THE EFFECT OF STIFFENER SMEARING IN A SHIP-LIKE BOX STRUCTURE SUBJECTED TO AN UNDERWATER EXPLOSION

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Shock trials for naval vessels are a requirement for each new class of surface ships in the U.S. Navy. With understanding the technology of underwater shock analysis and considering the rising costs of conducting actual shock tests, computer simulation of shock trials is becoming more and more attractive. Unfortunately, finite element models can be quite large and require sufficient amounts of computer memory and time to run a shock analysis. This thesis investigates the effects of reducing the element size of a shiplike box model subject to an underwater explosion. Known as smearing, this process combines the density and stiffness properties of the removed elements into the remaining material of the model. Positive results from computer simulation could greatly affect the manner in which shock trials are conducted with future ship classes.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Underwater Explosion, Smearing, Surface Model

THEORETICAL INVESTIGATION OF ROTOR ACCELERATION SCHEDULING THROUGH CRITICAL SPEED

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An analytical investigation was conducted to study the amplitude of lateral vibrations and vibrational energy and power of an unbalanced rotor passing through its first lateral bending critical speed. A two degree-of-freedom lumped mass, damping and stiffness model was developed to simulate the response of a simply supported, single disk rotor. Given an arbitrary input acceleration or deceleration, the equations of motion were solved numerically using a fourth order Runge-Kutta routine. The routine used a time step that corresponded to a constant angular phase of rotation. The relationship between the forcing function and lateral vibrational velocity was determined in order to predict the instantaneous power input to the rotor due to the unbalanced rotor. The computer model incorporating an acceleration schedule yielded a result that predicts acceleration scheduling in the location about the critical speed is unable to lower the amplitude of lateral vibrations.

KEYWORD: Accelerating Rotor

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Modeling and Simulation

MEASUREMENT OF SYNCHRONOUS FORCES AND FLOW NON-UNIFORMITY IN AN AXIAL COMPRESSOR

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Master of Science in Mechanical Engineering-December 1997
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Time resolved pressure measurements on a compressor case were acquired for several uniform and non-uniform tip clearances. High frequency response pressure transducers were placed at several axial locations near the second stage axial rotor on the outer casing of an Allison C-250 compressor. Data were acquired at several fixed time intervals. The amplitude of the

blade-to-blade variations and once per revolution static pressure distributions on the case were recorded for an "as is" compressor. The synchronous forces due to possible imperfections were determined using a high hub-tip ratio assumption.

KEYWORDS: Turbomachinery, Rotor Dynamics

DoD KEY TECHNOLOGY AREAS: Other (Turbomachinery, Rotor Dynamics)

MODEL FOR ESTIMATION OF THERMAL HISTORY PRODUCED BY A SINGLE PASS UNDERWATER WET WELD

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Thermal history calculations for single pass underwater wet weldments were made by solving the appropriate heat transfer equations using the three-dimensional Crank-Nicholson finite difference method. The Adams approach, which defines the fusion line temperature as a boundary condition, was adopted. Tsai and Masubuchi's semi-empirical correlation, defining the surface heat transfer coefficient of underwater weldments, was used to determine the heat loss through the surface of the welded plate. As expected, the calculated cooling rates in heat affected zones (HAZs) of underwater wet welded ferritic steels were found to be somewhat faster than equivalent cooling rates calculated for the same weldments generated in air. However, the effect of water temperature on cooling times in the HAZ between 800∞ and 500∞C (the parameter conventionally used to measure the cooling rate in the HAZ) was found to be minimal. These calculations suggest that HAZ microstructure of underwater wet welded ferritic steels should be independent of water temperature. This prediction was confirmed by microstructural studies of samples of ASTM A516 grade 70 steel which were underwater wet welded at water temperatures of 31∞, 10∞ and 3∞C respectively and for which similar HAZ microsructures were obtained in each case.

