TOTAL SHIP SYSTEMS ENGINEERING (TSSE) IN SUPPORT OF NAVSEA CONTRACT DESIGN

Charles N. Calvano, Professor (Department of Mechanical Engineering)
Associate Professor Fotis Papoulias (Department of Mechanical Engineering)
Associate Professor Robert C. Harney (Department of Systems Engineering)
Sponsor: Naval Sea Systems Command, SEA 05D

Project Description: This program is intended to support the ongoing Total Ship Systems Engineering program, which, in turn, works with and supports NAVSEA and NAVSEA activities in the performance of ship concept design studies and in the evaluation of ship designs. In addition to the general areas of effort described in the associated MOA (copy attached), the 2002 effort will include examination of the potential role and utility of a Joint Command and Control Ship, such as that currently being considered by the JCC(X) program office. TSSE and other campus design projects which TSSE supports will include examination of the capabilities and potential contributions of the JCC(X) to the expeditionary warfare cross discipline problem. Work done as part of this program will support student design education and be used to ensure classroom material continues to be relevant to ongoing Navy ship-related technology developments.

Keywords: Systems Engineering, Ship Design, Design Evaluation, Effectiveness Assessment.

DOD Key Technology Areas: Other.

PUBLICATIONS

TECHNICAL REPORT:
Calvano, C. N.; John Philip, Systems Engineering in an Age of Complexity, accepted for publication by "Systems Engineering", the Journal of the

JMEM AIR TO SURFACE TASKS 3,8,16

Morris Driels, Professor
Department of Mechanical Engineering
Sponsors: JTCG –Eglin AFB, US Naval Postgraduate School (DFR)

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

SUMMARY: This continuing task completed a major milestone in 2002 by delivering the prototype Joint Delivery Accuracy Program (JDAP) to the sponsors. This product will now be integrated by the contractor into JAWS version 2.3 due for release in July 2003.

PUBLICATION: None

CONFERENCE PRESENTATION: None

THESES DIRECTED: None

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Bombing accuracy, Weaponeering.

THE ACQUIRE MODEL AND ITS APPLICATION TO THE MOUT ENVIRONMENT

Morris Driels, Professor
Department of Mechanical Engineering
Sponsors: TRAC-Monterey (WSMR)

OBJECTIVE: Review Army target acquisition methodologies applying to MOUT

SUMMARY: This project focused on the applicability of the US Army's standard target acquisition model Acquire to a MOUT environment. A literature review revealed that it could be used with some minor modifications, and limiting constraints.

PUBLICATION: None

CONFERENCE PRESENTATION: None

THESES DIRECTED:
Target Acquisition Model for Military Operations in Urban Terrain – David Neal, MSME March 2002.

DoD KEY TECHNOLOGY AREA: CS

KEYWORDS: Target acquisition, MOUT, combat modeling.

INTERFACIAL SLIDING IN MULTI-COMPONENT SYSTEMS

Principal Investigator : I. Dutta
Department of Mechanical Engineering
Sponsor : National Science Foundation (NSF)

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 tempertaures. A combination of experimental and analytical means are being utilized to investigate the kinetics of interfacial sliding and its effect on thin film systems.

JOURNAL PAPERS:
K. A. Peterson, I. Dutta and M.W. Chen, "Measurement of Creep Kinetics at Al-Si Interfaces", Scripta Mater., 47 (2002) p. 649.

K. A. Peterson, I. Dutta and M.W. Chen, "Processing and Characterization of Diffusion Bonded Aluminum-Silicon Interfaces", J. Mater. Proc. Tech., in press (accepted November 2002).

K. A. Peterson, I. Dutta and C. Park, "Interfacial Creep in Multi-Component Material Systems", J. Metals, Minerals and Materials Soc. (JOM), 55, no. 1 (2003) pp. 37-43.

K. A. Peterson, I. Dutta and M.W. Chen, "Diffusionally Accommodated Interfacial Sliding in Metal-Silicon Systems", Acta Mater., in press (accepted Dec. 2002).

C. Park and I. Dutta, "An Environmentally Protected Hot-Stage Atomic Force Microscope for Studying Deformation in Microelectronic Device Structures", in review (Rev. Sci. Instrum.).

CONFERENCE PAPERS:
I. Dutta, K. Peterson and M.W. Chen, "Plasticity and Interfacial Sliding in Cu Thin Film:Si Substrate Systems During Thermal Cycling", in Plasticity, Damage and Fracture at Macro, Micro and Nano Scales, A.S. Khan and O. Lopez-Pamies, eds., Proc. Ninth International Symposium on Plasticity, NEAT Press, 2002, pp. 117-119.

K. A. Peterson, C. Park and I. Dutta, "Interfacial Sliding in Back-End Interconnect Structures in Microelectronic Devices", Silicon Materials - Processing, Characterization and Reliability, J. Veteran, D.L. O' Meara, V. Misra, P. Ho, eds., Proc. MRS Symp., MRS, vol. 716, 2002, p. 483.

CONFERENCE PRESENTATIONS :
I. Dutta, K. A. Peterson and M.W. Chen, "Interfacial Sliding in Multi-Component Materials Systems and Its Mechanism", Modelling the Performance of Engineering Structural Materials III, T. S. Srivastan, D.R. Leseur and E.M. Taleff, eds., 2002, TMS, pp. 253-267 (invited).

THESES DIRECTED:
Keith Peterson, "Interfacial Creep in Multi-Material Systems", PhD dissertation, Sept. 2002.

M. Thornell, "A Methodology for Studying Interfacial Creep at Thin Film/Silicon Interfaces", MS thesis, Dec. 2002 (final thesis submission still pending).

DoD KEY TECHNOLOGY AREA: Materials, Processes and Structures

KEYWORDS: Composite, Multi-layers, Thin Films, Creep, Interfacial Sliding

THERMO-MECHANICAL BEHAVIOR OF SOLDER JOINTS FOR ELECTRONIC PACKAGING

Principal Investigator: I. Dutta
Department of Mechanical Engineering
Sponsors: (1) National Science Foundation (NSF)
(2) Semiconductor Research Corporation (SRC)
(3) INTEL Corporation

OBJECTIVE: To obtain a mechanistic understanding of the relationship between microstructural 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 micrsotructural coarsening on the plastic strain state in a solder joint during thermo-mechanical cycling.

THESES DIRECTED:
N. Anastasio, Development of an Impression Creep Apparatus for Testing Lead-Free Microelectronic Solder Joints, M.S. thesis, June 2002.

E. Crocker, Microstructure and Creep of Pb-free Ball Grid Array Solder Joints, M.S. thesis, expected June 2003.

M. Phaneuf, Impression Creep testing of Lead-Free Microelectronic Solder Balls, Engineer's degree thesis, expected Dec. 2003.

JOURNAL PAPERS:
I. Dutta, A. Gopinath and C. Marshall, "Underfill Constraint effects during Thermo-Mechanical Cycling of Flip Chip Solder Joints", J. Electronic Mater., 31 (2002) p. 253.

I. Dutta, "A Constitutive Model for Creep of Lead-Free Solders Undergoing In-situ Microstructural Coarsening: A First Report", J. Electronic Mater., 32, in press (to appear in April 2003; accepted October 2002).

CONFERENCE PAPERS:
I. Dutta, C. Park and S. Choi, "Creep and Microstructural Coarsening in Lead-Free Microelectronic Solder Joints" to appear in Proc. InterPACK 2003 (Intl. Electronic Packaging Technology Conference, Maui, Hawaii, July 2003).

