2000

Summary of Research 2000, Department of Mechanical Engineering

Faculty of the Naval Postgraduate School, Department of Mechanical Engineering

Office of the Associate Provost and Dean of Research, Naval Postgraduate School.

Naval Postgraduate School
Monterey, California 93943-5138

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SUMMARY OF RESEARCH 2000

Department of Mechanical Engineering

Terry R. McNelley
Chair

Young Kwon
Associate Chair for Research

NAVAL POSTGRADUATE SCHOOL
Monterey, California

Rear Admiral David R. Ellison, USN
Superintendent

Richard Elster
Provost

This report was prepared for the Naval Postgraduate School, Monterey, CA.

Reviewed by:

[redacted]

Danielle Kuska
Director, Research Administration

Released by:

[redacted]

David W. Netzer
Associate Provost and
Dean of Research

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This report contains project summaries of the research projects in the Department of Mechanical Engineering. A list of recent publications is also included, which consists of conference presentations and publications, books, contributions to books, published journal papers, and technical reports. Thesis abstracts of students advised by faculty in the Department are also included.

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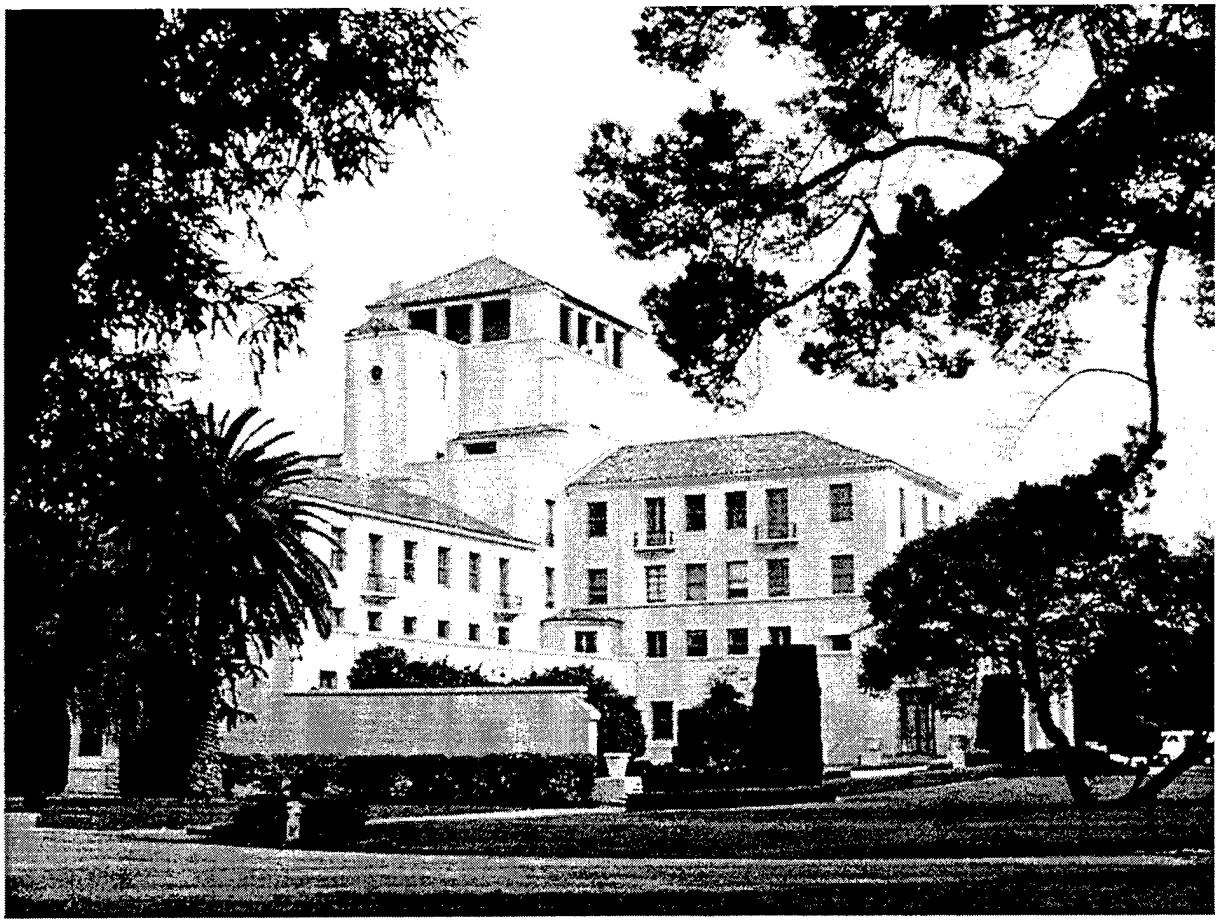

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PREFACE

Research at the Naval Postgraduate School is carried out by faculty in the four graduate schools (School of International Graduate Studies, Graduate School of Operations and Information Sciences, Graduate School of Engineering and Applied Sciences, and Graduate School of Business and Public Policy) and three Research Institutes (The Modeling, Virtual Environments, and Simulation (MOVES) Institute, Institute for Information Superiority and Innovation (I2SI), and Institute for Defense System Engineering and Analysis (IDSEA). This volume contains research summaries for the projects undertaken by faculty in the Department of Mechanical Engineering during 2000. The summary also contains thesis abstracts for those students advised by Mechanical Engineering faculty during 2000.

Questions about particular projects may be directed to the faculty Principal Investigator listed, the Department Chair, or the Department Associate Chair for Research. Questions may also be directed to the Office of the Associate Provost and Dean of Research. General questions about the Naval Postgraduate School Research Program should be directed to the Office of the Associate Provost and Dean of Research at (831) 656-2099 (voice) or research@nps.navy.mil (e-mail). Additional information is also available at the RESEARCH AT NPS website, http://web.nps.navy.mil/~code09/

Additional published information on the Naval Postgraduate School Research Program can be found in:

- *Compilation of Theses Abstracts:* A quarterly publication containing the abstracts of all unclassified theses by Naval Postgraduate School students.
- *Naval Postgraduate School Research*: A tri-annual (February, June, October) newsletter highlighting Naval Postgraduate School faculty and student research.
- *Summary of Research*: An annual publication containing research summaries for projects undertaken by the faculty of the Naval Postgraduate School.

This publication and those mentioned above can be found on-line at:
http://web.nps.navy.mil/~code09/publications.html.

INTRODUCTION

The research program at the Naval Postgraduate School exists to support the graduate education of our students. It does so by providing military relevant thesis topics that address issues from the current needs of the Fleet and Joint Forces to the science and technology that is required to sustain the long-term superiority of the Navy/DoD. It keeps our faculty current on Navy/DoD issues, to maintain the content of the upper division courses at the cutting edge of their disciplines. At the same time, the students and faculty together provide a very unique capability within the DoD for addressing warfighting problems. Our officers must be able to think innovatively and have the knowledge and skills that will let them apply technologies that are being rapidly developed in both the commercial and military sectors. Their unique knowledge of the operational Navy, when combined with a challenging thesis project that requires them to apply their focused graduate education, is one of the most effective methods for both solving Fleet problems and instilling the life-long capability for applying basic principles to the creative solution of complex problems.

The research program at the Naval Postgraduate School consists of both reimbursable (sponsored) and institutionally funded research. The research varies from very fundamental to very applied, from unclassified to all levels of classification.

- Reimbursable (Sponsored) Program: This program includes those projects externally funded on the basis of proposals submitted to outside sponsors by the School's faculty. These funds allow the faculty to interact closely with RDT&E program managers and high-level policymakers throughout the Navy, DoD, and other government agencies as well as with the private sector in defense-related technologies. The sponsored program utilizes Cooperative Research and Development Agreements (CRADAs) with private industry, participates in consortia with government laboratories and universities, provides off-campus courses either on-site at the recipient command, by VTC, or web-based, and provides short courses for technology updates.

- Naval Postgraduate School Institutionally Funded Research (NIFR) Program: The institutionally funded research program has several purposes: (1) to provide the initial support required for new faculty to establish a Navy/DoD relevant research area, (2) to provide support for major new initiatives that address near-term Fleet and OPNAV needs, (3) to enhance productive research that is reimbursably sponsored, and (4) to cost-share the support of a strong post-doctoral program.

In 2000, the level of research effort overall at the Naval Postgraduate School was 137 faculty work years and exceeded $43 million. The reimbursable program has grown steadily to provide the faculty and staff support that is required to sustain a strong and viable graduate school in times of reduced budgets. In FY2000, over 93% of the research program was externally supported. A profile of the sponsorship of the Naval Postgraduate School Research Program in FY2000 is provided in Figure 1.

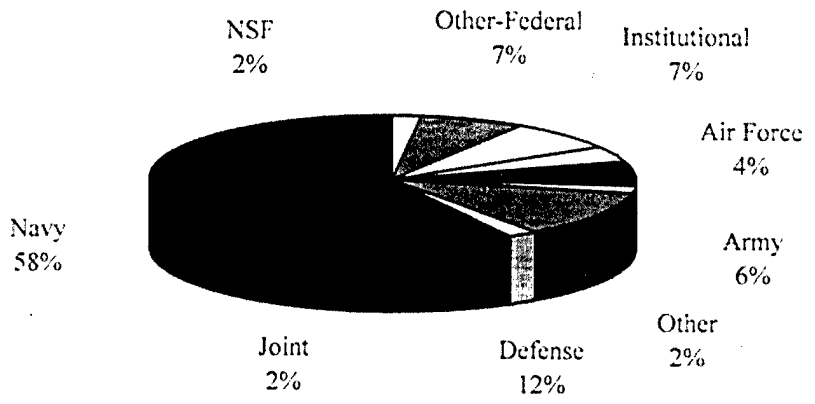


Figure 1. Profile of NPS Research and Sponsored Programs ($43M)

The Office of Naval Research is the largest Navy external sponsor. The Naval Postgraduate School also supports the Systems Commands, Warfare Centers, Navy Labs and other Navy agencies. A profile of external Navy sponsorship for FY2000 is provided in Figure 2.

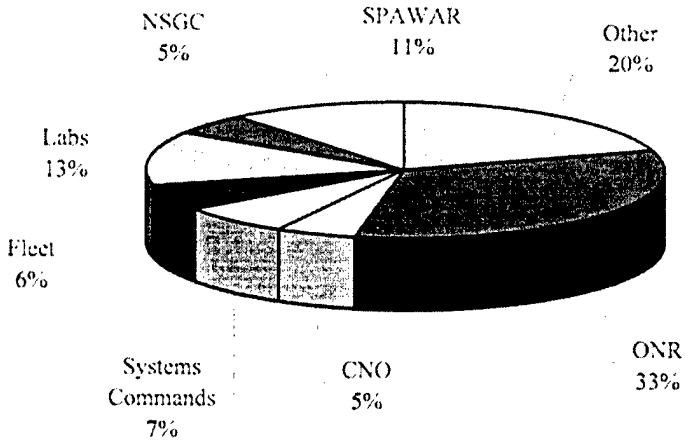


Figure 2. Navy External Sponsors of NPS Research and Sponsored Programs ($25M)

These are both challenging and exciting times at the Naval Postgraduate School and the research program exists to help ensure that we remain unique in our ability to provide education for the warfighter.

DAVID W. NETZER
Associate Provost and Dean of Research

December 2001

DEPARTMENT OF MECHANICAL ENGINEERING

TERRY MCNELLEY
CHAIR

DEPARTMENT SUMMARY

OVERVIEW:

The mission of the Department of Mechanical Engineering is to increase the combat effectiveness of U.S. and Allied armed forces and to enhance the security of the United States through advanced education that focuses on the ability to identify, formulate and solve technical and engineering problems in areas related to mechanical engineering and that spans issues of research, design, development, procurement, operation, maintenance and disposal of components and systems for Naval platforms.

RESEARCH MISSION:

The research mission of the Department of Mechanical Engineering is to increase the combat effectiveness of U.S. and Allied armed forces and to enhance the security of the United States through research in areas related to mechanical engineering and that spans the field from basic phenomena to engineering design, development, operation, maintenance and disposal of components and systems for Naval platforms.

CURRICULA SERVED:

The Mechanical Engineering Department serves the Naval and Mechanical Engineering Curriculum (570) and the Mechanical and Reactors Engineering Curriculum (571). Both curricula are in support of Navy needs for individuals having advanced technical education in mechanical engineering and related fields. The 570 Curriculum provides the educational component for the Engineering Duty Officer program and the research program in the Department is designed to support the requirement for Officers having the ability to identify, formulate and solve technical and engineering problems in areas related to mechanical engineering.

DEGREES GRANTED:

- Master of Science in Mechanical Engineering
- Mechanical Engineer
- Doctor of Philosophy
- Doctor of Engineering

RESEARCH THRUST:

There are five different disciplines of research thrusts such as Fluid Dynamics, Heat Transfer and Turbomachinery; Dynamics Systems, Controls and Robotics; Solid Mechanics, Vibrations, and Shock; Materials Science and Engineering; Total Ship Systems Engineering

FACULTY EXPERTISE:

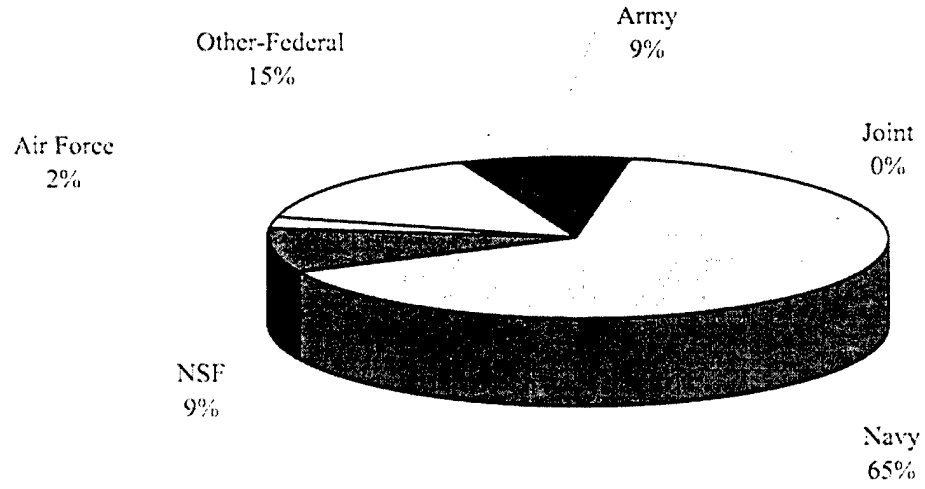
- Fluid Dynamics, Heat Transfer and Turbomachinery:
  Distinguished Professor Turgut Sarpkaya, Professor Matthew Kelleher, Associate Professor Knox Millsaps, Jr., Associate Professor Ashok Gopinath
- Dynamics Systems, Controls and Robotics:
  Professor Anthony Healey, Professor Morris Driels, Associate Professor Fotis Papoulias
- Solid Mechanics, Vibration, and Shock:
  Professor Young Shin, Professor Young Kwon, Associate Professor Joshua Gordis
- Materials Science and Engineering:
  Professor Terry McNelley, Professor Alan Fox, Associate Professor Indranath Dutta
- Total Ship Systems Engineering:
  Professor Charles Calvano

RESEARCH FACILITIES:

The Mechanical Engineering Laboratories are designed as complements to the educational mission and research interests of the department. In addition to extensive facilities for the support of student and faculty research, a variety of general use equipment is available. This includes equipment and facilities for the investigation of problems in engineering mechanics; a completely equipped materials science laboratory, including advanced scanning electron microscopes, an Auger microprobe, a transmission electron microscope and X-ray diffractometers; an oscillating water tunnel, a unique underwater towing tank and a low turbulence water channel; a vibration analysis laboratory; a fluid power controls laboratory; a robotics and real-time control laboratory; facilities for experimentation with low velocity air flows; equipment for instruction in thermal transport phenomena; a laser doppler velocimeter; nuclear radiation detection equipment and an interactive CAD/CAE computer graphics laboratory. Experimentation is further enhanced by a broad selection of analog and digital data acquisition and processing equipment and instrumentation.

RESEARCH PROGRAM-FY2000:

The Naval Postgraduate School's research program exceeded $43 million in FY2000. Over 93% of the Naval Postgraduate School Research Program is externally funded. A profile of the external research sponsors for the Department of Mechanical Engineering is provided below along with the size of the FY2000 externally funded program.



