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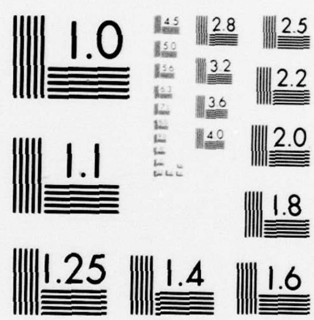

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First Annual Joint Symposium

ENGINEERING FOR THE DEEP OCEAN

University of Notre Dame
University of Massachusetts

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Project THEMIS

CONTRACT ONR-N00014-68-A-0152

University of Notre Dame
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46556

Notre Dame
THEMIS Project

First Annual Joint Symposium

ENGINEERING FOR THE DEEP OCEAN

University of Notre Dame
University of Massachusetts

Notre Dame
THEMIS Project

(6)

First Annual Joint Symposium (1st)
~~under~~
~~Project THEMIS~~
on

ENGINEERING FOR THE DEEP OCEAN

Held
December 13, 14, 1968
at
University of Notre Dame,
Notre Dame, Indiana,

(11) 1968

Co-Sponsors:
The University of Notre Dame
The University of Massachusetts (12) 46

Under the Technical Direction
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The Office of Naval Research (15)

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PARTIAL CONTENTS:

JOINT SYMPOSIUM PROGRAM

Thursday, December 12, 1968

4:00- 8:00 P.M. - Registration
Lobby, Center for Continuing Education

Friday, December 13, 1968

8:00- 9:00 A.M. - Registration
Lobby, Center for Continuing Education

9:00-10:10 A.M. - General Session I
Auditorium, Center for Continuing Education
Chairman: Dr. Charles E. Carver, Jr.
Co-Manager, Project THEMIS,
University of Massachusetts, Amherst

9:00- 9:15 A.M. - Welcome: Dr. Frederick D. Rossini,
Vice-President for Research and Special Programs,
University of Notre Dame

9:15 A.M. - Lecture: "DEEP SUBMERGENCE VEHICLE DEVELOPMENT",
Mr. Roger D. Fuller, Program Manager,
Deep Submergence Search Vehicle,
Lockheed Missiles and Space Company,
Sunnyvale, California

10:10-10:30 A.M. - Coffee Break - Patio

10:30-12:00 P.M. - Technical Session IA & IB (Concurrent)

Technical Session IA
Room 112, Center for Continuing Education
Chairman: Dr. S. M. Bemben,
Department of Civil Engineering
University of Massachusetts

10:30-11:00 A.M. - "STATISTICAL ERROR ANALYSES NAVIGATION SYSTEMS",
C. E. Hutchinson,
University of Massachusetts

11:00-11:30 A.M. - "SENSITIVITY OF STABILITY OF A CLASS OF NON-LINEAR TIMEVARYING NETWORKS",
R. W. Liu, University of Notre Dame

over

Friday, December 13, 1968 (cont'd.)

11:30-12:00 P.M. - "SUBSYSTEM VALUE AND COST-DEEP OCEAN SYSTEMS"
W. E. Heronemus,
University of Massachusetts

Technical Session IB
Room 210, Center for Continuing Education
Chairman: Dr. K. T. Yang,
Department of Mechanical Engineering
University of Notre Dame

10:30-11:00 A.M. - "TURBULENT FREE CONVECTION"
A. A. Szewczyk,
University of Notre Dame

11:00-11:30 A.M. - "SURFACE WAVE ATTENUATION FOR OCEAN ENGINEERING PURPOSES"
J. M. Cornell, University of Massachusetts

11:30-12:00 P.M. - "DRAG EFFECTS OF POLYMER ADDITIVES IN TURBULENT NON-NEWTONIAN FLAT PLATE BOUNDARY LAYER FLOW"
R. L. Sampson, University of Notre Dame

12:15- 2:00 P.M. - Luncheon, Center for Continuing Education
Presiding: William B. Walker, Commander, USN,
Director Undersea Programs,
Office of Naval Research, Washington, D.C.

Address: "THE AIMS AND OBJECTIVES OF PROJECT THEMIS" → over
Dr. Arwin A. Dougal, Assistant Director (Research) and Chairman,
Project THEMIS Task Group, Office of the Director of Defense Research and Engineering, Washington, D. C.

2:00- 4:00 P.M. - Technical Session IIA & IIB (Concurrent)

Technical Session IIA
Room 112, Center for Continuing Education
Chairman: Dr. C. E. Hutchinson,
Department of Electrical Engineering
University of Massachusetts

2:00- 2:30 P.M. - "THE VERTICAL HOLDING CAPACITY OF MARINE ANCHORS IN SANDS"
S. M. Bemben
University of Massachusetts

2:30- 3:00 P.M. - "FATIGUE STRENGTH OF SODA-LIME-SILICA GLASS"
J. E. Ritter, Jr.
University of Massachusetts

3:00- 3:30 P.M. - "THE EFFECT OF STRESS ON MAGNETOSTRICTION"
C. W. Allen
University of Notre Dame

3:30- 4:00 P.M. - "DEVELOPMENT OF HIGH MAGNETOSTRICTION TRANSDUCER ALLOYS"
A. E. Miller
University of Notre Dame

4:00- 4:15 P.M. - Coffee Break - Lobby

Technical Session IIB
Room 210, Center for Continuing Education
Chairman: Dr. A. A. Szewczyk
Department of Mechanical Engineering
University of Notre Dame

2:00- 2:30 P.M. - "ON THE FLOW FIELD AROUND A MARINE DUCTED PROPELLOR"
D. E. Cromack,
University of Massachusetts

2:30- 3:00 P.M. - "PHYSICAL AND NUMERICAL EXPERIMENTS IN HYDRODYNAMIC WAKE FLOWS"
T. J. Mueller
University of Notre Dame