J.E. Dunne, V. E. Smith, A. Gopinath and I. Dutta, "Modeling the Effects of Cycling of a Localized Heat Source on the Durability of a FCOC with Defects", Proc. 52nd Electron. Comp. Tech. Conf. (ECTC-IEEE), 2002, p. 622.

CONFERENCE PRESENTATIONS:
I. Dutta, S. Choi and N. Anastasio, "Microstructural Coarsening and Creep Response of Microelectronic Solder Joints", Symp. on Lead Bearing and Lead-Free Solders, 2002 TMS Fall Meeting, Columbus, Ohio, Oct. 6-10, 2002. (INVITED)

DoD KEY TECHNOLOGY AREA: Materials, Processes and Structures

KEYWORDS: Electronic Packaging, Solder, Thermal Cycling, Deformation.

DEVELOPMENT OF SMART MICROELECTRONIC SOLDER JOINTS FOR MICROELECTRONIC PACKAGING

Principal Investigator: I. Dutta
Department of Mechanical Engineering
Sponsor: Army Research Office (ARO)

OBJECTIVE: To develop smart, adaptive solder joints for high-end microprocessor packaging applications in advanced military and commercial sectors.

SUMMARY: Flip Chip solder joints in electronic packaging applications are subjected to extreme thermo-mechanical conditions during many high-end defense and commercial applications. 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 develop a new generation of smart solders, which take advantage of the shape-memory effect of reinforcements to internally actuate themselves to reduce internal strain concentrations and thereby enhance joint and package life.

THESES DIRECTED:
W. Wright, Processing and Characterization of Smart Lead-free Solder Joints, M.S. thesis, expected September 2003.

S. Horton, Micro-mechanics of Smart Solder Joints during Thermo-mechanical Cycling, M.S. thesis, expected September 2003.

JOURNAL PAPERS: None

CONFERENCE PAPERS: None

CONFERENCE PRESENTATIONS:
I. Dutta, B.S. Majumdar, S. Choi and W. Wright, "A Strategy for Producing Adaptive Lead-Free Solder Joints Via Shape-Memory Alloy Reinforcement of Solder Alloys", presented at the 132nd TMS Annual Meeting, March 3-6, 2003. (INVITED)

DoD KEY TECHNOLOGY AREA: Materials, Processes and Structures

KEYWORDS: Electronic Packaging, Solder, Thermal Cycling, Deformation

TURBINE CONVECTIVE COOLING CONCEPTS EVALUATION

Ashok Gopinath, Associate Professor
Department of Mechanical Engineering
Sponsor: NAVAIR/NAWC & DARPA

OBJECTIVE: To provide support and validatory analyses of ongoing work in a new MEMs-based micro-heat exchanger turbine cooling concept.

SUMMARY: This project is a continuation from FY-2001. The primary thrust of the project was to develop a multi-physics computational analysis of the proposed heat exchanger design. The micro- heat exchanger is based on the concept of the use of pin fins in the narrow gap of a shroud enclosed turbine blade to obtain a large volumetric density of heat transfer area. A finite element numerical analysis based on the package ANSYS has been initiated to predict the flow and heat transfer characteristics of such a micro pin fin heat exchanger. In such a short pin fin enclosed array configuration, both the pins and the end wall make substantial contributions to the heat transfer, which need to be identified. For the small pin fin size relative to the blade radius of curvature, a planar model was assumed and a fully three dimensional numerical analysis was carried out of a staggered array configuration. Various streamwise and spanwise pin fin spacings were used to determine both row-averaged and array-averaged heat transfer coefficients for the heat exchanger. A range of flow Reynolds numbers was covered and different turbulence models were evaluated and the results corroborated with available experimental data in the literature. The heat transfer performance was compared with overall pressure drop characteristics to predict an optimal configuration. An experimental phase of the project was also commenced and will continue into FY-2003.

PUBLICATIONS:

Hamilton, L. J., Adametz, D. S., Lind, E. K. and Gopinath, A., "Numerical Analysis of the Performance of a Staggered Cross-Pin Array Heat Exchanger," *8th AIAA/ASME Joint Thermophysics and Heat Transfer Conference*, St. Louis, MO, 24-26 June 2002.

Hamilton, L. J., and Gopinath, A., "Numerical Analysis of the Performance of a Staggered Cross-Pin Array Heat Exchanger," *Turbine Engine Technology Symposium*, Dayton, OH, 9-12 September 2002.

THESES DIRECTED:

Lind, E. K., "Analysis of Turbulence Models in a Cross Flow Pin Fin Micro-Heat Exchanger," Master's Thesis, Naval Postgraduate School, June 2002.

DoD KEY TECHNOLOGY AREA: Aerospace Propulsion & Power

KEYWORDS: Pin-Fin Array, Compact Heat Exchanger, Micro Heat Exchanger, Turbine Blade Cooling

THERMOPHOTOVOLTAIC (TPV) POWER CONVERSION

Ashok Gopinath, Associate Professor
Department of Mechanical Engineering
Sponsor: Currently None

OBJECTIVE: To model the large radiative energy transfer rates in Micro-TPV devices and to carry out a design study of the parameters that influence its performance.

SUMMARY: TPV technology is of great interest to Naval Reactors as a potential solution for direct energy conversion for submarine propulsion in the future. The device works by transfer of thermal energy by radiation from a high temperature emitter to a semiconductor collector placed in close proximity in which it is converted to electrical energy. When the gap between emitter and collector in a TPV device is of the order of the wavelength of radiation, the now so-called Micro-TPV device can yield very large power densities. In this project a Micro-TPV device based on an InGaAs collector was modeled to determine the radiative transfer rates from emitter to collector, as well as the resulting electrical power density and efficiency. Different emitter materials and temperatures, various collector band gap levels, and a range of

(micron and sub-micron) level spacings between emitter and collector surfaces were considered. The results have been presented in numerical and graphical form for a wide ranging parameter space and could help the device designer in making an optimal choice of operating conditions. In particular, it was found that among the metals, tungsten and rhenium are superior emitter materials, although silicon carbide can exceed their performance for gap spacing levels limited by current technology. However if advances in spacing control technology make smaller (sub-micron) gaps feasible, rhenium emitter devices could provide a significant increase in power density (10–100 W/cm^2), with efficiencies as high as 20 %. In CY-2003 an experimental phase of the project under the sponsorship of Naval Reactors will commence to demonstrate suitable techniques for back-end cooling of high power density MTPV devices.

PUBLICATIONS:
Bierley, J. M., and Gopinath, A., "A Parametric Design Study of InGaAs MTPV Cells Coupled to Various Emitters at Near and Far Spacings," *The Fifth International Conference on Thermophotovoltaic Generation of Electricity*, Rome, Italy, 15-19 September 2002.

THESES DIRECTED:
Bierley, J. M., "A Parametric Design Study of InGaAs MTPV Cells Coupled to Various Emitters at Near and Far Spacings," Master's Thesis, Naval Postgraduate School, March 2002.

DoD KEY TECHNOLOGY AREA: Propulsion & Power (Nuclear)

KEYWORDS: Thermophotovolatic (TPV), Micro-TPV, Emitter, Collector, Receiver, Radiation, Quantum Efficiency, Fill Factor, Dark Current, Power Density.

MODELING OF HEAT TRANSFER IN A ROCKET ENGINE COMBUSTION CHAMBER

Ashok Gopinath, Associate Professor
Department of Mechanical Engineering
Sponsor: AFRL (PI: Chris Brophy of Code AA)

OBJECTIVE: To model the large radiative energy transfer rates in Micro-TPV devices and to carry out a design study of the parameters that influence its performance.