KEYWORDS: Underwater Wet Welding, Modeling of Heat Transfer in Welding

DoD KEY TECHNOLOGY AREA: Materials, Processes, and Structures

EXPERIMENTAL STUDY OF ZERO MEAN OSCILLATORY FLOW FORCES ON CIRCULAR CYLINDERS

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This thesis examines the forces in a zero mean current oscillatory fluid flow on circular cylinders. Experimental force data on different sized aluminum rods exposed to a standing acoustic wave in a nitrogen filled acoustic chamber is obtained from suitably mounted strain gages. Drag, inertia, and lift coefficients and KC, Reynolds, and beta numbers are determined, and the rods' temporal and spatial deformations are examined. The use of high nitrogen pressures reduces kinematic viscosity yielding high Reynolds number flow regimes. This technique can be used in the prediction of forces on ocean structures exposed to oscillatory flows.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Other (Marine and Offshore Structures)

KEYWORDS: Oscillatory Flow, Acoustic Standing Wave, Sea Forces, Offshore Structures, Cable Runs, Structural Response, Drag Coefficient

A MODEL FOR DEFORMATION OF CONTINUOUS FIBER COMPOSITES UNDER ISOTHERMAL CREEP AND THERMAL CYCLING CONDITIONS

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A model to describe the internal stress and strain states in a continuous fiber composite during thermal cycling and/or isothermal excursion has been developed. The model extends a previously developed model by incorporating the effects of: (1) changing matrix creep mechanisms and (2) fiber-matrix interfacial sliding via diffusional creep. Results from sample calculations incorporating these effects during both thermal cycling and isothermal creep are presented. It is envisioned that such a model will be useful in discerning the predominant matrix creep mechanism at various times for a given applied stress and temperature, and thus enable the generation of transient deformation mechanism maps for the composite.

KEYWORDS: Continuous Fiber, Metal Matrix Composites, Creep Mechanisms, Isostrain, Non-isostrain Deformation, Interfacial Sliding, Deformation Mechanism Maps

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

AXIAL CONDUCTION EFFECTS IN LAMINAR DUCT FLOWS

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A numerical model for heat transfer in laminar duct flows has been developed using the finite difference method to explore the significance and extent of "back-conduction" at low Peclet numbers. The calculations have been carried out for flows between parallel plates and in circular tubes by using different Peclet numbers in the range of 0.05 to 100. For both situations constant heat flux and constant wall temperature boundary conditions were used. The validity of the results has been checked by comparison with some existing results in the literature, and extended to a wider range of parameters including conjugate wall conduction effects. The results are presented for bulk mean temperature variation, Nusselt number behavior, and energy absorbed before the heated section, for cases with and without wall conduction. Such axial conduction effects may be an important feature in the thermal characterization of microtubes, which are to be used in microheat exchangers.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Laminar Duct Flows, Convection and Conduction Heat Transfer, Axial Conduction, Micro-heat Exchangers

DEVELOPMENT AND CALIBRATION OF A TORSIONAL ENGINE MODEL FOR A THREE-CYLINDER, TWO-STROKE DIESEL ENGINE

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Master of Science in Mechanical Engineering-December 1997
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An experimental and analytical investigation was conducted to develop a calibrated torsional model of a three-cylinder, two-stroke diesel engine. A Detroit Diesel 3-53 engine was instrumented for time-resolved measurement of cylinder firing pressures and high resolution near instantaneous shaft speed using a 720 and a 3,600 count per revolution optical encoder. Data were taken for three speeds and three torques for a total of nine conditions. A six degree-of-freedom torsional vibra-

tion model of the crankshaft, connecting rods, and pistons was developed. The nonlinear inertias, due to the reciprocating pistons, were included along with linear stiffness and damping. The equations of motion were numerically integrated over a cycle to obtain predicted response. The predicted response was compared to the measured response at the free end of the crankshaft.

KEYWORDS: Diesel, Torsional Vibration Model, Cylinder Pressure Prediction

DoD KEY TECHNOLOGY AREAS: Aerospace Propulsion and Power, Environmental Quality, Ground Vehicles, Modeling and Simulation

INVESTIGATION OF BIOMECHANICAL RESPONSE DUE TO FRAGMENT IMPACT ON BALLISTIC PROTECTIVE HELMET

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Advisor: Young W. Kwon, Department of Mechanical Engineering

