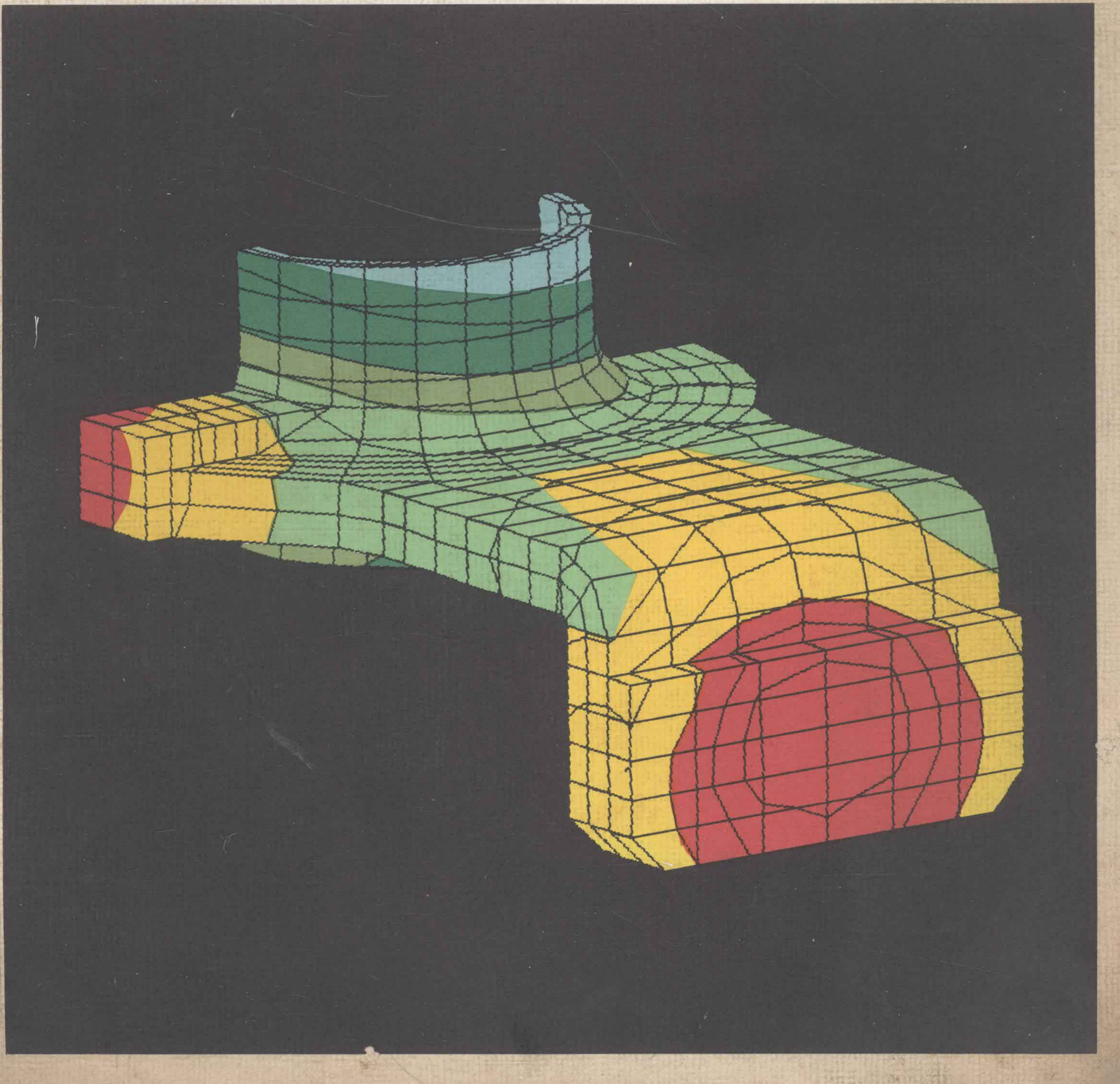
1984
the summary of engineering research

A REPORT OF ACTIVITIES DURING CALENDAR YEAR 1983
COLLEGE OF ENGINEERING•UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN•UIUC



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COVER

Computed temperature distribution in a solidifying cast iron part, 50 sec after pouring. Calculations were done using a method developed by J. A. Dantzig and coworkers in the Department of Mechanical and Industrial Engineering.