Size of Program: **$1414K**

FACULTY LISTING

McNelley, Terry R.
Professor and
Chair
ME/Mc
656-2589/2586
tmcnelley@nps.navy.mil

Kwon, Young
Professor and
Associate Chair for Research
ME/Kw
656-3385
ykwon@nps.navy.mil

Calvano, Charles N.
Professor
ME/Ca
656-2364
ccalvano@nps.navy.mil

Gordis, Joshua H.
Associate Professor
ME/Go
656-2866
jgordis@nps.navy.mil

Papoulias, Fotis A.
Associate Professor
ME/Pa
656-3381
fapapoulias@nps.navy.mil

Driels, Morris R.
Professor
ME/Dr
656-3383
mrdriels@nps.navy.mil

Healey, Anthony J.
Professor
ME/Hy
656-3462
ajhealey@nps.navy.mil

Pucci, Paul F.
Professor Emeritus
ME/Pc
656-2216
pfpucci@nps.navy.mil

Dutta, Indranath
Associate Professor
ME/Du
656-2851
dutta@nps.navy.mil

Kelleher, Matthew D.
Professor
ME/Kk
656-2530
mkelleher@nps.navy.mil

Sarpkaya, Turgut
Distinguished Professor
ME/Si
656-3425
sarp@nps.navy.mil

Fox, Alan G.
Professor
ME/Fx
656-2142
fox@nps.navy.mil

Millsaps, Knox T.
Associate Professor
ME/Mi
656-3381
millsaps@nps.navy.mil

Shin, Young S.
Professor
ME/Sg
656-2568
yshinr@nps.navy.mil

Gopinath, Ashok
Associate Professor
ME/Gk
656-3400
gopinath@nps.navy.mil

Owen, Kevin
Senior Lecturer
ME/Ok
656-3428
kowen@nps.navy.mil

EXPLORATION OF METHODS TO ENHANCE LFT&E AND TOTAL SHIP SURVIVABILITY IN LPD-17

Charles N. Calvano, Professor
Department of Mechanical Engineering
Robert Harney, Senior Lecturer
Department of Physics
Sponsor: Commander Operation Test and Evaluation Force

OBJECTIVE: COMOPTEVFOR will conduct an operational assessment of LPD-17 during the detail design stage, and innovative attempt to more effectively and efficiently ensure the delivery of a ship, which meets all fleet needs. COMOPTEVFOR will assess the value of this innovative approach to assessing the potential operational effectiveness of the ship. To support this effort, COMOPTEVFOR is assembling a team of "subject matter experts" to assist in the experiment and has requested the investigators to provide evaluation in the areas of live fires test and evaluation and total ship survivability.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles-Ship and Watercraft

KEYWORDS: Live Fire Test and Evaluation, Ship Survivability, Ship Design, Operational Assessment

DESIGN AND ANALYSIS OF HINGE CONNECTOR FOR SLICE-TRAILER TOWING

Charles N. Calvano, Professor
Fotis A. Papoulias, Associate Professor
Joshua H. Gordis, Associate Professor
Department of Mechanical Engineering
Sponsor: Office of Naval Research

OBJECTIVE: The objective of this project was to support the Office of Naval Research in further development of the novel SLICE hull form with a trailer hull.

SUMMARY: The focus of this project was on a hinge connection between the "tractor" and "trailer" SLICE vessels. This provides a number of technical challenges in high-speed high sea state ocean towing systems that have not been studied in the past. The investigators reviewed industry designs, participated in discussions of the work with industry and ONR, analyzed design alternatives and commented on them, and suggested modifications or alternatives as part of the hinge design Integrated Product Team (IPT). A detailed study of the maneuvering and seakeeping qualities of the two interconnected bodies was initiated focusing primarily on hinge load prediction in a given sea. Current efforts are focusing on ways to mitigate motions and/or loads during high-proximity towing.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles-Ships and Watercraft

KEYWORDS: Towing, Seakeeping

IMPROVEMENT OF DELIVERY ACCURACY METHODOLOGY

Morris Driels, Professor
Department of Mechanical Engineering
Sponsor: United States Army Aeronautical Systems Center

OBJECTIVE: To review delivery accuracy methodologies applicable to GPS/INS Weapons Systems, including dispenser weapons. To review AGM65 (MAVERICK) field trial data and analyze for consistent DA parameters for inclusion into JAWS.

DoD KEY TECHNOLOGY AREAS: Command, Control, and Communications

KEYWORDS: Weapon Effects, Delivery Accuracy, Weaponeering

JMEM AIR TO SURFACE TASKS 3, 8, 16

Morris Driels, Professor
Department of Mechanical Engineering
Sponsors: Joint Technical Coordinating Group and Naval Postgraduate School

OBJECTIVE: To improve delivery accuracy methodology and to develop a real time DA capability.

SUMMARY: The first part of the project was to develop a spreadsheet that would compute delivery accuracy of unguided weapons. This was accomplished with the assistance of LT T. Smith. The second part was to begin translating this methodology into a C++ environment capable of being integrated directly into JAWS. The third task related to the analysis of accuracy for the AGM-65 Maverick missile, and the calculation of accuracy parameters for the JAWS program.

THESIS DIRECTED:

Smith, T., "Real Time Computation of the Delivery Accuracy for Air Launched Unguided Weapons," Masters Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Bombing Accuracy, Weaponeering

IMPLEMENTATION OF THE DELPHI TARGET ACQUISITION MODEL

Morris Driels, Professor
Department of Mechanical Engineering
Sponsors: United States Army TRADOC Analysis Command-Monterey

OBJECTIVE: To further refine earlier work on the development of a visual performance model based on a public domain version of the BAe ORACLE model.

SUMMARY: This small carry-over project from FY99 was to document the results and provide a user manual for the sponsor.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Software, Target Acquisition, Combat Models

BOUNDARY ENHANCEMENTS TO THE ACQUIRE MODEL

Morris Driels, Professor
Department of Mechanical Engineering
Sponsors: United States Army TRADOC Analysis Command-Monterey

OBJECTIVE: To adapt the US Army ACQUIRE model to include the detectability of edges.

SUMMARY: This was a collaborative project with UC Berkeley, where Professor Stark's team had an experimental facility to allow the measurement of visual targets by human subjects. The NPS contribution was to specify the type and scope of the tests UCB would do, and to interpret the results in a military context. Work is continuing on the formulation of a model to embody the results.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Human Vision, Search, Target Detection

COMPUTING UNGUIDED DELIVERY ACCURACIES IN REAL TIME

Morris Driels, Professor
Department of Mechanical Engineering
Sponsor: Aeronautical Systems Command

OBJECTIVE: The project will develop the methodologies for computing delivery accuracy data for unguided weapons in real time rather than off-line, and will document the modes and mechanizations applicable for the aircraft studied.

DoD KEY TECHNOLOGY AREAS: Command, Control, and Communications

KEYWORDS: Weapon Accuracy, Weaponeering

INFRARED CONTRAST SIGNATURE MODELING

Morris Driels, Professor
Department of Mechanical Engineering
Sponsors: United States Army TRADOC Analysis Command-Monterey

OBJECTIVE: To develop initial standards for the U. S. Army modeling and simulation effort in the area of IR target detection methodologies. The effort will be part of a combined proposal from NPS, IDA and NVESD.

SUMMARY: A technical description of the Electro-Optical Tactical Decision Aid (EOTDA) was written in the form of U. S. Army standard and submitted to the ACQUIRE Standards Committee. This is now becoming the Standard for U. S. Army model of IR signatures.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Software, Target Acquisition, Combat Models

INTERFACIAL SLIDING IN MULTI-COMPONENT SYSTEMS

Indranath Dutta, Associate Professor
Department of Mechanical Engineering
Sponsor: National Science Foundation

OBJECTIVE: To investigate the mechanisms of creep at interfaces of dissimilar materials.

SUMMARY: The goal of this project is to develop a phenomenological understanding of the mechanisms operative during sliding of interfaces at high temperatures. A combination of experimental and analytical means are being utilized to investigate the kinetics of interfacial sliding and its effect on thin film systems.

PUBLICATIONS:

Dutta, I., "Role of Interfacial and Matrix Creep During Thermal Cycling of Continuous Fiber Reinforced Metal-Matrix Composites," *Acta Materialia,* 48, 2000, pp. 1055-1074.

Chen, M.W. and Dutta, I., "Atomic Force Microscopy Study of Plastic Deformation and Interfacial Sliding in Al Thin Film: Si Substrate Systems due to Thermal Cycling," *Applied Physics Letters,* 77, 2000, pp. 4298-4300.

THESIS DIRECTED:

Peterson, K., "An Experimental Set-up for Studying the Creep Behavior of Planar Al-Si Interfaces," Masters Thesis, Naval Postgraduate School, June 2000.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures

KEY WORDS: Composite, Multi-layers, Thin Films, Creep, Interfacial Sliding

PROCESSING AND FRACTURE OF PARTICULATE REINFORCED METAL-MATRIX COMPOSITES

Indranath Dutta, Associate Professor
Department of Mechanical Engineering
Sponsors: Air Force Research Laboratory

OBJECTIVE: To correlate processing, microstructure and fracture properties in particulate reinforced aluminum (PRA) composites.

SUMMARY: The purpose of this project is to investigate microstructural development during processing of PRA, specifically with respect to the evolution of particulate distribution and matrix grain and precipitate structure, and to evaluate the impact of fracture properties and mechanisms. The eventual goal is to design the material microstructure in such a way so as to result in substantially improved fracture toughness, while retaining the stiffness and strength advantage of PRA relative to unreinforced aluminum alloys.

PUBLICATION:

Nagarajan, R. and Dutta, I., "A Novel Approach for Optimizing the Fracture Toughness of Precipitation Hardenable Al-SiCp Composites," to appear in *Metallurgical and Materials Transactions A,* 2001 (accepted in October 2000).

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures

KEY WORDS: Composites, Fracture, Matrix Microstructure

THERMO-MECHANICAL BEHAVIOR OF SOLDER JOINTS FOR ELECTRONIC PACKING

Indranath Dutta, Associate Professor
Ashok Gopinath, Associate Professor
Department of Mechanical Engineering
Sponsor: Unfunded

OBJECTIVE: To obtain a mechanistic understanding of the relationship between micro structural coarsening and applied constraints during thermo-mechanical cycling of solder joints.

SUMMARY: Flip Chip and Ball Grid Array solder joints in electronic packaging applications are subjected to large imposed strains and temperature variations during service conditions. During cycling, the microstructure coarsens, plastic strains localize, and the solder joint eventually fails by low-cycle fatigue induced by permanent creep deformation. The purpose of this project is to understand the dependence of micro-structural coarsening on the plastic strain state in a solder joint during thermomechanical cycling.

PUBLICATION:

Dutta, I., Gopinath, A., and Marshall, C.,"Effect of Underfill Constraints on Thermal Cycling Behavior of Flip Chip Solder Joints," presented at the 2000 TMS Fall Meeting and Exhibition, St. Louis, MI, 4-8 October 2000.

THESIS DIRECTED:

Marshall, C., "Constraint Effects During Thermo-Mechanical Cycling of Flip Chip Solder Joints Under Shear," Masters Thesis, Naval Postgraduate School, December 2000.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures

KEY WORDS: Electronic Packaging, Solder, Thermal Cycling, Deformation

EVALUATION OF THE EFFECTS OF WATER DEPTH ON WELD METAL MICROSTRUCTURE WHEN USING NICKEL-BASED AUSTENITIC ELECTRODES FOR THE UNDERWATER WET WELDING OF HIGH-STRENGTH FERRITIC STEELS

Alan G. Fox, Professor
Department of Mechanical Engineering
Sponsor: Naval Sea Systems Command

OBJECTIVE: To evaluate the use of Ni-based austenitic electrodes for the underwater wet welding of high strength ferritic steels

SUMMARY: Previous work in collaboration with NSWC on the underwater wet welding of high strength ferritic steels indicated that the use of ferritic electrodes often led to hydrogen-assisted underbead cracking, especially at low water temperatures. In the present work, in order to try and alleviate this cracking, more ductile Ni-based austenitic electrodes were used. The use of austenitic electrodes proved highly successful with no underbead cracking encountered in any of the weldments. Unfortunately, at water depths greater than about 30 feet, especially when welding in the overhead position, significant amounts of porosity were encountered which occasionally put the weldments out of specification. Further work is needed to understand and provide a means for the elimination of this porosity.

THESIS DIRECTED:

Sheakley B.J., "Effect of Water Depth on the Underwater Wet Welding of Ferritic Steels Using Austenitic Ni-based Alloy Electrodes," Masters Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures

KEYWORDS: Underwater Wet Welding, Ferritic Steels, Ni-based Electrodes

COMPOSITIONAL AND MICROSTRUCTURAL ANALYSIS OF ADVANCED ULTRA-LOW CARBON FERRITIC STEEL WELDMENTS-SEGREGATION OF CARBON IN THE WELD METAL

Alan G. Fox, Professor
E. Sarath K. Menon, Research Associate Professor
Department of Mechanical Engineering
Sponsor: Naval Research Laboratory

OBJECTIVE: To evaluate the segregation of carbon in weld metal deposited with ultra-low-carbon (ULC)-alloy steel consumables

SUMMARY: Previous work in collaboration with NRL on this topic has shown how the segregation of carbon between the microconstituents, martensite, ferrite and retained austenite in ultra-low carbon steel weld metals (containing about 0.03 wt.% C) could be quantified by the use of parallel electron energy loss spectroscopy (PEELS) in the transmission electron microscope (see the publication below). These studies have more recently been extended to include weld metals deposited with the most recently developed Navy ULC steel weld consumable electrodes and segregation of carbon in the microconstituents present in these has been evaluated. These studies are still ongoing.

PUBLICATION:

Menon, E.S.K. and Fox, A.G, "Detection, Distribution and Quantification of Carbon in Steel Microstrucures by Parallel Electron Energy Loss Spectroscopy," accepted for publication in *Microscopy and Microanalysis.*

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures

KEYWORDS: Ultra-Low Carbon Steel Welding Consumables, Analysis of Carbon in Steels by Parallel Electron Energy Loss Spectroscopy

MICROSTRUCTURAL STUDIES OF ULTRA-LOW CARBON STEEL WELD METAL

Alan G. Fox, Professor
Department of Mechanical Engineering
Sponsor: Naval Surface Warfare Center-Carderock

OBJECTIVE: To evaluate the microstructures that develops in Navy ultra-low carbon steel weld metals with particular emphasis on the role of non-metallic inclusions.

SUMMARY: Previous work in collaboration with NSWC on this topic has shown how non-metallic inclusions have a significant effect on the microstructure and mechanical properties (strength and toughness) of ultra-low carbon (ULC) steel weld metal deposited by the gas-metal-arc welding process. In this work we studied the effect of non-metallic inclusions on the weld metal microstructure and strength and toughness as a function of welding parameters and weld metal composition for a series of ULC samples. These results indicated that Military Specifications for 100 ksi yield strength weld metal could be met with ULC consumable electrodes provided the weld metal composition was carefully controlled.

THESIS DIRECTED:

Van Slyke, J.J., "Factors Affecting the Strength and Toughness of Ultra-Low Carbon Steel Weld Metal," Masters Thesis, Naval Postgraduate School, January 2000.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures

KEYWORDS: Ultra-Low Carbon Steel Welding Consumables, Non-Metallic Inclusions

THERMOACOUSTIC EFFECTS AT A SOLID-FLUID BOUNDARY: THE ROLE OF A SECOND ORDER THERMAL EXPANSION COEFFICIENT

Ashok Gopinath, Associate Professor
Department of Mechanical Engineering
Sponsor: National Aeronautics and Space Administration-Lewis

OBJECTIVE: To conduct fundamental material and transport studies on thermo-acoustic phenomena in microgravity with future application to thermoacoustic based energy processes aboard the Space Station.

SUMMARY: An analytical study was conducted to show that small particles in a strong acoustic field can be heated by very substantial heat fluxes. The study provides a theoretical basis for the development of a novel technique that could find use in the simultaneous levitation and heating of particles by acoustic means for "ultra-clean" materials processing applications. Results from an experimental study on the development of empirical correlations of use in the design of heat exchangers for thermoacoustic engines was also reported.

PUBLICATIONS:

Gopinath, A. and Harder, D. R., "An Experimental Study of Heat Transfer from a Cylinder in Low-Amplitude Zero-Mean Oscillatory Flows," *International Journal of Heat & Mass Transfer*, Vol. 43, No. 4, pp. 505-520, February 2000.

Gopinath, A., "Thermoacoustic Streaming on a Sphere," *Proceedings of the Royal Society (series A), London*, Vol. 456, No. 2002, pp. 2419-2439, October 2000.

Gopinath, A., "Thermoacoustic Streaming on a Cylinder," *Proceedings of the Symposium on Energy Engineering*, Vol. 3, pp. 1170-1177, Ping Cheng, ed., Hong Kong, January 2000.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures, Modeling and Simulation, Other (Basic Science)

KEYWORDS: Thermoacoustics, Acoustic Streaming, Acoustic Levitation, Thermo-Physical Property Measurement, Thermodynamic Moduli, Oscillatory Flows, Asymptotic Techniques.

ACOUSTIC STREAMING IN MICROGRAVITY: FLOW STABILITY AND HEAT TRANSFER ENHANCEMENT

Ashok Gopinath, Associate Professor
Department of Mechanical Engineering
Sponsor: National Aeronautics and Space Administration-Jet Propulsion Laboratory

OBJECTIVE: To conduct fundamental material and transport studies on the role of acoustic streaming in enhancing transport rates in microgravity with application to materials processing.

SUMMARY: The problem of steady streaming on an object in an acoustic field was generalized to provide new results on the effect of object location, and fluid compressibility. The results show that dramatic changes are possible in the flow, and are a likely explanation for the intermittent and fleeting flow patterns that have been observed in experimental studies on acoustic levitation.

PUBLICATION:

Gopinath, A. and Trinh, E. H., "Compressibility Effects on Steady Streaming from a Non-Compact Rigid Sphere," *Journal of the Acoustical Society of America*, Vol. 108, No. 4, pp. 1514-1520, October 2000.

THESIS DIRECTED:

Lowe, G., "Acoustically Forced Heat Transfer from a Tube Bank," Master's Thesis, Naval Postgraduate School, June 2000.

DoD KEY TECHNOLOGY AREAS: Other (Energy Systems)

KEYWORDS: Acoustic Streaming, Heat Transport, Asymptotic Techniques

EXPERIMENTAL STUDIES OF LIQUIDS IN TENSION

Ashok Gopinath, Associate Professor
Department of Mechanical Engineering
Sponsor: Unfunded

OBJECTIVE: To study the tensile load bearing capabilities of thin trapped liquid layers.

SUMMARY: An experimental study was initiated to study the behavior of thin trapped liquid layers subject to separating tensile forces. Both quantitative (force-displacement) data and qualitative (visual) data were gathered in the course of a second student thesis. The data support the basic model of a viscous dominated resistance to the separation of the liquid layers.

THESIS DIRECTED:

Rehkop, C. H., "An Experimental Study of Liquids in Tension," Master's Thesis, Naval Postgraduate School, March 2000.

PRESENTATIONS:

Gopinath, A. and Isik, S., "An Experimental Study of Liquids in Tension," Interfaces for the 21st Century – New Research Directions in Fluid Mechanics & Materials Science, Monterey, CA, August 1999.