Technology has increased dramatically over the last 25 years. It has allowed the development of personnel body armor capable of preventing penetration of fragments traveling in excess of 2000 ft/s (609 m/s). However these strides have also exposed the body to greater impact energies without a lethal penetration. The objective of this research was to examine how the body in particular the Head-Neck Complex responds to these impacts. A finite element model was developed to characterize the behavior of this biomechanical system. This model was then validated against existing experimental work from the automotive industry. The validated model was then subjected to impacts at different positions to induce different load cases. Each set of results was then compared to Head Injury Criteria (HIC), Abbreviated Injury Scale (AIS), and the Injury Assessment Reference Values (IARVS) for evidence of injury potential. Disc stiffness was found to be proportional to the injury potential. Rupture of the disc was considered likely for five of the six cases examined. Fracture of the vertebral body was considered likely in three of the six cases. Suggestions for future research are included in the hopes of furthering research into this area.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Finite Element Modeling, Spine, Cervical, Biomechanics, Body Armor

A NUMERICAL STUDY OF HEAT TRANSFER BEHAVIOR IN WELDING

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A numerical model has been developed for three-dimensional transient conduction based temperature calculations in underwater wet welding on a thick rectangular plate. The numerical scheme is based on a fully implicit finite volume method. A variable mesh size centered around the moving heat source, and temperature dependent thermal properties have been used in the calculations. Convective, radiative and boiling surface thermal conditions have also been included. The weld pool region itself has been modeled as a solid region of thermal conductivity higher than the surrounding unmelted region. The validity of the results was checked by comparison with Rosenthal's three-dimensional solution for a moving point heat source, and other results in the literature.

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

KEYWORDS: Underwater Wet Welding, Heat Transfer, Finite-Volume Numerical Method

INVESTIGATION OF BIOMECHANICAL RESPONSE DUE TO FRAGMENT IMPACT ON BALLISTIC PROTECTIVE HELMET

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Master of Science in Mechanical Engineering-March 1998
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Technology has increased dramatically over the last 25 years. It has allowed the development of personnel body armor capable of preventing penetration of fragments traveling in excess of 2000 ft/s (609 m/s). However these strides have also exposed the body to greater impact energies without a lethal penetration. The objective of this research was to examine how the body in particular the Head-Neck Complex responds to these impacts. A finite element model was developed to characterize the behavior of this biomechanical system. This model was then validated against existing experimental work from the automotive industry. The validated model was then subjected to impacts at different positions to induce different load cases. Each set of results was then compared to Head Injury Criteria (HIC), Abbreviated Injury Scale (AIS), and the Injury Assessment Reference Values (IARVS) for evidence of injury potential. Disc stiffness was found to be proportional to the injury potential. Rupture of the disc was considered likely for five of the six cases examined. Fracture of the vertebral body was considered likely in three of the six cases. Suggestions for future research are included in the hopes of furthering research into this area.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Finite Element Modeling, Spine, Cervical, Biomechanics, Body Armor

PHASE SINTER FORMING OF A MODEL CERAMIC SYSTEM

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The feasibility of a new manufacturing process of ceramic materials in which net shaped products are produced via sintering and simultaneously deforming is studied. A suitable model system of SiO_2-B_2O_3 is chosen due to its desirable properties for liquid phase sintering and its ability to be tested under atmospheric conditions. Samples of compacted powder are prepared and characterized via x-ray diffraction and scanning electron microscopy. Tests to determine the ability of the system to undergo Liquid Phase Sintering are studied. Deformation of samples in compression with concomitant liquid phase sintering at nominally constant true strain rates is performed, and the effects of the amount of liquid phase present are investigated. Problems associated with the liquid phase sinter forming process are identified, and recommendations are suggested for future studies.

DoD KEY TECHNOLOGY AREA: Materials, Processes, and Structures

KEYWORDS: Ceramic Powder Processing, Liquid Phase Sintering, High Temperature Deformation, Superplasticity in Ceramics, Creep Mechanisms, Deformation in the Presence of a Liquid Phase

ANALYSIS OF UNDERBEAD CRACKING IN UNDERWATER WET WELDMENTS ON A516 GRADE 70 STEEL

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The use of underwater weldments on U.S. Naval Vessels is highly desirable due to the ability of performing repairs without costly dry dock expenses. The primary problem with underwater wet weldments is underbead cracking in the heat affected zone (HAZ). The fundamental factors causing underbead cracking in underwater wet weldments using a shielded metal arc welding (SMAW) process are high quench rates, slag inclusions, diffusible hydrogen levels and porosity.