Compiled and edited by Ann R. Sapoznik, Engineering Publications Office

Photography by R. T. Gladin

Copies of this publication are available free of charge from the Engineering Publications Office, 112 Engineering Hall, 1308 W. Green St., Urbana, IL 61801

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Inside *The Summary*

The Summary of Engineering Research 1984 represents the extensive engineering research program conducted in 1983 at the University of Illinois at Urbana-Champaign. These pages summarize a research effort in excess of $36 million, involving more than 400 faculty and professional staff and 1,800 graduate students working on over 800 projects.

Detailed statistics about the research in the College of Engineering are available in the college's listing in the *Annual Directory, Engineering College Research and Graduate Study,* published by the American Society for Engineering Education, Washington, D.C.

Research projects are listed by their title, followed by the names of the investigators and the sponsoring agencies. The index lists the projects by major topic areas. Publications of the faculty, technical reports, and theses resulting are listed at the end of each unit's project descriptions. Awards and honors are also shown.

The reader will discover that a number of research project descriptions appear in more than one section. This duplication indicates the interdisciplinary research character of the college and at the same time affords each unit an opportunity to present its research program in full.

As *The Summary* is meant to be a general guide to the research program, space does not permit detailed description of individual projects. **Further information concerning a project may be obtained from the investigator in charge (denoted by an asterisk).** Copies of Ph.D. theses are available from University Microfilms, Ann Arbor, Michigan, and their prices are listed in *Dissertation Abstracts.* Information about departmental technical reports may be obtained from the Engineering Documents Center, University of Illinois at Urbana-Champaign, 112 Engineering Hall, 1308 W. Green St., Urbana, IL 61801.

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contents

* Multidisciplinary, multidepartmental program.

* Multidisciplinary, multidepartmental program.

aeronautical and astronautical engineering

H. H. HILTON, Head
101 Transportation Building, 104 S. Mathews Ave., Urbana, IL 61801

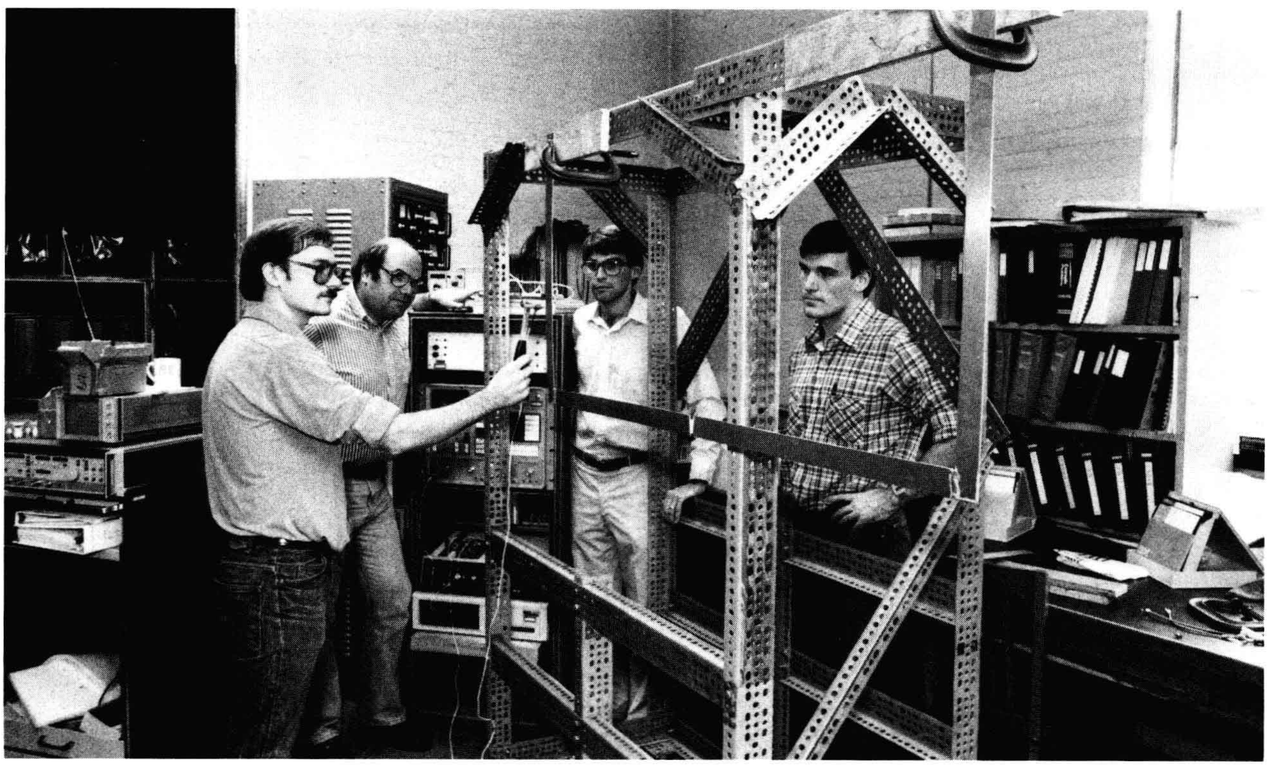
Diverse and multidisciplined fundamental research programs have been developed in the Department of Aeronautical and Astronautical Engineering in the fields of reactive and computational gas dynamics, applied aerodynamics, flight dynamics, aeroelasticity, structural mechanics, optimal structural control of space structures, stochastic dynamics, combustion, detonation, noise pollution control, chemical lasers, and solar and wind energy. The department's international reputation in fundamental stochastic dynamics has added new dimensions in various engineering applications. Current projects include the study of the response of multispan aircraft panels to noise loading, the modeling of atmospheric turbulence and random maneuver loads, the prediction of jet engine inlet fan noise, and structural response to wind and seismic excitations.

