated Waves

Researcher: Professor David L. Kriebel
Sponsor: Naval Facilities Engineering Services Center (NFESC)

Waves generated by passing commercial ships often create problems in Navy ports. For example, these waves can excite large dynamic motions of moored Naval vessels and, as a result of the large forces transmitted in the mooring lines, either the moored ship or the pier can experience damage. Because of these damages, the Naval Facilities Engineering Command has initiated an investigation of the ship-generated waves with the goal of developing engineering design guidance for predicting the characteristics of these waves as a function of ship hull geometry, ship speed, water depth, and the distance from the passing ship sailing line. While ship-generated waves in deep water are understood fairly well, ship-generated waves in shallow water are not well understood. As a result, model tests are planned in the Naval Academy Hydromechanics Laboratory in shallow water conditions where the ship draft is 50 to 90 percent of the water depth.

Investigation and Integration of Technical, Operational and Economic Issues Affecting Navigation Channel Design and Maintenance

Researchers: Professor David L. Kriebel, Associate Professor Robert H. Mayer
and Assistant Professor Jennifer K. Waters
Sponsor**:** Institute for Water Resources, U.S. Army Corps of Engineers (IWR-USACE)

The goal of the Institute for Water Resources (IWR) work unit #33123: "Impacts of Navigation Trends on Channel Usage and Design" is to improve the design and maintenance of navigation channels in order to achieve economic efficiency, reliability, and safety of shipping operations. Specifically, this study aims to investigate how changes occurring in the international shipping industry may impact the way the U.S. Army Corps of Engineers (USACE) designs and maintains its channels. The study is also concerned with how navigation trends on channel usage may contribute to safety, piloting, and maintenance problems.

A critical element in the work unit is an updated review of both domestic and international practices for the design and maintenance of navigation channels. Another critical element of the work unit is an investigation into how channels are actually being maintained and utilized, *after* the design process has been completed. This part of the study must incorporate an analysis of channel accident data with specifics of vessel navigation and dredging operations. This is important since it is well recognized that navigation channels are not necessarily maintained or utilized as they were originally designed.

The goal of this work effort is to support IWR's work unit #33123 through completion of related tasks. Specifically, the researchers are involved in identifying, investigating and integrating many of the technical, operational, and economic issues affecting navigation channel usage, design and maintenance. Recommendations to mitigate any problematic issues in USACE policy, guidance, or practice are forthcoming.

Durability of Marine Composites

Researcher: Assistant Professor Paul H. Miller
Sponsor: American Bureau of Shipping (ABS)

This eight-year project was completed in the Fall of 2000. The project characterized fatigue durability of fiberglass (e-glass/polyester) marine composites and extended methods used for fatigue design of steel ships to composite vessels. These materials have been commonly used to construct hulls, decks and superstructures of small craft for the last three decades. The Navy and others have constructed larger craft with these materials but concerns exist whether the methods developed to predict fatigue effects are accurate.

To validate these methods the project looked at standard coupon test results and compared them with proposed panel test methods and full-scale results. The comparisons include both physical and numerical (finite element analysis) methods. To accurately simulate long-term exposure to the marine environment moisture effects were also tested. Results during the JUN00-JUN01 period included continued moisture exposure and extension of the S-N curves. Key results showed that a coupon/fea

program can predict stiffness reduction and that current Navy and ABS Guides may not provide sufficient material margins for long life. Papers were approved for publication in Marine Technology and Journal of Composite Materials.

Composite Pressure Vessel Fabrication Technology Project

Researcher: Associate Professor Sarah E. Mouring
Sponsor: Office of Naval Research (ONR)

The researchers at the Naval Academy are studying mechanical property characterization of coupon and structural composites as part of the Composite Pressure Vessel Fabrication Technology Project TDL 99-04. The experimental study includes an assessment of proposed experimental methodology, specimen testing, and subsequent mechanical property characterization. There are 30 K-fiber tow coupon specimens, 30 structural composite tubes, and 30 additional coupon specimens to be tested. Some of these specimens will be tested at elevated temperatures ranging between 300Eð F and 450EðF. Mechanical testing of the 30 K-fiber tow specimens started in the Spring of 2000 and continued through the Summer of 2000. Follow-on testing is planned for Summer or Fall of 2001.

Behavior of Composite Joints Adhesively Bonded Using an Innovative Joining Method

Researcher: Associate Professor Sarah E. Mouring
Sponsor: National Science Foundation (NSF)

The research involves the development of a new bonding method to join composite structural elements. The proposed method is a combination of liquid adhesive/adhesive tape technology, involving the use of adhesive tape to temporarily secure and to create a channel between structural parts to be joined. The liquid adhesive then is pumped into the channel to form a permanent bond. This allows multi-part structures to be "tacked" together quickly, checked for accuracy, and then permanently bonded later by injecting the adhesive. As part of the development and evaluation of the proposed joining method, analytical procedures are being developed to model several different joint configurations. These models are being used to optimize joint designs. Experimental tests are being performed to validate the analytical models. In the final year of the grant, analytical and experimental research will be performed on the current joining method used in Civil Engineering, and compared to the results of the proposed method. Also, guidelines on testing joints bonded using the new method will be suggested.

At this time, five technical papers on the results of the research have been published and one paper has been accepted for publication: "Fabrication of a Composite Superstructure using a New Assembly Method", MOURING, S.E., Associate Professor and Reichard, R., *The 11th International Offshore and Polar Engineering Conference Proceedings*, Stavanger, Norway, June 2001 (*reviewed paper* - accepted for publication).

Fiber Placed Inlet Duct Program

Researcher: Associate Professor Sarah E. Mouring
Sponsor: Office of Naval Research (ONR)

The study supported ongoing work in the Fiber Placed Inlet Duct Program. The researchers at the United States Naval Academy provided technical support for several aspects of mechanical behavior and testing of composite structures. This support was intended to lead to a knowledge base for the utilization of fiber placed sandwich composite structure for advanced aircraft.

Testing for the Fiber Placed Inlet Duct Program included static compression and damage testing of fiber placed sandwich structure specimens and addressed structural integration of this component. A total of twenty-four panels, with varying levels of impact damage, were tested at the Naval Academy including four control panels containing no impact damage. Each specimen was subjected to edge-wise compression as specified by ASTM C-364. Each panel was instrumented with eight strain gages. The resulting strain gage data was used not only to determine the mechanical response of the specimens but also to verify the quality of the milling process and to monitor the load transfer for any signs of global buckling or skin/core delamination. Testing was completed in the Fall of 2000.

BESTEAMS Model of Team Development Across the Curriculum

Researcher: Associate Professor Sarah E. Mouring
Sponsor: National Science Foundation (NSF)

The Building Engineering Student Team Effectiveness and Management Systems (BESTEAMS) Partnership is involved in engineering project team training research and includes faculty from the University of Maryland, Morgan State University, Howard University, and the U. S. Naval Academy. This partnership proposes to develop a four-year, team training curriculum model that can be integrated into any existing engineering curriculum. Full development of the model will include preparation of a complete undergraduate curriculum on team development topics, supportive faculty training workshops, and materials for formative and summative evaluation and research. The curriculum and supportive materials will be disseminated nationally via conferences, workshops, the BESTEAMS website and a national publication. Much of the early research will include development of the team training curriculum at the Partnership institutions including the Naval Academy.

Passively Controlled Semi-Closed/Closed Rebreather Development

Researcher: Professor Marshall L. Nuckols
Sponsor: Office of Naval Research (ONR)

The long-term goal of this research is to develop a versatile, passively-controlled semi-closed rebreather for deep diving applications that can be switched to closed-circuit mode during shallow water missions (depths less than 25 feet). Such a design is desired to safely satisfy the full range of Naval Special Warfare missions without the complexity and cost of electronically-controlled closed circuit rebreathers. The objectives of this effort are to optimize the design of respiratory-coupled circuit designs (using variable volume exhaust injection systems) using analytical predictive models, and verify from unmanned testing that safe alternatives to traditional semi-closed circuit designs are feasible. In so doing, we will demonstrate that respiratory-coupled rebreather designs will provide divers with stable, and predictable circuit oxygen levels across their full range of activity levels.

Hydrogen Catalytic Heater for SDV Applications

Researcher: Professor Marshall L. Nuckols
Sponsor: Office of Naval Research (ONR)

The long-term goal of this research is to develop a safe and efficient diver heater to minimize package size and power requirements and yet meet the entire diver heating requirements for long duration Naval Special Warfare (NSW) missions. The technical objectives of this effort are to a) conduct a tradeoff analysis of different active heating methods for swimmer delivery vehicle (SDV) applications to quantify and compare the energy densities of each approach, b) construct a prototype heating circuit containing a heat exchanger incorporating a palladium on carbon catalyst bed, and c) conduct laboratory testing of prototype hydrogen catalytic heater and water heat exchanger to verify the energy density available from this heating method.

Development of an Amphibian Thermal Suit for Combat Swimmers

Researcher: Professor Marshall L. Nuckols
Sponsor: Naval Surface Warfare Center (NSWC), Coastal Systems Station, Panama City, FL

A thermal analysis and laboratory testing of diver thermal protection garments was conducted in support of a project being run by the Coastal Systems Station. The objective of this suit development project is to provide the Navy SEAL community with a protective garment that will provide thermal comfort while swimming in moderately cold water, but also provide evaporative cooling while on land. Such a garment will allow the combat swimmer to maintain the same garment during a combat insertion into a hostile environment.

The Relationship Between the Detachment of Low Form Fouling at Lab and Ship Scales

Researcher: Assistant Professor Michael P. Schultz
Sponsor: Office of Naval Research (ONR)

The introduction of non-toxic, fouling-release coating systems as alternatives to traditional biocide based antifoulings has necessitated a change in coating evaluation protocol. Since fouling-release systems do not prevent settlement, various methods to quantify the tenacity of adhesion of fouling organisms on these systems have been offered. Data from these tests are of particular importance because fouling-release surfaces that cannot "self clean" due to hydrodynamic forces or be mechanically cleaned without significant damage will likely suffer large drag penalties. The question remains, however, how the results from these laboratory scale tests relate to the self-cleaning of a ship coated with a fouling-release surface. The goal of the proposed research is to better relate the detachment strength of low form fouling determined by the turbulent channel flow apparatus to the conditions necessary for detachment of these organisms in a turbulent boundary layer at ship scale.

Design and Construction of a Fully-Developed Turbulent Channel Flow Apparatus for the Determination of Strength of Adhesion of Low Form Fouling

Researcher: Assistant Professor Michael P. Schultz
Sponsor: Office of Naval Research (ONR)

Novel methods to evaluate the efficacy of non-toxic antifouling coatings are needed. To this end, a high aspect ratio channel was designed and constructed to challenge microfouling organisms with fully-developed turbulent flow. The device allows the mounting of six coated microscope slides in the test section where the Reynolds number based on the channel height and the bulk mean velocity can be varied from 3,000 – 55,000 with a corresponding wall shear stress of 1 Pa to 130 Pa. Testing with the device is currently underway at the Kewalo Marine Lab at the University of Hawaii.