The weld metal analysis included use of optical and scanning microscopy as well as microhardness testing. Three weld samples made at 5∞C, 12∞C, and 25∞C water temperature were analyzed in this thesis. HAZ underbead cracking was present in all three welds analyzed although the 5∞C sample was the only weld that exhibited extensive cracking whereas the 25∞C sample only had cracking near the upper 50% of the weld passes. Crack origination in all three samples near the cap was evident and was most likely due to small levels of bead tempering at this location.

This thesis addresses the mechanisms of the cracking as well as the effects of diffusible hydrogen, cooling rates, and water temperatures on wet weldments.

DoD KEY TECHNOLOGY AREAS: Materials, Processes, and Structures, Surface/Under Surface Vehicles – Ships and Watercraft

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

IDENTIFICATION OF RANDOM LOADS IMPINGING ON THE RAH-66 COMANCHE HELICOPTER EMPENNAGE USING SPECTRAL ANALYSIS

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Donald A. Danielson, Department of Mathematics
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The Army RAH-66 Comanche Helicopter is currently undergoing developmental flight testing. The empennage of the aircraft is experiencing buffeting where the horizontal and vertical tail vibrate at resonant frequencies. These high buffet loads are manifested in higher than anticipated fitting loads, particularly on the tail, and vibrations in the crew stations and at the nose cone where the targeting sensors are located. Significant effort has been devoted to identifying the sources of excitation and the nature of the structural response. This thesis determines the location and magnitude of empennage vibratory airloads. Because the nature of the excitation is a random function, spectral analysis is used. To obtain the loads, a three-step process was utilized. First, from aircraft differential pressure transducers and accelerometers, the spectral content of the response and excitation was determined Then, using a NASTRAN model modified to replicate the flight test aircraft, frequency response functions were determined between selected points on the aircraft's tail and the accelerometers. Finally, using this information, a solution was obtained for the vibratory airloads. Having provided information on the nature of the driving forces, structural modifications can be made that move the natural frequencies away from the frequencies of the applied airloads.

DoD KEY TECHNOLOGY AREA: Air Vehicles

KEYWORDS: RAH-66 Comanche Helicopter, Random Vibrations, Comanche Tail Section, Structural Analysis, Spectral Analysis, NASTRAN Analysis

FREQUENCY MODULATION TECHNIQUE FOR MACHINERY NOISE REDUCTION

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A ship's or submarine's acoustic signature is often characterized by the low frequency narrow band noise components of its rotating machinery. By reducing or altering machinery noise components, a naval vessel can reduce its vulnerability to detection and classification. This study presents and evaluates the frequency modulation technique as a potential method to reduce machinery narrow band noise levels.

The research examines both the experimental and numerical implementation of frequency modulation for the case of rotating machinery. Specifically, a dc motor's operating frequency is modulated about a center frequency of 50 hertz by adding a sinusoidally varying voltage to the base voltage. The amplitude and frequency of the sinusoidal signal are varied and the resultant effects on the noise spectra are studied. Experimental results demonstrate that machinery narrow band signatures may be reduced at the expense of elevated broad band levels. The numerical simulation characterizes general trends and the relative reductions obtainable with frequency modulation.

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

KEYWORDS: Frequency Modulation, Vibration Reduction, Noise Reduction, Permanent Magnet Motor, Quieting

APPLICATION OF NUMERICAL OPTIMIZATION TECHNIQUES TO SURFACE COMBATANT DESIGN SYNTHESIS

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Charles N. Calvano, Department of Mechanical Engineering

This thesis presents the effort to incorporate a numerical optimizer into an existing ship design synthesis math model. The goal is to improve the functionality of the model while retaining the intrinsic value of the model's friendly user interface, which is greatly advantageous for its use as a learning tool. A description of the math model and its origin and intent are presented along with a discussion of numerical optimization techniques and tools. The integration and linking software is described along with the actual Integrated Ship Design System. Results of comparison and sensitivity studies are also presented.

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

KEYWORDS: Ship Design Synthesis, Numerical Optimization, MIT Simplified Math Model, Mathcad, Matlab Optimization, MathConnex, Objective Function, Constraint Function

AUV FAULT DETECTION USING MODEL BASED OBSERVER RESIDUALS

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M.B.A., National University, 1995
Mechanical Engineer-June 1998
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In order for the Navy's next generation Unmanned Undersea Vehicles to be more robust to software/hardware faults, on-line failure detection and resolution is needed. Typically, fault detection methods include limits and trends analysis, model free, and model based techniques. Here, model based observers are proposed for the detection of fault induced dynamic signals in the diving, steering, and roll control systems. Such automatic fault detection systems were designed and implemented in a *Simulink* model of the "2 1UUV." In the course of conducting simulations with the model, numerous vehicle behaviors were studied and detection response was verified. In addition, the model based observer residuals may be designed to distinguish actuator faults from wave disturbances and fin faults from maneuvering responses.