Gopinath, A, "The Role of Viscous Fingering in the Separation Mechanics of Thin Interfacial Liquid Layers," Gallery of Fluid Motion, 52nd American Physical Society Meeting, New Orleans, LA, November 1999.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures

KEYWORDS: Surface Tension, Viscous Fingering, Cavitation, Lubrication

DESIGN OF LAB-SCALE MODEL TEST OF ISOLATION FOR RORO RAMP

J. H. Gordis, Associate Professor
F. A. Papoulias, Associate Professor
Sponsor: Naval Surface Warfare Center-Carderock

OBJECTIVE: The objective of this project was to perform frequency response analysis of the DTMB runs 1-503 and NRL runs 1-217 of the T-ACS seakeeping experiments.

SUMMARY: In Sea State 3 and above, the stern ramp of the Cape T ship is vulnerable to an overstress condition when off-loading vehicles. Therefore, there exists a need to design motion-compensation devices ("isolation") which when placed between the end of the ramp and the barge, precludes the possibility of a ramp overstress condition. Parallel to analytical studies conducted under separate funding, there is a need to establish an accurate and cost-efficient experimental set-up in order to validate the theoretical models. This need is addressed in this work. A basic experimental configuration has been designed and built. Actual testing and data analysis is set to begin during the month of February. Further data analysis and conclusions along with recommendations of the most promising designs will be reported during this year.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Frequency Response, Seakeeping, Vibration Isolation, Testing and Evaluation

REDUCING RAMP STRESS LEVELS VIA SEMI-ACTIVE DAMPING

J. H. Gordis, Associate Professor
F. A. Papoulias, Associate Professor
Sponsor: Naval Surface Warfare Center-Carderock

OBJECTIVE: The current ramp design used in roll-on roll-off operations has been determined to be structurally inadequate in sea state 3. The overall objective of this continuing project is to determine the isolation properties that are required in order to reduce ramp stress levels below the allowable for worst-case loading.

SUMMARY: A mathematical model describing the fundamental physics of a ship/ramp/barge system, including a passive isolator, was developed. The model properly accounts for hydrodynamic proximity effects and structural coupling between the bodies. Preliminary parametric studies, utilizing a standard second order model for the frequency response properties of the connecting body, of the response amplitude operator of the ramp motion were performed for varying wave directions and isolator stiffness and damping. These were utilized for random wave analysis in standard fully developed seas. The results indicated that rational selection of isolator properties could result in significant reduction of motions and stress levels in the connecting ramp. Current efforts include incorporation of actual FEM results coupled with the existing hydrodynamic prediction models.

PUBLICATION:

Gordis, J. H., Papoulias, F., and Leban, F., "Validation of Frequency Response Synthesis for Large-Scale Structural Isolation Design," *Proceedings, 71st Shock and Vibration Symposium,* Arlington, VA, 6-9 November 2000.

THESIS DIRECTED:

Konstantinou, D. S., "Random Wave Analysis of Ship/Ramp/Barge Response," Masters Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Frequency Response, Seakeeping, RORO Operations, Vibration Isolation

EFFICIENT NONLINEAR TRANSIENT DYNAMIC ANALYSIS FOR STRUCTURAL OPTIMIZATION USING AN EXACT INTEGRAL EQUATION FORMULATION

Joshua H. Gordis, Associate Professor
Department of Mechanical Engineering
Beny Neta, Professor
Department of Mathematics
Sponsor: National Science Foundation

OBJECTIVE: This project is concerned with the theoretical development and computational implementation of a time domain theory for locally nonlinear transient structural synthesis. Application principally will be made to seismic isolation.

SUMMARY: This research concerns the continued development of a time domain theory for structural synthesis. This theory provides the previously unavailable capability of performing exact damped transient structural synthesis for systems with localized non-linear components with the order of the synthesis being independent of model size. The method is based on Volterra integral equations derived from the convolution integral, which describe substructure coupling and structural modification. Current results demonstrate an order of magnitude reduction in compute times as compared with widely used commercial finite element analysis packages. The use of the formulation for the optimal design of seismic isolation is

under development. The algorithm has been extended to treat nonlinear memory-type elements (e.g. elastoplastic hysteretic).

PUBLICATION:

Gordis, J. and Neta, B., "An Adaptive Method for the Numerical Solution of Volterra Integral Equations," *Recent Advances in Applied and Theoretical Mathematics,* N. Mastorakis, ed., World Scientific and Engineering Society International Conference, Athens, Greece, 1-3 December 2000, pp. 1-8.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Structural Dynamics, Transient Response, Nonlinear Dynamics, Seismic Isolation

STUDIES IN INTELLIGENT CONTROL OF AUTONOMOUS VEHICLES

Anthony J. Healey, Professor
Department of Mechanical Engineering
Sponsor: Ford Motor Company

OBJECTIVE: This grant is in the support of research in the subject matter without restriction, and serves to aid the ongoing programs in the Center for Autonomous Underwater Vehicle Research.

SUMMARY: This project has supported the purchase of radio ethernet communications devices and radio modem connections between the ARIES robot and a shore based operator station. Also, it has supported the purchase of mobile laboratory equipment necessary to the deployment of ARIES in Monterey Bay.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles-Ship and Watercraft

KEYWORDS: Autonomous Systems, Robotics, Vehicles, Navigation

HYDROTHERMAL VENT MAPPING WITH MULTIPLE AUTONOMOUS UNDERWATER VEHICLES

Anthony J. Healey, Professor
David. B. Marco, Mechanical Engineer
Department of Mechanical Engineering

OBJECTIVE: The Naval Postgraduate School (NPS) and the Institution Superior Technico, Lisbon (IST) have a long standing memorandum of agreement dating back to 1994 for the exchange of scientific ideas, visits of faculty and students, and to perform collaborative work. In the past we have collaborated on joint papers, the shared supervision of doctoral work, and a shared effort on the evaluation of AUV control system methodology and strategic level mission specifications using Petri net methods. This is a NICOP project aimed at developing the technology of multiple cooperating AUVs in a shallow water vent-mapping mission. The missions to be conducted in the AZORES off Terceira Island in 2001 will develop multi vehicle cooperative strategies and control using radio and acoustic communications. Results of both sonar and video images will be obtained in which the Portuguese vehicle - MARIUS and a surface catamaran (DELFIN) will perform broad area survey to identify vent clusters, while the NPS vehicle - ARIES will be used to reacquire vent cluster locations and perform local area searches with close in video data gathering.

The major goals of the mission are to demonstrate the use of multiple AUVs to map the shallow water areas of the Azores in the Joao de Castro Bank off Terceira. The waters are shallow (10 - 20 meters) around the peaks of the bank where large clusters of these vents are known to exist. Water depths in the crater go to 40 meters. The objectives include using multiple cooperating AUVs and the evaluation of methodologies employed for multi vehicle control, common control languages, and cooperative command and control. While there is a scientific need to study the vents with more detail than possible using divers and cameras,

this also presents a parallel to the minefield reconnaissance and mapping problem in very shallow water - so necessary to the US Navy.

The IST has been approved to conduct a mission in the Azores (the AZIMOV project) using cooperative behaviors between a surface catamaran vehicle (DELFIN) and an underwater vehicle (MARIUS). The project involves the French companies Thompson and ORCA, and personnel within the GESMA (French Navy), as well as faculty from IST. NPS will provide the cooperating underwater vehicle ARIES which has a video capability.

The approach for mapping these shallow water vent areas will be to employ a combination of low resolution sensors (sonar's) on one vehicle (Marius and / or Delphin) to detect the presence and general location of extensive clusters of vents, and to communicate the cluster location data information by acoustic and radio modems to the NPS ARIES AUV. The ARIES will have the capability to reaquire the vent area using its DGPS / Doppler / IMU navigational suite, and to conduct a survey of the local area with both a sector scanner sonar and a video camera. ARIES will provide geo-located video images of the vents, taken from a slow speed local search at constant altitude.

Since September 1999, we have been developing the capabilities of the ARIES vehicle, shown below at AUVFEST 99 in Gulfport, Mississippi, November 1999, [1] in which we have developed the propulsion system, the navigational system, and the C4I systems. The vehicle now runs in Monterey Bay in the very shallow waters and has been used to gather bathymetry data and video imagery of the bottom, including geo-locations superimposed on the images. The camera output is recorded to a DV recorder and played back after recovery. The vehicle is equipped with an acoustic ground locked Doppler Sonar, DGPS, compass, and a low cost inertial motion unit. Navigation accuracies have been improved through the use of an Extended Kalman Filter and reported in [2]. We are looking into radio video transmission for increased speed of data transfer. The ARIES and the Delphin vehicles are illustrated in the Figure1 and 2 below. The Delphin autonomous surface craft has been developed and field-tested this summer.

The vehicle is capable of 5 knots and can be driven to autonomous commands through its radio link, or interactively by 'joy stick' operator station, giving speed-heading commands. Navigation is accomplished using DGPS since the vehicle is always on the surface. Speed measurement and heading is taken from a Thompson acoustic ground locked Doppler sonar and a compass. The vehicle has been described at the IEEE 2000 Oceans meeting, [3, 4].

New technology being demonstrated include: (1) Multi vehicle cooperation via data sharing; (2) Shallow water target reacquisition and navigational accuracy; (3) Shallow water object mapping; and (4) Coordinated Mission Control.

PUBLICATIONS:

Marco, D. B. and Healey, A. J., "Current Developments in Underwater Vehicle Control and Navigation: The NPS ARIES AUV," *Proceedings of IEEE OCEANS 2000,* Providence, RI, September 2000.

Alves, J. et. al. "An Autonomous Surface Craft for Ocean Operations," *Proceedings of IEEE Oceans 2000,* Providence, RI, September 2000.

Pascoal, A., et. al., "Robotic Ocean Vehicles for Marine Science Applications: The European AZIMOV Project," *Proceedings of IEEE OCEANS 2000,* Providence, RI, September 2000.

Healey, A. J., "Optimal Fault Detection and Resolution During Maneuvering for AUVs," *Proceedings of MCMC 2000,* Aalborg University, Denmark, 23-25 August 2000.

Marco, D. B. and Healey, A. J., "Current Developments in Underwater Vehicle Control and Navigation: The NPS ARIES AUV," *Proceedings of IEEE OCEANS 2000,* Providence, RI, September 2000.

Riedel, J., "Shallow Water Stationkeeping of an Autonomous Underwater Vehicle: Experimental Results of a Disturbance Controller," *Proceedings of IEEE OCEANS 2000,* Providence, RI, September 2000.

Healey, A. J. and Kim, Y., "Control and Random Searching with Multiple Robots," accepted in *Proceedings of IEEE CDC2000*, Paper No. INV2303, Sydney, Australia, November 2000.

THESES DIRECTED:

Gibbons, A. S., "Optimal Fault Detection and Resolution During Maneuvering for Autonomous Underwater Vehicles," Masters Thesis, Naval Postgraduate School, March 2000.

Ludwig, P. M., "Formation Control for Multi-vehicle Robotic Minesweeping," Masters Thesis, Naval Postgraduate School, June 2000.

Allyne, J. "AUV Navigation with Range Only Measurement," Masters Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles-Ship and Watercraft

KEYWORDS: AUV, Shallow Water Vent Mapping

TACTICAL DECISION AIDS FOR AUTONOMOUS UNDERWATER VEHICLES

Anthony J. Healey, Professor
Department of Mechanical Engineering
Sponsor: Office of Naval Research

OBJECTIVE: This work is aimed at developing Tactical Decision Aids for the use of AUVs. The primary focus is on gathering AUV data and building a common operating environment in which to view simulation results as well as near to real time actual results for mine counter measures work.

SUMMARY: Since the US Navy already uses an established Tactical Decision Aid (the MEDAL system), our approach is to supplement MEDAL with additional data server features. By this means, unclassified data from developmental assets may be integrated into the common operating environment and to enable increases in timeliness of data gathering to be accomplished.

NPS has developed an automated data server (ADS) which links into the accepted input and output channels already active in the Navy's Global Command And Control System (GCCS-M) and MEDAL. We have set up a working stand-alone MEDAL station, received training on its use from SAIC, and demonstrated how data for vehicle positions, contact locations, mine-like contact images, and bathymetry data can be displayed in near to real time. Data gathered during FBE-Hotel included Remus, Morpheus, OEX, and BPAUV vehicle data files with bathymetry, positions, image files and contact locations.

DoD KEY TECHNOLOGY AREAS: Command, Control, and Communications

KEYWORDS: Autonomous Systems, Robotics, Command and Control, Tactical Decision Aids, Other (Autonomous Systems)

MINE SWEEPING WITH MULTIPLE VEHICLES AND ATTRITION

Anthony J. Healey, Professor
Department of Mechanical Engineering
Sponsor: Coastal Systems Station

OBJECTIVE: This work is aimed at developing a study of sweeping effectiveness for AUV's used as electromagnetic/mechanical minesweepers. The primary focus is on developing a simulation studying the use of multiple vehicles carrying magnetic sweepers through a minefield. As mines explode, some vehicles are lost. By selection of vehicle spacing, the minimum range between vehicles can be maximized, thus reducing the likelihood of collateral damage between vehicles. The key point here is that as vehicles are lost, a supervisor reassigns sweep tracks to remaining vehicles so that area coverage is retained.

SUMMARY: The study of effectiveness was accomplished by developing a computer simulation code. The code is written in "C" and runs on an SGI workstation. The data developed by the simulation is

transferred to Matlab and variables of interest such as vehicle positions, paths, locations of mines exploded, and summary statistics, may be plotted as desired.

A study was completed and detailed in an invited paper to the IEEE CDC Conference, 2001. The details are contained in the Thesis work of LT P. Ludwig. What is shown is that this approach to minesweeping is very encouraging. The sweep rates using multiple (20) vehicles are practically useful with a span of 4 hours. We would like to continue the work in the area of more detailed swimmer guidance laws, Account for mines already sensed that did not detonate (smart mines with ship counters), and, optimize the results.

PUBLICATION:

Healey, A. J., "Application of Formation Control for Multi-Vehicle Robotic Minesweeping," *Proceedings of the IEEE CDC Conference*, Paper No. CDC01-INV3103.

THESIS DIRECTED:

Ludwig, P. M., "Formation Control for Multi-Vehicle Robotic Minesweeping," Masters Thesis, Naval Postgraduate School, June 2000.

DoD KEY TECHNOLOGY AREAS: Command, Control, and Communication, Other (Autonomous Systems)

KEYWORDS: Autonomous Systems, Robotics, Command and Control, Tactical Decision Aids

MODELING OF FIRE AND SMOKE PROPAGATION IN SHIPBOARD SPACES

Matthew D. Kelleher, Professor
Department of Mechanical Engineering
Sponsor: Naval Sea Systems Command

OBJECTIVE: The objective of this proposed work is to model the propagation of fire and smoke in the shipboard environment. Work has been continuing to investigate the modeling of smoke propagation in shipboard compartments and passageways. It is very important that an understanding of the propagation of fire and smoke in the various shipboard spaces be developed and that some means be developed to apply that understanding to incorporate survivability considerations in the design of future combatants and to the development of fire fighting procedures.

SUMMARY: A commercial code developed by CFD Research Corporation (CFDRC) is being used to model the effects of fire in various shipboard spaces. Modeling of smoke propagation in various spaces representative of DD51 have been modeled. Recently modeling of the live fire experiments performed aboard the Navy's full scale DT&E facility, the ex-USS Shadwell, in 1994 has begun. These experiments were performed to investigate shipboard smoke control using a forced counter-flow air supply. The present modeling study is investigating the effects of open hatches or doors on the propagation of smoke from adjacent spaces.

THESES DIRECTED:

Mehls, M., "Propagation of Fire Generated Smoke in Shipboard Spaces," Masters Thesis, Naval Postgraduate School, March 2000.

Abaya, A. F., "Propagation of Fire Generated Smoke in Shipboard Spaces with Geometric Interferences," Masters Thesis, Naval Postgraduate School, September 2000.

Vegara, B. J., "Propagation of Fire Generated Smoke and Heat Transfer in Shipboard Spaces with a Heat Source," Masters Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Fire Propagation, Smoke Spread, Ship Survivability, Damage Control

INVESTIGATION OF THE USE OF ARTIFICIAL NEURAL NETWORKS IN HEAT TRANSFER

Matthew D. Kelleher, Professor
Department of Mechanical Engineering
Sponsor: Unfunded

OBJECTIVE: The objective of this study is to investigate the feasibility of using artificial neural networks as a method of developing predictive algorithms from complex heat transfer experimental data.

SUMMARY: Experimental heat transfer taken for complex situations which involve several independent length scales such as finned tube banks or for multi-fluid systems is usually very difficult if not impossible to correlate. If algebraic correlations are developed in the standard manner the results are usually accompanied by a high degree of uncertainty. Many times the data can only be presented in tabular or graphical form. Application of such data for design calculations can be very difficult.

This work explores the use of artificial neural networks to develop a predictive algorithm using experimental heat transfer data for a complex situation. The data from a series of experiments investigating the boiling heat transfer from a vertical bank of tubes in refrigerant 114 with variable amounts of oil present has been used to illustrate the process. Both finned and unfinned tubes were investigated. The network was trained with a partial set of the available data. The prediction obtained using the trained network was then compared to the remaining experimental data. The artificial neural network provided an excellent predictive method.

THESIS DIRECTED:

Cronley, T. J., "The Use of Neural Networks as a Method of Correlating Thermal Fluid Data to Provide Useful Information on Thermal Systems," Masters Thesis, Naval Postgraduate School, June 2000.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Artificial Neural Networks

MODELING AND SIMULATION OF DAMAGE AND CRACKS IN PARTICULATE COMPOSITE MATERIALS: EFFECTS OF HYDROSTATIC PRESSURE

Young W. Kwon, Professor
Department of Mechanical Engineering
Sponsors: Air Force Research Laboratory

OBJECTIVE: This was a continuing research project from past several years during which a numerical modeling and simulation technique, called a multi-level (micro-macro) technique, had been developed and evaluated against experimental results. This year's effort was to study the effect of hydrostatic pressure on damage initiation and growth and to model the effect in the damage mechanics.