3:00- 3:30 P.M. - "TRANSMISSION OF SOUND THROUGH WIRE SCREENS IN A STEADY FLOW"
G. A. Russell
University of Massachusetts

3:30- 4:00 P.M. - "LAMINAR FREE CONVECTION FROM A NON-ISOTHERMAL VERTICAL PLATE IN A TEMPERATURE-STRATIFIED ENVIRONMENT"
K. T. Yang
University of Notre Dame

over

4:00- 4:15 P.M. - Coffee Break - Lobby

4:15- 5:10 P.M. - General Session II
Chairman: Professor W. E. Heronemus
Department of Civil Engineering
University of Massachusetts
Lecture: "RESEARCH NEEDS FOR THE DEEP OCEAN"
Dr. Allyn C. Vine,
Senior Oceanographer,
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts

5:45- 6:45 P.M. - Cocktail Reception,
Mahogany Room - Morris Inn

6:45- 8:30 P.M. - Symposium Banquet- Morris Inn
Presiding: Dr. Joseph C. Hogan
Dean, College of Engineering
University of Notre Dame

8:30 P.M. - General Session III
Auditorium, Center for Continuing Education
Chairman: Dr. Harry C. Saxe
Program Manager, Project THEMIS
University of Notre Dame
Lecture: "CONSTRUCTION AND PROPOSED USES OF THE SUBMERSIBLE- BEN FRANKLIN"
Walter H. Scott, Jr.
Director, Ocean Systems Department
Grumman Aircraft Engineering Corporation
Bethpage, New York

Saturday, December 14, 1968

9:00- 9:55 A.M. - General Session IV
Auditorium, Center for Continuing Education
Chairman: Dr. L. H. N. Lee
Department of Engineering Science
University of Notre Dame
Lecture: "DEEPSTAR 4000 - AN OCEANOGRAPHIC RESEARCH TOOL"
Mr. Richard Usry
Deepstar Marketing Representative
Westinghouse Underseas Division
Ocean Research and Engineering Center
Baltimore, Maryland

over

9:55-10:15 A.M. - Coffee Break - Patio

Saturday, December 14, 1968 (cont'd.)

10:15-11:45 A.M. - Technical Session IIIA & IIIB (Concurrent)

Technical Session IIIA
Room 112, Center for Continuing Education
Chairman: Dr. B. D. Cullity
Department of Metallurgical Engineering and Materials Science
University of Notre Dame

10:15-10:45 A.M. - "THE APPLICATION OF DYNAMIC RELAXATION TO THE FINITE ELEMENT METHOD OF STRUCTURAL ANALYSIS"
S. Kelsey
University of Notre Dame

10:45-11:15 A.M. - "NON-LINEAR ANALYSIS OF PLATES AND SHELLS"
M. M. Miller
University of Massachusetts

11:15-11:45 A.M. - "INELASTIC AXISYMMETRIC BUCKLING OF RING STIFFENED CYLINDRICAL SHELLS"
L. H. N. Lee
University of Notre Dame

Technical Session IIIB
Room 210, Center for Continuing Education
Chairman: Dr. J. F. Ritter, Jr.
Department of Mechanical and Aero-Space Engineering
University of Massachusetts

10:15-10:45 A.M. - "LIGHT SCATTERING AS A METHOD OF DETERMINING THE ACOUSTICAL AND TRANSPORT PROPERITIES OF FLUIDS"
A. A. Monkewicz
University of Notre Dame

10:45-11:15 A.M. - "DYNAMIC PROGRAMMING AND THE DISCRETE MAXIMUM PRINCIPLE"
R. J. Leake
University of Notre Dame

11:15-11:45 A.M. - "MICROSTRUCTURE EFFECTS IN THE ANALYSIS OF COMPOSITES"
T. Ariman
University of Notre Dame

over

12:00- 1:45 P.M. - Luncheon
Center for Continuing Education
Presiding: Dr. C. E. Carver, Jr.
Co-Manager, Project THEMIS
University of Massachusetts
Lecture: "SEALAB - III"
John R. Lindsay, Captain USN
Deputy Project Manager
Deep Submergence Systems Project Office
Chevy Chase, Maryland

1:45- 3:30 P.M. - Closing Session
Auditorium for Continuing Education
Panel Discussion - Topic: "WHAT'S AHEAD IN OCEAN ENGINEERING".
Moderator: Dr. Kenneth G. Picha
Program Manager, Project THEMIS
and Dean, School of Engineering
University of Massachusetts

Panel Consisting of:

Dr. Victor C. Anderson
Acting Director, Marine Physical Laboratory
Scripps Institution of Oceanography
La Jolla, California

Dr. Frank A. Andrews
Director, Institute of Ocean Engineering
The Catholic University of America
Washington, D.C.

Captain Henry A. Arnold
Marine Sciences Council
Executive Office of the President
Washington, D.C.

Commander William B. Walker
Director, Undersea Programs
Office of Naval Research

STATISTICAL ERROR ANALYSES OF NAVIGATION SYSTEMS

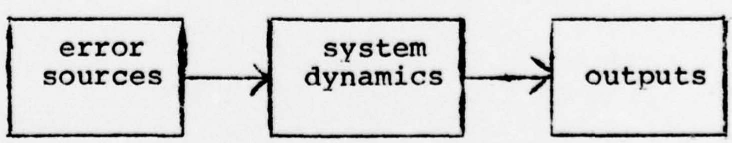
by

Charles E. Hutchinson
Electrical Engineering Department
University of Massachusetts
Amherst, Massachusetts

The problem of accurate navigation is critical to any marine operation. Specifically one would like to have precise continuous position information in all types of weather at all operating locations. This of course, is not possible, but it is a commendable goal for any navigation system. Due to the importance of navigation and the expense of obtaining precise position information considerable effort is expended trying to analyze the errors inherent to any system. Historically, however, it is only recently that the problem of error analyses of navigation systems has been approached from a statistical viewpoint.