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

KEYWORDS: Model Based Observers, 21UUV, AUVs, Fault Detection

SPRAY GENERATION FROM LIQUID WALL JETS OVER SMOOTH AND ROUGH SURFACES

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M.E., Naval Postgraduate School, 1993
Doctor of Philosophy in Mechanical Engineering-September 1998
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Committee: Matthew D. Kelleher, Department of Mechanical Engineering
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David Canright, Department of Mathematics

This is an experimental investigation of the filaments and drops generated at the free surface of liquid wall jets formed over smooth- and sand-roughened surfaces. The jet characteristics and the geometric properties of the filaments and drops were measured from images captured using high-speed digital cameras. A statistical investigation of the various properties revealed the characteristic behavior of the filaments and drops as a function of the relative wall roughness, wall curvature and jet inertia. For this investigation, the wall jet Reynolds number ranged from $2.6¥10^4$ to $4.5¥10^4$, the Froude number from 19 to 33 and the Weber number from 1600 to 4700.

The emphasis herein was on the physics of the process rather than the development of empirical relationships. As such, the results indicate that spray generation from a wall jet is a boundary-layer-driven phenomenon, requiring that the jet be in a highly supercritical state (Fr » 1). Wall roughness reduces the minimum necessary level of supercriticality, but it is not a prerequisite condition for the formation of drops. While increasing the jet inertia enhances the drop formation process, concave wall curvature tends to reduce the quantity and the energy of the drop forming events.

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

KEYWORDS: Spray, Drops, Jets, Bow Sheets, Turbulent Boundary Layers, Liquid Sheets

AIRCRAFT TRAILING VORTICES: GREENE'S MODEL VERSUS FIELD DATA

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Trailing vortices shed from aircraft pose great danger to following aircraft. Too much separation time reduces the effective use of airports, while too little separation poses grave dangers. The accurate determination of the optimal separation time between two following aircraft in a landing corridor became a major international concern. The LIDAR data, obtained by the Lincoln/MIT laboratories at various airports, have been used to analyze in as much detail as possible the velocity, circulation, and the decay mechanisms of trailing vortices. The results have been used to assess the predictions of Greene's model for a number of cases towards the creation of a more reliable model for use in all types of environmental conditions.

DoD KEY TECHNOLOGY AREA: Air Vehicles

KEYWORDS: Vortex, Aircraft, Wake

EVALUATION OF THE MECHANICAL PROPERTIES AND EFFECTIVENESS OF COUNTERMINE BOOTS

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Advisor: Young W. Kwon, Department of Mechanical Engineering

The first goal of this project was to determine the mechanical properties of countermine boots and protective overboots that are currently available to U.S. soldiers. The second goal of this project was to conduct a qualitative analysis to determine the effectiveness of the boots. This was done by determining their ability to dissipate a blast force equivalent to a typical anti-personnel landmine. This was followed by a parametric study which involved altering the component materials in an effort to determine if the effectiveness of the boots varied as the materials changed.

The soles of both boots were made from identical materials. All the materials used in the boots' soles were tested to determine their mechanical material properties using an Instron uniaxial testing machine. All testing was conducted on multiple specimens to verify repeatability. The material data was tabulated and the stress-strain curves are included in this report.

A finite element analysis was conducted to evaluate the effectiveness of the countermine boot based upon accepted tolerance levels of the lower bones of the body. Next, the materials and their dimensions were modified in the finite element model to determine how these modifications would impact the boots' effectiveness.