New numerical methods have been developed to solve directly basic gas dynamics equations for complex problems using large computers. The solution to the nonlinear Boltzmann equations, applying a Monte Carlo method, has been obtained to simulate molecular interactions for a wide range of nonequilibrium fluid mechanics problems.

Research dealing with determination of minimum structural weight under prescribed probability of failure and viscoelastic analysis with random material properties is directed toward the goal of obtaining a realistic understanding of actual material behavior. A related study involves the energy dissipation in composite materials due to viscoelastic effects in dynamic structural loading. Analytical research in the areas of substructure representation in dynamic synthesis and in active control of space structures has been carried out.

Applied aerodynamics investigations include theoretical studies leading to the design of high performance airfoils suitable for application to propellers, and general aviation aircraft. A major effort involves the design of a low-noise propeller. Theoretical studies are complemented by an experimental program, involving wind tunnel studies of high performance airfoils, with special emphasis placed on detailed flow phenomena and on performance at low Reynolds numbers.

Theoretical and experimental studies are being undertaken to determine the role of rotational nonequilibrium in determining the power spectral performance of chemical lasers. The aerodynamics of wind energy systems is being studied to determine efficient power generation.



AERODYNAMICS

Interactions Between Multiple Objects in a Hypervelocity Flow Regime

S. M. Yen,* S. H. Lee, R. R. Chamberlain

U. S. Army Ballistic Research Laboratories, DAAK-11-81-C-0011

This research has two tasks: (1) to determine the hypersonic flow field associated with the lead (first) particle of a series of hypervelocity particles and the influence of the resulting nonuniform flow field on the motion of sequential particles, and (2) to find the flow field associated with a slender rod traveling at hypersonic speeds and passing through a circular aperture. Several numerical methods have been used to solve these problems.

Numerical Solution of the Euler and Navier-Stokes Equations for a Compressible Flow Problem

S. M. Yen,* S. H. Lee

University of Illinois

We have solved the Euler as well as the Navier-Stokes equations for a triconic body in the Mach number range of 0.5 to 2.75 by using Warming-Beam's implicit factored scheme developed for solving the Navier-Stokes equation. The principal tasks are the development of mesh systems appropriate for subsonic, transonic, and supersonic flow fields and methods to implement the boundary conditions.