This paper presents the concept of error analysis, both deterministic and stochastic. The procedures are outlined using the inertial system as an example, however, the techniques have application to any navigation system.

The task of analyzing errors in navigation systems may be illustrated by the following diagram.



That is, three separate sub-problems exist. Starting from the right in the diagram above, the first task is to determine what system outputs are critical to the system mission. For most applications this would simply be latitude and longitude. Although there are cases where other outputs become important as well. For the sake of example we will consider latitude error in an inertial system, as the specific output of concern.

The next phase of the analysis is to determine the sources of error and then the dynamics which describes how these sources effect the outputs. For any system of practical value there will be many such error sources. For the inertail system the list might include such items as:

gyro drift rates
accelerometer errors
velocity reference errors
platform misalignments
initialization errors
etc.

Each of these error sources might in turn be further divided. Such as, under gyro errors we might have:

mass unbalance
temperature effect
g sensitive drift
etc.

The dynamics involved are normally determined by noting the physical properties of the system. The various components must be analyzed to determine their individual dynamic behavior. This portion of the problem is probably the most readily available to the analyst. Much work has been done in this area.

SENSITIVITY OF STABILITY OF A CLASS OF NON-LINEAR TIMEVARYING NETWORKS

by

R. W. Liu
Electrical Engineering Department
University of Notre Dame
Notre Dame, Indiana 46556

Sensitivity problems of stabilities of network models are considered. There are two reasons to choose a nonlinear network model, instead of a nonlinear systems model (state equations). Firstly, since any nonlinear system equation can be synthesized by a nonlinear network, no generality is lost by studying nonlinear networks. Secondly, unlike system models, a network has a structure: interconnections of components. Therefore, it is more convenient to consider sensitivity problems in a network model.

The problem is to study the effect on the stability behavior of a network with a variation of a (nonlinear) component. Two kinds of stabilities are studied: the global asymptotic stability with zero-input and the convergence of solutions with an input.

Two classes of networks are considered: passive networks and two-element-kind networks. Necessary and sufficient conditions for each case are obtained. The conditions are in terms of network topology and characteristic equations of network elements. Therefore, it is very easy to test.

SUBSYSTEM VALUE AND COST-DEEP OCEAN SYSTEMS

by

William E. Heronemus
Civil Engineering Department
University of Massachusetts
Amherst, Massachusetts

This paper is intended to describe the total scope of a University of Massachusetts THEMIS project in which four principal investigators and five graduate assistants are conducting research as individuals, but all correlating with one central project theme. The project title in itself is deliberately broad: "Deep Submergence Vehicle System Design." We are interested in the DSV System in its broadest and narrowest connotations. We are interested in the designs of others, and we fully intend to create many designs of our own. We are conducting research in the highly specialized field of subsystems and components for navigation, guidance and control, but we want to evaluate them and the value of our research only in terms of what they mean to the cost and value of a Deep Ocean System.

This is the first attempt at a summarizing report on the entire research project. It is a very early report: the project has scarcely been started from the broad point of view albeit it is a year-and-a-half along in some of its specialized efforts to date are reported by Hutchinson and Monopoli et al. in several other THEMIS reports, one of which will be read here at this meeting.

The Deep Ocean System is thus a working system, a mission and task accomplishing system, not an inanimate object. Seven examples of major working devices which could be found in the 02 tier for a Deep Ocean System are:

(a) A Deep Submergence Vehicle--any one of many different varieties, depending upon the Mission and Tasks of the Deep Ocean System

(b) An Off-shore Oil Drilling Rig

(c) An Off-shore Oil Production, Storage and Distribution Plant

(d) A Fish Food Processing Ship

(e) A Sea Bed Mining Dredge

(f) An Observational Laboratory for Marine Sciences Education

(g) A "Sea Lab"

The current University of Massachusetts THEMIS Project limits the 02 tier to a Deep Sea Vehicle.

Results to Date

This project in its broad sense has just been started. Results to date are:

(a) Verification that the one, two and three sphere "hulls" are best suited for the initial scope of the investigation.

(b) Determination of a set of sphere diameters appropriate to one through five man occupancy.

(c) Calculations that demonstrate that the three selected energy storage subsystems are reasonably competitive.

(d) Verification that the project should neither ignore the lower depth bands nor the lower cost less sophisticated pressure hulls.

(e) Verification that the many published computer programs for naval architectural computations are not directly applicable to computation of the DSV hull which is a chain of displacement shapes enveloped by a free-flooding outer hull.

(f) Collection and partial analysis of considerable data describing existing DSV's, their subsystems and their components.

(g) Initial computations with a DSV Simulation Computer Program.

(h) Formulation of policy concepts for the kinds of navigation, command and control subsystems to which emphasis will be applied.

(i) Initial description of kinds of variable ballast and trim subsystems to which emphasis will be applied.

Plans for Future Work

During the spring and summer considerable effort will be expended on the mathematical and computer aids required on the project. The collection and analysis of data defining existing DSV's will continue. The collection and analysis of subsystem and component data and synthesis of subsystems for the initial families of DSV's will continue. Synthesis and graphic delineation of the initial families of DSV's will be started. Definition of subsystem value and cost parameters will continue. By iteration those subsystems found to be of most value will become ever more apparent. The possibilities for more versatile Deep Sea Vehicles of lower initial and ongoing cost will follow the identification of value and cost of their subsystems.

The long-range goal is that any new subsystem, component, material, fabrication process, any research product, aimed toward improved Deep Submergence Vehicles, can be evaluated for value and cost in any of a very large number of DSV families. The long-range goal is a continuing trade-off study in the entire field of DSV technology.