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

KEYWORDS: Finite Element Method, Material Properties, Mechanical Testing

AN EXPERIMENTAL INVESTIGATION OF VORTEX BREAKDOWN IN TUBES AT HIGH REYNOLDS NUMBERS

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Richard Franke, Department of Mathematics

This thesis deals with non-cavitating swirling flows with vortex breakdown in various tubes. Phenomenological and quantitative investigations were carried out at Reynolds numbers ($Re_D = U_0D_0/n$) as high as 300,000. It was shown that a high Re_D vortex transitions to its new state (breaks down) via a rapidly spinning spiral form, as demonstrated with 4,000 frame per second video, short exposure time (6 ns) imaging, and Digital Particle Image Velocimetry. Of the known types, the spiral emerges as the fundamental breakdown form, and the axisymmetric bubble may now be regarded as a relatively low Re_D occurrence that is bypassed at sufficiently high Re_D. Some new phenomena were observed at high Re_D: Extremely rapid spiral rotation (over 1,000 revolutions per second), core bifurcation, and reversals in the sense of the spiral windings. Familiar features of breakdowns, such as the transition from jet-like to wake-like axial velocity profiles and the rapidly expanding vortex core, were observed in extensive time averaged velocity and turbulence profiles ascertained with Laser Doppler Velocimetry. However, a mean stagnation point and recirculation were absent in the highest Re_D flow. The core meandering and stagnation point darting in the turbulent flow field were quantified and discussed in detail.

DoD KEY TECHNOLOGY AREA: Air Vehicles

KEYWORDS: Vortex Breakdown, Turbulence, Laser Doppler Velocimetry, Particle Image Velocimetry, Swirling Flow, Spectra

TRANSIENT RESPONSE ANALYSIS OF THE 72 INCH TAC-4 RUGGEDIZED SHIPBOARD RACK SUBJECTED TO AN UNDERWATER EXPLOSION EVENT

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Mechanical Engineer-June 1998
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The finite element modeling and subsequent transient analysis of the 72 Inch TAC-4 Rugged Rack computer system (configurations 000 1AA and OOO3AA only), currently employed in U.S. Navy shipboard applications, has been performed to determine the system's response to simulated shock inputs. This rack is designed to allow incorporation of commercial-off-the-shelf (COTS) computer systems for naval tactical computing requirements while still meeting MJL-STD-901D, the applicable shock specification. By showing the viability of this computer simulation of the shock response of the current TAC-4 rack system, an argument for a lessening of the actual physical testing requirements for acceptance of future TAC systems can be made.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Transient Analysis, Finite Element Method, TAC-4, COTS, Shock Analysis, UNDEX

HUMAN MALE AND FEMALE BIODYNAMIC RESPONSE TO UNDERWATER EXPLOSION EVENTS
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Ship survivability is a complex issue. For a ship to remain a viable warfighting asset following damage resulting from enemy munitions such as mines or torpedoes, the ship's crew must remain sufficiently uninjured to be capable of employing the ship's weapons systems. Sophisticated computer simulations of human response, such as those made possible by the Articulated Total Body (ATB) Model, may be used to estimate injury potentials, and thus crew survivability, during underwater explosion events. With this goal in mind, accelerometer data and video footage recorded during live fire testing were used to generate and validate ATB models for both a seated and a standing Hybrid III Anthropomorphic Test Device (ATD). Subsequently, these models were used to estimate the biodynamic response and injury potentials for both male and female human subjects in a vessel subjected to underwater explosion events. This established a method for evaluating crew survivability for a given underwater explosion induced deck excitation.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Biodynamic Response, Underwater Explosion, Articulated Total Body Program

PRELIMINARY DESIGN STUDY FOR AN ENHANCED MIXING EDUCTOR FOR GAS TURBINE EXHAUST SYSTEMS
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A preliminary design study was conducted to scale the geometry for a new, enhanced mixing eductor for gas turbine exhaust systems. An analytical model was developed to predict the secondary flow and hence the exhaust temperature at the exit to the mixing tube. The model consists of an ideal one-dimensional flow model with a correction factor applied to the secondary mass flow. This factor was chosen to match existing experimental data. This calibrated model was then used to perform a design study to scale the cross sectional areas and assess pressure loss versus performance. A concept with a square mixing tube and multiple high aspect ratio primary nozzles was developed and the baseline geometry was scaled. Two primary nozzles pattern arrangements are provided that should obtain the required mixing in the reduced length.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Other (Surface Ships)

KEYWORDS: Modeling and Simulation, Gas Turbines, Eductors

BIAS EFFECTS ON MOTION STABILITY OF SUBMERSIBLE VEHICLES
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Master of Science in Mechanical Engineering-September 1998
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This thesis analyzes the nonlinear characteristics of motion stability of a submersible vehicle in combined sway, yaw, and roll motions. Previous results, at zero pitch angles, indicate that limit cycles are generated as a result of loss of stability. In

this work, these results are extended to include nonzero pitch angles. This analysis can determine how changes in vehicle parameters and loading conditions will affect its operation and performance. Stability domains are generated for a variety of vehicle and environmental parameters. A nonlinear analysis is conducted in order to assess the stability characteristics of the resulting limit cycles. The results can lead to design guidelines for improving vehicle operational envelopes.