SUMMARY: The stress-strain behavior of a particulate composite specimen under hydrostatic pressure was modeled using the multi-scale approach. The approach was developed in the past by the investigator. The damage was described at the micro-level analysis in terms of the respective damage of each constituent material. In the present study, a damage theory was developed based on the two components of strain energy density: dilatational and deviatoric energy densities. The dilatational energy associated with the hydrostatic pressure was assumed to hold back the damage initiation. Using this concept, qualitatively acceptable stress-strain behaviors of the particulate composite were predicted under various levels of the hydrostatic pressure. The predicted results agreed well with the behavior observed in experimental studies.

The initial crack sizes at circular notch tips were predicted and compared to the experimental measurement when there was no hydrostatic pressure. The predicted values compared very well to the test data. When the study included a hydrostatic pressure, the initial crack size did not vary even though the crack formed at a higher applied strain level. This study did not include the pressure penetration into the crack to be applied to the crack faces. This effect needs to be studied in the subsequent study.

PUBLICATIONS:

Kwon, Y.W. and Liu, C.T., "Prediction of Initial Crack Size in Particulate Composites with a Circular Hole," *Mechanics Research Communications,* Vol. 27, No. 4, 2000, pp. 421-428.

Kwon, Y.W. and Eren, H., "Micromechanical Study of Interface Stresses and Failure in Fibrous Composites Using Boundary Element Method," *Polymers and Polymer Composites,* Vol. 8, No. 6, 2000, pp. 369-386.

McDermott, P.M. and Kwon, Y.W., "A Stable Algorithm for Void Growth and Nucleation in Transient, Elasto-plastic Analysis of Plate Bending," *Engineering Computations,* Vol. 17, No. 7, 2000, pp. 857-873.

Kwon, Y.W. and Liu, C.T., "Effect of Particle Distribution on Initial Cracks Forming from Notch Tips of Composites with Hard Particles Embedded in a Soft Matrix," accepted for publication in *Composites, Part B: Engineering.*

Kwon, Y.W. and Craugh, L.E., "Progressive Failure Modeling in Notched Cross-Ply Fibrous Composites," accepted for publication in *Applied Composite Materials.*

Kwon, Y. W. and McDermott, P. M., "Effects of Void Growth and Nucleation on Plastic Deformation of Plates Subjected to Fluid-Structure Interaction," submitted for publication.

Kwon, Y.W. and Altekin, A., "Multi-level, Micro-Macro Approach for Analysis of Woven Fabric Composites," submitted for publication.

Kwon, Y. W. and Liu, C. T., "Modeling of Hydrostatic Pressure Effect on Progressive Damage in Particulate Composites," *Recent Advances in Solids and Structures -2000,* ASME PVP Vol. 415, 2000, pp. 65-72.

PRESENTATIONS:

Kwon, Y.W., Eren, H., and Liu, C.T., "Study of Fiber/Matrix Interface Stresses and Failure Using Boundary Element Method," International Congress on Advanced Materials, their Processes and Applications, September 2000.

Kwon, Y. W., "Multilevel Approach for Failure in Woven Fabric Composites," International Congress on Advanced Materials, their Processes and Applications, September 2000.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power

KEYWORDS: Particle Reinforced Composite, Solid Rocket Propellant, Damage and Crack, Modeling and Simulation, Initial Crack Size, Hydrostatic Pressure

COMPUTER MODELING AND SIMULATION OF THE HUMAN THORAX UNDER BULLET IMPACT

Young W. Kwon, Professor
Department of Mechanical Engineering
Sponsor: United States Army Soldier and Biological Chemical Command
Armed Forces Institute of Pathology

OBJECTIVE: This was a continuing research project from the previous years. This year's effort was to model the human thorax with protective body armors hit by high-speed bullets in order to evaluate potential injury.

SUMMARY: The finite element analysis model was developed for the human thorax of skeleton including ribs, sternum, vertebrae, vertebral discs, facet joints, costal cartilages, muscle, etc. Two different body armors, one with a kevlar vest and the other with a vest and armor plate, were also modeled. The results of the computer model were compared to the experimental data obtained with human cadavers with body armors hit by bullets. In the model, the measured speed of the bullet was used. The comparison of accelerations in the sternums and spines were very good, especially the sternum accelerations for two different body armors. Those results provided reliability of the developed computer model. The next step is to implement major internal organs for their potential injury evaluation.

PUBLICATIONS:

Kwon, Y. W., Jolly, J. E., and Hughes, T. A., "Ballistic Impact Analysis of the Human Thorax with a Protective Body Armor," *Recent Advances in Solids and Structures -2000,* ASME PVP Vol. 415, 2000, pp. 11-15.

Jolly, J. E. and Kwon, Y. W., "Computer Modeling and Simulation of Bullet Impact to the Human Thorax," Naval Postgraduate School Technical Report, NPS-ME-00-002, June 2000.

Kwon, Y. W., Jolly, J. E., and Hughes, T. A., "Modeling of Dynamic Response of the Human Thorax with Protective Body Armors under Projectile Impact," submitted for publication.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Finite Element Method, Human Thorax Model, Body Armors, Dynamic Response

GLOBAL DAMAGE DETECTION IN COMPOSITE STRUCTURES

Young W. Kwon, Professor
Department of Mechanical Engineering
Sponsor: Unfunded

OBJECTIVE: This project was to develop a technique for damage detection and identification in sandwich composite structures containing interfacial cracks.

SUMMARY: The project was about damage detection and identification in sandwich structures containing embedded interface cracks. A global damage detection technique using dynamic characteristics was used in numerical experiments. The study models interface cracks as they were without artificially smearing either material or geometric properties. The study showed that proper modeling of cracks with contact elements was important for representation of the behavior of cracks. In addition, smearing geometric or material properties to represent such interface cracks was found to be generally unacceptable. Measuring local dynamic strains (stresses) shed lights for hidden damage detection and identification of locations.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures

KEYWORDS: Damage Detection, Sandwich Structures, Embedded Cracks, Interface Cracks, Finite Element Analysis

PROCESSING, GRAIN BOUNDARIES AND SUPERPLASTICITY IN ALUMINUM

Terry R. McNelley, Professor
Department of Mechanical Engineering
Sponsor: Unfunded

OBJECTIVE: The goal of this program is to determine the mechanisms of grain boundary development during deformation processing, the mechanisms by which deformation microstructures may transform to a fine-grained, superplastic state, and the deformation behavior of such microstructures.

SUMMARY: Our current understanding of microstructural refinement by deformation and recyrstallization is largely empirical and so the ability to predict and then produce refined microstructures for various purposes, such as superplasicity, is severely limited for aluminum and its alloys. Recently developed computer-aided electron microscopy diffraction analysis methods have been applied to the investigation of the mechanisms of grain boundary development during deformation processing of several aluminum alloys. Materials have been examined following various thermomechanical processing schedules and deformation histories. Aluminum alloy 5083 transforms to a refined, superplastic microstructure via a primary (discontinuous) recrystallization reaction involving the formation and migration of high-angle grain boundaries while Supral 2004 and Al-5Ca-5Zn materials transform by a continuous process. These different transformation processes may be distinguished by distinct differences in grain boundary characteristics and deformation behaviors.

PUBLICATIONS:

McNelley, T.R. and Pérez-Prado, M.T., "A Computer Simulation of Grain Boundary Character in a Superplastic Aluminum Alloy," in *Symposium Proceedings: Superplasticity - Current Status and Future Potential,* Vol. 601 (P.B. Berbon, M.Z. Berbon, T. Sakuma and T. G. Langdon, eds.), Materials Research Society, Pittsburgh, PA, 2000, pp. 3-14.

McNelley, T.R., "A Processing, Recrystallization and Superplasticity in Aluminum Alloys," in *Deformation, Processing and Properties of Structural Materials, Symposium in Honor of Oleg D. Sherby,* E.M Taleff, C.K. Syn and D.R. Lesuer, eds., TMS, Warrendale, PA, 2000, pp. 339-53.

Pérez-Prado, M.T., McNelley, T.R., González-Doncel, G., and Ruano, O.A., "A Texture, Grain Boundaries and Deformation of Superplastic Aluminum Alloys," in *Proceedings of ICSAM 2000, International Conference on Superplasticity in Advanced Materials,* N. Chandra, ed., in press.

McNelley, T.R., "A Continuous Recrystallization in Grain Boundaries in a Superplastic Aluminum Alloy," Chapter 22 in *Electron Backscatter Diffraction in Materials Science,* A.J. Schwartz, M. Kumar and B.L. Adams, eds., Kluwer Academic/Plenum Publishers, New York, 2000, pp. 277-90.

Eddahbi, M., McNelley, T.R., and Ruano, O.A., "A Characterization During Superplastic Deformation of an Al-6%Cu-0.4%Zr Alloy," *Metallurgical and Materials Transactions*, in press.

Pérez-Prado, M.T., Swisher, D.L., and McNelley, T.R., "A Deformation Banding, Grain Boundaries and Continuous Recrystallization in a Superplastic Aluminum Alloy," in *Proceedings of THERMEC 2000, International Conference on Processing and Manufacturing of Advanced Materials,* T. Chandra, ed., in press.

Pérez-Prado, M.T., González-Doncel, G., Ruano, O.A., and McNelley, T.R., "A Texture Analysis of the Transition from Slip to Grain Boundary Sliding in a Discontinuously Recrystallized Superplastic Aluminum Alloy," accepted for publication in *Acta Mater.*

PRESENTATIONS:

McNelley, T.R. and Pérez-Prado, M.T., "A Computer Simulation of Grain Boundary Character in a Superplastic Aluminum Alloy," Symposium HH: Advances in Superplasticity and Superplastic Forming, 1999 Fall MRS Meeting, Boston, MA, 29 November 1999.

McNelley, T.R., "A Processing, Recrystallization and Superplasticity in Aluminum Alloys," Symposium in Honor of Oleg D. Sherby, 2000 Annual TMS Meeting, Nashville, TN, 15 March 2000.

Pérez-Prado, M.T., McNelley, T.R., González-Doncel, G., and Ruano, O.A., "A Texture, Grain Boundaries and Deformation of Superplastic Aluminum Alloys," ICSAM 2000, International Conference on Superplasticity in Advanced Materials, ICSAM 2000, Orlando, FL, 6 August 2000.

McNelley, T.R.,"A Continuous Recrystallization in Grain Boundaries in a Superplastic Aluminum Alloy," Symposium on Electron Backscatter Diffraction in Materials Science, 2000 Fall Meeting of ASM and TMS, St. Louis, MO, 18 October 2000.

Pérez-Prado, M.T., Swisher, D.L., and McNelley, T.R., "A Deformation Banding, Grain Boundaries and Continuous Recrystallization in a Superplastic Aluminum Alloy," THERMEC 2000, International Conference on Processing and Manufacturing of Advanced Materials, THERMEC 2000, Las Vegas, NV, 5 December 2000.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures

KEYWORDS: Aluminum, Superplasticity, Recrystallization, Grain Boundaries, Thermo-mechanical Processing

ULTRA-FINE AND NANO-GRAIN MICROSTRUCTURES BY SEVERE PLASTIC DEFORMATION

Terry R. McNelley, Professor
Department of Mechanical Engineering
Sponsor: Unfunded

OBJECTIVE: The goal of this program is to determine mechanisms by which ultra-fine grain structures form in severely deformed materials, such as those processed by equi-channel angular (ECA) pressing

SUMMARY: Ultra-fine grain sizes in the sub-micrometer or even nanometer range can be achieved in metallic materials by imposing extremely large plastic strains during deformation processing. Such grain refinement will result in drastic improvements in strength/toughness combinations for structural applications as well as in improved ductility during elevated temperature forming. Methods such as ECA pressing are required in order to impart stains large enough to produce such refinement. ECA pressing is accomplished by pressing a billet of material through a die having two channels, of equal cross section, that intersect at an angle. Such a billet experiences simple shear without change in cross-sectional area and so the process is amenable to repetition. Billet rotation between successive pressing operations allows the shear plane orientation to be changed in order to achieve further control of microstructural refinement. The characteristics of the grain structures and, especially, the nature of the grain boundaries produced by such processing have remained in question. However, grain-to-grain misorientations may be readily determined by newly developed computer-aided electron backscatter pattern (EBSP) analysis methods.

PUBLICATIONS:

McNelley, T.R., "A The Application of EBSD Methods to Evaluate Grain Boundary Character of Fine-Grained Pure Aluminum," in *Ultra-Fine Grained Materials and Processing*, R. Mishra, ed., TMS, Warrendale, PA, 2000, pp. 339-53.

Terhune, S.D., Oh-ishi, K., Horita, Z., Langdon, T.G., and McNelley, T.R., "An Investigation of Grain Boundary Character Evolution during ECA Pressing of Pure Aluminum," submitted to *Metallurgical and Materials Transactions.*

PRESENTATION:

McNelley, T.R., "A The Application of EBSD Methods to Evaluate Grain Boundary Character of Fine-Grained Pure Aluminum," Symposium on Ultra-Fine Grained Materials and Processing, 2000 Annual TMS Meeting, Nashville, TN, 14 March 2000.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures

KEYWORDS: Aluminum, Grain Refinement, Nano-Grain Materials, Recrystallization, Grain Boundaries, Materials Processing

REDUCING RAMP STRESS LEVELS VIA SEMI-ACTIVE DAMPING

Fotis A. Papoulias, Associate Professor
Joshua H. Gordis, Associate Professor
Department of Mechanical Engineering
Funding: Naval Surface Warfare Center-Carderock

OBJECTIVE: The current ramp design used in roll-on roll-off operations has been determined to be structurally inadequate in sea state 3. The overall objective of this continuing project is to determine the isolation properties that are required in order to reduce ramp stress levels below the allowable for worst-case loading.

SUMMARY: A mathematical model describing the fundamental physics of a ship/ramp/barge system, including a passive isolator, was developed. The model properly accounts for hydrodynamic proximity effects and structural coupling between the bodies. Preliminary parametric studies, utilizing a standard second order model for the frequency response properties of the connecting body, of the response amplitude operator of the ramp motion were performed for varying wave directions and isolator stiffness and damping. These were utilized for random wave analysis in standard fully developed seas. The results indicated that rational selection of isolator properties could result in significant reduction of motions and stress levels in the connecting ramp. Current efforts include incorporation of actual FEM results coupled with the existing hydrodynamic prediction models.

PUBLICATION:

Gordis, J.H., Papoulias, F. and Leban, F., "Validation of Frequency Response Synthesis for Large-Scale Structural Isolation Design," *Proceedings of the 71st Shock and Vibration Symposium,* Arlington, VA, 6-9 November 2000.

THESIS DIRECTED:

Konstantinou, D.S., "Random Wave Analysis of Ship/Ramp/Barge Response," Masters Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles-Ships and Watercraft

KEYWORDS: Frequency Response, Seakeeping, RORO Operations, Vibration Isolation

FREQUENCY RESPONSE ANALYSIS OF THE T-ACS SEAKEEPING EXPERIMENTS

Fotis A. Papoulias, Associate Professor
Department of Mechanical Engineering
Funding: Naval Surface Warfare Center-Carderock

OBJECTIVE: The objective of this project was to perform frequency response analysis of the DTMB runs 1-503 and NRL runs 1-217 of the T-ACS seakeeping experiments.

SUMMARY: Trial runs of a 1:24 scale model crane ship were conducted in the David Taylor Model Basin. The model's responses to regular waves under various ship configurations, crane configurations, sea states and ship headings relative to the incoming waves were recorded. This project analyzed the frequency response characteristics of the model and generated the model and full-scale spectra and Response Amplitude Operators, or RAOs. Several techniques of data filtering were utilized and compared. Accurate generation of full-scale RAOs enables future prediction, using the principle of linear superposition, of ship motions in an irregular sea. Such predictions can be compared to actual, full-scale trial runs that are currently being conducted.

THESIS DIRECTED:

Elvis, G.G., "Frequency Response Analysis of T-ACS Experimental Data," Masters Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles-Ships and Watercraft

KEYWORDS: Frequency Response, Seakeeping

VORTEX BREAKDOWN IN TURBULENT SWIRLING FLOWS

T. Sarpkaya, Distinguished Professor
Department of Mechanical Engineering
Sponsor: National Science Foundation and Naval Postgraduate School

OBJECTIVE: Vortex breakdown is the transformation of a slender vortex into three-dimensional forms. Where, how, and under what circumstances does this transformation occur in *viscous* vertical flows constitute the essence of the breakdown problem. Neither a stagnation point, nor a region of reversed flow, nor the bridging of laminar–turbulent states is necessary. Trailing vortices, swirling flows in pipes, vortical flows above sweptback wings at large angles-of-attack, flows in closed containers with a rotating lid, and columnar vortices in atmosphere may experience breakdown. Where, how, and under what circumstances does the breakdown occur in *viscous* vortical flows constitute the essence of the investigation.

SUMMARY: The definition of the spectral characteristics of the conical region is the subject of the ongoing investigation. The mean velocities and turbulence intensities were measured in forward-scattering mode with a three-component Laser Doppler Anemometer. The results refute the conjectures that the circumstances of breakdown are insensitive to the Reynolds number and the local turbulence properties. These two factors have a strong influence on the evolution of the flow. Of all the known forms, the spiral emerges as the most fundamental breakdown form. All other forms may be regarded as transient states affected by various types of instabilities. At very high Reynolds numbers the breakdown acquires forms and characteristics never seen before: Extremely high rates of revolution, onset of core-bifurcation or core-trifurcation, intense nonisotropic turbulence, and a conical shape.