TURBULENT FREE CONVECTION

by

A. A. Szewczyk
Department of Mechanical Engineering
University of Notre Dame
Notre Dame, Indiana

The engineering relevance of turbulent free convection on heated surfaces in connection with under-sea heat rejection systems is first emphasized. The talk describes a differential phenomenological theory for turbulent free convection along a heated vertical plate. The total viscosity is taken to be governed by a rate equation which takes into account turbulent convection, diffusion; generation and decay, while the turbulent thermal diffusivity is based on a constant turbulent Prandtl number. Calculations based on experimental data for air show that the turbulent boundary layer consists of a viscous sublayer with nonlinear velocity distribution, an inner layer dominated by turbulent generation and decay and sensitive to the Grashof number, and an outer layer governed by turbulent convection and diffusion, and that Corrsin's viscous super layer also exists in the present case.

Also described is the progress on the accompanying experimental study in which temporal and spectral details of the turbulent boundary layer of air on a cooled vertical plate 23 feet and 6 inches in height, are to be measured. The primary purpose here is to provide much needed data to further substantiate the theoretical findings.

SURFACE WAVE ATTENUATION FOR OCEAN ENGINEERING PURPOSES

by

Dr. C. E. Carver, Jr.
Dr. J. M. Colonell
Department of Civil Engineering
University of Massachusetts
Amherst, Massachusetts

The lauching and recovery phases of submersible vehicle operation can be extremely hazardous to personnel and the vehicle itself when surface wave activity exceeds specified operating limits. To minimize dangers produced by high seas and the resulting excessive vehicle motions, it is suggested that mobile breakwater devices be deployed by the mother ship. The primary objective of this investigation is to evaluate the feasibility of using either hydraulic or pneumatic breakwater devices to create an acceptable environment for the lauching and recovery of a submersible vehicle.

Previous studies of these breakwater devices are summarized and a brief of the associated hydrodynamical theory is presented. The experimental program for this investigation will be conducted in a wind and water wave research facility now under construction. This facility, which has a cross-section that is 2 feet wide by 4 feet high and has a length of 48 feet, will enable the study of waves generated by winds with speeds up to 60 fps. The experimental schedule for the investigation is discussed with particular attention to the program objectives.

DRAG EFFECTS OF POLYMER ADDITIVES IN TURBULENT NON-NEWTONIAN FLAT PLATE BOUNDARY LAYER FLOW

by

R. L. Sampson
Department of Chemical Engineering
University of Notre Dame
Notre Dame, Indiana

The current status on drag reduction with polymer additives in pipe flows as well as in boundary layer flows is briefly reviewed. This THEMIS project deals essentially with the experimental study of drag reduction effects of polymer additives in the turbulent boundary layer on a flat plate. A fully instrumented water-tunnel facility, specially designed for this experimental study with suitable control in flow and temperature, has been constructed and will become operational shortly. A laser velocimeter system is developed and its measurements have been compared with that of a pitot tube.

A predictive analysis of drag coefficients for turbulent non-Newtonian flat plate boundary layer flow has also been developed. With computer assistance, flat plate drag coefficients are calculated as functions of a generalized Reynolds number and fluid rheological properties. In utilizing both the laser velocimeter and pitot tubes for velocity measurements and the capillary tube viscometer for determination of rheological properties, data for turbulent boundary layer flow will be obtained for water and aqueous carbopol solutions. Dilute carbopol solutions are characterized by non-Newtonian power low behavior with negligible elasticity. These experimental data will be compared with the theoretical predictions.

THE VERTICAL HOLDING CAPACITY OF MARINE ANCHORS IN SAND

by

S. M. Bemben
Department of Civil Engineering
University of Massachusetts
Amherst, Massachusetts

A large-scale outdoor test bin facility has been constructed. The appurtenances include a well point system for drawdown and recharge purposes and a movable reaction frame. Pulling loads are applied by a hydraulic jack and chain assembly and are measured by strain gage load cells.

To date, model anchors having projected horizontal areas of about 1.5, 15, 30, 60 and 120 square inches have been inserted to various depths ranging between 2 feet and 6 feet in a flooded sand soil and load tested for vertical holding capacities. For insertion, the anchors are attached to the lower end of a rigid pipe and vibrated into place by means of a vibrator unit attached to the upper end. A horizontally cancelling double eccentric vibrator and a single eccentric vibrator have been employed; both units are driven by a controlled variable speed motor.

Preliminary test data indicate that, for the anchors tested in the one sand used, an optimum resisting load develops when the ratio of the depth of burial to the square root of the horizontal projected area of the anchor is about 5 to 1. The ratio of the peak resisting loads to horizontal projected area appears to increase slightly with increasing anchor size.

FATIGUE STRENGTH OF SODA-LIME-SILICA GLASS

by

J. E. Ritter, Jr.
Aerospace & Mechanical
Engineering Department
University of Massachusetts
Amherst, Massachusetts

The effect of strain rate on the room-temperature strength of soda-lime-silica glass was determined. The strength of acid-etched glass rods increased continuously from 190 200 to 284 800 psi on increasing the strain rate from $9X10^{-4}$ to $15X10^{-2}$in./in./min. No difference in strengths was observed on testing in laboratory atmosphere or with the specimens wetted with distilled water. For abraded glass rods the strength in laboratory atmosphere varied from 12 555 to 16 540 psi on varying the strain rate from $3X10^{-3}$ to $9X10^{-2}$in./in./min. Tests conducted with the abraded samples wetted with distilled water caused approximately a 10% reduction in strength, but no appreciable change in the strain-rate sensitivity. The stress corrosion model proposed by R. J. Charles successfully predicts the room temperature strain-rate sensitivity of the failure process for both acid-etched and abraded glass samples. Using relationships derived from this model, it was further shown that the stress concentration relationship proposed by Inglis is valid for acid-etched glass.