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

KEYWORDS: Roll, Sway, Yaw, Stability of Motion, Periodic Solutions, Bifurcations

COMPUTER SIMULATION OF A TWO-PHASE CAPILLARY PUMPED LOOP (CPL) USING SINDA/FLUINT
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Master of Science in Mechanical Engineering-December 1997
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The heat transfer performance of a prototype capillary pumped loop (CPL) test bed from the U.S. Air Force Phillips Laboratory is modeled using numerical differencing techniques. A commercial computer code was used to create the model and simulate performance over a wide range of operating conditions. Steady-state and transient performance were modeled as part of the initial phase of testing in a program designed to evaluate the effectiveness and reliability of capillary pumped loop technology for use in spacecraft thermal control. The performance baseline developed in this phase of testing will serve as the foundation for continued research and development of this technology.

KEYWORDS: Capillary Pumped Loop (CPL), Evaporator, Noncondensible Gas (NCG) Trap

DoD KEY TECHNOLOGY AREAS: Space Vehicles, Modeling and Simulation

MULTIPLE AUTONOMOUS VEHICLES FOR MINEFIELD RECONNAISSANCE AND MAPPING
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The development of numerical search modeling for Autonomous Search Vehicles (ASV's) is an essential tool for development of ASV strategy using groups of small, crawling vehicles. Reconnaissance of surf-zone bottoms for mines and obstacles, as well as providing an environmental mapping capability, is the objective. These models allow numerical simulations to be conducted that determine the relationships between search times, target and obstacle sensing radius, vehicle speed and numbers of vehicles using simple, preprogrammed search strategies. The results from these simulations on initial models can then be used to determine the overall system performance. More complex models can then be developed using search strategies that include directed search, avoidance behaviors, networking and mapping with sufficient navigational accuracy. With sufficient information on the behavior of these vehicles, the ultimate goal of providing an autonomous reconnaissance and neutralization capability in very shallow water and surf zones can be realized.

KEYWORDS: ASV, Surf Zone Reconnaissance Mission, Simulation, State-Based Robotics

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

DEVELOPMENT OF A CONTROL SYSTEM FOR A SHAPE MEMORY ALLOY (SMA) ACTUATED MEDICAL MANIPULATOR

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This thesis discusses the development of a digital control system used to operate a conceptual robotic manipulator for use in minimally invasive surgery. The motion of the manipulator is envisioned to be accomplished with actuators made of a Shape Memory Alloy (SMA). SMA has the ability to recover permanent deformation by undergoing a phase transformation. The recovery of the deformation results in motion of the SMA material which can be exploited for useful work. SMA was chosen as the actuator because it can be miniaturized and has a very high power density as compared to conventional actuators. An Actuator Matrix Driver (AMD) board was designed, as part of the digital control system, to power and control the SMA actuators. The matrix configuration of the AMD architecture and the use of Amplitude Modulated Pulsed (AMP) current allows for a reduction in the number of leads for the powering and control of the actuators. The electrical resistance, a physical property of SMA which characteristically changes with phase transformation, can be used to determine the state or phase of the SMA actuators and can therefore be used for closed loop control.

KEYWORDS: Shape Memory Alloy (SMA), Actuator Matrix Driver (AMD) Board, Amplitude Modulated Pulsed (AMP) Current

DoD KEY TECHNOLOGY AREA: Sensors

MICROCHEMICAL ANALYSIS OF NON-METALLIC INCLUSIONS IN C-MN STEEL SHIELDED METAL ARC WELDS BY ANALYTICAL TRANSMISSION ELECTRON MICROSCOPY