Effect of Mechanical and Manufacturing Defects on the Ultimate Strength Marine Composite Panels

Researcher: Professor Gregory J. White
Sponsor: Naval Surface Warfare Center – Carderock Division (NSWC-CD Code 6552)

During the period of the report, eight 3' x 4' composite sandwich panels with embedded defects (2 with skin-to-core dis-bonds, 6 with impact damage) were tested in the USNA Ship Structures Laboratory grillage test fixture to determine the effects of defects on panel structural integrity under compressive end loading. This work is in support of ongoing efforts by the Survivability, Structures, & Materials Directorate, Structures and Composites Department, Marine Composites Branch, Mechanics Section of NSWC-CD.

Independent Research

Bioengineering Study of the Cardiovascular System of Mammals

Researcher: Professor Thomas H. Dawson

The cardiovascular system of mammals is studied using engineering principles and their application to the design and processes of the system. Publications include the earlier book: *Engineering Design of the Cardiovascular System of Mammals* (T.H. Dawson, Prentice Hall Bioengineering Series, 1991), and the recent paper: Similitude in the Cardiovascular System of Mammals (T.H. Dawson, *Journal of Experimental Biology*, Vol. 204, pp.395-407, 2001).

Performance Improvement of Navy 44

Researcher: Ensign Aaron P. DeMeyer, USN
Adviser: Assistant Professor Paul H. Miller

This Temporary Assigned Duty (TAD) project focused on improving the performance of the new Navy 44's while maintaining the qualities needed for safe training offshore. The project focused on modifying principal dimensions such as length, stability, keel and rudder design to determine performance improvements. A spreadsheet-based velocity prediction program developed by the AmericaOne America's Cup Syndicate was used as the primary analytical tool. To verify its accuracy, full-scale resistance and stability tests were performed on a Navy 44. Results showed speed improvements of 3-18% were possible. These results were partially incorporated into the EN476 Navy 44 project and were subsequently partially incorporated into the new Navy 44.

Research Course Projects

Redesign of Navy 44 Hull Laminate

Researcher: Midshipman 1/C Mark H. Arvidson, USN
Adviser: Assistant Professor Paul H. Miller

This summer internship continued an EN494 project and addressed the laminate design used in the Navy 44 sail training vessel. The current vessel used composite technology common in the late 1970's. The resulting laminate used knitted fabrics combined with random chopped mat in vinyl ester resin. Feedback from the Naval Station indicated a desire for a more durable and easier to repair laminate. Feedback from the sailors indicated a desire for a lighter weight laminate.

Input from vendors and boatbuilders was combined with laminate analysis using classical lamination theory to predict more efficient laminates for the next set of vessels. Toughened vinyl ester and epoxy resins were studied along with Airex, CoreCell and Divinycell cores. New laminate stacking sequences and materials were also considered. These led to three proposed laminates; one matching the weight of the current laminate but having substantially higher toughness, one having an equal toughness but substantially reduced weight, and a compromise laminate that had an estimated 30% improvement in toughness and 25% reduced weight. Testing included: 4-point, 2x2 panel, heat distortion and impact. Final recommendations favored a toughened vinyl ester or infused epoxy combined with CoreCell. A paper was submitted and approved for publication in Naval Engineers Journal.

Redesign of Navy 44 Deck and Cockpit Layout

Researcher: Midshipman 1/C Cecily E. Taylor, USN
Adviser: Assistant Professor Paul H. Miller

This voluntary summer internship developed proposed deck and cockpit layouts for the new Navy 44-foot sail training vessel. Beginning with interviews of the current vessels' primary user groups, a list of desirable and undesirable features of the current design was cataloged. Further interviews of sailors and an evaluation of other vessels decks, cockpits and post-storm reports identified design features that would address the deficiencies. A new deck layout was then drawn on CAD that increased crew efficiency on the foredeck, reduced equipment interference, improved comfort and removed two hazardous conditions. The new cockpit layout reduced crowding, improved visibility and communications, removed a hazardous condition, increased drainage, and improved man-overboard recovery. Many characteristics of the improved cockpit were incorporated into the new Navy 44 design.

Study of Submerged Parasitic Bodies on a Parent Hull

Researcher: Midshipman 1/C Ethan R Fiedel, USN
Adviser: LCDR Richard A. Schoenwiesner, USNR

The initial goal of this project was to determine the resistance resulting from the addition of a parasitic body to a submerged parent hull. This study was performed using a scale model of the Advanced SEAL Delivery System (ASDS) mounted on a body of revolution submarine model. Four configurations were run to determine drag: the body of revolution model, the body with the flat deck, the body with the flat deck and full ASDS, and the body with the flat deck and top half of the ASDS. The configurations were to show the change in resistance created if the actual ASDS was mated on top of a submarine or semi-internally. The results show that the actual difference in resistance between the configurations was less than 5%.

Additional tests were later performed: the drag from varying the longitudinal position of the parasitic body and a flow visualization study were performed. For the flow tests, a second ASDS model and a submarine sail model were constructed, and over 250 tell tales were attached to the composite model. Four test configurations were run: an ASDS model with the flat deck, an ASDS model with the flat deck and sail, two ASDS models mounted side by side with the flat deck and sail, and the sail and flat deck. Like the first set of tests or each run, the drag change was generally less than 5%. The video footage showed some potential flow problems and merit further investigation.

Calm Water Testing of the HYSWAS Concept "Streetfighter"

Researcher: Midshipman 1/C Peter C. Mitalas, USN
Adviser: Professor Bruce C. Nehrling

The purpose of this research effort was to investigate the lift characteristics and powering requirements of a HYSWAS "Streetfighter" concept. A HYSWAS (Hydrofoil Small Waterplane Area Ship) is a vessel characterized by a conventional upper hull mounted on a slender strut connected to a cylindrical lower hull. Attached to the lower hull are two sets of foils, one forward and one aft. The ship lifts out of the water and "flies" using a combination of buoyant lift from the submerged lower hull and dynamic lift from the foils.

The model used for these experiments was a 1/25th scale variant of the 850-ton HYSWAS "Streetfighter" designed by MAPC (Maritime Applied Physics Corporation). Experiments were conducted in the Naval Academy Hydromechanics Laboratory's 380-foot towing tank using a two-phase test program. During the first phase of testing, lift and drag data were collected for three conditions: bare hull, bare hull with forward (main) foils only, and bare hull with both sets of foils. The second phase of the program established angles of attack for the main and aft foils that gave the required amount of lift while also balancing moments at various speeds. During both phases, video pictures were taken.

Results include the angles of attack found, the amount of lift achieved, and how the total amount of lift was divided between the bare hull, main foils, and aft foils. Effective horsepower (EHP) curves for the bare hull and for the bare hull with main and aft foils attached, both with the hull trimmed 3.5° by the stern, were developed. Finally, using video analysis, sketches of the waterline and underwater flow patterns were made. The amount of lift required to raise the model to its flying waterline was achieved at a model speed of 9.45 fps. At all speeds, the EHP curve showed high powering requirements due to the significant amount of drag the foils added to the bare hull. The visual flow analysis showed that the strut and foils significantly affect the water flow around the model.

Dynamic Response of a Compliant Tower to Rogue Waves

Researcher: Midshipman 1/C Ian J. Lilyquist, USN
Adviser: Professor David L. Kriebel

This study examined the effects of extreme rogue waves on a simplified model of an offshore structure. Rogue waves arise out of a background random sea and can impart large impulsive loads on offshore structures. For compliant offshore structures, the rogue waves can excite dynamic structural motions with a combination of motions at the incident wave frequency and at the structure's natural frequency. The goal of this project was to investigate the dynamic motions of an offshore structure

through physical modeling in the naval Academy Hydromechanics Lab. A small-scale model of a simple compliant offshore structure was built and was instrumented to measure both structural motions and base shear forces. Random seas were created in the wave tank using Fourier transform methods, and then isolated large or rogue waves were embedded in the random sea using a technique developed in a previous Midshipman research project. Results of testing showed that the statistical variability of structure motions and forces was not as great as that of the wave field. For example, incident rogue waves were generated that were 2.7 times larger than the significant wave height of the random sea. In response, however, peak structure motions were only 1.6 times larger than the significant structural motions, while peak forces were only 1.7 times as large as the significant force. These results show that compliant structures are capable of withstanding rogue waves without undue amplifications of the motions or structural loads.

Gravity Based Anchor for the San Clemente Island Mooring System

Researcher: Midshipman 1/C David M. Matvay, USN
Adviser: Professor David L. Kriebel
Sponsor: EN495 and Naval Facilities Engineering Services Center (NRESC)

Gravity-based anchors are anchors that are built to hold moored ships on station through their weight without embedment into the seafloor. The midshipman worked on the design for a rapidly deployed gravity anchor for San Clemente Island, California, while on a voluntary internship with the Naval Facilities Engineering Services Center; and, laboratory tests were conducted on a scale model of this anchor during the fall semester after the internship. The anchor was circular in plan form with a full-scale diameter of 32 feet and a height of 10 feet. The interior of the anchor contained buoyancy tanks that could be pumped dry in order to float the anchor into position, and then flooded with seawater to sink the anchor to the seafloor. The model tests specifically investigated the dynamic response of the anchor during the sinking process. A 1-to-20 scale model the anchor was built and placed at the water surface in one of the wave tanks in the Hydromechancis Lab. The anchor was then allowed to flood and fall to the tank floor, with measurements being made of the speed of descent, the orientation and motions of the anchor, and the position of the anchor at rest. Results were also simulated with a numerical model. Results showed that the anchor would strike the seafloor with a velocity of 10 ft/sec at full scale, that it would “flutter” as it fell and strike the seafloor at a steep angle, and that the landing location would be within one diameter of the initial drop location. While the accuracy of the landing was deemed sufficient, the impact velocity and orientation would likely cause structural damage.

Performance Testing of Historic Sailing Warships

Researcher: Midshipman 1/C Jennie E. Hill, USN
Adviser: Professor Gregory J. White
Sponsor: RADM Guy Schaffer, USN, Class of 1951

The U.S. Naval Academy’s Class of ’51 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 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.

Publications

Journal (Refereed) Manuscripts

ARVIDSON, Mark H., Midshipman 1/C, (USN) and MILLER, P.H., Assistant Professor, "Hull Material Evaluation for Navy 44 Sail Training Vessel," accepted for publication in the *Naval Engineers Journal*.

> Material characterization tests were performed at the US Naval Academy to identify a toughened laminate for the new Navy 44-foot sail training vessels. After preliminary analysis using classical lamination theory, four different cores, five laminates and seven resin systems were tested in UV exposure, four-point bending, lateral panel pressure, and simulated bow impact. Results showed substantial improvements in strength, toughness, cost and weight were possible over the existing laminate, with the lightest acceptable laminate yielding a weight savings equivalent to 3.5% of the vessel's displacement.