THE EFFECT OF STRESS ON MAGNETOSTRICTION

by

C. W. Allen
Metallurgical and Materials Science Engineering
University of Notre Dame
Notre Dame, Indiana 46556

An elementary introduction to a number of facts regarding magnetostriction, including its anisotropy, is presented. The effect of stress on magnetostriction enters in terms of the effect of stress on the distribution of magnetization, a change of which in turn modifies the magnetostriction. This is illustrated by experimental curves showing the effect of applied tensile and compressive loads on the magnetization curves for iron and nickel of commercial purity and on the technical magnetostriction curves for these situations. Preliminary data are presented on magnetostriction of iron and nickel with very low frequency magnetic field cycling at several levels of applied stress and average magnetization.

DEVELOPMENT OF HIGH MAGNETOSTRICTION TRANSDUCER ALLOYS

by

A. E. Miller
Metallurgical & Materials Science
Engineering Department
University of Notre Dame
Notre Dame, Indiana

A simple model of a magnetostrictor as an electromechanical energy conversion device is presented and examined to delineate those materials variables of prime importance in magnetostrictive transducers. The efficiency of the model presented is examined and it is concluded that design goals for magnetostrictive transducer materials should be to obtain materials lacking porosity and internal residual stresses and having a large magnetostrictive strain and a small magnetic anisotropy.

The magnetostrictive character of iron rich Fe-Co and Fe-Al alloys is presented and the possibility of optimizing magnetic anisotropy and magnetostrictive strain in an iron rich Fe-Co-Al alloy is discussed.

ON THE FLOW FIELD AROUND A MARINE DUCTED PROPELLER

by

J. A. Fillo
D. E. Cromack
Mechanical and Aerospace Engineering
University of Massachusetts
Amehurst, Massachusetts

This report describes the research currently being conducted on marine ducted propellers at the University of Massachusetts under Project THEMIS. A brief summary of the progress is included.

The experimental test facility that has been designed and is being constructed, along with some of the instrumentation and tests to be conducted are described. A summary of experimental and analytical methods used by other investigators for ducted propellers is presented. Methods of improving and extending these analyses are also discussed. A theoretical approach to the analysis of ducted propellers appears to be more beneficial than an experimental parametric study because of the enormity of doing the latter. Thus the theoretical results are eventually to be compared to selected experimental conditions.

PHYSICAL AND NUMERICAL EXPERIMENTS IN HYDRODYNAMIC WAKE FLOWS

by

Thomas J. Mueller
Aerospace & Mechanical
Engineering Department
University of Notre Dame
Notre Dame, Indiana

Experimental and numerical studies were performed to determine the structure of the viscous wake flow behind a backward facing step. The experimental program was performed in a hydrodynamic towing facility using two backstep models. The first model had a distance from nose to backstep of 10 inches, a step height of 0.50 inches and a step aspect ratio of 6. The second model was exactly the same as the first model except that it had a step aspect ratio of 9. Both models measured 9 inches from the bottom of the step to the end of the splitter plate.

The backstep model was submerged in the hydrodynamic twoing facility, and rigidly attached to a motor driven camera cart above the tank. Aluminum powder was suspended in the water so that streak-time photographs could be taken. From a large number of streak-time photographs and using an optical comparator, it was possible to determine the velocity distribution in the boundary layer upstream of the step as a function of Reynolds number. These velocity distributions formed part of the input for the numerical studies. The streak-time photographs also produced data for the length of the separated flow region to reattachment as a function of step Reynolds number.

The variation of measured boundary layer thickness with Reynolds number based on length from the leading edge of the model was compared with the values obtained by Blasius, i.e., $\delta/x \sim [R_{ex}]^{-1/2}$. As R_{ex} decreases, the Blasius result indicates that δ increases for a fixed X. The measured δ approximately agreed with the Blasius result from R_{ex} of 7000 to about 2000. As R_{ex} decreased below 2000 to the lowest value obtained of 400, however, the measured value of δ decreased while the Blasius δ increased sharply.

For each Reynolds number, the measured velocity distribution was inserted as part of the inflow boundary condition for the numerical study of planar incompressible laminar flow over a backstep. This numerical method used the appropriate time-dependent finite difference equations with physically meaningful boundary conditions. A direct comparison of the numerical results with the corresponding experiments was made for the variation of length of the separated flow with step Reynolds number. As the step Reynolds number increased from 27 to about 200, the dimensionless length of the separated region increased for both the numerical and experimental results. Furthermore, this comparison indicated a very good quantitative agreement.

TRANSMISSION OF SOUND THROUGH WIRE SCREENS IN STEADY FLOW

by

G. A. Russell
S. N. B. Murthy
Mechanical and Aerospace Engineering
University of Massachusetts
Amherst, Massachusetts

The transmission of sound across a wire grid located cross-sectionally in a small tube carrying a low velocity flow is studied. A brief history of this and related problems is presented together with a technical justification for the present research.

The physical arrangement of the wire grid and tube is presented and the assumptions necessary for writing linearized perturbation equations are discussed. The equations are given and a derivation of a subsequent equation involving the steady flow velocity, screen constant, acoustic frequency, and sound transmission coefficient is outlined. The interpretation of this equation in terms of the limiting case of no flow is discussed. Numerical solutions of the equation are presented and briefly interpreted in terms of air flow. An extension to the case of other flowing fluids is also outlined.

Experimental results obtained to date are presented and some of the measurement problems are discussed. Plans for future analytical and experimental studies and possible applications for deep submersible vehicles are given.

LAMINAR FREE CONVECTION FROM A NON-ISOTHERMAL VERTICAL PLATE IN A TEMPERATURE-STRATIFIED ENVIRONMENT

by

K. T. Yang
Aerospace & Mechanical
Engineering Department
University of Notre Dame
Notre Dame, Indiana

The temperature-stratified ocean environment may significantly influence the rate of heat transfer from a heated surface and thus the performance of a practical heat-rejection system. Such temperature stratification also exists in underwater habitats. In this study the phenomenon of laminar free convection along a non-isothermal vertical plate in a temperature or density-stratified environment is investigated both analytically and experimentally.