SUMMARY: A numerical study was conducted to predict the combined convective and radiative heat transfer rates on the walls of a small aspect ratio cylinder representative of the scaled model of a rocket engine combustion chamber. A high-temperature, high-pressure environment was simulated in the cylinder, with gas velocities at low subsonic levels typical of the conditions leading to the entrance of the nozzle section of a rocket engine. The composition of the gases in the cylinder was determined from the TEP program for the burning of rocket fuel at typical values of the O/F ratio. The thrust of the study was to determine the radiative contribution to the heat transfer rate from the hot participating chamber gases to the cooler wall so as to provide data that can be used to improve the prediction capabilities of currently used computer codes such as PERCORP that treat the radiation in an *ad hoc* manner. The results from the numerical model will be corroborated with data obtained by the ongoing experimental effort by the PI. The calculations were carried out using the commercial CFD package CFDACE, and were first benchmarked against known results in the literature for the simpler case of gray chamber walls and a gray participating medium. The non-gray computations were subsequently carried out using gas absorption coefficient values obtained from the exponential wide band model with the help of the fire-modeling program, RADCAL. The effect of different chamber wall temperatures and gas compositions was examined. The main findings of the study are that the radiative contributions at the high gas temperatures being considered are comparable to the convective values, and strongly spectral in nature. Furthermore, this radiative contribution reaches a maximum at a unique optimal optical thickness of the gas that lies within the extremes of the optically thin and thick limiting cases.

PUBLICATIONS:

THESES DIRECTED:

Savur, M. K., "A Numerical Study of Combined Convective and Radiative Heat Transfer in a Rocket Engine Combustion Chamber," Master's Thesis, Naval Postgraduate School, December 2002.

DoD KEY TECHNOLOGY AREA: Other (Missile Signatures)

KEYWORDS: Missile, Propulsion, Signature, Infrared (IR), Soot

EVALUATION OF COOLING TECHNOLOGIES FOR MAGNETORESTRICTIVE ACTUATORS

Ashok Gopinath, Associate Professor
Department of Mechanical Engineering
Sponsor: NSWC-Carderock

OBJECTIVE: To evaluate available cooling technologies that would work within the design constraints of magnetorestrictive actuators and maintain operating temperatures below a safe threshold.

SUMMARY: This project was a short-term piece of work for NSWC. The goal of the project was to investigate and recommend possible cooling technologies that would maintain the temperature of magnetorestrictive actuators under safe operating limits. After exploring various options, and keeping the design constraints in mind, it was recommended that for baseline use simple low maintenance off the shelf heat exchanger components with no moving parts be used for robust and reliable performance of the actuator in the harsh environments envisioned. It was found that the basic cooling needs could be met with an extended surface natural convection cooling design such as a press fitted pin fin assembly. The working constraints were that the ambient temperature could be a high as 35 C while the actuator temperature was not to exceed 95 C, and that the final package was to fit within a cylindrical package of dimensions no more than one foot in length and diameter. Sample baseline calculations were provided for a typical case of an assembly of 35 circular/annular aluminum fins that could provide a heat transfer rate of as much as 650 W. In addition, active cooling enhancement strategies were recommended through the use of vortex tubes that work off standard high pressure air lines to provide a jet/stream/curtain of cold air. It was suggested that strategically located vortex tubes could be used to provide an empirically calibrated blast(s) of cold air on the actuator along the length of its travel to maintain its temperature within safe operating limits.

PUBLICATIONS:
Gopinath, A., "Evaluation of Cooling Technologies for Magnetorestrictive Actuators," *Technical Report*.

THESES DIRECTED:

DoD KEY TECHNOLOGY AREA: Other (Cooling Technologies)

KEYWORDS: Magnetorestrictive Actuator, Natural Convection, Fin Assembly, Vortex Tubes

EVALUATION OF VENDOR-PROPOSED CONCEPTS FOR MOTION COMPENSATION FOR ROLL-ON/ROLL-OFF STERN RAMPS

J. H. Gordis, Associate Professor
F. A. Papoulias, Associate Professor
Sponsor: NSWC-Carderock Division

OBJECTIVE: The current stern ramp designs on many Navy ships (Cape T, Cape H, LMSR, etc) used in roll-on roll-off operations has been determined to be structurally inadequate in sea state 3 and above. This phase of this continuing project involved the technical evaluation of two concepts for motion compensation systems to be placed between the foot of the ramp and the RRDF (barge) on which the ramp rests. The two concepts were proposed to NSWC/Carderock by two independent vendors, and NPS (Gordis/Papoulias)

were funded by NSWC/Carderock to critically evaluate these concepts for effectiveness in reducing ramp stresses.

SUMMARY: A mathematical model describing the fundamental physics of a ship/ramp/barge system, including the motion compensators as proposed by the vendors, 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. These models were used to generate wave motion inputs to large finite element models of the ramps and motion compensators, and ramp stress was calculated. The results indicated neither of the vendor-proposed motion compensation systems would be effective in reducing ramp stress, and in fact, under certain circumstances, would increase ramp stress.

DELIVERABLES:
NSWC/Carderock did NOT fund these two vendor concepts based on our work, which showed the ineffectiveness of the concepts. This resulted in significant savings of funds for the Navy.

Technical Report: "Motion Compensator Analysis Executive Summary" Prof. Joshua H. Gordis, Prof. Fotis A. Papoulias, ENS John J. Haigh. March 2002.

Technical Report: "Motion Compensator Analysis" ENS John J. Haigh and Prof. Joshua H. Gordis. March 2002

THESES DIRECTED:
"Computational Dynamics And Stress Analysis Of Full-Scale Model Roll-On, Roll-Off (Roro) Stern Ramp With Wave Motion Compensation" ENS John J. Haigh MSME, June 2002.

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

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

Tactical Decision Aids Using Modeling and Simulation

A. J. Healey, J. D. Weekley, D. P. Brutzman*
Center for Autonomous Underwater Vehicle Research
Award # N0001401AF00002

OBJECTIVES:
The current mine warfare common operational picture used by the US Navy for mine countermeasures is MEDAL (Mine warfare Environmental Decision Aids Library). MEDAL is a component of the GCCS-M global command and control system used by the Navy. It is used to evaluate asset positions, minelike contacts, snippet images of contacts, snippet images of mines, and bathymetry maps. Other data such as classification of bottom type may be displayed if available. Current MEDAL capabilities are limited for importing and displaying the AUV collected data The NPS objectives include gathering, converting, archiving, and translating AUV data into the MEDAL format. The goal is to improve understanding of the overall mine warfare situational picture through the collection and display of AUV data into fleet Command and Control systems. This includes the timeliness of data gathering including the post processing of sonar and video images for import into MEDAL. Long term goals are to develop a standard XML tagset for storage, retrieval and transformation of data from AUV missions and to integrate 3D visualization of data to enhance decision making, particularly in regard to deciding whether a contact is in fact a mine.

APPROACH: One issue in this project is how to deal with data from unclassified assets that are in development from university institutions, translate into the form used by MEDAL, and import the results into the classified Navy systems used in the fleet. To this end we have defined an Automated Data Server system (ADS) that is linked through a local area network (LAN) to a stand alone MEDAL system. The

MEDAL system runs on a TAC4 or better HP workstation. At the present time, it only runs on the HP systems with the 10.20 OS and the GCCS-M operating system. The ADS has been refined and is now interactive through screen entry from an operator. Future versions will be automated without operator intervention so that the software could run inside the control system of the AUVs. The ADS allows the operator to view data through a VRML 3D viewer in which models of vehicles and contacts can be seen thereby extending MEDAL into 3-D views.