Numerical Studies of Nonlinear Free Surface Problems

S. M. Yen,* R. R. Chamberlain, S. H. Lee

U.S. Office of Naval Research, N00014-80-C-0740

Time-dependent numerical schemes have been developed for nonlinear steady and unsteady potential flows involving a moving disturbance on or near the surface of a liquid in a gravitational field. In these schemes, the finite-difference method is used for the time evolution, and both the finite-element and the finite-difference methods are used to make the field calculations. These schemes have been used to solve the free surface problems of a pressure distribution, an accelerating strut, and a submerged body and are being used to solve a nonlinear ship wave problem.

Study of Vapor Kinetics Problems

S. M. Yen*

University of Illinois

The problems of vapor motion in the vicinity of liquid-gas or solid-gas interphase for the case of strong evaporation and condensation are characterized by the existence of a nonequilibrium Knudsen layer at the interphase and should be solved by using kinetic theory. We have solved the Boltzmann, the Krook, as well as the Boltzmann transport equations for this Knudsen layer. We have found that the evaporation and condensation Knudsen layers have several distinct and unforeseen characteristics.

Study of Wake Pressure Recovery as a Factor in Airfoil Design

A. I. Ormsbee,* M. D. Maughmer

NASA-Langley Research Center, NAG-1-76

This is a program to study flow phenomena in the region of the trailing edge and wake of an airfoil and to apply the results to the design of airfoils for which a portion of the upper surface pressure recovery is extended into the wake.

Vortex Roll-Up Modeling

A. I. Ormsbee,* S. Siddiqi

University of Illinois

The objective of this program is to develop improved models for determining trailing vortex roll-up phenomena, including the effect of finite-thickness trailing-edge boundary layer.

APPLIED MATHEMATICS

A Mathematical Study of Flame Stability

J. D. Buckmaster,* A. Nachman, S. Taliaferro

National Science Foundation

The mathematical study of flames in the limit of high activation energy leads to a description of flame sheets in which diffusion balances chemical reaction. The stability problem for these structures leads to singular eigenvalue problems of the Schrodinger type. This project is concerned with identifying those structures that are unstable.

A Theoretical Study of Intumescent Paints

J. D. Buckmaster*

Southwest Research Institute

Intumescent paints are solid coatings that are applied to artillery shells to protect them against fire. On exposure to great heat these coatings swell to form an insulating layer. A model to describe this behavior is being developed which reduces the description to a free boundary problem of the Stefan type, easily amenable to numerical analysis.

ASTRONAUTICS AND CELESTIAL MECHANICS

Dynamics of Remote Orbital Capture

B. A. Conway,* J. W. Widhalm

University of Illinois

Retrieval of satellites by the space shuttle from all but very low altitude orbits will require the use of an independent, remotely operated spacecraft. This spacecraft must rendezvous with the target and must eliminate any tumbling motion of the target before retrieval is possible. Both Euler and Lagrange formulations of the system equations of motion are being developed and the motion is determined by numerically integrating these equations.

Optimal control theory applied to the two-body system yields a two-point boundary value problem. Numerical methods for solving this problem are being determined.

Evolution of Natural Satellite Orbits

B. A. Conway*

University of Illinois

Orbits of the natural satellites of the solar system evolve principally due to tidal friction. As such evolution occurs the satellite reaches or passes through possible resonant commensurabilities with either the nonhomogeneous gravitational field of the primary or the gravitational attraction

* Denotes principal investigator.

of another satellite or satellites. The possibility of capture into resonant motion and the subsequent evolution of the orbit of the satellite or satellites is being investigated for the satellite systems of Mars, Jupiter, Saturn, and Uranus. A closely related problem also to be studied is the determination of the configuration of the planetary satellite systems immediately following the creation of the solar system.

Optimal Multiple-Impulse Nonlinear Orbital Rendezvous

J. E. Prussing,* J.-H. Chiu
University of Illinois

Minimum-fuel, multiple-impulse, orbital rendezvous is being studied. Previously obtained linearized solutions for fixed-time rendezvous between close, coplanar circular orbits are used as approximate starting conditions for iterative solutions to the nonlinear problem. Primer vector theory is used to determine the locations and times of the thrust impulses which yield a minimum-fuel solution. Fixed transfer time solutions between coplanar circular orbits are being obtained, which require two, three, or four impulses.