Analytically, a similarity solution in terms of three physical parameters has been obtained. Two of these parameters refer to the wall and ambient temperature variations, while the third is the Prandtl number of the fluid in the environment. Extensive numerical solutions to the resulting ordinary differential equations have been carried out for wide ranges of these parameters which are of physical importance. To help determine the complete effect of Prandtl number, efforts have been directed toward obtaining, by asymptotic analyses, limiting behaviors for Prandtl numbers approaching zero or infinity. All numerical results are now complete, and have provided the basis for discussing the physical effects of the parameters or the heat-transfer characteristics at the plate, as well as for demonstrating the fact that approximate solutions based on quasi-uniform environmental temperatures are not adequate to predict the effects of ambient temperature variations and the analysis must include temperature stratification in the environment. Furthermore, several interesting, but unexpected behaviors dealing with the interaction of parameters have been noted, and have been explained in terms of the physical processes.

In the experimental study, an environmental tank, 60" in height and 30" in diameter, has been designed, fabricated, and will become operational shortly. An 6" Mach-Zehnder interferometer purchased by matching University and National Science Foundation funds, has been ordered and this interferometer will be used to map detailed temperature or density field surrounding the heated test vertical plate mounted in the environmental tank through 8" optical flat windows. The design of the tank stand, test vertical plate and instrumentation is still progressing.

THE APPLICATION OF DYNAMIC RELAXATION TO THE FINITE ELEMENT METHOD OF STRUCTURAL ANALYSIS

by

S. Kelsey
Civil Engineering Department
University of Notre Dame
Notre Dame, Indiana

Dynamic Relaxation, as developed by Day, Otter, Cassell et al, is a matrix iterative method for the solution of simultaneous linear equations. The application of the technique to problems of structural analysis under static stress conditions, as used by these investigators, has been almost exclusively associated with the finite difference formulation in space of both the equations of motion and the constitutive relationships.

In this report the authors discuss the constraints which the earlier investigators have placed on the method of Dynamic Relaxation by restricting themselves to the finite difference approach, particularly in relation to the static stress analysis of plates and shells having arbitrary geometric discontinuities and boundaries. To overcome this problem, an alternative approach using finite elements in space, in lieu of finite differences, is proposed and developed.

The mathematical basis for the application of Dynamic Relaxation to the solution of the equations of motion, and the constitutive equations is given for the finite element approach in space. The convergence of the method is analyzed by transforming the process into a standard eigenvalue problem for the error vector, and its dependence on the conditioning of the equations is demonstrated. Values of the parameters used in the iteration to optimize convergence are derived. The theory for the optimum asymptotic convergence of Dynamic Relaxation is shown to be applicable to a much wider range of problems than is the method of Successive Overrelaxation. For the special case of a tridiagonal form of the coefficient matrix, a comparison of the optimum convergence of Dynamic Relaxation is made with that of the other basic iterative methods, namely Point Jacobi, Gauss-Seidel, and Successive Overrelaxation. In this particular instance, the convergence of Successive Overrelaxation is shown to be better than that of Dynamic Relaxation.

A strategy for approaching the optimum convergence of Dynamic Relaxation is developed and demonstrated by the application to plane stress problems which include the static stress analysis of flat plates with circular, elliptical and filleted square holes.

THE NONLINEAR ANALYSIS OF PLATES & SHELLS

by

Dr. M. M. Miller
Dr. A. Chajes
Department of Civil Engineering
University of Massachusetts
Amherst, Massachusetts

Using the finite difference technique, a method for non-linear shell analysis is being perfected. Newton's method is used to linearize the nonlinear terms in the differential equation. A load-deflection curve is obtained by increasing the load in small increments. For each increment the variable coefficients that arise from Newton's expansion are obtained by an iteration procedure. Consequently, a large set of simultaneous linear algebraic equations is solved repeatedly. If the behavior of the shell is described by second order differential equations one obtains a tri-diagonal block system after substitution of the difference ratios. The solution is obtained by Gaussian elimination where the individual elements are blocks each consisting of several unknowns.

Using a shell with double curvature the above algorithm has been tested and found to be satisfactory.

The variables in the second order differential equations are inplane and transverse displacements. This formulation is useful only if the boundary conditions are given in terms of displacements. If the boundary conditions are given in terms of forces, a formulation consisting of two second order equations becomes more convenient. Using a plate loaded both axially and transversely, various boundary conditions were investigated. Both the second order equations and the fourth order equations gave satisfactory results when used in cases with appropriate boundary conditions.

For a shell subject to instability more than one equilibrium configuration may exist in the large deflection domain. It is possible that a shell may "snap through" from one of these to another. This phenomenon exists also in plates and has been studied extensively for that case.

The methods described above are now being applied to a cylindrical shell under external pressure and axial compression.

INELASTIC AXISYMMETRIC BUCKLING OF RING STIFFENED CYLINDRICAL SHELLS

by

L. H. N. Lee
Department of Engineering Science
University of Notre Dame
Notre Dame, Indiana

In this paper, the effects of prebuckling deformation caused by the ring constraints on the inelastic axisymmetric buckling of ring stiffened cylindrical shells under external pressure are studied. By Drucker's postulate of positive work in plastic deformation, a modified incremental theory of plasticity on the stress-strain relationships expressed in terms of Kirchhoff stress and Green strain rates is developed. Furthermore, a variational principle in Lagrangian descriptions and for quasi-static problems of finite plasticity is developed and employed to solve the problem.

It is shown that the modified constitutive relationships satisfy the coordinate and spatial invariance and energy requirements. Using the constitutive relationships, the existence of an extremum principle for a material having a sufficiently great rate hardening is shown and a criterion for the stability of a body under dead load is established.