WORK COMPLETED: The ADS has been developed and demonstrated during the Kernal Blitz 01, the AUVFEST 01, and the FBE-J exercises. While the REMUS / SAHRV vehicle was used mostly during FBE-J, the system gathered data from the Bluefin BPAUV vehicle. In particular we gathered environmental data and illustrated how to display the bathymetry, temperature, and sound speed and optical backscattering maps into MEDAL.

A. J. Healey and D. P. Horner
Center for AUV Research
Award Number N0001401AF00002

OBJECTIVES: This year, a horizontal model of the REMUS AUV has been developed and a simple avoidance behavior is studied for horizontal plane maneuvering. The approach used is based on computer simulation using MATLAB and motion visualization in the NPS AUV Workbench*

WORK COMPLETED: A Sliding Mode steering controller has been developed for REMUS based on a hydrodynamic model taken from the literature and modified based on experimental data gathered during Navy exercises. A track following guidance algorithm used by the vehicle has been implemented in the simulations and additive steering commands based on a weighted sum of range and bearing estimates to targets in the field has been studied for its effectiveness as a collision avoidance controller. The results have shown consistence avoidance with a controlled return to the track path even for multiple and complex obstacles. The overall goal of the program is a multi-step approach which includes going from simulated obstacle avoidance to incorporation of OA algorithms into the ARIES and REMUS vehicles. The first step of providing the OA simulation has been completed. The NPS AUVWorkbench is Java and XML based simulation software which includes sliding control vehicular motion and the OA algorithm described above. It permits easy generation of mission scenarios with flexible placement of mine and obstacles to validate, verify, and improve navigation algorithms.

PUBLICATIONS

L.T. Fodrea, and A. J Healey " Obstacle avoidance Control for the REMUS Autonomous Underwater Vehicle" Invited Presentation, IFAC Workshop on Guidance and Control of Unmanned Underwater Vehicles, Newport, UK, April 2003.

L R Fodrea MS Thesis September 2002

J.Keller ME Thesis September 2002

A. J. Healey, J. D. P. Horner D. P. Brutzman*
Center for Autonomous Underwater Vehicle Research
DURIP Project

LONG TERM GOAL: The goals are to develop Command and Control strategies for multi vehicle mine hunting systems using small autonomous underwater vehicles in very shallow water (VSW) environments. To this end, this project purchases a second vehicle for the NPS Center for Research. This is a DURIP project funded in FY 2002

OBJECTIVES: Command and Control with multiple vehicles in very shallow water requires vehicle to vehicle communication. The objectives of this work are to develop strategies for multi-vehicle command

and control for heterogeneous systems. This will be done by demonstrations of vehicle communication and mission re-configuration underwater. To this end, acoustic control of vehicles is a first step, leading to vehicle - vehicle communication and control underwater. Acoustic control is a requirement since radio control is not efficient unless vehicles are on the surface.

APPROACH: The approach - and the purpose of the approved funding is to purchase a REMUS vehicle in the Center for AUV Research so that coordinated control can be explored between the existing ARIES vehicle (see www.cs.nps.navy.mil/research/auv/auvframes.html) and the REMUS. Unfortunately, it will be a future activity to install an acoustic modem on REMUS although experiments are underway with acoustic modem control of ARIES. Experiments will be performed both in simulation and by validation in water.

WORK COMPLETED: At this point, a REMUS vehicle has been purchased by NPS. The delivery is expected April 2003. This vehicle will be used to 1) Map Monterey Bay bottom conditions in the shallow water areas. 2) It will be used to support the upcoming AOSN II experiment in Monterey Bay Summer 2003 with oceanographic measurements, and,3) We will study the possibilities to reconfigure the REMUS vehicle to carry a modem package. To date the purchase order has been placed for the full amount of funding available.

EFFECTS OF MICRO-STRUCTURAL VARIATION ON LOCAL DAMAGE INITIATION AND GROWTH OF SPECIMEN

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

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 micro-structural variation on local damage initiation and growth**.**

SUMMARY: This project discussed the effects of non-uniform, random particle distribution on damage initiation and growth, leading to short cracks and breakage of particle reinforced composite specimens. A multi-scale technique was employed to model and simulate damage. Damage was described at the constituent material level (i.e. micro-level) and the results were compared qualitatively and quantitatively with experimental observation. Both results agreed well. Non-uniform, random particle distribution yielded sporadic crack initiation and growth within a uniform tensile specimen. No local crack propagated beyond a certain size. Breakage of the specimens was not caused by the continuous growth of a single critical crack. Instead, coalescence of neighboring sporadic short cracks resulted in breakage of the specimens. Computer simulation indicated that random particle distribution affected the strength of the composite significantly, but as expected, not its effective stiffness. However, if there was a pre-existing crack in the specimen before loading, the effect of the random particle distribution on the initial crack and the strength of the composite was almost negligible.

PUBLICATIONS:

Kwon, Y. W. and Liu, C. T., "Microstructural Effects on Damage Behavior in Particle Reinforced Composites", Polymers and Polymer Composites, Accepted for publication.

Kwon, Y. W. and Roach, K., "Unit-Cell Model of 2/2-Twill Woven Fabric Composites for Multi-Scale Analysis", Computer Modeling in Engineering & Sciences, Accepted for Publication.

Kwon, Y. W. and Liu, C. T., "Study of Interaction between Non-uniform Particle Distribution and the Crack Initiation and Growth under Tensile Loading", International Conference on Computational Engineering & Sciences, Reno, Nevada, August, 2002.

Kwon, Y. W. and Liu, C. T., "Study of Microstructural Effects in Particulate Composites", Recent Advances in Solids and Structures -2002, IMECE 2002, New Orleans, LA, 2002.

THESIS DIRECTED:
One thesis student participated in the research and graduated.

DoD KEY TECHNOLOGY AREA: Aerospace Propulsion and Power; Materials, Processes, and Structures; Modeling and Simulation

KEYWORDS: Composite Materials, Particle Reinforcement, Solid Rocket Propellant, Damage and Crack, Modeling and Simulation, Initial Crack Size, Micro-structure

SHIP DAMPING STUDIES FOR ENERGY DISSIPATION IN SHIP SYSTEM

Young W. Kwon, Professor
Department of Mechanical Engineering
Sponsor: Naval Surface Warfare Center

OBJECTIVE: This study was to understand energy dissipation in a ship system and to learn how to model and simulate it. I was co-PI with Prof. Shin. The following summary was the contribution of my part.

SUMMARY: The purpose of this research was to study the effects that welding has on damping. Measurements and comparisons of the damping ratios of two welded stiffened plates, two flat plates and one machined stiffened plate were undertaken. The frequency response and natural frequencies of five steel structures are determined experimentally. A finite element model was created for three of the structures to determine the natural frequencies and associated mode shapes. The damping ratios were then determined using the half-power point method. The results showed that at frequencies less than 500 Hz, welding tended to cause the damping ratio to increase. The experimental and numerical results showed that the mode shapes that experienced the highest degree of stress at a weld were associated with the natural frequencies with the highest damping ratio.

PUBLICATION:
Carey, A. E., "Experimental Studies of Welding Effects on Damping for UnderSea Warfare Application", MSME, Sept., 2002.

THESIS DIRECTED:
One student participated in the project and graduated.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures

KEYWORDS: Damping, Ship Structures, and Welding

MODELING IN NANO-MECHANICS

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

OBJECTIVE: Molecular dynamics simulation technique was developed for static problems and coupled with the finite element method.