DAWSON, Thomas H., Professor, "Maximum Wave Crests in Heavy Seas," *Transactions ASME Journal of Offshore Mechanics and Arctic Engineering*, Vol. 122 (August 2000), pp. 222-224.

> Applicability of extreme-value theory in predicting the maximum crest amplitude in runs of ocean waves is demonstrated using data from extensive computer simulations of random linear waves. Extension of the theory to include wave crests in heavy seas is also made within the context of Stokes nonlinearities. Results are confirmed with scaled laboratory measurements.

DAWSON, Thomas H., Professor, "Similitude in the Cardiovascular System of Mammals," *Journal of Experimental Biology*, Vol. 204 (February 2001), pp. 395-407.

> Scaling laws governing the cardiovascular system of mammals are discussed in the present review in a manner emphasizing their experimental basis. Specific attention is given to the well-known experimental laws requiring the rate of oxygen consumption and the heart rate of mammals to vary with body mass raised to the powers ¾ and -¼ , respectively. This review involves reconsideration and further discussion of the previous work of the writer in which these and other scaling relations were developed from fundamental considerations.

Gangadharan, S.N., SCHULTZ, M.P., Assistant Professor, Collino, B., Clark, A., and Wimberly, C.R., (2001), "Experimental Investigation of *Enteromorpha clathrata* Biofouling on Lifting Surfaces of Marine Vehicles," *Marine Technology*, Vol. 38, pp. 31-50.

> Biological fouling can adversely affect the hydrodynamic performance characteristics of hydrofoil surfaces and lead to deterioration in the vehicle performance and maneuvering abilities and higher fuel and maintenance costs. Much attention has been drawn to the frictional resistance caused by large organisms, such as barnacles, bryozoa, and tubeworms in the past. Resistance to adhesion of many of these large organisms has been demonstrated by the use of antifouling paints. This paper describes the experimental results for fouling of *Enteromorpha clathrata* on marine surfaces and its impact on the hydrodynamic performance characteristics, in conjunction with the design, construction, and operation of a water tunnel. It includes a description of the force balance system, laser Doppler velocimeter (LDV) system, and the data acquisition system used to conduct the experimental study. Results of the experiments with *Enteromorpha clathrata* fouling are presented, and the effects of biofilms on turbulent boundary layer structure are outlined. The experimental results of the force balance experiment showed a constant increase in zero-lift angle of attack by 10 degrees for as little as 10 percent fouling, and a reduction in the maximum lift by as much as 70 percent. Similarly, the LDV experiment found an increase in the skin friction coefficient for all fouled surfaces, and an average increase of 187 percent for a surface dominated by *Enteromorpha*.

Kavanagh, C.J., SCHULTZ, M.P., Assistant Professor, Swain, G.W., Stein, J., Truby, K., and Wood, C.D., (2001), "Variation in Adhesion Strength of Three Hard-Fouling Types to Fouling-Release Coatings," accepted and in final form for *Biofouling*.

This study compared the shear adhesion strength of barnacles, oysters and tubeworms on eight RTV 11-based silicone fouling-release coatings containing different silicone oil additives. It was found that adhesion strength differed among species and coating types. In most cases, oysters and tubeworms had higher adhesion strength than barnacles. Barnacle adhesion strength was reduced on all coatings containing oil additives; however, this was not generally true for oysters and tubeworms. The difference in the adhesion strength among the three organisms tested in this study emphasizes the importance of understanding the fundamental interaction between marine invertebrate adhesives and the substrate.

MILLER, P.H., Assistant Professor, "Effects of Moisture Absorption and Test Method on the Properties of E-glass / Polyester Hull Laminates," accepted for publication in the *Journal of Composite Materials*.

Effects of moisture absorption on the tensile, compressive, shear, bending and bending fatigue properties of an iso-polyester/E-glass hull laminate were studied. Fickian diffusion constants were found that closely modeled moisture absorption. Comparisons were made of standard moisture experiments using boiling water versus long-term exposure. Results indicated the boiling water test yielded significantly conservative values. Fatigue endurance limits were found to be near 25% of static load, indicating a fatigue design factor of four is required for infinite service with this material. Coupon results were used with finite element analysis (FEA) to predict panel deformations and strains. Good correlation was achieved.

MILLER, P.H., Assistant Professor, "Fatigue Prediction Verification of Fiberglass Hulls," accepted for publication in *Marine Technology*.

The growing use of marine composite materials has led to many technical challenges, including predicting lifetime durability. Analytical models based on classical lamination theory, finite element analysis, ship motions, probability and wind and wave mechanics were used in this project to predict hull laminate strains and fatigue tests were used to determine S-N residual stiffness properties of coupons. These predictions and test data were compared against two cored fiberglass sisterships having significantly different fatigue histories and undamaged laminates representing a new vessel. Strains were measured while underway and good correlation was achieved between predictions and measurements. Fatigue damage indicators were identified which could be used in vessel inspection procedures. Endurance limits were found to be near 25% of static failure load.

A rational explanation for using thicker outer skin laminates in marine composites was identified through single-sided moisture flex tests. These showed that the reduced strength and stiffness due to moisture of the outer hull skin laminate could be compensated by increased thickness.

MOURING, S.E., Associate Professor, BARTON, Oscar, Jr., Associate Professor, and SIMMONS, D. Kevin, (Trident Scholar, Class of 1999), "Reinforced Concrete Beams Externally Retrofitted with Advanced Composites," *Advanced Composite Materials Journal*, 2001.

Reinforced concrete structures deteriorate over time due to environmental aging, fatigue, excessive loading, chemical attack, and other factors. Strengthening and rehabilitating these concrete structures by externally bonding carbon laminates is one of many economical engineering solutions. This study investigates the structural behavior of reinforced concrete beams externally retrofitted with carbon fiber reinforced polymer (CFRP) laminates. More specifically, the effects on strength and ductility are of major importance. Eight rectangular beams with varying internal steel reinforcement were retrofitted by externally bonding CFRP laminates onto the tension faces and tested under four-point bending. Each beam was instrumented to monitor deflection, curvature, and strain over the entire loading spectrum, and to determine its structural response. A modified energy-based model is used to predict ductility. Results from this research indicate a decrease in ductility, an increase in strength, and validate the modified analytical model.

Saylor, J.R., FLACK, K.A., Associate Professor, SCHULTZ, M.P., Assistant Professor, and Smith, G.B., (2001), "The Correlation between Surface Temperature and Subsurface Velocity during Evaporative Convection," accepted for publication in for *Experiments in Fluids*.

Correlation coefficients between measurements of temperature at a water surface and velocity at a location beneath the water surface undergoing evaporative convection are presented. The surface temperature measurements were obtained via quantitative infrared imaging and the velocity measurements were obtained using a two-component LDV system. The water surface was covered with a surfactant monolayer that did not impede evaporation. The largest measured correlation coefficient was 0.375. Correlation coefficients obtained after shifting the velocity and temperature traces with respect to each other revealed a peak in the correlation coefficient very close to a zero time shift. The significance of these results and their implications for the remote sensing of underwater objects via infrared imaging are discussed.

SCHULTZ, M. P., Assistant Professor, (2000), "Turbulent Boundary Layers on Surfaces Covered with Filamentous Algae," *ASME Journal of Fluids Engineering*, Vol. 122, pp. 357-363.

Turbulent boundary layer measurements have been made on surfaces covered with filamentous marine algae. These experiments were conducted in a closed return water tunnel using a two-component, laser Doppler velocimeter (LDV). The mean velocity profiles and parameters as well as the axial and wall-normal turbulence intensities and Reynolds shear stress are compared with flows over smooth and sandgrain rough walls. Significant increases in the skin friction coefficient for the algae-covered surfaces were measured. The boundary layer and integral length scales were also increased. The results indicate that profiles of the turbulence quantities for the smooth and sandgrain rough walls collapse when friction velocity and boundary layer thickness are used as normalizing parameters. The algae-covered surfaces, however, exhibited a significant increase in the wall-normal turbulence intensity and the Reynolds shear stress, with only a modest increase in the axial turbulence intensity. The peak in the Reynolds shear stress profiles for the algae surfaces corresponded to the maximum extent of outward movement of the algae filaments.

SCHULTZ, M. P., Assistant Professor and Swain, G.W., (2000), "The Influence of Biofilms on Skin Friction Drag," *Biofouling*, Vol. 15, pp. 129-139.

The contribution of biofilms to skin friction drag is not clearly defined, and as regulations continue to restrict the use of biocides in antifouling paints, they are likely to form a greater presence on ship hulls. This paper reviews the flow regime around a ship's hull, the basics of boundary layer structure, and the effects of rigid surface roughness on drag. A review of experimental studies of biofilms in turbulent shear flows at laboratory and ship-scale is made. The consensus of these show that biofilms increase skin friction drag. Some measurements of the authors carried out in turbulent boundary layer flow using a two-component, laser Doppler velocimeter (LDV) are also presented. These results indicate an increase in skin friction for biofilms that is dependent on composition as well as thickness.

SCHULTZ, M.P., Assistant Professor, Finlay, J.A., Callow, M.E., and Callow, J.A., (2000), "Turbulent Channel Flow Apparatus for the Determination of the Adhesion Strength of Microfouling Organisms," *Biofouling*, Vol. 15, pp. 243-251.

The development of novel, fouling-release surfaces has led to the need for better test methods to evaluate their performance. A water channel has been designed to measure the adhesion strength of microfouling organisms to test surfaces. The apparatus allows six replicate microscope slides to be mounted in a fully-developed, turbulent channel flow. Wall shear stress in the test section can be varied from 0.9 Pa – 30 Pa over a Reynolds number range of 2,800 to 27,000 based on the bulk mean velocity and channel height. Calibration of the device indicates that the accuracy and repeatability in the wall shear stress is within 4% throughout the range. Experiments using the fouling diatom *Amphora* settled on acid-washed glass slides are presented. The results show significant differences in the shear stress required to remove *Amphora* cells with settlement time. No significant differences among the replicate slides were observed, indicating flow uniformity in the test section.

Swain, G., Anil, A., Baier, R., Bosoolai, L., Conte, E., Cook, A., Hadfield, M., Haslbeck, E., Holm, E., Kavanagh, C., Kohrs, D., Lee, C., Mazzella, L., Meyer, A., Qian, P., Sawant, S., SCHULTZ, M. P., Assistant Professor, Sigurdsson, J., Smith, C., Terlizzi, A., Wagh, A., Zimmerman, R., and Zupo, V., (2000), "Biofouling and Barnacle Adhesion Data for Fouling-Release Coatings Subjected to Static Immersion at Seven Marine Sites," *Biofouling*, Vol. 16, pp. 331-344.