The variational principle in conjunction with the incremental Rayleigh-Ritz technique is used to determine the deformation process of an idealized cylindrical shell composed of four thin load-carrying sheets made of a general work hardening material. A comparison of the theoretical predictions obtained numerically by an Univac 1107 digital computer with available experimental results is made. The comparison is favorable.

LIGHT SCATTERING AS A METHOD OF DETERMINING THE ACOUSTICAL AND TRANSPORT PROPERTIES OF FLUIDS

by

A. A. Monkewicz
Department of Engineering Science
University of Notre Dame
Notre Dame, Indiana

A high sensitivity, high resolution system for the study of light scattered from thermal fluctuations in gases has been constructed. A Bendix Channeltron photomultiplier tube with a dark noise of one-tenth of a photoelectron/sec is the basis of an experimental setup which includes a Fabry-Perot interferometer having a band-width of 10 MHz with a piezo-electric scan and single mode He-Ne laser. Resolution of 10 MHz is, therefore, attainable and signal levels as low as four-tenths of a photoelectron/sec yield reliable data.

With this apparatus the density-density correlation function, $G(\bar{r},t)$, of several gases has been investigated for a range of pressures. Whether the form of $G(\bar{r},t)$ is derived from a kinetic or hydrodynamic view depends on the value of the Knudsen number, i.e. the ratio of the acoustic wavelength to the mean free path. Previous studies have concentrated on varying the angle of scattering (Changing the acoustic wavelength) while this study varies the gas pressure itself (changing the mean free path) allowing a more detailed investigation of the transition from the kinetic to the hydrodynamic view.

DYNAMIC PROGRAMMING AND THE DISCRETE MAXIMUM PRINCIPLE

by

R. J. Leake
Department of Electrical Engineering
University of Notre Dame
Notre Dame, Indiana

As with continuous dynamical system optimization, the basic approaches to optimal control of discrete time systems have their origin in the variational theory of mechanics; Dynamic Programming stemming from the Hamilton-Jacobi Theory and the Discrete Minimum Principle based on the Hamilton Canonical Equations.

Necessary and sufficient conditions for optimality of discrete time systems over arbitrary sets are given, followed by some interesting observations concerning global successive approximations. Examples are given, and connections between the minimum principle and dynamic programming are established.

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MICROSTRUCTURE EFFECTS IN THE ANALYSIS OF COMPOSITES

by

T. Ariman
Department of Engineering Science
University of Notre Dame
Notre Dame, Indiana

In this report the theory of micropolar continua has been used to analyze the stresses and displacements within the separate components of a fibrous composite material. The separate constituent materials are assumed to be linearly micropolar elastic, isotropic, and homogeneous. A model chosen consists of parallel fine fibers, embedded in a matrix material. The problem is formulated as one of plane micropolar elasticity and solved for some special cases. Various numerical results are presented and compared to those of the classical and indeterministic couple stress theories.

LIST OF PARTICIPANTS

Charles E. Hutchinson
University of Massachusetts
Electrical Engineering Department
Amherst, Massachusetts 01002

Dr. Russell Keim
Executive Secretary, Ocean Engineering
National Academy of Engineerying
Washington, D.C. 20360

Roger D. Fuller
Lockheed Missiles & Space Co.
24 Greenooks Drive
Atherton, California 94065

William E. Heronemus
University of Massachusetts
Civil Engineering Department
Amherst, Massachusetts 01002

Dr. Frank S. Gardner
Office of Naval Research
495 Summer Street
Boston, Massachusetts 02210

Omar H. Shemdin
University of Florida
Department of Coastal & Ocean Engineering
Gainesville, Florida 32601

Dr. Howard Harrenstein
University of Hawaii
2565 The Mall
Honolulu, Hawaii 96822

D. K. Ela
Westinghouse
Ocean Research & Engineering Center
Annapolis, Maryland 21404

John E. Ritter, Jr.
University of Massachusetts
Engineering Building
Amherst, Massachusetts 01002

LCDR R. D. Kelley
U. S. Naval Academy
Annapolis, Maryland 21402

Henry A. Arnold
United Aircraft Corporation
400 Main Street
E. Hartford, Connecticut 06604

John C. Flynn
General Dynamics/
Electric Boat Division
Eastern Point Road
Groton, Connecticut 06340

Dr. Charles E. Carver, Jr.
University of Massachusetts
Amherst, Massachusetts 01002

D. B. Usry, Jr.
Westinghouse
Post Office Box 1488
Annapolis, Maryland 21401

Dr. Joseph C. Hogan
College of Engineering
University of Notre Dame
Notre Dame, Indiana 46556

Captain John R. Lindsay, USN
Deputy Project Manager
Navy Deep Submergence Systems Project
6900 Wisconsin Avenue
Chevy Chase, Maryland 20015

Mr. Nicholas L. Basdekas
Office of Naval Research
Structural Mechanics Program
17th & Constitution Avenue
Washington, D. C. 20360

Stanley M. Bemben
Department of Civil Engineering
University of Massachusetts
Amherst, Massachusetts 01002

Lawrence D. Johnson
Uniroyal, Inc.
407 N. Main Street
Mishawaka, Indiana 46544

E. A. Peretti
University of Notre Dame
Box E,
Notre Dame, Indiana 46556

Daniel Frederick
Virginia Polytechnic Institute
Blacksburg, Virginia 24061

Arthur T. McClinton
Naval Research Laboratory
Washington, D. C. 20390

LDCR Philip M. Palmer
ONR (Code 466)
Navy Department
Room 4226
Washington, D. C. 20360

Arnold M. Hanson
Office of Naval Research Branch Office
219 S. Dearborn
Chigago, Illinois 60604

Professor Frank A. Andrews
Catholic University of America
Michigan Avenue
Washington, D. C. 20550

Robert D. Lynch
Villanova University
Villanova, Pennsylvania 19085

Richard H. Evans
Office of the Oceanographer of the Navy
732 North Washington St.
Alexandria, Virginia 22314