PUBLICATION:

Novak, F. and Sarpkaya, T., "Vortex Breakdown at High Reynolds Numbers," *American Institute of Aeronautics and Astronautics Journal,* Vol. 38, No. 5, May 2000, pp. 1671-1679.

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Air Vehicles

KEYWORDS: Vortex Breakdown, Vorticity, Swirling Flow

DEVELOPMENT OF A NEW VORTEX-DECAY MODEL IN THE ATMOSPHERE

T. Sarpkaya, Distinguished Professor
Department of Mechanical Engineering
Sponsor: National Aeronautics and Space Administration-Langley

OBJECTIVE: The purpose of this continuing investigation is (a) to develop a new vortex decay model for the prediction of the descent of aircraft trailing vortices subjected to realistic environmental conditions (stratification, turbulence, cross wind, headwind, shear effects, and ground effect), and (b) to apply the model to field data obtained with Lidar in Memphis and Dallas–Fort Worth airports.

SUMMARY: A robust and relatively simple physics-based vortex decay model has been devised. It does not violate any hydrodynamical principles, has only one model constant, uses the turbulence eddy dissipation rate in conjunction with a theoretical model (as verified by experiments and numerical simulations), and it requires no cumbersome algorithms to account for the ground effects. Acquisition of better and more detailed field data (vortex velocities and positions; wind, shear and their gradients; better temperature, humidity, and eddy dissipation profiles), the quantification of the consequences of unstable stratification, and the optimization of the new model parameters constitute the essence of this continuing research of vital international importance.

PUBLICATIONS:

Sarpkaya, T., "New Model for Vortex Decay in the Atmosphere," *Journal of Aircraft (AIAA),* Vol. 37, No. 1, January/February 2000, pp. 53-61.

Sarpkaya, T., "Resistance in Unsteady Flow: Search for an In-Line Force Model," *International Journal of Offshore and Polar Engineering,* Vol. 10, No. 4, December 2000, pp. 1053-5381.

Sarpkaya, T., Robins, R.E., and Delisi, D.P., "Wake-Vortex Eddy Dissipation Model Predictions Compared with Observations," *Journal of Aircraft (AIAA),* Vol. 38, No. 4, July-August 2000, pp. 234-240.

OTHER:

The model has now been incorporated into NASA's AVOSS program for the management of aircraft landings at large airports (JFK, Memphis, DFW, New Orleans).

DoD KEY TECHNOLOGY AREAS: Air Vehicles

KEYWORDS: Trailing Vortices, Aircraft Wakes, Wake Hazard

SPRAY FORMATION AT THE FREE SURFACE OF LIQUID WALL JETS

T. Sarpkaya, Distinguished Professor
Department of Mechanical Engineering
Sponsor: Office of Naval Research and Naval Postgraduate School

OBJECTIVE: This continuing basic research is an experimental investigation of the ligament and drop formation at the free surface of liquid wall jets, flowing over smooth and sand-roughened plates towards the understanding of the physics of droplet formation, in general, and of the spray formation on bow-sheets, in particular.

SUMMARY: Measurements were made with several high-speed imagers, a pulsating laser, and a Digital Particle Image Velocimeter (DPIV) system and analyzed through the use of appropriate software. The wall-jet Reynolds number ranged from 2.4×10^4 to 4×10^4, the Froude number from 15 to 30, and the Weber number from 1,500 to 3,000. The characteristics of the ligament forest and droplets were determined from the digitized images.

PUBLICATIONS:

Sarpkaya, T. and Merrill, G., "Spray Formation at the Free Surface of Liquid Wall Jets," *Naval Hydrodynamics*, Vol. 22, October 1999, pp. 145-154.

Sarpkaya, T. and Vaidyanathan, R., "Spray Generation from Free and Half-Free Jets," AIAA 2000-0817, January 2000, *AIAA Journal.*

Sarpkaya, T., "Characterization of the Free Surface Structuers on High-Speed Liquid Jets," *Proceedings of the ICLASS (International Congress on Liquid Atomization and Spray Systems),* Pasadena, CA, July 2000, pp. 1-8.

Sarkaya, T. and Merrill, C.F. "High Speed Laser-PIV Imaging for the Eulerian-Lagrangian Measurement and Visualization of Spray on Wall-Bounded Jets," *Proceedings of the ICLASS (Ingernational Congress on Liquid Atomization and Spray Systems)*, Pasadena, CA, July 2000, pp. 9-17.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles-Ships and Watercraft

KEYWORDS: Hydrodynamics, Drop Formation, Spray

A UNIVERSAL FORCE MODEL FOR BLUFF BODIES IN UNSTEADY FLOW

T. Sarpkaya, Distinguished Professor
Department of Mechanical Engineering
Sponsor: Office of Naval Research

OBJECTIVE: A combined analytical, numerical, and physical analysis has been carried out to devise a physics-based model for the prediction of flow-induced unsteady forces on bluff bodies immersed in time-dependent flows. The new model, based on a sounder scientific rational is superior to the well-known Morison equation and offers greater universality and higher engineering reliability, particularly in the so-called inertia/drag regime.

SUMMARY: Over 3,000 digital force-time-data files have been evaluated during the course of the investigation in order to evaluate the residue for each combination of the Keulegan-Carpenter number Kc, Frequency parameter b, the Reynolds number Re, and the relative roughness k_S/D. It has been shown that the viscous drag force and the inviscid inertia force do not operate independently and it is not possible to divide the measured time-dependent force into an inviscid inertial force and a viscous drag force. The modification proposed herein to the existing Morison equation through the addition of a third term offers greater universality and higher engineering reliability, particularly in the so-called drag–inertia regime.

PUBLICATION:

Sarpkaya, T., "Resistance in Unsteady Flow: Search for an In-Line Force Model," *International Journal of Offshore and Polar Engineering,* Vol. 10, No. 4, December 2000, pp. 1053-5381.

THESIS DIRECTED:

Osgood, D. B., "Flow About Perforated Bodies," Masters Thesis, Naval Postgraduate School, June 2000.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Bluff Body, Resistance, Unsteady Flows, Vorticity

SHOCK AND VIBRATION ANALYSIS IN SUPPORT OF DDG-51 CLASS SHOCK FOLLOW-ON ACTIONS

Young S. Shin, Professor
Department of Mechanical Engineering
Sponsor: Naval Sea Systems Command and Naval Postgraduate School

OBJECTIVE: To perform shock and vibration analysis in support of DDG-51 Class shock follow-on actions including DDG-51 Flight IIA ship shock analysis to predict dynamic responses of ship system and subsystem structures to underwater explosions.

SUMMARY: This task is a part of team project consisting of NAVSEA, NSWC, General Dynamics, Weindlinger Associates, Gibs & Cox, and NPS. The CY2000 was final year to complete the project. I was responsible to perform 3-D surface ship shock modeling and simulation of USS John Paul Jones, DDG53. The task includes investigating whether the ship shock modeling and simulation can predict the dynamic transient responses of ship system and subsystem structures accurately. The ship shock trial data of DDG53 conducted in June 1994 were used for data comparison. The analysis takes into account of the effects of the fluid-ship structure interaction and cavitation effects on a surface ship model (DDG-53) due to a large scale underwater explosion. The simulation results were favorably compared well with those of ship shock trial data. This analysis was a first attempt to conduct 3-D full ship shock simulation of navy ship and the results was successful.

PUBLICATIONS:

Shin, Y.S., "Total Ship Shock Modeling and Simulation Using LS-DYNA/USA," *Proceedings of LS-DYNA Users Conference 2000,* Osaka, Japan, 3-4 October 2000.

Malone, P.E. and Shin, Y.S., "Sensitivity Analysis of Coupled Fluid Volume to Ship Shock Simulation," *Proceedings of 71st Shock and Vibration Symposium,* Crystal City, VA, 6-9 November 2000.

Shin, Y.S., "Surface Ship Shock Simulation Subjected to Underwater Explosion," *Proceedings of NAV2000 Conference*, Venice, Italy, 20-22 September 2000.

PRESENTATIONS:

Shin, Y.S., "Total Ship Shock Modeling and Simulation Using LS-DYNA/USA," LS-DYNA Users Conference 2000, Osaka, Japan, 3-4 October 2000.

Malone, P.E. and Shin, Y.S., "Sensitivity Analysis of Coupled Fluid Volume to Ship Shock Simulation," 71st Shock and Vibration Symposium, Arlington, VA, 6-9 November 2000.

Shin, Y.S., "Overview of Underwater Shock and DDAM," 3-Hour Tutorial presented at the 71st Shock and Vibration Symposium, Arlington, VA, 6-9 November 2000.

THESES DIRECTED:

Trevino, T., "Applications of Arbitrary Lagrangian-Eulerian (ALE) Analysis Approach to Underwater and Air Explosion Problems," Masters Thesis, Naval Postgraduate School, September 2000.

Malone, P.E., "Surface Ship Shock Modeling and Simulation: Extended Investigation," Masters Thesis, Naval Postgraduate School, December 2000.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles – Ships and Watercraft

KEYWORDS: ALE Analysis, Underwater Explosion, Cavitation, Fluid-structure Interaction

FRAGMENTATION AND DETONATION OF ANTIPERSONNEL MINE AND SURVIVABILITY OF SENSORS IN THE GRIZZLY

Young S. Shin, Professor
Department of Mechanical Engineering
Naval Postgraduate School
Sponsor: U.S. Army Tank Automotive Command and Naval Postgraduate School

OBJECTIVE: The Grizzly has various sensors including control sensors, laser systems, hydraulic lines, wires and various cameras mounted on the Grizzly armor hull, which is exposed to various types of landmine detonation. The objective is to study the detonation and fragmentation process of mine such as OMZ-72 antipersonnel mine and to extend the study on effect of shock wave and fragmentation to the survivability of sensors, laser systems, cameras, wires and hydraulic lines exposed to the threat. Based on the results investigated, NPS will provide design guidance on protecting sensors, laser systems, wires and hydraulic lines, etc., from the threat. The pop-up anti-personnel mines such as the OZM-72 has unique and of interesting features about its horizontal dispersion of fragmentation. The project results will provide design guidance from a better understanding of the threat.

SUMMARY: The Grizzly meets a long-standing requirement for a vehicle that can defeat complex obstacles and clear mines on the battlefield. Minefields, barb wire entanglements, tank ditches and other fortifications are often used in combination to divert, deny and paralyze the forward momentum of mechanized forces during offensive operations. In addition, the Grizzly has a full camera vision systems installed. The author, post-doctorates and graduate students in Naval Postgraduate School have been involved in research and development on shock testing, modeling and simulation of detonation and explosion processes for the span of last twenty years. We also conducted the studies on armor base plate responses subjected antitank landmine for various material types. The response types include shock wave response, impact, penetration and perforation.

THESIS DIRECTED:

Trevino, T., "Applications of Arbitrary Lagrangian-Eulerian (ALE) Analysis Approach to Underwater and Air Explosion Problems," Masters Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: ALE Analysis, Fragmentation and Detonation, Land Mine

IMPACT ANALYSIS AND ACTIVE VIBRATION DAMPING ON ORBITAL VEHICLES

Young S. Shin, Professor
Department of Mechanical Engineering
Sponsor: National Aeronautics and Space Administration-Dryden

OBJECTIVE: To develop a method to determine the location, force, and orientation of an impact on a space truss using a minimal distributed sensor grid. Also achieve improved active control of vibrations induced in the truss by installed equipment operating at a constant frequency. The active control is to be achieved using piezoelectric elements installed as truss members and should be able to control the vibration at multiple nodes and sensitive to various axis without relocating the active elements. A FEM of the truss, generated using ANSYS, is to be used to assess the ability to model the implementation of the control algorithm and will be compared to the actual experimental results.

SUMMARY: This task is in collaboration with both the Aeronautical Engineering and Electrical Engineering curriculums using facilities located in H-022. The NPS Space Truss is used to simulate a generic orbital platform and is mounted on a vibration isolation table. The truss also has potential to be scaled up to a larger application such as ALPHA, the International Space Station. The ability to validate the application of the control method using a computer model has even broader potential for future applications, with the ability to be applied to any valid FEM. The impact analysis motivation is to allow remote monitoring of systems that are subjected to the potential impacts of micrometeorites. This includes all orbital systems, but is specifically tuned in this research to truss applications. The potential application of similar technology to more conventional aircraft is also of interest to the sponsor.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Other (Space Systems)

KEYWORDS: Space Truss, Active Vibration Damping, Piezoelectric Elements, Impact Analysis, ANSYS, FEM Simulation of Active Control Method

DEPARTMENT OF MECHANICAL ENGINEERING

2000
Faculty Publications and Presentations

PUBLICATIONS/PRESENTATIONS

JOURNAL PAPERS

Chakrabarty, J. and Kwon, Y.W., "Influence of Elastic-Deformation of the Strip on the Roll Force and Torque in Cold-Rolling," *Arabian Journal for Science and Engineering,* Vol. 16, pp. 385-396.

Chen, M.W. and Dutta, I., "An AFM Study of Interfacial Sliding at Edges of Thin Films During Thermal Cycling," *Applied Physics Letters*, 77, 2000, p.4298.

Chen, M.W. and Dutta, I., "Atomic Force Microscopy Study of Plastic Deformation and Interfacial Sliding in Al Thin Film:Si Substrate Systems due to Thermal Cycling," *Applied Physics Letters,* 77, 2000, pp. 4298-4300.

Dutta, I., "Role of Interfacial and Matrix Creep During Thermal Cycling of Continuous Fiber Reinforced Metal-Matrix Composites," *Acta Materialia*, 48, 2000 p.1055.

Gopinath, A. and Harder, D.R. "An Experimental Study of Heat Transfer from a Cylinder in Low-Amplitude Zero-Mean Oscillatory Flows," *International Journal of Heat & Mass Transfer*, Vol. 43, No. 4, pp. 505-520, February 2000.

Gopinath, A. and Trinh, E.H., "Compressibility Effects on Steady Streaming from a Non-Compact Rigid Sphere," *Journal of the Acoustical Society of America*, Vol. 108, No. 4, pp. 1514-1520, October 2000.

Kwon, Y.W. and Eren, H., "Micromechanical Study of Interface Stresses and Failure in Fibrous Composites Using Boundary Element Method," *Polymers and Polymer Composites*, Vol. 8, No. 6, 2000, pp. 369-386.

Kwon, Y.W. and Liu, C.T., "Prediction of Initial Crack Size in Particulate Composites with a Circular Hole," *Mechanics Research Communications*, Vol. 27, No. 4, 2000, pp. 421-428.

Kwon, Y.W., Jolly, J.E., and Hughes, T.A., "Ballistic Impact Analysis of the Human Thorax with a Protective Body Armor," *Recent Advances in Solids and Structures –2000,* ASME PVP Vol. 415, 2000, pp. 11-15.

Kwon, Y.W. and Liu, C.T., "Modeling of Hydrostatic Pressure Effect on Progressive Damage in Particulate Composites," *Recent Advances in Solids and Structures -2000*, ASME PVP Vol. 415, 2000, pp. 65-72.

McDermott, P.M. and Kwon, Y.W., "A Stable Algorithm for Void Growth and Nucleation in Transient, Elasto-plastic Analysis of Plate Bending," *Engineering Computations*, Vol. 17, No. 7, 2000, pp. 857-873.

Novak, F. and Sarpkaya, T., "Vortex Breakdown at High Reynolds Numbers," *American Institute of Aeronautics and Astronautics Journal,* Vol. 38, No. 5, May 2000, pp. 1671-1679.

Sarpkaya, T., "New Model for Vortex Decay in the Atmosphere," *Journal of Aircraft (AIAA)*, Vol. 37, No. 1, January/February 2000, pp. 53-61.

Sarpkaya, T. and Merrill, G., "Spray Formation at the Free Surface of Liquid Wall Jets," *Naval Hydrodynamics*, Vol. 22, October 1999, pp. 145-154.

Sarpkaya, T. and Vaidyanathan, R., "Spray Generation from Free and Half-Free Jets," AIAA 2000-0817, January 2000, *AIAA Journal.*

Sarpkaya, T., "Resistance in Unsteady Flow: Search for an In-Line Force Model," *International Journal of Offshore and Polar Engineering,* Vol. 10, No. 4, December 2000, pp. 1053-5381.

Sarpkaya, T., Robins, R.E., and Delisi, D.P., "Wake-Vortex Eddy Dissipation Model Predictions Compared with Observations," *Journal of Aircraft (AIAA),* Vol. 38, No. 4, July-August 2000, pp. 234-240.

PUBLICATIONS/PRESENTATIONS

CONFERENCE PAPERS

Alves, J., et. al., "An Autonomous Surface Craft for Ocean Operations," *Proceedings of IEEE Oceans 2000,* Providence, RI, September 2000.

Fox, A.G. and Saunders, M., "Crystal Structure Refinement by Zone Axis Convergent Beam Electron Diffraction," in *Proceedings of the 24th ANZIP Condensed Matter Physics Meeting,* Wagga Wagga, New South Wales, Australia, 1-4 February 2000, talk FM9.

Gopinath, A., "Thermoacoustic Streaming on a Sphere,'' *Proceedings of the Royal Society (Series A), London*, Vol. 456, No. 2002, pp. 2419-2439, October 2000.

Gopinath, A., "Thermoacoustic Streaming on a Cylinder,'' *Proceedings of the Symposium on Energy Engineering*, Vol. 3, pp. 1170-1177, Ping Cheng, ed., Hong Kong, January 2000.

Gordis, J. and Neta, B., "An Adaptive Method for the Numerical Solution of Volterra Integral Equations, *Recent Advances in Applied and Theoretical Mathematics,* N. Mastorakis, ed., World Scientific and Engineering Society International Conference, Athens, Greece, 1-3 December 2000, pp. 1-8.