Little is known about the performance of fouling-release coatings at different geographical locations. An investigation was designed to measure the differences in biofouling and biofouling adhesion strength that became established on three known silicone formulations and an epoxy control at seven static immersion sites located in California, Florida, Hawaii, Hong Kong, India, Italy and Singapore. The study found that whilst the relative performance of the coatings was the same at each site, there were statistically significant differences in the type and intensity of fouling community and in the adhesion strength of species. The results emphasize the importance of evaluating potential coatings at more than one static immersion site.

WHITFORD, D.J, Captain, (USN), VIEIRA, M.E.C., Associate Professor and WATERS, J.K., Assistant Professor, "Teaching Time-Series Analysis: Part 1, Using Finite Fourier Analysis,"*American Journal of Physics*, Vol. 69, No. 4, April 2001, pp. 490-496.

Analysis of progressive, wind-generated surface gravity waves is a fundamental learning objective for students majoring in ocean engineering and physical oceanography. Students usually find the transition from understanding monochromatic (i.e. single frequency) waves to understanding a more realistic random sea to be difficult. A two-part laboratory exercise is described which addresses this problem. The first exercise introduces the manual arithmetic steps of a finite Fourier analysis of a wave record, develops a wave energy spectrum, and compares these results to the results obtained using a Fast Fourier Transform (FFT). The second part of the exercise, described in the subsequent article, takes a longer wave record, and addresses the theoretical and observed wave probability distributions of wave heights and sea surface elevations. These results are then compared to an FFT, thus linking the two laboratory exercise parts for a more complete understanding. The exercise's benefits are cross-disciplinary in nature and can be used in any fields that deal with signal analysis.

WHITFORD, D.J., Captain, (USN), WATERS, J.K., Assistant Professor, and VIEIRA, M.E.C., Associate Professor "Teaching Ocean Wave Analysis: Part 2, Using Wave Height and Water Surface Elevation Probability Distributions," *American Journal of Physics*, Vol. 69, No. 4, April 2001, pp. 497-504.

Analysis of water surface waves is a fundamental learning objective for undergraduate and graduate students majoring in ocean engineering and physical oceanography. Students usually find the transition from studying monochromatic waves, i.e. single frequency waves, to studying a more realistic complex and random sea of many different frequencies to be difficult. Two computer laboratory exercises are presented which enable students to make this transition with less difficulty and more understanding. The first exercise, described in the previous article, utilized spreadsheet software on which the students execute the manual arithmetic operations of a finite Fourier analysis on a complex wave record. The results were then compared to those obtained by a Fast Fourier Transform. This article, the second of this two-part series, addresses analysis of a complex sea using observed and theoretical wave height and water surface elevation probability distributions and wave spectra. These results are compared to a Fast Fourier Transform analysis, thus providing a link back to the first exercise.

Conference Proceedings

FINLAYSON, W.S., Lieutenant, (USN), NUCKOLS, M.L., Professor, and Tobin, J., "Design Guidelines for Constant Mass Injection Underwater Breathing Apparatus," *Proceedings of Underwater Intervention 2001*, 15-17 January 2001, Tampa, FL (CD-ROM Paper E.2.1)

With the current popularity of constant mass injection rebreathers in the recreational market, a simple procedure for determining the optimum volume fraction and injection rate for such breathing apparatus is required. By

assuming diver could be working at a rate between a minimum and maximum at any depth, the operational boundary conditions of high work rate at shallow depth and low work rate at deeper depth are examined using an accepted method for prediction of circuit oxygen levels to develop non-dimensional relationships between injection rate and oxygen consumption. These relationships are presented in a single figure that can be used to predict optimum design parameters for constant mass injection systems. By first specifying the divers minimum and maximum activity level and mission depth (operation variables), a single non-dimensional figure is used to determine the mixture of the make-up gas, and injection rate (design variables). Examples are provided to illustrate the design approach and stress the dependence this type of underwater breathing apparatus has on diver work rates. This approach is also shown to be useful in determining actual operational limitations of existing constant mass injection rebreathers.

Henkener, J.A. and NUCKOLS, M.L., Professor, "Maximizing Thermal Performance of Divers' Gloves By Use of Insulating Liquids," *Proceedings of Oceans 2000, Marine Technology Society*, 11-14 September 2000, Providence, RI, pp. 1375-1381.

A diver's ability to perform meaningful work is greatly diminished in long duration missions if his hands are cold when the mission objective has been reached. Unfortunately, in extremely cold water diving, conventional gloves use thick, foam neoprene or layered insulating materials worn beneath waterproof glove shells to reduce the loss of body heat to the surrounding cold water. These gloves tend to be inherently buoyant, highly variable in insulating effect due to material squeeze, excessively bulky, inhibiting articulation and tactile sensitivity, and difficult to keep waterproof — an uncertainty that could fatally reduce the diver's thermal protection during long duration missions. The authors are developing a unique approach to diver hand protection through the use of an inner glove liner filled with insulating fluid. The insulating liquids used in this glove system have been characterized to have insulation values comparable to foam neoprene at shallow depths and, due to the incompressible behavior of these liquids, superior to foam neoprene at depth. These fluid liners, engineered to be neutrally buoyant, minimize decrements in hand articulation and finger sensitivity. Unlike conventional foams or batt insulations, the liquid insulations disperse from the immediate contact points between the fingers and the underwater object, only to return in a uniform thickness after the object is released. Additionally, variable insulation values can be readily achieved by controlling the quantity of liquid injected into the glove liner. This paper describes the liquid diver glove design and presents an overview of the thermal testing conducted on this new diver glove system. It also describes the laboratory investigations conducted to identify and maximize the most thermally efficient insulating liquid.

JOYCE, P.J., Assistant Professor, BARTON, Oscar, Jr., Associate Professor and MOURING, S.E., Associate Professor, "Evaluation of the Effect of Impact Damage on the Mechanical Response of Composite Sandwich Structures," *American Society for Composites 16th Annual Technical Conference Proceedings*, Blacksburg, VA, September 2001, accepted for publication.

This research seeks to evaluate the effect of impact damage on the mechanical response of composite sandwich structures. The sandwich panels in this investigation are under consideration for aerodynamic structural applications. A total of twenty-four panels, with varying levels of impact damage, were tested including four control panels containing no impact damage. The remaining twenty specimens were grouped according to the size of the impactor, which varied from, 0.5 in. to 1 in. diameter and impact energy. The impact energy levels consisted of 6 ft-lbs, 20 ft-lbs, and 35 ft-lbs, representing relatively low, moderate, and high impact energy levels. Properties investigated BOTH included the compressive strength and elastic stiffness. Each panel was manufactured using fiber placement technology and consisted of AQII/977-3 Astroquartz/Ep OML upper and lower face sheets and HRP/F50-5.5 Flexcore core. General results were correlated both with impactor size and energy level, and indicated a reduction of compressive strength with an increase in impact energy and impactor size.

KRIEBEL, D.L., Professor, "Breaking Waves in Intermediate Depths With and Without Currents," *Proceedings of the 27th International Conference on Coastal Engineering*, Sydney, Australia, July 2000.

Results of large-scale laboratory tests are used to evaluate breaking criteria for waves in intermediate depth with and without favorable or in-line currents. The laboratory tests simulated design waves for the near-shore Gulf of Mexico, where breaking waves with heights of up to 12.2 m (40 ft) are expected in a water depth of 15.2 m (50 ft),

and where wind-driven currents are expected. This paper compares the observed breaking wave heights to those predicted using three breaking criteria of Miche, Battjes and Janssen, and Goda. Results show that all three work reasonably well for the zero-current conditions. All three also work well when a current is present, provided the Doppler-shifted wave period is used. In addition, the paper shows that the breaking criteria work best when the wavelength is computed using Stokes 3rd-order wave theory.

KRIEBEL, D.L., Professor, and ALSINA, M.V., Midshipman 1/C, (USN), "Simulation of Extreme Waves in a Background Random Sea," *Proceedings of 9th International Conference On Offshore and Polar Engineering*, Seattle, WA, June 2000.

Laboratory experiments were conducted to embed a large transient wave within a random sea as a means of simulating rogue or freak wave events in a wave tank. The total wave energy spectrum was split into two parts: one for the background random sea and the other for the transient or freak wave. It is shown that a freak wave, having a height of more than twice the significant wave height can be generated using just 15% to 20% of the total wave energy in the transient wave and 80% to 85% of the energy in the random sea. This implies that a freak wave may occur relatively easily due to the focusing of only a small part of the overall wave energy.

KRIEBEL, D.L., Professor and WALLENDORF, L., P.E., "Air Gap Model Tests on a MOB Module," *Proceedings of the 10th International Conference On Offshore and Polar Engineering*, Stavanger, Norway, June 2001.

Physical model tests were conducted on a large semi-submersible model, representing a 1-to-70 scale model of a single module of the Mobile Offshore Base (MOB). Tests were conducted in head seas in two random sea states, with the model ballasted to a deep operating draft. This paper discusses the characteristics of the MOB model, the experimental setup and test conditions, the observed platform motions, and the degree of wave amplification under the hull leading to reductions in the effective air gap. These last measurements are based on nine wave gages located under the model, from which basic statistics, spectra, and probability distributions have been computed.

MAYER, R. H., Associate Professor, "A Compendium on Environmental Engineering for Ocean Engineering Majors," *Proceedings of the ASEE 2000 Annual Conference*, St. Louis, MO, June 2000.

This paper describes a new area of concentration within the ocean engineering major at the U.S. Naval Academy. This environmental engineering option finds its essence in two fundamental courses within the major that are complimented by multidisciplinary opportunities in other majors. The first fundamental course, Ocean Environmental Engineering, focuses on marine pollution: its principal causes, effects, and its remediation. The second, Ocean Resources Engineering, emphasizes methods for ocean resource assessment, recovery and utilization. Other environmental engineering opportunities include the capstone design course required of all engineering majors, and elective courses in such disciplines as environmental economics, environmental oceanography, environmental security, and marine environmental engineering. The purpose of this paper is to address the evolution of this environmental engineering option and to describe the content of its two fundamental courses. The paper also provides a brief description of recent environmental-related capstone design projects and reviews topical coverage of selected elective courses.

MOURING, S.E., Associate Professor, "A Novel Method for Adhesively Bonding Composite Joints," *The Adhesive and Sealant Council Conference Proceedings*, pp.1-10, Minneapolis, MN, October 2000 (invited paper).

Composite structural elements are joined using two different methods: bonding and bolting. Adhesive bonding has a number of advantages over bolting and is the preferred joining method for most marine applications. Adhesive structural joints typically are formed using a three-step process beginning with the application of an adhesive bead on the surface of one structural element, next joining the structural elements, and finally clamping to insure an adequate bond. This is a labor-intensive procedure that can result in high labor costs. Therefore, there is a need to develop an improved joining method for marine applications. A new technique using a combination of liquid adhesive/adhesive tape technology is now being considered as an alternative to current joining techniques. In short, adhesive tape is used to temporarily "tack" structural elements together and to create a channel between the

structural elements in which liquid adhesive can be injected at some later time. Overall, this method has the potential to be a more cost-effective, less labor-intensive joining method while providing good structural bonds.