SUMMARY: A computational technique was developed to model and simulate molecular or atomic behavior of materials under static loads. Interatomic potential was used to maintain equilibrium among molecules or atoms under loads and constraints. In addition, a smeared continuum model was derived to represent a very large number of molecules or atoms collectively based on energy equivalency. The finite element method was applied to the smeared continuum model. Then, the molecular or atomic model was

coupled with the finite element analysis model so that more flexible loads and constraints could be applied to the molecular or atomic model. In addition, such a coupling would be useful for transition from nanoscale to continuum scale. Some example problems were presented to illustrate the developed techniques. An example included a multi-scale technique for woven fabric composites made of carbon nanotubes. The effective stiffnesses at different stages of the nano-composites were computed.

PUBLICATION:
Kwon, Y. W., "Computational Nanomechanics", Submitted for Publication in Journal.

Kwon, Y. W. and Jung, S. H., "Atomic Model and coupling with Continuum Model for Static Equilibrium Problems", Submitted for publication in Journal.

Kwon, Y. W. and Jung, S. H., "Atomistic Model for Static Equilibrium Problems", Proceedings of the Sixth International Conference on Computational Structures Technology, CST02/paper no. 2, 1-12, Prague, Czech Republic, September, 2002,

Kwon, Y. W. and Jung, S. H., "Computational Nanomechanics", Recent Advances in Solids and Structures -2002, IMECE 2002, New Orleans, LA, 2002.

THESES DIRECTED:
One student graduated last December.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures

KEYWORDS: Nanomechanics, Molecular Dynamics, Continuum Mechanics

DEVELOPMENT OF INTERACTIVE FINITE ELEMENT METHOD ON THE WORLD WIDE WEB

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

OBJECTIVE: This was to develop a finite element method course on the world wide web for distributed learning classes.

SUMMARY: The finite element method course offered at NPS (ME-4613) was developed on the world wide web for DL students. The web tools called Blackboard was used to developed the course. The course materials contained concepts of the finite element technique and its application to various mathematical problems in mechanical engineering disciplines including boundary value problems, initial value problems, and eigenvalue problems.

DoD KEY TECHNOLOGY AREAS: Other

KEYWORDS: Finite Element Method, DL program

THE MECHANICAL AND MICROSTRUCTURAL CHARACTERIZATION OF COMMERCIAL AA5083 MATERIALS

Sponsor: University of Texas – Austin
PI: Terry R. McNelley, Professor, Mechanical Engineering

OBJECTIVE: The objective of this program is to determine the mechanisms of elevated temperature deformation and the conditions for transition from grain boundary sliding to solute-drag controlled dislocation creep. Also, the mechanisms associated with cavitation failure during superplastic deformation will be clarified.

SUMMARY: Superplastic forming of aluminum alloys has become an established technology for aerospace systems and is being used increasingly in transportation and other applications. The commercial alloy AA5083 is an aluminum-base material having Mg and Mn as the main alloying additions, and it provides a combination of superplastic forming characteristics, corrosion resistance, weldability, and post-forming mechanical properties that make it suitable for a wide range of aerospace, marine and automotive applications. There are two particular difficulties: (1) empirically developed methods for production of fine-grained AA5083 sheet material result in high cost, and (2) available sheet materials exhibit widely different ductility values at elevated temperature even when their grain sizes are essentially identical. In this research program, newly developed orientation imaging microscopy and related microtexture methods are being employed to investigate grain size refinement during thermomechanical processing and transitions from grain boundary sliding to dislocation deformation mechanisms. Of particular concern are the relationships among alloy constitution, deformation mechanism, and failure by the formation and coalescence of cavities. The influence of stress state will be considered as well by including materials deformed under balanced biaxial tension and plane strain conditions as well as under uniaxial tension.

PUBLICATIONS:

M.T. Peréz-Prado, G. González-Doncel, O.A. Ruano and T. R. McNelley, "Texture Analysis and the Transition from Slip to Grain Boundary Sliding in a Discontinuously Recrystallized Superplastic Aluminum Alloy", Acta Materialia, vol. 49 (2002) pp. 2259-68

T.R. McNelley, D.L. Swisher and M.T. Peréz-Prado, "Deformation Bands and the Formation of Grain Boundaries in a Superplastic Aluminum Alloy", Metallurgical and Materials Transactions A, vol. 33A (2002), pp. 279-90

M.A. Kulas, P.E. Krajewski, T.R. McNelley and E.M. Taleff, " Deformation and Failure Mechanisms in Commercial AA5083 Materials", to appear in Hot Deformation of Aluminum Alloys III (Z. Jin, et al., eds.), TMS, Warrendale, PA

CONFERENCE PRESENTATION:

T.R. McNelley, T.A. Maestas, M.A. Kulas and E.M. Taleff, "Investigation of the Deformation and Failure Mechanisms in AA5083 Materials", invited presentation in the Symposium on Superplasticity and Superplastic Forming, ASMI Fall Meeting, Columbus, OH, October 9, 2002

THESIS DIRECTED:

A. Maestas, "Study of Processing and Microstructure of a Superplastic 5083 Aluminum Alloy", MS Thesis, Naval Post Graduate School, Monterey, CA, March 2002

DOD KEY TECHNOLOGY AREA: Materials and Processes

KEYWORDS: Aluminum, Superplasticity, Recrystallization, Grain Boundaries, Thermomechanical Processing.

MICROSTRUCTURE EVOLUTION AND CONTROL DURING FRICTION STIR PROCESSING (FSP) OF CAST NAVAL BRONZE MATERIALS

Sponsor: DARPA

PI: Professor Terry R. McNelley, Professor, Mechanical Engineering

OBJECTIVES: The objective of this program is to determine the effect of friction stir processing (FSP) on the microstructure and properties of a cast nickel-aluminum bronze (NAB) material utilizing various micro-analytical methods as well as conventional mechanical testing. Of particular concern is to determine the mechanism of microstructure refinement during FSP as well as the influence of processing parameters.

SUMMARY: NAB materials are copper-based alloys that are widely used to produce cast components for marine applications due to excellent corrosion resistance; good fracture toughness combined with moderate

strength; low coefficients of friction and good wear characteristics; non-sparking behavior; high damping capacity; and good fatigue resistance. Many cast components produced in NAB involve thick sections and the slow cooling rates contribute to coarse microstructures and reduced physical and mechanical properties. In many NAB applications it would be desirable to have alternative methods available to selective strengthen the surface layers of cast components. During FSP, friction between a rotating tool and the surface of the material results in a 'stirring' action that, in turn, produces adiabatic heating and local softening. The tool rotation results in very large deformations in the softened regions, and thus microstructure refinement and homogenization leading, in turn, to improved strength and ductility in processed material. FSP may also result in closure of porosity and redistribution of inclusions thus conferring improved corrosion resistance. The influence of FSP on NAB materials will be examined by various methods including conventional scanning electron microscopy, orientation imaging microscopy, transmission electron microscopy, and related characterizations of the physical and mechanical properties of processed materials.