Gordis, J.H., Papoulias, F., and Leban, F., "Validation of Frequency Response Synthesis for Large-Scale Structural Isolation Design," *Proceedings of the 71st Shock and Vibration Symposium,* Arlington, VA, 6-9 November 2000.

Healey, A.J., "Optimal Fault Detection and Resolution During Maneuvering for AUVs," *Proceedings of MCMC 2000,* Aalborg University, Denmark, 23-25 August 2000.

Healey, A. J., "Application of Formation Control for Multi-Vehicle Robotic Minesweeping," *Proceedings of the IEEE CDC Conference*, Paper No. CDC01-INV3103.

Healey, A.J., "Optimal Fault Detection and Resolution During Maneuvering for AUVs," IFAC Conference on Modeling and Control of Marinecraft, Aalborg, Denmark, August 2000.

Healey, A.J. and Kim, J., "Control and Random Searching with Multiple Robots," *Proceedings of IEEE CDC Conference,* Sydney, Australia, July 2000, Paper No. INV-2303.

Malone, P.E. and Shin, Y.S., "Sensitivity Analysis of Coupled Fluid Volume to Ship Shock Simulation," *Proceedings of 71st Shock And Vibration Symposium,* Crystal City, VA, 6-9 November 2000.

Malone, P.E. and Shin, Y.S., "Sensitivity Analysis of Coupled Fluid Volume to Ship Shock Simulation," *Proceedings of 71st Shock and Vibration Symposium,* Arlington, VA, 6-9 November 2000.

Marco, D.B. and Healey, A. J., "Current Developments in Underwater Vehicle Control and Navigation: The NPS ARIES AUV," *Proceedings IEEE OCEANS 2000*, Providence, RI, September 2000.

McNelley, T.R., "A Processing, Recrystallization and Superplasticity in Aluminum Alloys," *Deformation, Processing and Properties of Structural Materials, Symposium in Honor of Oleg D. Sherby,* E.M Taleff, C.K. Syn and D.R. Lesuer, eds., TMS, Warrendale, PA, 2000, pp. 339-353.

McNelley, T.R., "The Application of EBSD Methods to Evaluate Grain Boundary Character of Fine-Grained Pure Aluminum," *Ultra-Fine Grained Materials and Processing,* R. Mishra, ed., TMS, Warrendale, PA, 2000, pp. 339-353.

McNelley, T.R. and Pérez-Prado, M.T., "A Computer Simulation of Grain Boundary Character in a Superplastic Aluminum Alloy," *Symposium Proceedings: Superplasticity - Current Status and Future Potential,* Vol. 601, P.B. Berbon, M.Z. Berbon, T. Sakuma and T. G. Langdon, eds., Materials Research Society, Pittsburgh, PA, 2000, pp. 3-14.

Pascoal, A., et. al., "Robotic Ocean Vehicles for Marine Science Applications: The European AZIMOV Project," *Proceedings of IEEE OCEANS 2000,* Providence, RI, September 2000.

Pérez-Prado, M.T., McNelley, T.R., González-Doncel, G. and Ruano, O.A., "A Texture, Grain Boundaries and Deformation of Superplastic Aluminum Alloys," *Proceedings of ICSAM 2000, International Conference on Superplasticity in Advanced Materials,* N. Chandra, ed., Orlando, FL, August 2000.

Pérez-Prado, M.T., Swisher, D.L., and McNelley, T.R., "A Deformation Banding, Grain Boundaries and Continuous Recrystallization in a Superplastic Aluminum Alloy," *Proceedings of THERMEC 2000, International Conference on Processing and Manufacturing of Advanced Materials,* T. Chandra, ed., Las Vegas, NV, December 2000.

Riedel, J., "Shallow Water Stationkeeping of an Autonomous Underwater Vehicle: Experimental Results of a Disturbance Controller," *Proceedings of IEEE OCEANS 2000,* Providence, RI, September 2000.

Sarpkaya, T., "Characterization of the Free Surface Structures on High-Speed Liquid Jets," *Proceedings of the ICLASS (International Congress on Liquid Atomization and Spray Systems),* Pasadena, CA, July, 2000, pp. 1-8.

Sarpkaya, T. and Merrill, C.F., "High Speed Laser-PIV Imaging for the Eulerian-Lagrangian Measurement and Visualization of Spray on Wall-Bounded Jets," *Proceedings of the ICLASS (International Congress on Liquid Atomization and Spray Systems),* Pasadena, CA, July 2000, pp. 9-17.

Shin, Y.S., "Total Ship Shock Modeling and Simulation Using LS-DYNA/USA," *Proceedings of LS-DYNA Users Conference 2000*, pp.12-1-12, Osaka, Japan, 3-4 October 2000.

Shin, Y.S., "Surface Ship Shock Simulation Subjected to Underwater Explosion," *Proceedings of NAV2000 Conference*, Venice, Italy, 20-22 September 2000.

CONFERENCE PRESENTATIONS

Dutta, I., Gopinath, A., and Marshall, C.,"Effect of Underfill Constraints on Thermal Cycling Behavior of Flip Chip Solder Joints," 2000 TMS Fall Meeting and Exhibition, St. Louis, MO, 4-8 October 2000.

Dutta, I., Gopinath, A. and Marshall, C., "Effect of Underfill Constraints on Thermal Cycling Behavior of Flip Chip Solder Joints," 2000 TMS Fall Meeting and Exhibition, St. Louis, MO, 4-8 October 2000.

Gopinath, A. and Isik, S., "An Experimental Study of Liquids in Tension," Interfaces for the 21st Century – New Research Directions in Fluid Mechanics & Materials Science, Monterey, CA, August 1999.

Gopinath, A, "The Role of Viscous Fingering in the Separation Mechanics of Thin Interfacial Liquid Layers," Gallery of Fluid Motion, 52nd American Physical Society Meeting, New Orleans, LA, November 1999.

Healey, A.J., "AUVs in Mine Countermeasures," NPS Symposium on Technology and the Mine Problem, Naval Postgraduate School, Monterey, CA, April 2000.

Kwon, Y.W., "Multilevel Approach for Failure in Woven Fabric Composites," International Congress on Advanced Materials, their Processes and Applications, September 2000.

Kwon, Y.W., Eren, H. and Liu, C.T., "Study of Fiber/Matrix Interface Stresses and Failure Using Boundary Element Method," International Congress on Advanced Materials, their Processes and Applications, September 2000.

McNelley, T.R. and Pérez-Prado, M.T., "A Computer Simulation of Grain Boundary Character in a Superplastic Aluminum Alloy," Symposium HH: Advances in Superplasticity and Superplastic Forming, 1999 Fall MRS Meeting, Boston, MA, 29 November 1999.

McNelley, T.R., "A Processing, Recrystallization and Superplasticity in Aluminum Alloys," Symposium in Honor of Oleg D. Sherby, 2000 Annual TMS Meeting, Nashville, TN, 15 March 2000.

McNelley, T.R.,"A Continuous Recrystallization in Grain Boundaries in a Superplastic Aluminum Alloy," Symposium on Electron Backscatter Diffraction in Materials Science, 2000 Fall Meeting of ASM and TMS, St. Louis, MO, 18 October 2000.

Pérez-Prado, M.T., Swisher, D.L., and McNelley, T.R., "A Deformation Banding, Grain Boundaries and Continuous Recrystallization in a Superplastic Aluminum Alloy," International Conference on Processing and Manufacturing of Advanced Materials, THERMEC 2000, Las Vegas, NV, 5 December 2000.

Pérez-Prado, M.T., McNelley, T.R., González-Doncel, G., and Ruano, O.A., "A Texture, Grain Boundaries and Deformation of Superplastic Aluminum Alloys," International Conference on Superplasticity in Advanced Materials, ICSAM 2000, Orlando, FL, 6 August 2000.

Sarpkaya, T. and Vaidyanathan, R., "Spray Generation from Free and Half-Free Jets," AIAA 2000-0817, January 2000.

Shin, Y.S., "Total Ship Shock Modeling and Simulation Using LS-DYNA/USA," LS-DYNA Users Conference 2000, Osaka, Japan, 3-4 October 2000.

MEETING ABSTRACT

Sabine T.M., Bertram W.H. and Fox A.G., "Studies of the Development of the C-S-H Amorphous Gel in Ordinary Portland Cement by Small-Angle Neutron Scattering," Cement and Concrete Science Meeting, Sheffield University, U.K., September 2000.

Sarpkaya, T., "Quantification of Bow Sheets," *ONR Proceedings of the Annual Review on Advances in Fluid Dynamics*, Pasadena, CA, 28 February-1 March 2000.

BOOK

Kwon, Y.W. and Bang, B., *The Finite Element Method Using MATLAB*, 2nd Edition, CRC Press, Boca Raton, FL, 2000.

CONTRIBUTIONS TO BOOKS

McNelley, T.R., "A Continuous Recrystallization in Grain Boundaries in a Superplastic Aluminum Alloy," Chapter 22 in *Electron Backscatter Diffraction in Materials Science,* A.J. Schwartz, M. Kumar and B.L. Adams, eds., Kluwer Academic/Plenum Publishers, NY, 2000, pp. 277-290.

McNelley, T.R., "The Application of EBSD Methods to Evaluate Grain Boundary Character of Fine-Grained Pure Aluminum," Symposium on Ultra-Fine Grained Materials and Processing, 2000 Annual TMS Meeting, Nashville, TN, 14 March 2000.

PUBLICATIONS/PRESENTATIONS

TECHNICAL REPORTS

Calvano, C.N. and Harney, R. "The Surface Warfare Test Ship," Naval Postgraduate School Technical Report, NPS-ME-00-01.

Jolly, J.E. and Kwon, Y.W., "Computer Modeling and Simulation of Bullet Impact to the Human Thorax," Naval Postgraduate School Technical Report, NPS-ME-00-002, June 2000.

OTHER

Chung, H.H. and Kwon, Y.W., eds., *Recent Advances in Solids and Structures-2000*, ASME PVP-Vol. 415, 2000 ASME International Mechanical Engineering Congress and Exposition, Orlando, FL, November 2000.

Gopinath, A. and Sadhal, S.S., eds., *Heat Transfer in Microgravity Systems*, ASME International Mechanical Engineering Congress & Exposition, Orlando, FL, November 2000.

Shin, Y.S., "Overview of Underwater Shock and DDAM," 3-Hour Tutorial presented at the 71st Shock and Vibration Symposium, Arlington, VA, 6-9 November 2000.

DEPARTMENT OF MECHANICAL ENGINEERING

Thesis Abstracts

PROPAGATION OF FIRE GENERATED SMOKE IN SHIPBOARD SPACES WITH GEOMETRIC INTERFERENCES

Amado F. Abaya-Lieutenant, United States Navy
B.S., Miami University of Ohio, 1993
Master of Science in Mechanical Engineering-September 2000
Advisor: Matthew D. Kelleher, Department of Mechanical Engineering

The propagation of fire generated smoke into a shipboard space with a geometric interference has been modeled using commercial software from the Computational Fluid Dynamics Research Corporation (CFDRC). This study was based on the dimensions of compartment 01-163-2-L and the installed ladder aboard an Arleigh Burke Class Flight IIIA Destroyer. A test model was run which validated the hindrance of fluid flow by a geometric interference. Smoke propagation scenarios were run in the shipboard compartment model. The results of the first scenario showed that smoke propagation is limited by the geometric interference. The results of the second scenario showed that smoke that is directed vertically is diverted by the geometric interference. The overall goal of this study is to show that computational fluid dynamics software can successfully model smoke propagation in shipboard spaces with a geometric interference.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation

KEYWORDS: Convection, Smoke Modeling, Computational Fluid Dynamics, Damage Control

DESIGN AND CONSTRUCTION OF A SOLAR POWERED THERMOACOUSTIC REFRIGERATOR

Jay Andrew Adeff-DoD Civilian
B.S., University of California, 1987
M.S., Naval Postgraduate School, 1990
Master of Science in Engineering Science-December 1999
Advisors: Ashok Gopinath, Department of Mechanical Engineering
Thomas J. Hofler, Department of Physics

This thesis describes the design, construction, and testing of a solar thermal powered thermoacoustically driven thermoacoustic refrigerator. This device uses an 18 inch diameter Fresnel lens to concentrate sunlight at 500°C directly onto the hot end of a heat driven prime mover stack, thereby eliminating the need for a hot heat exchanger. The one inch diameter prime mover and refrigerator stacks are located at opposite ends of a 12 inch long half-wave resonator pressurized to six atmospheres absolute with helium and argon, and operating at 600 Hz. The prime mover is capable of producing peak sound pressure levels of up to 5.5% of the resonator's ambient mean pressure, while the refrigerator has produced a maximum of four Watts of cooling power with an ultimate cold temperature of 5°C and a temperature span of 18°C. This refrigerator requires no external power to operate, and uses solar voltaic cells to run electric cooling fans to reject heat from the ambient heat exchangers.

DoD KEY TECHNOLOGY AREA: Environmental Quality

KEYWORDS: Thermoacoustic Refrigerator, Thermoacoustic Prime Mover, Solar Thermal Powered

POSITION ESTIMATION FROM RANGE ONLY MEASUREMENTS

Jason C. Alleyne-Lieutenant, United States Navy
B.S., United States Naval Academy, 1993
Master of Science in Mechanical Engineering-September 2000
Advisor: Anthony J. Healey, Department of Mechanical Engineering

In order for a team of several Automated Underwater Vehicles (AUVs), such as the ARIES, to operate cooperatively, operators require a cost effective position estimation method. Range only measurement

(ROM) position estimation provides this and a means for the AUVs to identify each other's position. Position estimation usually requires at least two range measurements from known points to solve for a vessel's position. However, under certain conditions, one range only measurement can provide a simpler solution. This thesis proves ROM as a viable means of target tracking and position estimation. Determining the accuracy and observability of ROM serve as the primary focus. The ROM model setup and execution are discussed with specific attention given to the details of the Extended Kalman Filter (EKF) and calculations required to determine the system's observability.

DoD KEY TECHNOLOGY AREAS: Sensors, Surface/Under Surface Vehicles-Ships and Watercraft, Modeling and Simulation

KEYWORDS: Autonomous Underwater Vehicles, Unmanned Underwater Vehicles, Robotics, Navigation

EFFECT OF BISMUTH OXIDE AS A LIQUID PHASE SINTERING AID ON THE DENSIFICATION OF ALUMINA POWDER

Arlen E. Aspenson-Lieutenant, United States Navy
B.S., United States Naval Academy, 1993
Master of Science in Mechanical Engineering-March 2000
Advisors: Indranath Dutta, Department of Mechanical Engineering
Ashok Gopinath, Department of Mechanical Engineering

The effect of a liquid forming additive on the densification of ceramic powders is studied. A suitable model system of Al_2O_3-Bi_2O_3 is chosen because of favorable properties for liquid phase sintering and its ability to be processed under atmospheric conditions. Samples of solution deagglomerated slip cast powder compacts are prepared and characterized by x-ray diffraction and scanning electron microscopy. Tests to determine the ability of the system to undergo liquid phase sintering are studied. Problems associated with this manufacturing process are identified and recommendations for future studies are suggested.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures, Manufacturing Science and Technology (MS&T)

KEYWORDS: Liquid Phase Sintering, LPS, Alumina, Al_2O_3, Bi_2O_3, Bismuth Oxide, Ceramic Powder Processing, Slip Casting, Sintering Aids

A COMPUTER SIMULATION APPROACH TO THE STUDY OF EFFECTS OF DECK SURFACE COMPLIANCE ON INITIAL IMPACT IMPULSE FORCES IN HUMAN GAIT

David A. Bretz-Lieutenant, United States Navy
B.S., United States Naval Academy, 1993
Master of Science in Mechanical Engineering-March 2000
Advisors: Young W. Kwon, Department of Mechanical Engineering
Robert B. McGhee, Department of Computer Science

The Navy's leadership is looking at improving quality of life and reducing long term health problems through the reduction of knee disorders. One proposal for reducing knee disorders is to install more compliant decking. The goal of this thesis is to develop a computer model of the human gait that estimates the transarticulation forces in the knee during walking on various surfaces. This model can be used to evaluate the reduction of the heel strike forces during walking when deck surface modifications are made. Previous analytical and computer models of the human gait are reviewed. The major contribution of this thesis is a detailed dynamic model of foot-ground interaction during the initial phase of load bearing in human gait.