MOURING, S.E., Associate Professor, "Investigation into a New Technique for Fabricating Composite Joints," *Seventh International Conference on Computer Methods in Composite Materials and Structures (CADCOMP 2000) Proceedings,* Bologna, Italy, September 2000.

Composite structural elements used in marine applications are joined typically by adhesive bonding. Adhesive structural joints usually are formed using a three-step, expensive, labor-intensive process and often require clamping overnight while the adhesive cures. A novel joining technique has been developed as an alternative to current practices. This new method used both liquid adhesive and adhesive tape to fabricate joints. In short, adhesive tape is used to temporarily "tack" structural elements together and create a channel between the elements in which liquid adhesive can be injected at some later time. One advantage of this technique is that the resulting bond lines are more consistent than bond lines formed using current methods. Secondly, multiple-part structures can be "tacked" together and checked for accuracy before the liquid adhesive is applied. Lastly, clamps are not needed during the curing process, because the tape securely holds the joint together while the adhesive cures. This paper summarizes the development and evaluation of this less expensive joining technique using experimental and numerical methods.

MOURING, S.E., Associate Professor, BARTON, Oscar, Jr., Associate Professor, and SIMMONS, D. Kevin, (Trident Scholar, Class of 1999), "Ductility of Reinforced Concrete Beams Externally Retrofitted with Carbon Fiber Reinforced Polymer Composites," *Ninth U.S.-Japan Conference on Composite Materials Conference Proceedings,* Mishima, Shizuoka, Japan, July 2000.

This study investigates the effect of externally bonded carbon fiber reinforced polymer (CFRP) laminates on the ductility of reinforced concrete beams used in the repair of damaged bridge structures. Reinforced concrete structures deteriorate over time due to environmental aging, fatigue, excessive loading, chemical attack, and other factors. Strengthening and rehabilitating these concrete structures by externally bonding carbon laminates is one of many economical engineering solutions. Eight rectangular beams with varying internal steel reinforcement were retrofitted with CFRP strips on the tension faces and tested under four-point bending. The beams were instrumented to monitor strains, deflection, and curvature over the entire spectrum of loading, and determine the structural response of the beams. An existing analytical model using the discrete yield and ultimate values of the load-deflection and moment-curvature curves was modified to an energy-based model, and used to predict the ductility of the beams. Numerical results indicated an increase in strength, a decrease in ductility, and validated the analytical model. Ultimately, this study will aid in the development of design guidelines governing the use of CFRP.

NUCKOLS, M.L., Professor, VanZandt, K.W., and FINLAYSON, W.S., Lieutenant, (USN), "Evaluation Of A Diver Heater Using Hydrogen Catalytic Reactions," *Proceedings of the Undersea and Hyperbaric Medical Society Meeting*, 13-15 June 2001, (Abstract accepted).

A concept assessment was recently conducted to determine the feasibility of using a hydrogen catalytic heater in conjunction with closed-circuit hot water suits as a heat source for divers in swimmer delivery vehicle (SDV) applications. A laboratory prototype heater using a semi-closed circuit design was tested in the Hydrospace Laboratory at the Coastal Systems Station in Panama City, FL during July 2000 to prove concept feasibility. The objective of this unmanned test series was to assess the performance of a laboratory prototype catalytic heater which releases thermal energy when passing air mixed with up to 1% hydrogen, by volume, through a catalyst bed consisting of extruded carbon pellets coated with 0.8 wt% palladium. Major findings in this test series included the following:

a) Confirmed that 1% hydrogen mixed in 100 psi air is adequate to produce over 2000 watts of heat (sufficient heat for 6 divers); b) The prototype heater is capable of delivering up to 6 gpm water flow rate at 100-102 F; c) Near 100% heating efficiency was achieved with the existing prototype heater; d) Hydrogen consumption rates of only

25 standard cubic feet (SCF) per hour is sufficient to deliver the desired heating level of 2 KW; e) Heat levels can be easily predicted and controlled; f) Start up and operation of catalyst bed does not appear to be affected by cold temperatures; and g) No pre-conditioning of the catalyst was found necessary.

NUCKOLS, M. L., Professor, and Henkener, J. A., "Thermal Protection of Diver Extremities By Use of Insulating Fluids," *Proceedings of the Undersea and Hyperbaric Medical Society Meeting*, 13-15 June 2001.

An inert, pourable liquid insulating medium consisting of a mixture of halocarbon oils, glass micro-spheres, and suspension-enhancing additives has been developed which provides superior thermal protection for divers' gloves and underwater cabins (chambers, submersible hulls, waterproof housings, etc). Two glove prototypes were recently designed and fabricated incorporating this liquid insulation medium. These glove prototypes were compared with commercial wet and dry gloves in thermal performance, tactile sensitivity and manual dexterity. Preliminary tactile sensitivity and manual dexterity comparisons between the liquid glove prototypes and commercial divers' gloves were evaluated using a battery of specially designed test apparatuses and test procedures. Hand calorimeter testing at the Naval Clothing and Textile Research Facility in Natick, MA confirmed that glove insulation levels comparable to commercial three-fingered dry gloves are achievable with the addition of approximately 400 ml of liquid insulation. The insulating medium was found to be neutrally buoyant in water (specific gravity, SG, of 1.0), eliminating the necessity for ballasting and, unlike conventional closed-cell foam or fibrous batt insulations, is not thermally degraded by compression at elevated hydrostatic pressures. The insulating medium can be custom engineered to provide the desired level of thermal protection by varying the additives in the fluid. When this liquid insulation medium is mixed with approximately 45 vol% hollow, glass micro-spheres thermal conductivity, K, values comparable to those of uncompressed foam neoprene were achieved. A colloidal clay additive keeps the glass micro-spheres in liquid suspension in the halocarbon/glass mixtures.

NUCKOLS, M.L., Professor, VanZandt, K, and FINLAYSON, W.S., Lieutenant, (USN), "A Whole-Body Diver Heating System Using Hydrogen Catalytic Reactions," *Proceedings of Underwater Intervention 2001*, 15-17 January 2001, Tampa, FL (CD-ROM Paper E.2.2)

In fiscal year 2000 a concept assessment was conducted to determine the feasibility of using a hydrogen catalytic heater in conjunction with closed-circuit hot water suits to provide a heat source for divers in a Naval Special Warfare application. The objective of this unmanned test series was to assess the performance of a laboratory prototype which releases thermal energy when passing air mixed with up to 1% hydrogen, by volume, through a catalyst bed consisting of extruded carbon pellets coated with 0.8 wt% palladium. Specific variables investigated included (1) the percentage of hydrogen (between 0.25% and 1.0%) required to be mixed in the circuit gas to achieve heating goals, (2) the variation in reactions between different catalyst beds, and (3) the effects, if any, of the water circuit volume and flow rate on hydrogen reaction efficiency and heat production.

Major findings in this test series included the following:

- Confirmed that 1% hydrogen in 100 psi air is adequate to produce over 2000 watts of heat (sufficient heat for 6 divers)
- The prototype heater could deliver up to 6 gpm water flow rate to divers at 100-102 F
- Near 100% heating efficiency was achieved with the existing prototype heater.
- Heat levels can be easily predicted and controlled.
- Start up and operation of catalyst bed does not appear to be affected by cold temperatures.
- No pre-conditioning of the catalyst was necessary.
- Repeatable heater performance observed in repeated testing (no catalyst degradation observed).

NUCKOLS, M.L., Professor, VanZandt, K, and FINLAYSON, W.S., Lieutenant, (USN), "Diver Heater Using Hydrogen Catalytic Reactions," *Proceedings of the Oceans 2000, Marine Technology Society*, 11-14 September 2000, Providence, RI, pp. 1371-1374.

A simple hydrogen catalytic combustion heater for divers is described consisting of a canister filled with a chemical catalyst including precious metals such as platinum or palladium deposited on a support matrix of porous carbon particles. A small percentage of hydrogen is injected into an oxygen-rich (nitrox or heliox) gas mixture prior to passing it through the catalyst bed. As the gas mixture flows through the canister the catalyst facilitates the reaction of hydrogen with a small amount of oxygen to produce water vapor and approximately 104,000 Btu's (110,000 kJ) of heat. This approach was recently tested to produce a closed, or semi-closed heating cycle to provide a hot water heating circuit to be used with thermal protection garments for divers. Preliminary analysis has shown that over 2 kilowatts of heat can be produced, sufficient heat to sustain up to 6 divers in 32°F water, with only 25 standard cubic feet of hydrogen per hour. This paper describes the operation of this hydrogen catalytic water heater and these recent laboratory tests.

Roberts, J.C., Boyle, M.P. and WHITE, G.J., Professor, "Experimental Buckling, Collapse and Bending of FRP Sandwich Panels," *Proceedings of the 7th International Conference on Composites Engineering (ICCE/7)*, Vol. 7, 2000.

In previous studies by Roberts, et al solid, hat-stiffened and sandwich panels were tested under uniaxial in-plane compression and out-of-plane uniform pressure. This study was carried out and the experimental results compared to analytic and numerical results in Roberts, et al. However, the sandwich panels were not sized to result in global elastic buckling. Instead the balsa core sandwich panels failed prematurely in local buckling at a much reduced load from the predicted global panel buckling load.

Therefore, this investigation started with a parametric FEA of the sandwich plate to ascertain at what thickness plate global buckling would occur. The plate thickness varied from 9.5 to 19 mm (0.375 to 0.75 inches) and plate aspect ratio of 1.33 and 2.0 for plates 91 cm (36 inches wide). A plate 12.7 mm (0.5 inches) thick resulted in global buckling for both of the plate aspect ratios. Panels using this thickness were fabricated using the SCRIMP processing technique. They were tested under uniaxial compression and uniform out-of-plane pressures.

Schmidt, L., Mead, P., Natishan, M., Bigio, D., Greenberg, J., Lathan, C., Brown, S., MOURING, S.E., Associate Professor, and Goswami, I., "BESTEAMS: Student Team Experience Differs by Institution Type," *American Society for Engineering Educators Annual Conference Proceedings*, St. Louis, MO, June 2000.

Recently there has been an increasing emphasis on the use of teams in the engineering curriculum. This has the increased interaction and collaborative aspects of the learning process for engineering students and faculty. However, a corresponding emphasis on preparation for students and faculty has not occurred. The translation from individual learning in a customized environment to learning in a group environment can be challenging, even in a homogeneous team atmosphere. This process is even more complex against a backdrop of diversity, including communication style and learning style differences. This article presents results from a series of interviews and focus groups of engineering students regarding the use of teams in their courses and the benefits and challenges they believe are a direct outcome of team-oriented approaches in engineering. Specifically, differences in student team experiences by institution type are outlined.