Orbit Circularization by Aerobraking

J. E. Prussing,* B. A. Conway,* S. J. Hoffman
University of Illinois

Aerobraking is a method for circularizing a highly eccentric elliptical spacecraft orbit about a planet. The technique utilizes aerodynamic forces due to repeated shallow passes through the planet atmosphere rather than propulsive forces due to rocket thrusts. The resulting savings in propellant mass allows a larger payload mass to be placed in orbit about the planet. Changes in orbit characteristics other than eccentricity are being investigated including the effects of a rotating planet atmosphere. The feasibility of combining aerobraking with small propulsive thrusts is being studied. The heating effects of atmospheric drag and radiation are included in the mathematical model.

Spacecraft Capture with Lunar Gravity Assist

B. A. Conway,* D. Snow
University of Illinois

This work is concerned with reducing the velocity change requirements of a spacecraft returning from outside the Earth-Moon system, for example, a Mars sample return mission, by employing a lunar flyby or multiple flybys. The analysis will consider the use of small propulsive maneuvers to set up encounters with the moon.

CONTROLS

Simultaneous Optimal Structural Design and Structural Control

A. L. Hale,* R. J. Lisowski, W. E. Dahl
University of Illinois

The high cost of launching massive structures dictates that the mass of future large space structures be kept to a practical minimum. However, a trade-off exists between the flexibility of a structure and its active control. Very flexible structures require considerable active control in order to meet exacting mission requirements. This research considers the trade-off quantitatively by defining a cost functional that penalizes the mass of the structure as well as its control forces. The work is concerned with maneuvering space structures. A simultaneous optimum for the structural design and the active control is sought.

ENERGY AND SOCIETY

The Technology and Socioeconomics of Renewable Energy Sources

C. E. Bond*
University of Illinois

This research focuses on the interaction between social and technological change, and on accompanying changes in rules-of-thumb for design and maxims for decision making, as they affect the solar transition.

FLIGHT VEHICLE SYNTHESIS

Computerized Flight Vehicle Synthesis

H. H. Hilton*
University of Illinois

An overall systems concept using an integrated approach incorporating basic aerodynamic, guidance, control, propulsion, and structural principles is being used to develop comprehensive generalized simulation computer programs for flight vehicle synthesis. The purpose is to develop educational and research tools to be used in the teaching of and research in flight vehicle synthesis and optimization. Current capabilities include space vehicle flight programs, airplane missions, various structural programs to determine minimum weight and optimum construction, and printed and teletype graphical output on Calcomp.

FLUID MECHANICS

Large-Scale Turbulence Wind Tunnel

K. R. Sivier*
University of Illinois

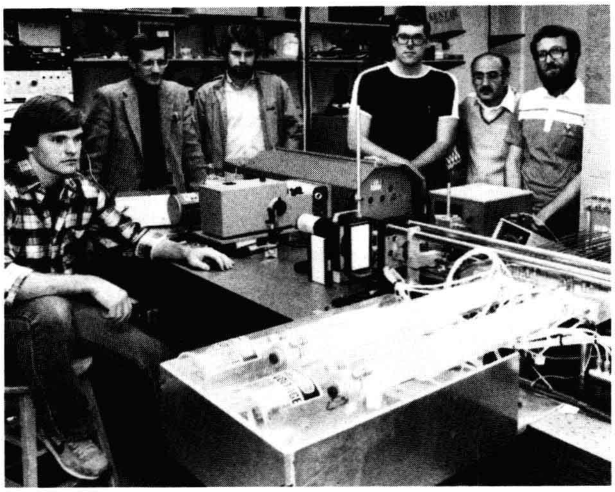
The objective of the work is to develop a wind tunnel facility in which controlled flows with large-scale turbulence can be generated. The work is being done in the University's multiple purpose, low-speed wind tunnel. The turbulent flows, produced by placing boards (with distributed circular holes) transverse to the mean flow, are being evaluated (using hot-film anemometry) for turbulence intensity and integral scale length distributions.