PUBLICATION:
K. Oh-ishi, A.M. Cuevas, D.L. Swisher and T.R. McNelley, "The Influence of Friction Stir Processing on Microstructure and Properties of a Cast Nickel Aluminum Bronze Material", to appear in Proceedings of THERMEC2003, International Conference on Thermomechanical Processing of Metals and Alloys (T. Chandra, et al., eds.), Trans Tech, Zurich

CONFERENCE PRESENTATION:
K. Oh-ishi, A.M. Cuevas, C. Park and T.R. McNelley, "Microstructure Evolution During FSP of an As-cast NAB Material" Workshop on Friction Stir Welding and Processing, Rockwell Scientific Corporation, Thousand Oaks, CA, December 2002

THESIS DIRECTED:
A.M. Cuevas, "Microstructure Characterization of Friction Stir Processed Nickel-Aluminum Bronze Through Orientation Imaging Microscopy", MS Thesis, Naval Post Graduate School, Monterey, CA, September 2002

DOD KEY TECHNOLOGY AREA: Materials and Processes

KEYWORDS: Nickel Aluminum Bronze, Friction Stir Processing, Castings, Propellers, Stir Zone, Thermomechanically Affected Zone, Shear Deformation

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

T. R. McNelley, Professor, Mechanical Engineering

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. In such a circumstance, the 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.

PUBLICATION:
S.D. Terhune, D.L. Swisher, K. Oh-ishi, Z. Horita, T.G. Langdon and T.R. McNelley, "An Investigation of Microstructure and Grain-Boundary Evolution during ECA Pressing of Pure Aluminum", Metallurgical and Materials Transactions A, vol. 33A (2002), pp. 2173-84

T.R. McNelley, D.L. Swisher, Z. Horita and T.G. Langdon, "Influence of Processing Route on Microstructure and Grain Boundary Development during Equal-Channel Angular Pressing of Pure Aluminum", in Ultra-Fine Grained Materials II (Y.T. Zhu, et al., eds.), TMS, Warrendale, PA, pp. 15-24

CONFERENCE PRESENTATION:
T.R. McNelley, D.L. Swisher, Z. Horita and T.G. Langdon, "Influence of Processing Route during Equal-Channel Angular Pressing of Pure Aluminum", invited presentation in the Second International Symposium on Ultra-Fine Grain Materials: Processing and Structure, TMS Annual Meeting, Seattle, WA, February 2002

DOD KEY TECHNOLOGY AREA: Materials and Processes

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

LOW OBSERVABLE MULTI-FUCTION STACK (LMS) EXHAUST ENHANCED MIXING SUPPRESSOR

Knox T. Millsaps, Associate Professor
Department of Mechanical Engineering
Sponsor: Naval Surface Weapon Center – Carderock Division

OBJECTIVE
To develop and demonstrate a gas turbine exhaust signature suppression system, which is capable of meeting specified infrared (IR) and radar cross-section (RCS) goals, under specific engine-imposed constraints and overall systems constraints that the system be integrated into a low observable topside.

SUMMARY
This was the final year of a 4-year advanced technology demonstrator (ATD) project to develop a low observable multi-function stack (LMS) as part of the series of ATDs to create integrated topside technology for the next generation of surface combatants. In previous years, the NPS part of this project was to create design concepts and develop supporting analytical codes for the preliminary design of enhanced mixing eductors, and to test and optimize cold-flow geometry for reducing plume radiation. These designs were next tested at larger scale at a hot-flow facility in Memphis with NPS assistance. Finally, last year the full-scale hardware was tested in an at-sea trial. NPS supplied engineering consulting services as well as integration advice throughout the project and was a member of the integrated product team (IPT).

PUBLICATIONS
1. Millsaps, K. T., Markowicz, J. C., "An Improved Preliminary Design Method for Ejectors" ASME TURBO EXPO 2003 LAND, SEA and AIR, June 16-19, 2003, Atlanta, GA, U.S.A., GT03-38141. Conference and Journal.

2. Millsaps, K. T., Imber, R. D., Ratcliffe, R. J., Development of the Enhanced Mixing Suppressor for the LMS (U), NSWCCD-74-TR-2001/010, January 2001. SECRET.

3. Ratcliffe, R., Imber, R., Bird, W., Millsaps, K. T., Test Report for LMS at Sea Trials (U). SECRET.

4. Ratcliffe, R., Imber, R., Bird, W., Millsaps, K. T., Final Report for the Low Observable Multi-Function Stack Advanced Technology Demonstrator Program (U), SECRET.

THESIS DIRECTED
LCDR Gombas, J. D., USN, Reduction of Marine Gas Turbine Exhaust Infrared Signature, M. S. Thesis, Naval Postgraduate School, March 2002.

DoD KEY TECHNOLOGY AREA: Other (Signature Control)

KEYWORDS: Propulsion, Signature, IR, Gas Turbines, Exhaust, Enhanced Mixing.

REVIEW OF ADVANCED TECHNOLOGY GAS TURBINE RESEARCH AND DEVELOPMENT PROGRAMS

Knox T. Millsaps, Associate Professor
Department of Mechanical Engineering
Sponsor: NSWC-CD, Naval Systems Engineering Station – NAVSES.

OBJECTIVE
To review and evaluate the current research and development program for the advanced technology gas turbine program for the U.S. Navy's surface fleet gas turbine life cycle manager and to make technical recommendations for program improvement and to help create the Technology Roadmap. To support the priority advanced technology programs with technical support.

SUMMARY
The gas turbine technology programs were reviewed and a technology roadmap for future programs was created. Two areas of particular interest were identified that required technical support from the Naval Postgraduate School. Specifically, improved methods for the detection and localization of gas turbine compressor fouling, and analysis of using reheat in marine gas turbine cycles for both propulsion and power production. An analytical model of a gas turbine compressor was created to predict the impact that blade roughness from fouling would have on the mass flow, work coefficient, and efficiency of a three-stage axial compressor as a function of the location of fouling. This model was used to create numerical values of influence coefficients, which relate percentage changes in one parameter to percentage changes in other parameter. This analysis suggested the appropriate parameters that are the most sensitive for predicting the location and severity of compressor fouling. A thermodynamic analysis of re-heat cycles in marine power and propulsion gas turbines was conducted to predict the utility of such re-heat cycles. In particular it was shown that both inter-turbine and intra-turbine reheat offer significant improvements in power density and fuel consumption.

PUBLICATIONS
Millsaps, K. T., Rodman, B. E., "Thermodynamic Analysis of Inter-Turbine and Intra-Turbine Reheat Gas Turbines for Marine Propulsion and Ship Service Applications", Turbine Engine Technology Symposium, Dayton, OH, September 9-12, 2002.

In addition there are three (3) publications are planned from to be created from this work in the future.

1. Baker, J. D., Millsaps K. T., "Using Condition Based Maintenance in Assessing the State of Fouling and Degradation in a Gas Turbine Compressor", ASNE Fleet Maintenance Conference, Norfolk VA, November 2003. Abstract submitted.

2. Millsaps, K. T., Baker, J. D., "Analysis of the Sensitivity of Multi-Stage Axial Compressors to Fouling at Various Stages", Abstract to be submitted in July of 2003 for the IGTI conference in May 2004.

3. Millsaps, K. T., Rodman, B. E., "Thermodynamic Analysis of Inter-Turbine and Intra-Turbine Reheat Gas Turbines for Marine Propulsion and Ship Service Applications", Abstract to be submitted in July of 2003 for the IGTI conference in May 2004.

THESIS DIRECTED

LT Jon D. Baker, USCG, Analysis of the Sensitivity of Multi-Stage Axial Compressors to Fouling at Various Stages, M. S. Thesis, September 2002.

DoD KEY TECHNOLOGY AREA: Sensors, Modeling and Simulation, Aircraft Propulsion, Other (Reduced Manning)

KEYWORDS: Propulsion, Gas Turbines, Condition Based Maintenance (CBM), and Compressor Fouling. Thermodynamic Analysis, Reheat, Intra-turbine and Inter-Turbine Combustion, Augmentors, Inter Turbine Burning.