SCHULTZ, M.P., Assistant Professor and FLACK, K.A., Associate Professor, "Experimental Investigation of Lift Modification on Double Delta Wings using Fillets," Paper # AIAA 2001-2048, *Proceedings of the AIAA 19th Applied Aerodynamics Conference*, 2001.

There is evidence that modifications to the geometry of the strake/wing junction on double-delta wings (fillets) can delay vortex breakdown and increase lift at moderate to high angle-of-attack (AOA). Flat-plate models are frequently employed to study the vortex dynamics. The objective of the present study was to investigate lift characteristics of three fillet geometries and compare the effect of fillets on a flat-plate model with that of a three-dimensional (3-D) model of a modern fighter/attack aircraft of the same planform. Both the 3-D and flat plate models, with and without fillets, were tested over a range of static AOA in a subsonic wind tunnel. The forces and

moments on the models were measured using a six-component, sting-type force balance. The results presented show that fillets increase lift at moderate to high AOA on the flat-plate model by 2.5% to 12.9%, however, the fillets had little effect on lift for the 3-D model. Since it was hypothesized that fuselage effects may have led to the disparity in the results, a centerbody was added to the flat-plate model and tested. These results also show an increase in lift with the fillets comparable to those seen without the centerbody.

SCHULTZ, M.P., Assistant Professor and VOLINO, R.J., Assistant Professor, "Effects of Concave Curvature on Boundary Layer Transition under High Free-Stream Turbulence Conditions," Paper # GT-2001-0191, *Proceedings of the ASME Turbo Expo 2001*.

An experimental investigation has been carried out on a transitional boundary layer subject to high (initially 9%) free-stream turbulence, strong acceleration ($K = (\nu / U_w^2)(dU_w / dx)$ as high as 9×10^{-6}), and strong concave curvature (boundary layer thickness between 2% and 5% of the wall radius of curvature). Mean and fluctuating velocity as well as turbulent shear stress are documented and compared to results from equivalent cases on a flat wall and a wall with milder concave curvature. The data show that curvature does have a significant effect, moving the transition location upstream, increasing turbulent transport, and causing skin friction to rise by as much as 40%. Conditional sampling results are presented which show that the curvature effect is present in both the turbulent and non-turbulent zones of the transitional flow.

VOLINO, R.J., Assistant Professor, SCHULTZ, M.P., Assistant Professor, and PRATT, C.M., Midshipman 1/C, (USN), "Conditional Sampling in a Transitional Boundary Layer under High Free-Stream Turbulence Conditions," Paper # GT-2001-0192, *Proceedings of the ASME Turbo Expo 2001*.

Conditional sampling has been performed on data from a transitional boundary layer subject to high (initially 9%) free-stream turbulence and strong ($K = (\nu / U_\infty^2)(dU_\infty / dx)$ as high as 9×10^{-6}) acceleration. Methods for separating the turbulent and non-turbulent zone data based on the instantaneous streamwise velocity and the turbulent shear stress were tested and found to agree. Mean velocity profiles were clearly different in the turbulent and non-turbulent zones, and skin friction coefficients were as much as 70% higher in the turbulent zone. The streamwise fluctuating velocity, in contrast, was only about 10% higher in the turbulent zone. Turbulent shear stress differed by an order of magnitude, and eddy viscosity was three to four times higher in the turbulent zone. Eddy transport in the non-turbulent zone was still significant, however, and the non-turbulent zone did not behave like a laminar boundary layer. Within each of the two zones there was considerable self-similarity from the beginning to the end of transition. This may prove useful for future modeling efforts.

Patents

NUCKOLS, M. L., Professor, Hughes, R. J., Grupe, C. E., and Fitzgibbon, S. W., "Passive Thermal Capacitor For Cold Water Diving Garments," United States Patent #6,120,530, September 2000.

A thermal liner for divers' wetsuits, drysuits and hot water suits is described which provides thermal protection, utilizing stored energy from phase change materials, for extreme cold water diving. The thermal liner can be used as an emergency backup heat source in the event of power failure when divers are using electrically-heated drysuits, or as an emergency backup heat source in the event of an interruption of warm water supply for divers wearing hot water diving suits. It can also be used as a supplemental source of heat for divers wearing passively-insulated wetsuits or drysuits to prolong acceptable durations in cold water missions.

Technical Reports, Book Reviews and Book Chapters

ARVIDSON, M. H., Midshipman 1/C, (USN), DEMEYER, A. P., Ensign, (USN); TAYLOR, C. E., Midshipman 1/C, (USN) and MILLER, P. H., Assistant Professor, "Navy 44 Sail Training Vessel Design Improvement Projects," U.S. Naval Academy Report EW-10-00, August 2000.

Three midshipmen, through independent research credit courses and summer internship projects studied potential improvements to the Navy 44-foot sail training vessel. All three projects were initiated based on feedback from various user-groups. The first project studied stability and performance issues. Full-scale inclining and resistance tests were performed on a Navy 44 at the Academy. This data was used in a Velocity Prediction Program to predict potential design improvements. Results indicated a lower center of gravity (CG) keel, combined with a longer waterline and reduced displacement, would produce a safer design with improved performance. A new, low CG keel was designed. The second project studied stiffness, flexural strength and impact resistance of proposed hull laminates. Testing included 4-point flex coupons and two-foot-square impact panels. Results indicated a lighter, stronger, and less expensive laminate than the current laminate is possible. The third project developed a preliminary deck plan that addresses safety and crew-efficiency issues of the current design. The new plan improves safety while providing a more comfortable working environment.

KRIEBEL, David L., Professor, ALSINA, Maria V., Midshipman 1/C, (USN), GODFREY, Mary L., Midshipman 1/C, (USN), WATERS, Jennifer K., Assistant Professor and MAYER, Robert H., Associate Professor, "Deep-Draft Navigation Channel Design: A Comparison of U.S. and International Practice," Institute for Water Resources, U.S. Army Corps of Engineers, Alexandria, VA, August 2000.

This report compares U.S. and international design practices for sizing deep-draft navigation channels. The U.S. practice is based on U.S. Army Corps of Engineers (USACE) guidance while the international practice is based on guidance published by the Permanent International Association of Navigation Congresses (PIANC) and by the International Association of Ports and Harbors (IAPH).

In some instances, U.S. and international design practices are essentially identical. For example, both U.S. and international design of deep draft navigation channels makes use of the "design ship" concept in which the channel dimensions are expressed as multiples of the design ship length, beam, and draft. Both the USACE and PIANC also determine the design channel depth in a similar way, by adding a series of depth allowances to the static draft of the design ship to account for squat, fresh water sinkage, wave action, underkeel or "safety" clearance, maintenance dredging, and dredging tolerance. Notable differences in the design procedures for setting channel depth are found only in the detailed procedures by which ship squat and ship motions in waves are computed.

In other instances, however, there are significant differences in the design methods used by the USACE and PIANC. Most notable are the methods by which each organization determines the design channel width. Recent USACE guidance, based on ship simulator studies, specifies a single overall channel width. PIANC guidance, in contrast, relies on a "summation" approach in which separate analyses are performed for the basic maneuvering lane, bank clearance lanes, and any passing lane. In addition, PIANC guidance accounts for "Additional Width Factors," which add extra width allowances based on prevailing cross wind, cross current, significant wave height, aids to navigation, bottom type, depth, and cargo hazards, factors not accounted for by the USACE. The methods used to design channel bends and turns also differ, with the U.S. practice generally making use of the "apex" or "cutoff" methods in which two straight sections of a channel are joined by an angled turn with the angle sectioned widened, while PIANC guidance recommends using a constant radius circular arc to connect two straight channel sections.

MAYER, Robert H., Associate Professor, WATERS, Jennifer K., Assistant Professor, and KRIEBEL, David L., Professor, "Design & Maintenance of Deep-Draft Navigation Channels – An Overview of Current Practice with an Annotated Bibliography," Institute for Water Resources, U.S. Army Corps of Engineers, Alexandria, VA, July 2000.

Among the vital missions of the U.S. Army Corps of Engineers (Corps) is the development and maintenance of inland and coastal waterways in support of commercial navigation. Currently, the Corps is responsible for main-

taining and improving more than 200 deep-draft ports and harbors. In fulfillment of this responsibility, the Corps' Institute for Water Resources (IWR) has initiated a study entitled "Impacts of Navigation Trends on Channel Usage and Design." Its principal goal is to improve the design and maintenance of navigation channels in order to sustain effective channel navigation and port operations well into the next century.

As part of this study, a literature review was conducted and an annotated bibliography developed. The principal focus of the bibliography was current practices used domestically and internationally to design and maintain deep-draft navigation channels. However, related issues of navigational safety in coastal waterways and shipping trends were also included within the scope of the literature search. The bibliography, containing over 200 literature references and nearly 30 relevant web-site addresses, was prepared in an electronic database for future reference. Bibliographic information contained in the database is reproduced in the Appendix.

NUCKOLS, M. L., Professor and Gavin, W. A., "Passively Controlled Semi-Closed/Closed Rebreather." Ocean Engineering and Marine Systems 2000 Program, Office of Naval Research, ONR 32100-1, December 2000, pp 248-252.

The long-term goal of this research is to develop a versatile, passively-controlled semi-closed rebreather for deep diving applications that can be switched to closed-circuit mode during shallow water missions (depths less than 25 feet). Such a design is desired to safely satisfy the full range of Naval Special Warfare missions without the complexity and cost of electronically-controlled closed circuit rebreathers. The objectives of this effort were to optimize the design of respiratory-coupled circuit designs (using variable volume exhaust injection systems) using analytical predictive models, and verify from unmanned testing that safe alternatives to traditional semi-closed circuit designs are feasible. In so doing, we demonstrated that respiratory-coupled rebreather designs will provide divers with stable, and predictable circuit oxygen levels across their full range of activity levels.

NUCKOLS, M. L., Professor, "Diver Heating Using Hydrogen Catalytic Reactions: Concept Assessment," Ocean Engineering and Marine Systems 2000 Program, Office of Naval Research, ONR 32100-1, December 2000, pp. 253-258.

The long-term goal of this research is to develop a safe and efficient diver heater to minimize package size and power requirements and yet meet the entire diver heating requirements for long duration Naval Special Warfare (NSW) missions. The technical objectives of this effort were to a) conduct a tradeoff analysis of different active heating methods for swimmer delivery vehicle (SDV) applications to quantify and compare the energy densities of each approach, b) construct a prototype heating circuit containing a heat exchanger incorporating a palladium on carbon catalyst bed, and c) conduct laboratory testing of prototype hydrogen catalytic heater and water heat exchanger to verify the energy density available from this heating method.

NUCKOLS, M. L., Professor, Gavin, W.A., and FINLAYSON, W.S., Lieutenant, (USN), "Unmanned Testing of a Modified US Divers OxyMix Semi-Closed UBA with Variable Exhaust Volume Ratios," U.S. Naval Academy Technical Report EW-13-00, December 2000.