DoD KEY TECHNOLOGY AREAS: Biomedical, Computing and Software, Manpower, Personnel, and Training, Surface/Under Surface Vehicles - Ships and Watercraft, Modeling and Simulation

KEYWORDS: Human Gait, Computer Model, Simulation, Deck Surface Compliance, Ground Reaction Forces, Dynamics

THE USE OF NEURAL NETWORKS AS A METHOD OF CORRELATING THERMAL FLUID DATA TO PROVIDE USEFUL INFORMATION ON THERMAL SYSTEMS

Thomas J. Cronley-Ensign, United States Navy
B.S., University of Notre Dame, 1999
Master of Science in Mechanical Engineering-June 2000
Advisor: Matthew D. Kelleher, Department of Mechanical Engineering

A study on the use of neural networks as a method of correlating thermal fluid data to provide useful information on thermal systems was conducted using a neural network code package. Two separate thermal fluid systems were analyzed: tube bank data with variable geometries and tube bank boiling data with variable parameters. Both studies show the effectiveness of neural networks as a viable alternative to the current practice of correlating data. This is achieved by displaying a reduction in error, requiring fewer assumptions, and providing an easier method of devising predictions and correlations.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation

KEYWORDS: Neural Networks, Data Correlation, Thermal Systems

COMPUTATIONAL FLUID DYNAMICS PREDICTION OF SUBSONIC AXIS-SYMMETRIC AND TWO-DIMENSIONAL HEATED FREE TURBULENT AIR JETS

Michael D. DeWulf-Lieutenant, United States Navy
B.S., Iowa State University, 1993
Mechanical Engineer-September 2000
Master of Science in Mechanical Engineering-September 2000
Advisor: Knox T. Millsaps, Jr., Department of Mechanical Engineering
Second Readers: Garth V. Hobson, Department of Aeronautics and Astronautics
Arthur Shavit, Department of Mechanical Engineering
Terry R. McNelley, Department of Mechanical Engineering

A study was conducted to evaluate the accuracy of a commercial computational fluid dynamics (CFD) code (CFDRC-ACE+) for predicting incompressible air jet flows with simple geometries. Specifically, the axis-symmetric and two-dimensional heated air-jets were simulated using a standard k-ε turbulence model. These CFD predictions were directly compared to an extensive compilation of experimental data from archive literature. The round jet results indicated that the code over-predicted the velocity-spreading rate by 24% and the temperature-spreading rate by 29%. In addition, the centerline velocity and temperature decay rates were also over-predicted by 21% and 30%, respectively. The geometric and kinematic virtual origins were over-predicted, as well, by approximately 7.5 diameters for the velocity profiles and 10.5 diameters for the temperature profiles. The planar jet simulation was generally closer to experimental data ranges, with an under-prediction of the velocity-spreading rate of approximately 17% with an over-predicted temperature-spreading rate of 12%. The centerline velocity and temperature decay rates were both under-predicted at 22% and 27%, respectively. Again, the geometric and kinematic virtual origins were over-predicted by approximately 7.5 slot heights for the velocity profiles and 10.5 slot heights for the temperature profiles.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Computational Fluid Dynamics (CFD), Eductor, Ejector, Gas Turbine, Exhaust, Axisymmetric Jet, Two-Dimensional Jet, Air Jet, Free Turbulent, Jet

FREQUENCY RESPONSE ANALYSIS OF T-ACS EXPERIMENTAL DATA

Gary G. Elvik-Lieutenant, United States Navy
B.S., University of Oklahoma, 1995
Master of Science in Mechanical Engineering-September 2000
Advisor: Fotis A. Papoulias, Department of Mechanical Engineering

Trial runs of a 1:24 scale model crane ship were conducted in the David Taylor Model Basin. The model's response to regular waves under various ship configurations, crane configurations, sea states and ship headings relative to the incoming waves were recorded. The Response Amplitude Operator (RAO) Program analyzes the frequency responses to controlled, regular waves and generates full-scale RAOs as a prediction of the actual ships response. Accurate generation of these full-scale RAOs enables future prediction, using the principle of linear superposition, of ship motions in an irregular sea to be compared to actual, full-scale trial runs being conducted off the coast of California near Camp Pendleton in September 2000.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles-Ships and Watercraft, Modeling and Simulation

KEYWORDS: Power Spectral Density, PSD, Response Amplitude Operator, RAO

MICROMECHANICAL STUDY OF INTERFACE STRESS IN A FIBER-REINFORCED COMPOSITE UNDER TRANSVERSE LOADING USING BOUNDARY ELEMENT METHOD

Hakan Eren-Lieutenant Junior Grade, Turkish Navy
B.S., Turkish Naval Academy, 1994
Master of Science in Mechanical Engineering-March 2000
Advisor: Young W. Kwon, Department of Mechanical Engineering
Second Reader: Terry R. McNelley, Department of Mechanical Engineering

Composite materials are involving in engineering applications at a growing speed, due to their stiffer, stronger and lighter properties. This growth requires fast and powerful numerical methods like Boundary Element Method (BEM), and Finite Element Method (FEM). BEM has become popular especially in the last decade due to its advantage of requiring less computation time for the same accuracy. The objective of this study is, by using Boundary Element Method, to examine different shapes of reinforcement elements under unit displacement boundary conditions in transversal direction and at perfect interfacial bonding. The stress variations along the interface of the matrix and reinforcing material, effective elastic modulus of composites were studied due to different shapes and different volume fractions of reinforcement elements. These calculations were made for both the internal Representative Volume Element (RVE), and boundary RVE, which are the internal and boundary cells of composite material respectively. Finally, using an appropriate failure criterion, the failures of different shapes were examined and also the effective elastic modulus variations of the shapes during the progress of the failure for both internal and boundary RVE were studied.

DoD KEY TECHNOLOGY AREA: Materials, Processes, and Structures

KEYWORDS : Micro Mechanics, Interface, Boundary Element Method, Debonding

AN APPROACH FOR STUDYING THE CREEP/ SLIDING BEHAVIOR OF PLANAR METAL-SILICON INTERFACE

Ioannis Farsaris-Lieutenant J.G., Hellenic Navy
B.S., Hellenic Naval Academy, 1992
Master of Science in Mechanical Engineering-December 1999
Mechanical Engineer-December 1999
Advisor: Indranath Dutta, Department of Mechanical Engineering

There has been considerable recent interest in interfacial sliding during creep of multi-phase materials. The effect of interfacial creep is crucial for the deformation of metal-matrix composites and thin film systems, where the isostrain condition between the constituent components is often violated. An experimental approach has been developed to investigate the deformation kinetics of planar interfaces, using a double-shear specimen geometry where the interfaces are loaded in shear. In addition to shear stresses, the apparatus is capable of applying normal stresses (tension or compression) on the interface. In the experimental arrangement, the relative displacements of the constituents at the top and bottom of the specimen are measured independently with high precision using a resistance gauge and a capacitance sensor, respectively. The experimental set-up is suitable for both constant displacement-rate and constant-load creep tests, and can be operated up to a temperature of 500°C. In the current study, preliminary creep tests were conducted on planar aluminum-silicon interfaces prepared by diffusion bonding in argon atmosphere at 565°C. During the tests, the interfaces were subjected to nominally constant shear stresses ranging from 0.8-2 MPa, with the test temperatures ranging from 100-200°C. In all cases, the interface was found to slide via a time-dependent relaxation mechanism, indicating the suitability of the proposed test for studying interfacial sliding. Further studies are needed to determine the mechanistic details of interfacial sliding.

DoD KEY TECHNOLOGY AREA: Materials, Processes, and Structures

KEYWORDS: Composite, Planar Interface, Interfacial Sliding, Creep

OPTIMAL FAULT DETECTION AND RESOLUTION DURING MANEUVERING FOR AUTONOMOUS UNDERWATER VEHICLES

Andrew S. Gibbons-Lieutenant, United States Navy
B.S., United States Naval Academy, 1993
Master of Science in Mechanical Engineering-March 2000
Advisor: Anthony J. Healey, Department of Mechanical Engineering

In order to increase robustness, reliability, and mission success rate, autonomous vehicles must detect debilitating system control faults. Prior model-based observer design for 21UUV was analyzed using actual vehicle sensor data. It was shown, based on experimental response, that residual generation during maneuvering was too excessive to detect manually implemented faults. Optimization of vehicle hydrodynamic coefficients in the model significantly decreased maneuvering residuals, but did not allow for adequate fault detection. Kalman filtering techniques were used to improve residual reduction during maneuvering and increase residual generation during fault conditions. Optimization of the Kalman filter's system noise matrix, measurement noise matrix, and input gain scalar multiplier produced fault resolution which allowed for accurate detection of faults of relatively minor magnitude within minimal time constraints.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles - Ships and Watercraft, Modeling and Simulation, Other (Autonomous Systems, Robotics)

KEYWORDS: Autonomous Underwater Vehicles, Robotics, Robust Fault Detection, Reliable Fault Sensitivity, Extended Kalman Filtering, Optimization

IMPACT ANALYSIS OF A BIOMECHANICAL MODEL OF THE HUMAN THORAX

Johannes E. Jolly-Ensign, United States Navy Reserve
B.S.E., Tulane University, 1999
Master of Science in Physics-June 2000
Advisors: Young W. Kwon, Department of Mechanical Engineering
Steven R. Baker, Department of Physics

The biomechanical response of a finite element model of the human thorax and a protective body armor system was studied under impact loading from a projectile. The objective of the study was to create a viable finite element model of the human thorax. This objective was accomplished through the construction of a three-dimensional finite element model in DYNA3D, a finite element analysis program. The model was validated by comparing the results of tests of body armor systems conducted on cadavers to results obtained from finite element analysis. A parametric study was undertaken to determine the essential components of the model. The results from this investigation determined that the path of force propagation from a body armor system to the thorax upon bullet impact is directly through the vest to the sternum and then through the skeleton to the rest of the body. Thus, any parameters that affect the components in this pathway were essential to the model. This included the muscles, their geometries, material properties, and viscosity, as well as the Young's modulus of the sternochondral cartilage and the bones themselves.

DoD KEY TECHNOLOGY AREAS: Clothing, Textiles, and Food, Modeling and Simulation, Other (Biomechanical)

KEYWORDS: Finite Element Analysis, Human Thorax Model, Impact Analysis

QUANTITATIVE ENERGY DISPERSIVE X-RAY SPECTROMETRY USING AN EMISPEC VISION SYSTEM

Carlos A. Kasemodel-Major, Brazilian Air Force
B.S., Instituto Tecnológico de Aeronáutica, Brazil, 1980
Master of Science in Applied Physics-December 1999
Advisors: Alan G. Fox, Department of Mechanical Engineering
James H. Luscombe, Department of Physics
Nagarajan Rajagopalan, Department of Mechanical Engineering

The purpose of this work was to investigate the use of an Emispec Vision System to analyze energy dispersive x-ray spectra (EDS) obtained with the Topcon 002B transmission electron microscope (TEM) in the Materials Science Laboratory at the Naval Postgraduate School.

A series of tests performed with a standard NiO sample revealed that the TEM column and EDS detector were operating in a satisfactory fashion. NiO spectra acquired with different sample tilt-angles were used to test the Emispec software. An improved setup configuration, in which accurate quantification is obtained with the sample at zero tilt-angle, was developed.

Quantification tests performed with TiO_2, Cu-Al_2O_3 and alumina-YAG (with 2.5% TiO_2) samples confirmed the accuracy of the new software setup. Line profiles across the alumina-YAG interfaces were also recorded to verify the performance of the Emispec system for spectrum profile acquisition and to investigate the Ti distribution at the interface of the alumina-YAG heat-treated sample.

DoD KEY TECHNOLOGY AREA: Materials, Processes, and Structures

KEYWORDS: Transmission Electron Microscopy, Energy Dispersive X-Ray Spectra, EDS Quantitative Analysis

RANDOM WAVE ANALYSIS OF SHIP/RAMP/BARGE RESPONSE

Dimitrios Konstantinou-Lieutenant, Hellenic Navy
B.S., Hellenic Naval Academy, 1989
Master of Science in Mechanical Engineering-September 2000
Advisor: Fotis A. Papoulias, Department of Mechanical Engineering

A mathematical model describing the fundamental physics of a ship/ramp/barge system, including a passive isolator, is developed. The model properly accounts for hydrodynamic proximity effects and structural coupling between the bodies. A standard second order model is used, for demonstration purposes, in order to model the frequency response properties of the connecting body.

Parametric studies of the response amplitude operator of the ramp motion are performed for varying wave directions and isolator stiffness and damping. These are utilized for the random wave analysis in standard fully developed seas. The results indicate that rational selection of isolator properties can result in significant reduction of motions and stress levels in the connecting ramp.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles-Ships and Watercraft, Modeling and Simulation

KEYWORDS: Isolator, Hydrodynamic Modeling, Roll On/Roll Off, Random Waves, Response Spectral Analysis

MODELING THE PROGRESSIVE FLOODING CHARACTERISTICS OF THE ARLEIGH BURKE CLASS DESTROYER USING SIMSMART AND EXCEL

Keith S. Kulow-Ensign, United States Navy
B.S., United States Naval Academy, 1999
Master of Science in Mechanical Engineering-June 2000
Advisors: Charles N. Calvano, Department of Mechanical Engineering
Fotis A. Papoulias, Department of Mechanical Engineering

The goal of this thesis is to contribute further to the development of a design tool for the modeling of dynamic progressive flooding in ships. In an earlier thesis, LT Thomas Anderson, USN, modeled a generic, mathematically-describable hull form; in this thesis the work is extended by applying his methods and generating new ones in order to accurately model an actual ship hullform, (the Arleigh Burke (DDG-51)), in a progressive flooding scenario. A secondary goal is to create an organized process, complete with any necessary programs or software, which can be applied to any hullform in the future in order to create a progressive flooding model. These goals contribute to the ultimate goal of creating a viable design tool that will allow the Naval Architect to evaluate the potential of a prototype vessel to withstand damage in a progressive flooding scenario.

DoD KEY TECHNOLOGY AREA: Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Ship Design, Survivability, Flooding

VALIDATION OF LOW OBSERVABLE STACK EDUCTOR DESIGN FOR GAS TURBINE EXHAUST SYSTEMS

Brian D. Lawrence-Lieutenant, United States Navy
B.S., United States Naval Academy, 1994
Master of Science in Mechanical Engineering-June 2000
Advisor: Knox T. Millsaps, Jr., Department of Mechanical Engineering

The performance of several configurations for an enhanced mixing eductor was measured in a one-fifth scale, cold flow facility. All the configurations consisted of 16 high aspect-ratio nozzles. The impact on the exit flow and secondary flow entrainment of several variations was measured. Specifically, the influence of nozzle height on the tendency of the high-speed jets to coalesce was characterized along with

the impact of the mixing tube inlet shape on aerodynamic performance. Also, the entire eductor was placed inside the shroud to ascertain the reduction in secondary flow resulting from the depressed static pressure from the shroud inlet blockage. A qualitative understanding of the flow field into the shroud and mixing tube was obtained from a smoke technique. A total pressure rake was designed and manufactured for more efficiently measuring the exit velocity profile out of the mixing tube. An analysis of the results is provided along with entrainment projections for hot flow.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare, Modeling and Simulation, Other (Signatures)

KEYWORDS: Modeling and Simulation, Gas Turbine Exhaust, Eductors, Mixing, Cold Flow Testing

NUMERICAL STUDY FOR GLOBAL DETECTION OF CRACKS EMBEDDED IN BEAMS

Stephen A. Lipsey-Lieutenant, United States Navy
B.S.M.E., United States Naval Academy, 1994
Master of Science in Mechanical Engineering-December 1999
Advisor: Young W. Kwon, Department of Mechanical Engineering

Damage reduces the flexural stiffness of a structure, thereby altering its dynamic response. Considerable effort has been put into obtaining a correlation between the changes in modal parameters and the location and amount of the damage within the structure. Most numerical research employed elements with reduced beam stiffness to simulate damage in the beam. This approach to damage simulation neglects the non-linear effect that a crack has on the structural dynamic response. In the present study, finite element modeling techniques are utilized to directly represent an embedded crack. The results of the dynamic analysis of the present model are then compared to the results of the dynamic analysis of the reduced modulus finite element model. Different modal parameters are investigated to determine the most sensitive indicator of damage and its location. Nonlinear effects, such as crack closure and opening, of an embedded crack on the structural dynamic response were also studied from transient nonlinear analysis. The modeling technique is then applied to sandwich composite beams with simulated delamination to investigate damage detection techniques through the use of damping caused by frictional dissipation of energy on the crack surface.

DOD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures, Modeling and Simulation

KEYWORDS: Finite Element Analysis, Modal Analysis, Non-destructive Damage Detection, Composite Materials

ACOUSTICALLY FORCED HEAT TRANSFER FROM A TUBE BANK

Gabriel A. Lowe-Ensign, United States Navy
B.S., United States Naval Academy, 1999
Master of Science in Mechanical Engineering-June 2000
Advisor: Ashok Gopinath, Department of Mechanical Engineering

Experimental work was carried out on the steady state heat transfer behavior from a tube bank in a zero mean oscillatory flow. The oscillatory flow across the tube bank was created by an acoustic field inside an isolated resonant chamber. The tube bank was represented by smooth walled cylinders placed parallel to each other, with their plane normal to the direction of fluid oscillation, similar to the arrangement found in many heat exchangers. The spacing between the cylinders was varied to examine the effects of boundary layer interference on the heat transfer behavior . Heat transfer correlations were developed in the form of Nusselt number as a function of the streaming Reynolds number for each tube spacing. This experimental study is relevant to the design of heat exchangers for thermoacoustic engines.

DoD KEY TECHNOLOGY AREAS: Electronics, Manufacturing, Science, and Technology (MS&T)

KEYWORDS: Thermoacoustic Engines, Heat Exchangers, Oscillatory Flows, Heat Transfer, Tube Bank

FORMATION CONTROL FOR MULTI-VEHICLE ROBOTIC MINESWEEPING

Peter M. Ludwig-Lieutenant, United States Navy
B.A., Tulane University, 1993
Master of Science in Mechanical Engineering-June 2000
Advisor: Anthony J. Healey, Department of Mechanical Engineering

Current methods of minefield reconnaissance and clearance operations prove to be tedious, time consuming, expensive, and dangerous. In an effort to find an effective low cost solution, the U.S. Navy is considering using fleets of robotic underwater vehicles equipped with detection sensors and/or magnetic and acoustic minesweeping devices. To ensure maximum sweeping of the minefield, all vehicle movements are coordinated through a supervisor vehicle. Here, a computer simulation was conducted using a lawnmower minesweeping pattern. As the minefield is swept, vehicles are lost to mine detonations and the supervisor re-tasks all remaining vehicles. The algorithm for track control and vehicle reconfiguration was studied and evaluated.