LASERS

Nonlinear Interactions Between the Pumping Kinetics, Fluid Dynamics, and Optical Resonator of CW Fluid Flow Lasers

L. H. Sentman,* M. H. Nayfeh* (Physics), S. Townsend, G. Tsioulus, K. King, J. Bichanich
U.S. Air Force Office of Scientific Research, G-80-0133

The study of the performance of a CW HF chemical laser has resulted in the first data from a CW laser for a



Standing from left to right, professor L. H. Sentman and associate professor M. H. Nayfeh (Physics) direct graduate students K. King, J. Bichanich, S. Townsend, and G. Tsioulus in a study of mode-media interactions in CW HF chemical lasers. The study of mode-media interactions should result in the design of more efficient CW fluid flow lasers.

near resonant energy transfer from $v = 3, J = 3,4$ to $v = 2, J = 14$. The stable resonator data indicated that the polarization introduced by Brewster windows affects the power spectral distribution. The amplitude, frequency, and Fresnel number dependence of the time-dependent oscillations which may occur on lines whose saturated gain does not fill the unstable resonator have been measured and shown to agree with the theoretical predictions. A mode beating also has been observed in the unstable resonator experiments.

PROPULSION AND COMBUSTION

Flame Acceleration Under Conditions of Partial Confinement

R. A. Strehlow,* A. I. Ormsbee, T. W. Yip, S. H. Reichenbach

Gas Research Institute

The initiation of detonation can occur by flame accelerations and by large eddy turbulent mixing processes. The latter is thought to be important in the production of detonations during accidental explosions. The phenomenon of flame accelerations via large eddy folding is studied using a combustible mixture confined in a channel open at the top. After determining the propagation velocities and dynamic pressures developed when there are no obstacles present, various eddy-producing barriers are placed on the bottom of the channel to study their effect on the flame velocity and the pressure waves generated. A schlieren system is used to observe the flame propagation process.

Flammability Limits at Low Gravity Levels

R. A. Strehlow,* K. A. Noe

NASA-Lewis Research Center, NAS-3-23770

The effect of gravity on the propagation and extinction of lean limit flames will be studied in the NASA Lear jet

Professor Roger A. Strehlow observes as graduate student Kurt A. Noe inserts an igniter into a combustion experiment apparatus. Strehlow leads a project seeking to learn more about combustion in space, and this experiment is scheduled to be run on a space shuttle mission.

facility using a standard 51 mm flammability tube. Methane will be used as the fuel and propagating flames will be photographed during 15 seconds of controlled g levels of 0.0, 0.25, 0.5, 0.75, 1.0, 1.5, and 2.0. The effect of g on flame shape, flame speed in the tube, and extinction limits will be investigated for both downward and upward propagation.

The Mechanism of Flame Holding in the Wake of a Bluff Body

R. A. Strehlow,* S. Malik

NASA-Lewis Research Center, NAG 3-60

The flame-holding process is not understood even for premixed laminar flames. This study is an experimental study of blowoff of premixed flames from the trailing edge of a flat plate mounted parallel to the flow direction. Observations of the detailed flow profiles near the flame when close to the blowoff limits will be made with the department's two-color, frequency-shifted laser Doppler anemometer.

Pulsations, Bifurcations, and Related Phenomena Important in Flame Stability

J. D. Buckmaster,* D. S. Stewart

National Science Foundation

This project deals with the nonlinear stability analysis of flames anchored to linear condensates and burner rims. It seeks to model pulsating flames and cellular flames, both of which are seen experimentally. Most importantly it seeks to model polyhedral flame tips, multifaceted Bunsen burner flames that sometime remain stationary and sometime spin very rapidly.

Second Shock Formation in Spherical Shock Tubes

H. O. Barthel*
University of Illinois

Numerical methods are being used to find values of the time lapse before the second shock forms on the tail of the rarefaction fan in a spherical shock tube. For initial lead shock Mach numbers greater than two, the results are reasonably consistent with previous results obtained using power series expansions for the characteristics in the fan and in the region between the tail of the fan and the contact surface. Difficulties in performing the numerical integrations are encountered as the leading edge of the fan approaches the center of the sphere.