An analytical model has recently been developed for predicting the circuit oxygen levels in semi-closed underwater breathing apparatus at various mission depths and diver activity levels (Nuckols, Clarke, Marr, 1999). Unmanned testing in June 2000 with a commercially available US Divers Aqualung OxyMix rebreather (NEDU Test Plan Number 00-06 dated May 2000) showed good agreement with this analytical model over a wide range of diver depths, orientations and activity levels (Nuckols, Gavin, Finlayson, 2000). However, the model indicated that an enhanced performance capability could possibly be achieved with the OxyMix by modifying the size of its exhaust bellows and changing the oxygen content of the supply gas. Following the tests in June, an optimization approach was applied to the analytical model to define desired design parameters for the OxyMix rebreather to maximize its excursion depth capability. Optimized exhaust volume ratios (EVR), the ratio of the small inner bellows volume relative to the main breathing bellows, and supply gas oxygen concentrations were identified to maximize safe operations for the OxyMix design. US Divers agreed to fabricate two modified exhaust bellows of varying volumes for testing to verify the predicted performances of the modified OxyMix rebreather. During the week of 18 December 2000, unmanned testing with these modified OxyMix rebreathers at the Experimental Dive Facility at NEDU verified predicted performances. Specific findings in these tests included:

a) a modified OxyMix rebreather using an exhaust volume ratio of approximately 6.25% and a supply gas mixture containing 37% oxygen was shown to give an excursion capability to 130 FSW while maintaining circuit PO_2 levels below 1.32 Ata (excursions to 150 FSW were shown to be possible with maximum PO_2 levels below 1.6 Ata)

b) similar to the results seen in the June tests, circuit PO_2 levels were shown to be unaffected by diver activity rates between RMV's of 22.5 LPM and 62.5 LPM.

The addition of a diluent injection system on the modified OxyMix design provided minimum circuit oxygen levels of 0.42 Ata at 20 FSW and 0.25 Ata at 0 FSW while still maintaining circuit PO_2 levels below 1.32 Ata for excursions up to 130 FSW.

NUCKOLS, M. L., Professor,Gavin, W.A., FINLAYSON, W.S. Lieutenant, (USN), "Passively-Controlled Semi-Closed/ Closed Rebreather," U.S. Naval Academy Technical Report EW-07-00, August 2000.

The objective of this effort was to optimize the design of a respiratory-coupled circuit using current predictive models, and verify that safe alternatives to traditional circuit designs are feasible. In so doing, this respiratory-coupled design will provide divers with stable, and predictable circuit oxygen levels across their full range of activity levels. One anticipated application of this technology would be Naval Special Warfare personnel deployed from the Advanced SEAL Delivery System (ASDS). The desired lockout depth from the ASDS is deeper than can be supported with closed-circuit, pure oxygen rebreathers such as the Draeger LAR V. Although the MK 16 mixed-gas closed-circuit rebreather could support the depths required for ASDS diving operations, its size and complexity would make its use unpopular. It is anticipated that a passively-controlled semi-closed rebreather, which can be switched to closed-circuit mode, could satisfy the full range of the ASDS mission without the complexity and cost of the MK 16. The simple respiration-coupled gas supply feature of this design could give the diver a predictable oxygen level in his circuit that would minimize the determination of oxygen dosage levels and any decompression obligations. These capabilities directly support the desired emphasis on equipment versatility addressed in the 1999 Naval Special Warfare Command Capability Issues (CCI) for Worldwide Mobility dated May 1999. Another potential user of this technology could be the MCM VSW mission. A switchable closed/ semi-closed UBA design would allow the Explosive Ordnance Disposal (EOD) personnel to conserve gas in closed-circuit mode while in shallow water depths, and switch to semi-closed mode only when the diver is required to make deeper excursions beyond 20-25 feet. This could greatly reduce the requirement in gas storage capacity carried by the diver, resulting in a more compact rig, without sacrificing mission capability.

NUCKOLS, M. L., Professor, VanZandt, K.W., and FINLAYSON, W.S., Lieutenant, (USN), "Design and Evaluation of a Diver Heater Using Hydrogen Catalytic Reactions," U.S. Naval Academy Technical Report EW-08-00, August 2000.

In FY00 a concept assessment was conducted to determine the feasibility of using a hydrogen catalytic heater in conjunction with closed-circuit hot water suits to provide a heat source for divers in an SDV application. A laboratory prototype heater using hydrogen catalytic reactions was tested in the Hydrospace Laboratory at the Coastal Systems Station in Panama City, FL during July 2000. The objective of this unmanned test series was to assess the performance of a laboratory prototype which releases thermal energy when passing air mixed with up to 1% hydrogen, by volume, through a catalyst bed consisting of extruded carbon pellets coated with 0.8 wt% palladium. In all tests, hydrogen levels in the heating circuit were maintained below its flammable limits of 4.0%. Specific variables investigated included (1) the percentage of hydrogen (between 0.25% and 1.0%) required to be mixed in the circuit gas to achieve heating goals, (2) the variation in reactions between different canisters filled with the same catalyst, and (3) the effects, if any, of the water circuit volume and flow rate on hydrogen reaction efficiency and heat production. Previous analysis had shown that up to 2 KW of heat could be produced, sufficient heat to sustain up to 6 divers in 32°F water, with only 25 standard cubic feet of hydrogen per hour. These heating levels could be achieved by flowing 1% hydrogen in air mixtures through the catalyst bed at a pressure of 100 psia. This analysis further indicated that we could provide the thermal protection requirements for these six divers for up to 6 hours in an SDV using only two 80 SCF bottles of hydrogen. Higher heating levels could be achieved at these low hydrogen percentages by either increasing the operating pressure of the catalyst bed or increasing the

air/hydrogen flow rates passing through the catalyst bed.

Major findings in this test series included the following:

- •Confirmed that 1% hydrogen in 100 psi air is adequate to produce over 2000 watts of heat (sufficient heat for 6 divers)
- •The prototype heater could deliver up to 6 gpm water flow rate at 100-102 F
- •Near 100% heating efficiency was achieved with the existing prototype heater.
- •Hydrogen consumption: 25 SCF per hour is sufficient to deliver heating level of 2 KW. (Over 3 hours duration from a single 80 SCF cylinder)
- •Driving gas consumption: Approx 1.5 SCFM of air was required to maintain circuit flow rate at 6 acfm in a semi-closed circuit (can possibly use this air for heating and humidifying the onboard air supply)
- •Heat levels can be easily predicted and controlled.
- •Start up and operation of catalyst bed does not appear to be affected by cold temperatures.
- •No pre-conditioning of the catalyst was necessary.
- •Repeatable heater performance observed in repeated testing (no catalyst degradation observed).

VOLINO, R.J., Assistant Professor, SCHULTZ, M.P., Assistant Professor, and PRATT, C.M., Midshipman 1/C, (USN), "Conditional Sampling in a Transitional Boundary Layer under High Free-Stream Turbulence Conditions," *Bulletin of the American Physical Society, 53rd Annual Meeting of the Division of Fluid Dynamics*, Vol. 45, No. 9, pp. 133-134 (2001).

Conditional sampling has been performed on data from a transitional boundary layer subject to high (initially 9%) free-stream turbulence and strong ($K = (\nu / U_\infty^2)(dU_\infty / dx)$ as high as 9×10^{-6}) acceleration. Methods for separating the turbulent and non-turbulent zone data based on the instantaneous streamwise velocity and the turbulent shear stress were tested and found to agree. Mean velocity profiles were clearly different in the turbulent and non-turbulent zones, and skin friction coefficients were as much as 70% higher in the turbulent zone. The streamwise fluctuating velocity, in contrast, was only about 10% higher in the turbulent zone. Turbulent shear stress differed by an order of magnitude, and eddy viscosity was three to four times higher in the turbulent zone. Eddy transport in the non-turbulent zone was still significant, however, and the non-turbulent zone did not behave like a laminar boundary layer. Within each of the two zones there was considerable self-similarity from the beginning to the end of transition. This may prove useful for future modeling efforts.

WATERS, J.K., Assistant Professor, MAYER, R.H., Associate Professor and KRIEBEL, D.L., Professor, "Shipping Trends Analysis," a document prepared in fulfillment of Milestone Number 11 of the U.S. Army Corps of Engineers R&D Work Unit entitled: Impacts of Navigation Trends on Channel Usage and Design, September 2000.

The aim of this "Shipping Trends Analysis" is to identify current and future navigation trends and analyze them for potential impacts on channel design and safety. This report draws significantly on data from another U.S. Army Corps of Engineers study entitled, "National Dredging Needs Study (NDNS)." That study documented the growth in world trade, increasing containerization, changes in the world fleet, vessel design trends, and operational and organizational changes of the maritime industry. An assessment of future trends resulting form these changes was included.

This report augments the NDNS study and elucidates several issues related to vessel characteristics and ship designs not fully addressed therein. Specifically, vessel characteristics and trends over the past thirty years are analyzed, future vessel design issues are identified, and corresponding navigation channel design, maintenance and safety impacts are discussed. For example, while vessel draft has increased marginally over time, the average beam-to-draft ratio has significantly increased for all merchant vessel types investigated. This trend directly impacts channel width and layout. Also, the effect of an increased vessel blockage factor within a channel cross-section contributes to higher vessel squat experienced, and may result in (or require) decreased vessel speed within channels. Other vessel related issues, such as the impacts of two-way traffic and tug assistance within navigational channels, are also addressed in this report.

WATERS, J.K., Assistant Professor, MAYER, R.H., Associate Professor, and KRIEBEL, D.L., Professor, "Shipping Trends Analysis," Institute for Water Resources, U.S. Army Corps of Engineers, Alexandria, VA, September 2000.

This report summarizes vessel characteristics and trends over the past thirty years and discusses future vessel design issues and corresponding navigation channel design, maintenance and safety impacts. For example, it is shown that the average beam-to-draft ratio has significantly increased over the past thirty years for all merchant vessel types investigated. This vessel parameter trend most directly impacts channel width and layout. Channel width and channel layout features such as bends must enlarge (for same depth) in order to accommodate ships with these changing proportion trends. Channel depth, for this type of vessel change, is impacted to a much lesser degree; an increase in beam-to-draft ratio does not impact typical design conventions for channel depth nearly as significantly. The effect of an increased vessel blockage factor within a channel cross-section also contributes to higher vessel squat experienced, and may likely result in decreased vessel speeds within channels. Other vessel-related issues, such as the impact of tug assistance within navigation channels and two-way traffic, are also addressed in this report.

WATERS, J.K., Assistant Professor, MAYER, R.H., Associate Professor, KRIEBEL, D.L., Professor and Smith, S., "Deep-Draft Navigation Channel Design: Summary & Analysis of Design & Maintenance Survey Results," Institute for Water Resources, U.S. Army Corps of Engineers, Alexandria, VA, September 2000.