EXTENDED STATE SPACE MODELING OF RRDF

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

OBJECTIVE: The goal of this project was to develop a model in order to bridge the gap between existing constant coefficient time domain and more accurate hydrodynamic models.

SUMMARY: A mathematical model describing the fundamental dynamics in the interface problem between a ship, a barge, and a connecting ramp was developed and solved. The hydrodynamics for the ship and the barge were described by a 12-degree of freedom fully coupled model, which was based on potential theory and incorporated proximity effects. Ramp structural dynamics were studied by a finite element model, which was calibrated based on detailed studies of commercially available codes. The models were coupled together through a spring/damper and the solution of the system was obtained in both regular waves and a representative sea state. Parametric studies with regards to different coupling conditions proved that optimization based on either relative motions or ramp maximum stress is possible. Work in this area is continuing.

DELIVERABLES: Student theses.

THESIS DIRECTED:
John J. Haigh, (Second Reader) "Computational Dynamics and Stress Analysis of Full Scale Model Roll-on, Roll-off Stern Ramp with Wave Motion Compensation," Master of Science in Mechanical Engineering, June 2002.

Brian Higgins, "Motion Analysis of a Trolley Interface for Ship-to-Ship Cargo Transfer," Master of Science in Mechanical Engineering, December 2002.

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

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

MOTION MINIMIZATION IN HIGH SPEED TOWING

Fotis A. Papoulias, 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. A model describing the dynamics of the two bodies under tow was developed. A series of runs was conducted in order to gain some insight into the seakeeping

behaviors of the two ships. A generic spring/damper connection was assumed to exist at the interface. Current studies aim at more realistic configurations, along with the establishment of a design and analysis procedure in order to quantify the performance degradation in a seaway. A simulation model for low frequency motions was also developed, and a comprehensive stability analysis is underway.

DELIVERABLES: Student theses, one conference publication to be presented during 2003.

THESIS DIRECTED:
Errol Glenn, "Close Proximity Vessel Towing in Six Degree of Freedom Motions in Short Crested Seas," Master of Science in Mechanical Engineering, September 2002.

Murat Korkut, "Nonlinear Dynamics of Close Proximity Ship Towing," Master of Science in Mechanical Engineering, December 2002.

Mersin Gokce, "Coupled Stability Analysis of Close Proximity Ship Towing," Master of Science in Mechanical Engineering, March 2002.

Orhan Okan, "A Design Procedure for Seakeeping Analysis of Close Proximity Ship Towing," Master of Science in Mechanical Engineering, March 2002.

Richard Rodriguez, "A Characterization of Sway Forces Induced by Close Proximity Ship Towing," Master of Science in Mechanical Engineering, March 2002.

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

KEYWORDS: Towing, Seakeeping.

ROBUST DISTRIBUTED CONTROL OF SHIPBOARD SYSTEMS

Fotis A. Papoulias, Associate Professor
Department of Mechanical Engineering
Sponsor: Office of Naval Research

OBJECTIVE: The goal of this ongoing project is to analyze the effectiveness of a market based approach to power distribution in warships.

SUMMARY: In an effort to more effectively and efficiently utilize the total installed power shipboard, the U.S. Navy is developing the technologies and systems to implement an Integrated Power System including high-power-density motors, converters, and pods. As such, the future Navy surface combatant offers considerable opportunities for control systems to monitor status, manage information, automate functions, direct reconfiguration, allocate capacity, and augment crew capabilities during both normal and combat scenarios. In cooperation with Biosgroup, the Naval Postgraduate School has provided domain expertise relevant to the development of multiagent systems for distributed control in warships. In this context, NPS has identified a target ship platform, the relevant IPS architecture and component technology, delineated reasonable component operational capabilities, created representative ship fault scenarios including cascading casualty situations, developed dynamic operational scenarios that require power system reconfiguration or reallocation, provided guidance as to the reasonableness of prospective "control" actions, and served as an interface to accommodate the application of such control actions in a reduced-scale Navy test-bed.

DELIVERABLES: Progress report to sponsor.

THESES DIRECTED: None.

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

KEYWORDS: Distributed Control, Casualty Control**.**

DISTANCE LEARNING SUPPORT FOR TS4001

Fotis A. Papoulias, Associate Professor
Department of Mechanical Engineering
Sponsor: CNET

OBJECTIVE: The goal of this project was to develop resources in support of ship design in the world wide web.

SUMMARY: The purpose of this project was to develop a web based class on Ship Design in support of the TSSE program. The outcome of this project was the development of a comprehensive web site on Naval Architecture and Ship Design, with over two thousand files, incorporating text, graphs, support information material, and fully interactive examples. The site is fully integrated into the Blackboard web based delivery system adopted by NPS.

DELIVERABLES: Web site.

THESES DIRECTED: None.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation; Computing and Software; Manpower, Personnel and Training.

KEYWORDS: Ship Design, Distance Learning**.**

MECHANISM OF SPRAY GENERATION AT THE FREE SURFACE OF LIQUID JETS

T. Sarpkaya, Distinguished Professor
Department of Mechanical Engineering
Sponsor: Office of Naval Research
Co-sponsor: 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 2.4x104 to 4x104, 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. In addition various surfactants were used to determine the effect of contamination on the integral length scale of turbulence.

PUBLICATIONS:

Sarpkaya, T. “Experiments on the Stability of Sinusoidally Oscillating Flow over a Circular Cylinder,” Journal of Fluid Mechanics, Vol. 457, 2002, pp. 157-180.

Markle, H. B., and Sarpkaya, T., “Bow Waves on a Free-Running, Heaving and/or Pitching Destroyer,” Naval Hydrodynamics, National Academy of Sciences, Washington, D.C., pp: 1-15, 2002

Markle, H. B., and Sarpkaya, T., “Bow Waves on a Free-Running, Heaving and/or Pitching Destroyer,” Proceedings of the 24th Naval Hydrodynamics Symposium, Fukuoka, Japan on 7-13 July 02, 2002.

THESIS DIRECTED:

Markle, Howard B., “An Experimental Investigation of the Bow Wave on USS Cole (DDG-67)”, M.S. and M.E. Thesis submitted to Mechanical Engineering Dept., Graduated In Sept. 2001.

OTHER
I have been invited to deliver two papers at two ONR meetings: at CALTECH in April 02 and in San Diego in September 02.

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

KEYWORDS: Hydrodynamics, drop formation, spray

REVIEW OF HYDRODYNAMIC LOADS ON STRUCTURES

T. Sarpkaya, Distinguished Professor
Department of Mechanical Engineering
Sponsor: Nuclear Regulatory Commission (NRC)

OBJECTIVE: To review the appropriate topical reports and any other relevant data on hydrodynamic loads on structures submerged in the pressure suppression pools of boiling-water nuclear reactors. The ultimate purpose of these reviews and detailed analyses is to provide sound technical advice to NRC on unsteady flow about specific types of strainers and, in particular, on the prevailing Keulegan-Carpenter numbers and acceleration drag loads so that NRC can perform its regulatory duties in the light of the expert opinion and complete its review of the strainers under their consideration.

SUMMARY: A thorough study of about 3,000-page reports and papers led to the conclusion that the determination of the typical values of the Keulegan-Carpenter number, K, and the acceleration drag coefficient, Cm, for the conditions expected following a loss-of-coolant accident (LOCA) and safety/relief valve (SRV) discharge requires the load carrying capacities (LCCs) of the strainers, the positions of the largest stresses on the strainers and/or their attachments; the velocities, accelerations, (their magnitudes and directions) and their distribution throughout the suppression pool during the first few seconds of LOCA and SRV. In summary, the existing analyses and experiments are inadequate for the assessment of the safety of the strainers in Boiling-Water Nuclear Reactors. Proper analyses and experiments have been performed to provide sound technical guidance to NRC towards the fulfillment of its regulatory duties.