Robert C. Kohrn and Frank Gerrligs
Uniroyal, Inc.
312 N. Hill Street
Mishawaka, Indiana 46544

William B. Walker, Comm., USN
Office of Naval Research
Navy Department
Washington, D. C. 20360

Dr. Joseph M. Colonell
University of Massachusetts
Amherst, Massachusetts 01002

Charles A. Babendreier
National Science Foundation
1800 G. Street, N.W.
Washington, D. C. 20550

Jan M. Jordaan, Jr.
University of Delaware
So. College Avenue
Newark, Delware 19711

J. Blaine Davidson
Florida Atlantic University
1190 S. W. 11th Street
Boca Raton, Florida 33432

Dr. Hsuan Yeh
Director, Towne School of Civil
and Mechanical Engineering
University of Pennsylvania
113 Towne Building
Philadelphia, Pennsylvania 19104

Dr. Frederick D. Rossini
University of Notre Dame
Notre Dame, Indiana 46556

Francis M. Kobayashi
University of Notre Dame
Notre Dame, Indiana 46556

Dr. Bernard Waldman
Dean, College of Science
University of Notre Dame
Notre Dame, Indiana 46556

Dr. Thomas E. Stewart
Assistant to President
for Planning & Analysis
314 Administration Building
Notre Dame, Indiana 46556

Harry McPherson
General Engineer
U. S. Naval Civil Engineering Laboratory
Port Hueneme, California 93041

Captain Richard J. Dzikowski
U. S. Navy
8714 Irvington Avenue
Bethesda, Maryland 20014

K. T. Yang
Mechanical Engineering
University of Notre Dame
Notre Dame, Indiana 46556

Mr. S. R. Wolff
Notre Dame
Electrical Engineering Department
(Grad Student)
Notre Dame, Indiana 46556

Dr. Allyn C. Vine
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts

Mr. S. P. Singh
Notre Dame
Electrical Engineering Department
(Grad Student)
Notre Dame, Indiana 46556

Walter H. Scott, Jr.
Director
Ocean Systems Department,
Grumman Aircraft
Engineering Corporation
Bethpage, New York 11714

Dr. Harry C. Saxe
Department of Civil Engineering
University of Notre Dame
Notre Dame, Indiana 46556

Ronald L. Sampson
University of Notre Dame
Department of Chemical Engineering
Notre Dame, Indiana 46556

J. Pitz
University of Notre Dame
Notre Dame, Indiana 46556

John Oras
Mechanical Engineering Department
University of Notre Dame
Notre Dame, Indiana 46556

Robert A. O'Leary
University of Notre Dame
Notre Dame, Indiana 46556

Victor W. Nee
Assistant Professor
University of Notre Dame
Mechanical Engineering
Notre Dame, Indiana 46556

Dr. Thomas J. Mueller
University of Notre Dame
Notre Dame, Indiana 46556

Joseph J. Morin
Engineering Science Department
Notre Dame, Indiana 46556

Professor Bruce Morgan
University of Notre Dame
Notre Dame, Indiana 46556

Alan Monkewicz
University of Notre Dame
Electrical Engineering Department
Notre Dame, Indiana 46556

Albert E. Miller
Assistant Professor
Department of Metallurgy
University of Notre Dame
Notre Dame, Indiana 46556

Professor Hugh Ackert
Mechanical Engineering
University of Notre Dame
Notre Dame, Indiana 46556

Professor Charles W. Allen
University of Notre Dame
Notre Dame, Indiana 46556

Dr. Victor C. Anderson
Scripps Institution of Oceanography
LaJolla, California 92037

T. Ariman
University of Notre Dame
Notre Dame, Indiana 46556

S. Bangalore
University of Notre Dame
Notre Dame, Indiana 46556

John C. Bratis
University of Notre Dame
1013 Notre Dame Avenue
South Bend, Indiana 46617

Professor B. D. Cullity
University of Notre Dame
Notre Dame, Indiana 46556

Dr. Arwin A. Dougal
Office of the Director
of Defense Research & Engineering
Washington, D. C. 20550

Mr. Akin Ecer
Department of Civil Engineering
University of Notre Dame
Notre Dame, Indiana 46556

Assistant Professor N. F. Fiore
Metallurgical Engineering &
Materials Science
University of Notre Dame
Notre Dame, Indiana 46556

H. V. Ganganna
Grad Assistant
University of Notre Dame
Notre Dame, Indiana 46556

Robert C. Haborak
G.R.A.
University of Notre Dame
Notre Dame, Indiana 46556

James Hayes
University of Notre Dame
Notre Dame, Indiana 46556

Roger E. Hoffman
Graduate Student
University of Notre Dame
Notre Dame, Indiana 46556

Patrick Horsbrugh
School of Architecture
University of Notre Dame
Notre Dame, Indiana 46556

F. Howard
University of Notre Dame
Notre Dame, Indiana 46556

E. W. Jerger
Associate Dean
University of Notre Dame
Notre Dame, Indiana 46556

Sydney Kelsey
University of Notre Dame
Civil Engineering Department
Notre Dame, Indiana 46556

Michael Kuruzar
University of Notre Dame
Notre Dame, Indiana 46556

L. H. N. Lee
University of Notre Dame
Notre Dame, Indiana 46556

Gary B. Lewis
Mechanical Engineering Department
University of Notre Dame
Notre Dame, Indiana 46556

Professor R. Liu
University of Notre Dame
Notre Dame, Indiana 46556

Stuart T. McComas
University of Notre Dame
Mechanical Engineering Department
Notre Dame, Indiana 46556

Professor Cary K. Mak
University of Notre Dame
Civil Engineering Department
Notre Dame, Indiana 46556

Duane E. Cromack
University of Massachusetts
Amherst, Massachusetts 01002