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Microchemical analyses of the inclusions present in several shielded metal-arc steel weld metals were made by analytical transmission electron microscopy (TEM). Low alloy C-Mn steel weld metal samples were studied in which only the titanium and aluminum contents varied significantly. Carbon extraction replicas were made from each of the weldments and the inclusions were analyzed in the TEM by energy dispersive x-ray (EDX) and parallel electron energy loss spectroscopy (PEELS). The results indicated that, for weld metals containing small amounts of Al (13 ppm), the inclusions were comprised of MnO-$Si0_2$, Tig (maybe as a compound) and Cu(Mn)S. As the Al content was increased to 160 ppm, Mn and Si no longer took part in the deoxidization process and the inclusion compositions were dominated by TiO and $A1_20_3$ along with some sulfides. For weld metal containing a much higher amount of Al (580 ppm) the inclusions became essentially mixtures of TiO, $A1_20_3$ and TiN sometimes complexed with sulfides. These inclusion chemistries were predicted by the use of equilibrium thermodynamics and their effect on the microstructure and mechanical properties of the steel weld metals investigated.

DoD KEY TECHNOLOGY AREA: Materials, Processes and Structures

KEYWORDS: Shielded Metal Arc Welding, C-Mn Steel Weldments, Non-Metallic Inclusions, Transmission Electron Microscopy

A MATHEMATICAL MODEL OF KNEE KINEMATICS UTILIZING THE PRINCIPLE OF MINIMUM ENERGY

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This thesis seeks to determine if the path of motion of the knee in passive flexion results from the minimization of potential energy in the joint ligaments. To investigate this hypothesis, a simulation modeling both collateral and cruciate ligaments was developed, with each cruciate ligament represented as two separate fibers. The model computed almost 8000 possible orientations of the femur during flexion through 120, with the surfaces of the femur and tibia serving as a constraint to motion. Each orientation of the femur inherently provided the position of the individual ligament attachment points, from which the extension or contraction and the potential energy of the ligament were derived. The energy of the entire six-ligament system resulted from the summation of the potential energy of individual ligaments. For each 10 of flexion, the femur position that produced the minimum energy of this six-ligament system was identified. Finally, the motion of the femur as it followed these positions was evaluated: it did not mirror known joint motion. There are several areas where further refinement of the simulation can be made before a complete evaluation of the hypothesis can be made.

DoD KEY TECHNOLOGY AREA: Biomedical

KEYWORDS: Energy Minimization, Knee, Flexion, Ligament

SENSITIVITY ANALYSIS OF DIVE PLANE REVERSAL OF SUBMERSIBLE VEHICLES AT LOW SPEEDS

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Second Reader: Terry McNelley, Department of Mechanical Engineering

The capability of a submersible vehicle to accurately maintain its commanded depth in a variety of operating speeds, depths and loading conditions is critical for mission accomplishment. Below a certain critical speed a phenomenon known as dive plane reversal occurs, where depth response changes sign with respect to a given dive plane command. This thesis builds on previous studies of the phenomenon and it presents a comprehensive sensitivity study of dive plane reversal envelopes in the presence of external forces and moments on the vehicle. Based on these results, rational design and operational decisions can be made in order to avoid unpredictable vehicle responses.

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

KEYWORDS: Dive Planes, Critical Speed

CAVITATION EFFECTS ON A SHIP-LIKE BOX STRUCTURE SUBJECTED TO AN UNDERWATER EXPLOSION

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Shock trials are required for the lead ship of each new construction shock hardened ship class. Live fire shock trials are both complex and expensive. Finite element modeling and simulation provides a viable, cost effective alternative to live fire shock trials. This thesis investigates the effect of bulk and local cavitation on a three-dimensional ship-like box model. The fluid surrounding the structure will be modeled
to capture the effect of cavitation. Viable results will validate the modeling and simulation method used and provide the basis for further investigation into the use of fluid modeling in underwater explosion simulation.

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

KEYWORDS: Underwater Explosion, Cavitation, Surface Model

IMPROVED COMPUTER MODELING OF SHIP PROGRESSIVE FLOODING AS A DESIGN TOOL

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When a ship suffers underwater damage, there is a rapid influx of water, followed by a period of slower progressive flooding. This results in flooding of compartments whose hull boundaries, but not interior bulkheads, are still intact. An existing computer model uses the FORTRAN computer language and formatted input files to model progressive flooding. This thesis uses MATLAB computer language and SIMULINK graphical user interface to provide a modular, expandable progressive flooding design tool.

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

KEYWORDS: Progressive Flooding, Computer Model