PUBLICATIONS:
Sarpkaya, T. “Revised Final Technical Evaluation Report to NRC,” Sept. 2002.

Sarpkaya, T., "On the Force Decompositions of Lighthill and Morison," Journal of Fluids and Structures, Vol. 15, No. 2, Feb. 2001, pp. 227-233.

THESIS DIRECTED:
Osgood, D. B., “Flow About Perforated Bodies,” M.S. Thesis submitted to Mechanical Engineering Dept., Graduated In June 2000.

DOD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Nuclear Reactors, inertial force, perforated bodies, unsteady flow.

FLOW-INDUCED VIBRATIONS

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

OBJECTIVE: To compose an inspired review of all that is best in the works of the past century on flow-induced vibrations for the next generation of researchers and engineers. Everything important, from the fundamental phenomena to new directions for research, from theory and numerical simulations to experiments, are to be covered in a seminal journal paper.

SUMMARY: Flow-induced vibrations occur in many engineering situations, such as bridges, stacks, transmission lines, offshore structures, heat exchangers, marine cables, flexible risers in petroleum production, and other hydrodynamic and hydroacoustic applications. During the past century, a great deal of work has been done on flow-induced vibrations and fluidelastic instability. The number of contributions has increased exponentially. Thus, the amount of time required for any one researcher to comprehend the literature and to plow through the empirical morass became an increasingly larger fraction of his research time. Clearly, to move forward and to make contributions that shape the art and science of flow-induced vibrations in the new century, one must know and fully understand the essence of the work done during the past century, i.e., the safeguiding as well as safeguarding hand of the understanding of the existing theoretical, experimental, numerical and empirical evidence must be periodically re-energized and marshaled for new discoveries and applications. This requires a comprehensive review, at least every 25 years.

PUBLICATIONS:
Sarpkaya, T., "A Compendious Review of Vortex Induced Vibrations," to be presented on June 2-6, 2002 at the IUTAM (International Union of Theoretical and Applied Mechanics" Congress, to be held at the Rutgers University.

THESIS DIRECTED: None

DOD KEY TECHNOLOGY AREA: Fundamental Science

KEYWORDS: VIV, Vortex, Vibration, Flow, Oscillation, and Structures

DYNAMICS OF BOW WAVES/SPRAY GENERATION

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

OBJECTIVE: This continuing basic research is an experimental investigation of the formation of bow waves on Destroyers. The objective is to understand enough of the hydrodynamics of the effect of bow shape on the jet separation in order to minimize the spray generation and resistance. In addition, the effect of the contaminants on the decay of turbulence in the wake of the destroyer is studied extensively.

SUMMARY: Measurements of bow waves 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 Reynolds number ranged from 2.4x104 to 4x104, the Froude number from 15 to 30, and the Weber number from 1,500 to 3,000. The characteristics of the separated sheet have been evaluated for a large number of bow motions and their combinations: heave, pitch and yaw in calm seas. Additional work involves the effect of waves on the heave and pitch of the test models (scale model of an actual destroyer).

PUBLICATIONS:
Markle, H. B., and Sarpkaya, T., "Bow Waves on a Free-Running, Heaving and/or Pitching Destroyer," Proceedings of the 24th Naval Hydrodynamics Symposium, Fukuoka, Japan on 7-13 July 02, 2002.

Markle, H. B., and Sarpkaya, T., "Bow Waves on a Free-Running, Heaving and/or Pitching Destroyer," Naval Hydrodynamics, National Academy of Sciences, Washington, D.C., pp: 1-15, 2002

THESIS DIRECTED:
Markle, Howard B., "An Experimental Investigation of the Bow Wave on USS Cole (DDG-67)", M.S. and M.E. Thesis submitted to Mechanical Engineering Dept., Graduated In Sept. 2001.

OTHER
I have been invited to deliver two papers at two ONR meetings: at CALTECH in April 02 and in San Diego in September 02.

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

KEYWORDS: Hydrodynamics, drop formation, spray

MODEL OF DYNAMICS AND DECAY OF WAKE VORTICES IN PRALLEL RUNWAYS

T. Sarpkaya, Distinguished Professor
Department of Mechanical Engineering
Sponsor: NASA-Langley Research CTR

OBJECTIVE: The purpose of the investigation was (a) to enhance the 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. In addition, to extend the results to parallel runways, wake transport between runways, vortex bouncing and lofting, and other decay phenomena.

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. The model has been successfully tested at the Dallas-Fort Worth airport in September 2001. It is now being recast for the prediction of landings on parallel runways

PUBLICATIONS:
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 2001, pp. 687-692.

OTHER:
The model has now been incorporated into NASA's AVOSS program for the management of aircraft landings at large airports (JFK, Memphis, DFW, and New Orleans). Sarpkaya is cited as one of the inventors of the model by NASA. In addition, NASA has presented Sarpkaya with the prestigious award of "Turning Goals into Reality" for his exceptional contributions.

DOD KEY TECHNOLOGY AREA: Air Vehicles

KEYWORDS: Trailing Vortices, Aircraft Wakes, and Wake Hazard.

SHOCK AND VIBRATION ANALYSIS IN SUPPORT OF DDG-81 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-81 Class shock follow-on actions including DDG-81 Flight IIA ship shock modeling and simulation to predict dynamic responses to underwater explosions. The predicted results will be compared with ship shock trial test data.

SUMMARY: This is a continuation of work sponsored by NAVSEA PMS400D. We have previously conducted 3D Ship Shock Modeling and Simulation for DDG-53 (FLT I) John Paul Jones and proved that we can predict ship shock responses well. This task includes the investigation of the ship shock modeling and simulation for DDG-81(FLY IIA), Winston Churchill. With the experience and knowledge acquired from DDG-53 work, the surrounding fluid model was significantly improved and the energy dissipation scheme is also improved. The dynamic transient responses of ship system and subsystem structures are computed. The results are to be compared with DDG-81 Ship Shock Trial Data.

PUBLICATIONS:

Shin, Y.S., "Ship Shock Modeling and Simulation for Far-Field Underwater Explosion," Proceedings of The Third International Conference on Engineering Computational Technology, Prague – Czech Republic, 4-6 September 2002. (This paper is to be appeared in Special Edition of Computer & Structures in Summer, 2003)

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DOD KEY TECHNOLOGY AREA: Surface/Under Surface Vehicles – Ships and Watercraft

KEYWORDS: Underwater explosion, Ship Shock, DDG-51 Class Ship, Modeling and Simulation

Ship Damping Studies for Energy Dissipation in Ship Structure System

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Sponsor: NSWC – Carderock Division

OBJECTIVE: To investigate ship damping mechanisms for energy dissipation in ship structure system

SUMMARY: The following tasks were performed, (1) a state-of-the-art literature survey for ship damping, (2) UNDEX test data analysis for identification of energy dissipation sources, (3) simple laboratory tests and simulations to explain the identified elements, (4) ship damping studies for distribution of energy dissipation and parametric studies using ship shock simulations, and (5) development of implementation strategy in transient ship shock analysis.

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DOD KEY TECHNOLOGY AREA: Others (Ship Damping in Ship Structure System)

KEYWORDS: ship damping, energy dissipation, underwater explosion.

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