DoD KEY TECHNOLOGY AREAS: Sensors, Surface/Under Surface Vehicles - Ships and Watercraft, Modeling and Simulation, Other (Minesweeping)

KEYWORDS: Autonomous Underwater Vehicles, Unmanned Underwater Vehicles, Robotics, Minesweeping

PROPAGATION OF FIRE GENERATED SMOKE IN SHIPBOARD SPACES

Michael D. Mehls-Lieutenant, United States Navy
B.S. United States Naval Academy, 1992
Master of Science in Mechanical Engineering-March 2000
Advisors: Matthew D. Kelleher, Department of Mechanical Engineering
Terry R. McNelley, Department of Mechanical Engineering

The propagation of fire generated smoke into a shipboard space has been computationally modeled using a commercial code generated by Computational Fluid Dynamics Research Corporation (CFDRC). This study was based on space 01-163-2-L of an Arleigh Burke Class Flight IIA Destroyer. However, with changes, the model can be reconfigured to represent other shipboard spaces. Multiple smoke scenarios are applied to the space. For all scenarios, the inlet used is forward water tight door. Smoke enters the upper half of the door, while air enters through the bottom half. The temperature of the inlet fluids is altered to observe its effect on propagation. In the last scenario, the floor temperature is isothermally held at 1200 K to simulate a fire in the space below. The results of this scenario shows that extreme temperatures of adjacent spaces has minimal effect on propagation. The overall goal of this study is to show how computational methods can be used to model propagation of smoke in shipboard spaces.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Convection, Smoke Modeling, Computational Fluid Dynamics

OSCILLATING FLOW ABOUT PERFORATED CYLINDERS

David B. Osgood-Lieutenant Commander, United States Navy
B.S.E.E., University of South Florida, 1986
Master of Science in Mechanical Engineering-September 2000
Advisor: Turgut Sarpkaya, Department of Mechanical Engineering

Circular cylinders of various sizes and perforations were subjected to sinusoidally-oscillating flow in a large U-shaped water tunnel. The force-transfer coefficients (drag and inertia) were determined in the range of Keulegan-Carpenter numbers (K) from about 1 to 40. The results have shown that the effect of the perforations is to decrease the inertia coefficient and to increase the drag coefficient. Thus, perforated cylinders are very efficient dampers and could be used in increasing the damping of cables and large structures in the ocean environment.

DoD KEY TECHNOLOGY AREAS: Sensors, Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Oscillating Flow, Perforation, Cylinder, Damping, Cable, Marine Hydrodynamics

ACTIVE VIBRATION CONTROL METHOD FOR SPACE TRUSS USING PIEZOELECTRIC ACTUATORS AND FINITE ELEMENTS

Carey M. Pantling-Lieutenant, United States Navy
B.S.A.E., University of Florida, 1993
Master of Science in Mechanical Engineering-December 1999
Master of Science in Astronautical Engineering-December 1999
Advisors: Young S. Shin, Department of Mechanical Engineering
Brij N. Agrawal, Department of Aeronautics and Astronautics

This thesis created an analytical model for active vibration control of the NPS space truss using ANSYS. The NPS space truss is a 3.7-meter long truss that simulates a space-borne appendage with sensitive equipment at its extremities. With the use of a dSPACE data acquisition and processing system, quartz force transducer and piezoelectric actuator, active controls using an integral plus double integral control law were used to damp out the vibrations caused by a linear proof mass actuator. Vibration reductions on the order of 15-20 dB were obtained with experiment.

The ANSYS finite element model used SOLID5 elements to model the piezoelectric characteristics and ANSYS Parametric Design Language to provide for an iterative approach to an active controls analysis. Comparative data runs were performed with the ANSYS model to determine its similarity to experiment. The analytical model produced power reductions of 18-22 dB, demonstrating the ability to model the control authority with a finite element model. This technique can be used and modified to enhance its flexibility to many types of controls and vibration reduction applications. An analytical model for active control of the NPS space truss using MATLAB/Simulink was also developed as an alternative to the ANSYS model.

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Materials, Processes and Structures, Modeling and Simulation

KEYWORDS: Active Vibration Control, Piezoceramic Actuators, ANSYS, Finite Element Method

AN EXPERIMENTAL APPROACH FOR STUDYING CREEP BEHAVIOR OF MODEL PLANAR INTERFACES

Keith A. Peterson-Lieutenant, United States Navy
B.S., Florida Institute of Technology, June 1990
Mechanical Engineer-June 2000
Master of Science in Mechanical Engineering-June 2000
Advisor: Indranath Dutta, Department of Mechanical Engineering

An apparatus for measuring the steady state creep behavior of interfaces in aluminum-silicon-aluminum multilayered specimens has been assembled. In the experiment scheme, a double-shear specimen geometry was used to load the interfaces in a state of nominally constant shear. The deformation kinetics for interfacial sliding during constant shear stress creep experiments were measured for various applied interfacial shear stress levels and temperatures. Interfacial shear strain rates were measured using displacement and capacitance gauges. The planar interfaces between the aluminum and silicon layers were prepared by diffusion bonding. Preliminary results indicate that that interfacial sliding occurs via time-dependent relaxation mechanisms and that there is a threshold stress for interfacial sliding, in agreement with previous work on lead-Quartz and lead-nickel interfaces. The preliminary values obtained for the activation energy for interfacial sliding in this aluminum-silicon-aluminum multilayered system is low (~30KJ/mol), and is believed to be due to interfacial diffusion of aluminum atoms. In general, the activation energy is thought to be dependent on the structure and chemistry of the interface.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures, Electronics

KEYWORDS: Interface Sliding, Diffusion Bonding, and Creep

EXPERIMENTAL INVESTIGATION OF SINKING A BUOYANT BODY IN WATER WITH BUBBLES

Leonard B. Pringle-Lieutenant Commander, United States Navy
B.E., Royal Military College of Canada, 1991
Master of Science in Applied Physics-June 2000
Advisors: Bruce Denardo, Department of Physics
Ashok Gopinath, Department of Mechanical Engineering

The introduction of gas bubbles into a liquid decreases the average density, and thus decreases the buoyant force on a floating body. This thesis investigates the critical average density required to sink a buoyant body in water with rising bubbles. A volume of bubbly water is created in a clear acrylic tube of inner diameter 30 cm and height 60 cm, that is closed at the bottom and open at the top. An array of diffusers at the bottom produces 2 mm diameter bubbles that are uniform over the cross section of the tube. A 10-cm diameter hollow steel ball whose average density is varied from 0.70 to 0.99 g/cm^3 is employed as the buoyant body. A theory of the critical density for sinking is developed, and predicts that the average fluid density is greater than the ball density for sinking. The experimental data, which include a quantitative error analysis, agree well with the theory for average ball densities from 0.94 to 0.99 g/cm^3, but show a definite trend of fluid densities that are smaller than those predicted for ball densities varying from 0.70 to 0.94 g/cm^3.

DoD KEY TECHNOLOGY AREA: Other (Fluid Dynamics)

KEYWORDS: Water, Density, Specific Gravity, Volume Fraction, Bubbles, Buoyancy, Nonnewtonian Fluid

THE ROLE OF VISCOUS FINGERING IN THE SEPARATION MECHANICS OF THIN INTERFACIAL LIQUID LAYERS

Christopher H. Rehkop-Lieutenant, United States Navy
B.S., Pennsylvania State University, 1993
Master of Science in Mechanical Engineering-March 2000
Advisor: Ashok Gopinath, Department of Mechanical Engineering

The mechanics of separation of a thin interfacial liquid layer trapped between two parallel surfaces was studied in a controlled manner. Different liquid viscosities, layer thicknesses and separation velocities were used to investigate the extensional behavior and determine its dependence on viscous fingering, and capillary number. Force, displacement and time data have been recorded for all experimental runs. Qualitative visual data have also been recorded to corroborate the trends in the onset of viscous fingering based on a simple interfacial stability analysis. The quantitative data has been used to generate force-displacement plots of the separation. The results of this work provide useful fundamental insight into the mechanics of this novel problem.

DoD KEY TECHNOLOGY AREAS: Material, Processes, and Structures, Other (Civil Engineering)

KEYWORDS: Thin Interfacial Liquid Layers, Capillary Number, Surface Tension, Viscous Fingering, Saffman Instability, Hele-Shaw Flow

SIMULATION AND ANALYSIS OF PROGRESSIVE FLOODING IN A DDG 51 FLT IIA DESTROYER USING SIMSMART AND EXCEL SOFTWARE

David C. Ruley-Lieutenant Commander, United States Navy
B.Eng., State University of New York, 1989
Master of Science in Mechanical Engineering-September 2000
Advisor: Charles N. Calvano, Department of Mechanical Engineering

Progressive flooding, if unchecked, can sink or mission kill even heavily compartmented naval ships. The designed watertight integrity and floodable length is negated by water intrusion into adjacent compartments through battle damage or material disrepair. This thesis uses a program set combining AHT Corporation's SIMSMART fluid flow analysis program with NPS-PF, a Microsoft Excel workbook, to analyze the effects of progressive flooding on the DDG 51 FLT IIA class of destroyers. The DDG 51 dewatering system is modeled using icons from the standard SIMSMART library, as well as USN-unique icons created in the course of this thesis. Multiple scenarios are run and analyzed simulating realistic progressive flooding due to gunfire, anti-ship missile hits and mine strikes. The program set is designed to enable total ship system engineers to model prototype ship designs and test their survivability in a wide range of realistic progressive flooding scenarios. Simulation results would aid in the determination of compartmentation, bulkhead spacing, dewatering system capacity and quantity of portable dewatering equipment.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles-Ships and Watercraft, Modeling and Simulation

KEYWORDS: Flooding, Progressive Flooding, Fluid Flow Analysis, Naval Architecture, Ship Damage, Damage Stability, DDG 51, Excel, SIMSMART

EFFECT OF WATER DEPTH ON THE UNDERWATER WET WELDING OF FERRITIC STEELS USING AUSTENITIC Ni-BASED ALLOY ELECTRODES

Brian J. Sheakley-Lieutenant, United States Navy
B.S., Illinois Institute of Technology, 1994
Master of Science in Mechanical Engineering-September 2000
Advisor: Alan G. Fox, Department of Mechanical Engineering

Underwater welding using shielded metal arc welding (SMAW) on U.S. Naval Vessels is very attractive because of the ability to effect repairs without costly dry dock expenses. In the past the primary problems with underwater wet weldments on steels utilizing SMAW with ferritic electrodes, were underbead cracking in the heat affected zone (HAZ), slag inclusions, oxide inclusions, and porosity.

To avoid underbead cracking three weld samples were made using an austenitic nickel weld metal with an Oxylance coating at 10 feet of salt water, 25 feet of salt water, and 33 feet of salt water. A final sample was made using austenitic nickel weld metal with a Broco coating at 33 feet of salt water. Because of the ductility of the austenitic nickel weld metal no underbead cracking occurred, however porosity and high inclusion counts were found in all four samples. The average size of the inclusion increased with increasing depth. The Broco sample exhibited far greater porosity than did the Oxylance samples.

This work addresses quality of the welds, mechanisms for the formation of the inclusions, and analysis of the difference between the Oxylance and Broco weld rods.

DoD KEY TECHNOLOGY AREA: Materials, Processes, and Structures

KEYWORDS: Underwater Wet Welding, Non-Metallic Inclusions, Shielded Metal Arc Welding

FACTORS AFFECTING THE STRENGTH AND TOUGHNESS OF ULTRA-LOW CARBON STEEL WELD METAL

Jonathon J. Van Slyke-Lieutenant, United States Navy
B.S., University of Idaho, 1993
Mechanical Engineer-December 1999
Master of Science in Mechanical Engineering-December 1999
Advisor: Alan G. Fox, Department of Mechanical Engineering

The factors that affect strength and toughness of ten ultra-low carbon steel weld samples (HSLA-80 and HSLA-100), welded using the gas metal arc welding (GMAW) process and new ultra-low carbon consumable electrodes, were studied. The analysis was confined only to the weld metal, and the base metal was not considered. Analysis methods included optical microscopy, scanning electron microscopy, and transmission electron microscopy. Energy dispersive x-ray analysis was performed in the transmission electron microscope to analyze the chemical composition of non-metallic inclusions.

The microstructure was found to be primarily granular ferrite with some primary ferrite, bainite, and martensite. Very little acicular ferrite was found (< 18 %). Because of this, to get the best mechanical properties in the weld, the size and volume fraction of non-metallic inclusions needs to be minimized. This can be accomplished by minimizing the amount of oxygen while increasing the amount of titanium and aluminum in the weld metal.

EDX analysis revealed that the non-metallic inclusions were multi-phase particles with two predominant phases: a TiO-MnO phase and a $MnO\text{-}SiO_2\text{-}Al_2O_3$ phase. Copper-sulfide caps were also found on the surface of some inclusions. This inclusion chemistry is typical of what is found in welding HSLA steel.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Training, Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: HSLA-80, HSLA-100, Gas Metal Arc Welding, Ultra-Low Carbon Steel, Non-Metallic Inclusions

REAL TIME COMPUTATION OF THE DELIVERY ACCURACY FOR AIR LAUNCHED UNGUIDED WEAPONS

Thadeous C. Smith-Lieutenant, United States Navy
B.S., University of Arizona, 1994
Master of Science in Mechanical Engineering-September 2000
Advisor: Morris Driels, Department of Mechanical Engineering

In order to calculate the probability of damaging a ground target with air launched weapons, it is necessary to know the accuracy of the weapon that is used. At present, these accuracies are only tabulated for a few, specific delivery conditions. The thesis objective was to develop a methodology capable of generating real time delivery accuracy data estimated from user supplied release conditions.

The methodology was developed by studying the theory for accuracy measures, weapon delivery, and an error budget analysis. The accuracy measures include the desired mean point of impact, range error probable, deflection error probable, and the circular error probable. The weapon delivery includes the aircraft release maneuver, ballistic trajectory of unguided weapons, mode, and mechanization. The error budget analysis includes the derivation and explanation of 49 sensitivity equations that contribute to the delivery accuracy. The theory was implemented using Microsoft Excel and Visual Basic for Applications to compute the error budget and run a high fidelity trajectory program for the weapon delivery.

This real time data generation tool was developed as a component for future integration into the Joint Munitions Effectiveness Manual (JMEM) Air-to-Surface Weaponeering System (JAWS) and to provide a reference media for future work in the weaponeering field.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Conventional Weapons, Modeling and Simulation

KEYWORDS: Delivery Accuracy, Weapon Accuracy, JMEM

THE EXPERIMENTAL EVALUATION OF A DGPS BASED NAVIGATIONAL SUITE IN THE ARIES AUV

Benjamin M. Stinespring-Ensign, United States Navy
B.S., United States Naval Academy, 1999
Master of Science in Mechanical Engineering-June 2000
Advisor: Anthony J. Healey, Department of Mechanical Engineering

Autonomous Underwater Vehicles (AUV) currently use varying methods for navigation, but incorporating GPS into those methods is becoming a popular technique. This thesis experimentally evaluates the configuration and implementation of the Navigational Suite within the Naval Postgraduate School's AUV, the Acoustic Radio Interactive Exploratory Server (ARIES). Specific attention is given to the configuration of the vehicle's newly completed Differential Global Positioning System (DGPS). A brief discussion of DGPS and Extended Kalman Filter theory continues with a description of the make-up and applications of components within the Suite. Details of a series of experiments, which begins with evaluation of the DGPS setup, then qualifies the system in an open-water environment, and finally qualifies the DGPS in conjunction with newly configured ARIES Navigational Filter, provide an examination of the Suite's performance.

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications, Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Autonomous Underwater Vehicles, Differential Global Positioning System, Extended Kalman Filtering, Underwater Navigation, Robotics

APPLICATIONS OF ARBITRARY LAGRANGIAN EULERIAN ANALYSIS APPROACH TO UNDERWATER AND AIR EXPLOSION PROBLEMS

Theodore Trevino-Lieutenant, United States Navy
B.S., University of Arizona, 1991
Master of Science in Mechanical Engineering-September 2000
Advisor: Young S. Shin, Department of Mechanical Engineering

A series of underwater and air explosion investigations was conducted using the Arbitrary Lagrangian-Eulerian (ALE) numerical technique. The investigation primarily examined the explosive-fluid, fluid-structure, and fluid-air interaction effects, and the shock wave pressure propagation through a subjected medium, with the intent of verifying and validating the ALE analysis. The research also noted the explosive-air and air-structure interaction effects as well as shock wave pressure propagation effects. Three-dimensional underwater explosion analyses was conducted using TNT detonations. Two-dimensional air explosion analyses was completed using TNT detonations. With viable ALE results, underwater and air explosion modeling and simulation could become dependable, cost-effective, and time-efficient.

DoD KEY TECHNOLOGY AREAS: Conventional Weapons, Materials, Processes, and Structures, Surface/Under Surface Vehicles-Ships and Watercraft, Modeling and Simulation

KEYWORDS: Underwater Explosion, Air Explosion, Arbitrary Lagrangian-Eulerian Analysis

PROPAGATION OF FIRE GENERATED SMOKE AND HEAT TRANSFER IN SHIPBOARD SPACES WITH A HEAT SOURCE

Billy J. Vegara-Lieutenant, United States Navy
B.S., Southern University and A&M College, 1992
Master of Science in Mechanical Engineering-September 2000
Advisor: Matthew D. Kelleher, Department of Mechanical Engineering

The propagation of fire generated smoke and heat transfer into a shipboard space has been computationally modeled using a commercial code generated by Computational Fluid Dynamics Research Corporation (CFDRC). The space modeled was 1-158-1-L of an Arleigh Burke Class Flight IIA Destroyer. Three smoke and heat scenarios are applied to the space. For all three scenarios, the inlet used is the forward, inboard watertight door. Smoke enters the upper half of the door, while air enters through the bottom half. The temperature of the inlet fluids is altered to observe its effect on propagation. In the last scenario, the floor temperature is isothermally held at 1200 K to simulate a fire in the space below. The results of this scenario show that extreme temperatures of adjacent spaces has minimal effect on propagation. The overall goal of this study is to show how computational methods can be used to model propagation of smoke in shipboard spaces.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation, Other (Damage Control)

KEYWORDS: Convection, Smoke Modeling, Computational Fluid Dynamics

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