This report presents and summarizes the findings of several face-to-face and mail surveys of U.S. Army Corps of Engineers (USACE) personnel performed during 1998-1999 regarding deep-draft channel design and maintenance practices, polices and guidance. This effort was undertaken as part of the USACE Institute for Water Resources' R&D work unit entitled, "Impacts of Navigation Trends on Channel Usage and Design."

Representatives from districts, divisions, the USACE Waterways Experiment Station (WES) and USACE headquarters with expertise in one or more aspects of the channel design process provided responses to the surveys.

Many significant findings about channel design and maintenance practices have been extracted from the surveys and appear in the results and conclusions sections of this report. Perhaps the most notable lie within the issues of technical review and the divisional impact on district projects. Each channel design project must undergo independent technical review; however, how and by whom this technical review is performed varies between districts. The divisions' impacts on channel design and, in particular, O&M plans appears unclear. In response to the question "What impact do you have on the final O&M plan?" six of eight division respondents did not (or could not) provide a direct answer. As further discussion in the text reveals, district personnel seem to want more technical guidance, references and/or technical consistency within the Corps structure.

Presentations

KRIEBEL, David L., Professor, "Simulation of Extreme Waves in a Background Random Sea," 9th International Conference On Offshore and Polar Engineering, Seattle, WA, 20 June 2000.

KRIEBEL, David L., Professor, "Breaking Waves in Intermediate Depths with and without Currents," 27th International Conference on Coastal Engineering, Sydney, Australia, 18 July 2000.

KRIEBEL, David L., Professor, "Floodborne Debris Impact Loads on Buildings," American Society of Civil Engineers Annual Meeting, Committee on Building Design Loads, Seattle, WA, 21 Oct 2000.

KRIEBEL, David L., Professor, "Efficient laboratory Generation of Extreme Waves in a Random Sea," Rogue Waves 2000 Conference, Brest, France, 7 November 2000.

KRIEBEL, David L., Professor, "An Overview of Coastal Engineering," Pennsylvania State University, Department of Civil Engineering, 12 March 2001. (Invited Lecturer)

KRIEBEL, David L., Professor, "U.S. Navigation Channel Design and Practice," Association of Coastal Engineers, Annual Meeting, Washington, DC, 16 May 2001

KRIEBEL, David L., Professor, "Air Gap Model Tests on a MOB Module," 10th International Conference On Offshore and Polar Engineering, Stavanger, Norway, June 2001.

MAYER, Robert H., Associate Professor, "A Compendium on Environmental Engineering for Ocean Engineering Majors," ASEE 2000 Annual Conference, St. Louis, MO, 19 June 2000.

MAYER, Robert H., Associate Professor, "Design Vessel and Vessel Mix," USNA / USACE Workshop: Deep-Draft Channel Design (DCD) for Planners and Economists, U.S. Naval Academy, Annapolis, MD, 6 June 2001.

MAYER, Robert H., Associate Professor, "Dredge Technology," USNA / USACE Workshop: Deep-Draft Channel Design (DCD) for Planners and Economists, U.S. Naval Academy, Annapolis, MD, 6 June 2001.

MAYER, Robert H., Associate Professor, "Dredge Resource Management," USNA / USACE Workshop: Deep-Draft Channel Design (DCD) for Planners and Economists, U.S. Naval Academy, Annapolis, MD, 6 June 2001.

MAYER, Robert H., Associate Professor, "Channel Optimization and Design Risk," USNA / USACE Workshop: Deep-Draft Channel Design (DCD) for Planners and Economists, U.S. Naval Academy, Annapolis, MD, 6 June 2001.

MILLER, Paul H., Assistant Professor, "Finite Element Analysis for Small Craft Structures," IBEX, Ft. Lauderdale, Florida, 7-9 February 2001.

MILLER, Paul H., Assistant Professor, "Offshore Attributes," Safety-at-Sea Seminar, U.S. Naval Academy, 1 April 2001.

MILLER, Paul H., Assistant Professor, "Fatigue Prediction Verification of Fiberglass Hulls," Society of Naval Architects and Marine Engineers Section Meeting, University of California, Berkeley, 12 April 2001.

MILLER, Paul H., Assistant Professor, "Marine Composites Theory and Application," Webb Institute of Naval Architecture, 2 May 2001.

MOURING, Sarah E., Associate Professor, "A Novel Method for Adhesively Bonding Composite Joints," The Adhesive and Sealant Council Conference, Minneapolis, MN, October 2000.

MOURING, Sarah E., Associate Professor, "Investigation into a New Technique for Fabricating Composite Joints," Seventh International Conference on Computer Methods in Composite Materials and Structures (CADCOMP 2000), Bologna, Italy, September 2000.

MOURING, Sarah E., Associate Professor, BARTON, Oscar, Jr., Associate Professor, and SIMMONS, D. Kevin, (Trident Scholar, Class of 1999), "Ductility of Reinforced Concrete Beams Externally Retrofitted with Carbon Fiber Reinforced Polymer Composites," *Ninth U.S.-Japan Conference on Composite Materials Conference Proceedings,* Mishima, Shizuoka, Japan, July 2000.

NEHRLING, Bruce C., Professor, "Ship Design Research and Education," Invited presentation at a workshop organized by Office of Naval Research on Naval Engineering Research and Education, National Academy of Sciences, Washington, D.C., 21 May 2001.

NUCKOLS, Marshall L., Professor, "Maximizing Thermal Performance of Divers' Gloves By Use of Insulating Liquids," Oceans 2000, Marine Technology Society Meeting, 11-14 September 2000, Providence, RI.

NUCKOLS, Marshall L., Professor, VanZandt, K., and FINLAYSON, W.S., Lieutenant, (USN), "Diver Heater Using Hydrogen Catalytic Reactions," Oceans 2000, Marine Technology Society Meeting, 11-14 September 2000, Providence, RI.

NUCKOLS, Marshall L., Professor, "Design of Semi-Closed Underwater Breathing Apparati to Maximize Mission Capability," NAUI Technical Diving Conference 2000, Key West, FL, 5-9 October 2000.

NUCKOLS, Marshall L., Professor, "Engineering Aspects of Life Support Equipment," Duke University Medical Center, Durham, NC, 17 Nov 2000. (Invited Lecturer)

NUCKOLS, Marshall L., Professor, VanZandt, K, and FINLAYSON, W.S., Lieutenant, (USN), "A Whole Body Diver Heating System Using Hydrogen Catalytic Reactions," Underwater Intervention 2001, Tampa, FL, 15-17 January 2001.

NUCKOLS, Marshall L., Professor, "Theoretical Considerations in Diver Thermal Protection," Workshop on Current and Future Concepts in Diver Thermal Protection, State University of Buffalo, Buffalo, NY, 6-7 Feb 2001.

NUCKOLS, Marshall L., Professor, "Preparing for Our Future Ocean Presence," Ginger Cove Men's Group, U.S. Naval Academy Speakers Bureau, 10 April 2001. (Invited Lecturer)

NUCKOLS, Marshall L., Professor, VanZandt, K.W., and FINLAYSON, W.S., Lieutenant, (USN), "Evaluation of a Diver Heater Using Hydrogen Catalytic Reactions," Undersea and Hyperbaric Medical Society Annual Scientific Meeting, San Antonio, TX, 13-15 June 2001.

NUCKOLS, Marshall L., Professor, and Henkener, J. A., "Thermal Protection of Diver Extremities By Use of Insulating Fluids," Undersea and Hyperbaric Medical Society Annual Scientific Meeting, San Antonio, TX, 13-15 June 2001

Roberts, J.C., Boyle, M.P. and WHITE, Gregory J., Professor, "Experimental Buckling, Collapse and Bending of FRP Sandwich Panels," 7th International Conference on Composites Engineering (ICCE/7), Denver, CO, July 2, 2000.

Schmidt, L., Mead, P., Natishan, M., Bigio, D., Greenberg, J., Lathan, C., Brown, S., MOURING, Sarah E., Associate Professor, and Goswami, I., "BESTEAMS: Student Team Experience Differs by Institution Type," American Society for Engineering Educators Annual Conference, Saint Louis, MO, June 2000.

Schmidt, L., Natishan, M., Schmidt, J., Bigio, D., MOURING, Sarah E., Associate Professor, and Goswami, I., BESTEAMS Faculty Workshop II, University of Maryland, College Park, MD, 29 September 2000.

SCHULTZ, Michael P., Assistant Professor and VOLINO, Ralph J., Assistant Professor, "Effects of Concave Curvature on Boundary Layer Transition under High Free-Stream Turbulence Conditions," Paper # GT-2001-0191, ASME Turbo Expo 2001, June, New Orleans, LA.

SCHULTZ, Michael P., Assistant Professor and FLACK, Karen A., Associate Professor, "Experimental Investigation of Lift Modification on Double Delta Wings using Fillets," Paper # AIAA 2001-2048, AIAA 19th Applied Aerodynamics Conference 2001, June, Anaheim, CA.

SCHULTZ, Michael P., Assistant Professor, "Fully Developed Turbulent Duct Flow Apparatus for the Determination of the Adhesion Strength of Larval Biofouling," Kewalo Marine Laboratory, University of Hawaii, October 2000, Honolulu, HI.

SCHULTZ, Michael P., Assistant Professor and VOLINO, Ralph J. Assistant Professor, "Effects of Concave Curvature on Boundary Layer Transition under High Free-Stream Turbulence Conditions," American Physical Society, 53rd Annual Meeting of the Division of Fluid Dynamics (2000), November, Washington, DC.

VOLINO, Ralph J., Assistant Professor, SCHULTZ, Michael P., Assistant Professor, PRATT, C.M., Midshipman 1/C, (USN), "Conditional Sampling in a Transitional Boundary Layer under High Free-Stream Turbulence Conditions," American Physical Society, 53rd Annual Meeting of the Division of Fluid Dynamics (2001), November, Washington, DC.

VOLINO, Ralph J., Assistant Professor, SCHULTZ, Michael P., Assistant Professor, and PRATT, C.M., Midshipman 1/C, (USN), "Conditional Sampling in a Transitional Boundary Layer under High Free-Stream Turbulence Conditions," Paper # GT-2001-0192, ASME Turbo Expo 2001, June 2001, New Orleans, LA.

WATERS, Jennifer K., Assistant Professor and MAYER, Robert H., Associate Professor, "Background: a.k.a. Why are We (and You) Here," USNA / USACE Workshop: Deep-Draft Channel Design (DCD) for Planners and Economists, U.S. Naval Academy, Annapolis, MD, 5 June 2001.

WATERS, Jennifer K., Assistant Professor, "Channel Design Criteria," International Workshop on Channel Design and Vessel Maneuverability, Norfolk, Virginia, May 3-4, 2001. (Workshop co-organizer and paper presenter).

WATERS, Jennifer K., Assistant Professor, KRIEBEL, David L., Professor and MAYER, Robert H., Associate Professor, "Deep-Draft Navigation Channel Design for Planners and Economists," Workshop, U.S. Naval Academy, Annapolis, Maryland, June 5-8, 2001. (JKW: Workshop organizer and presenter).