STRUCTURAL DYNAMICS

Analysis of Aeroelastic Problems in Orthotropic, Composite Material Wings

A. R. Zak,* M. E. Schaffner
University of Illinois

The consideration of using orthotropic, composite material structures in aerospace applications is increasing rapidly. The use of these materials in the wing analysis offers some new analytical challenges as well as potential benefits. In this investigation an analytical model is being developed for handling monocoque and semi-monocoque wings composed of laminated, thin-walled construction. The model is applied to the analysis of aeroelastic phenomena, and the effects of the orthotropic properties are examined in detail. The aeroelastic phenomena examined include static problems such as divergence and the dynamic problem of bending-torsion flutter.

Dynamic Response Analysis of Complex Thin Shell Structures

Y. K. Lin,* Y. Yong
National Science Foundation, CEE-80-24882

Theoretical investigations are being continued into the dynamic behavior of cooling tower-type shell structures under earthquake and wind load excitations. A transfer matrix formulation has been developed to analyze the problem and the dynamic loads are treated as random functions in time and space. Theoretical results have been obtained for model excitation fields which exhibit the basic statistical properties of actual earthquake and wind pressure records. This project is carried out jointly with Purdue University.

Effects of Vertical Ground Acceleration and Soil Compliancy on Structural Response to Random Excitations

Y. K. Lin,* W. F. Wu
National Science Foundation, CEE-81-20438

Random vibration of tall buildings under excitations of seismic and wind loads are investigated. The effect of vertical ground acceleration is found to be important only when the structural response is in nonlinear hysteretic range, in which case the effect is of a similar order of magnitude as that of the static gravitational force. The soil compliancy is found to reduce the response due to earthquake excitation, but in the case of wind excitations, the shifting of spectrum peaks to lower frequency locations may, sometimes, increase the rms response if the available wind energy is greater near new peak locations.

Gap-Contact Finite-Element Model

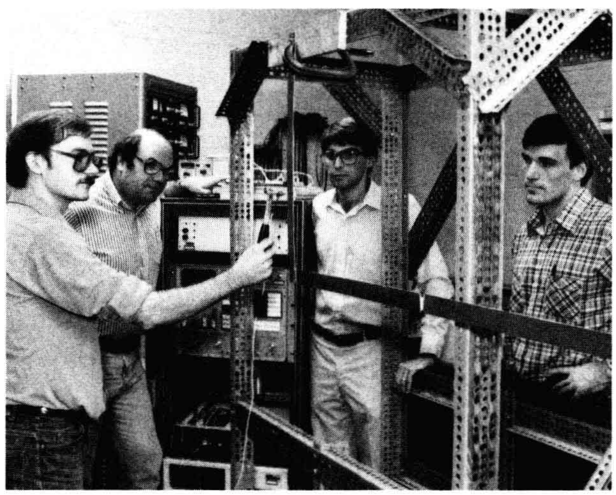
A. R. Zak,* J. Van Es
University of Illinois

In many highly loaded structures there are a number of situations where very low clearance exists between portions of the structure. This leads to the nonlinear gap-contact problem which in this investigation is formulated in terms of a finite-element model. In the past the finite-element method of analysis has proved to be the most practical approach for solving complicated, nonlinear structural problems, especially those containing general configurations. The model takes into consideration elastic-plastic material properties and is based on the incremental approach. The gap-contact phenomenon is modeled by nonlinear gap elements which have variable properties according to whether contact exists or does not exist.

Linear System Identification Via the Method of Poisson Moment Functionals

L. A. Bergman,* A. L. Hale,* J. M. Goodding
University of Illinois
(In conjunction with the Departments of Civil Engineering and Theoretical and Applied Mechanics)

The method of Poisson moment functionals (PMF) is being studied as an effective system identification algorithm in the time domain for linear time-invariant systems. The PMF method is desirable because (1) identification is done



Research assistant Jim Goodding applies an impact hammer to an assemblage of two simple frames as assistant professors L. A. Bergman and A. L. Hale and research assistant Larry Downey (left to right) observe. The experiment is part of their work on parameter identification of structures and the synthesis of separately identified substructure models.

in continuous time, (2) the method is somewhat naturally immune to zero-mean additive noise, and (3) the PMFs of process signals can be obtained online as the response of a Poisson filter chain.

Nonlinear Static and Dynamic Synthesis of Complex Structures

A. L. Hale,* E. Marek

National Science Foundation, DME-81-05535

(In conjunction with the Department of Civil Engineering)

Presently, this research is concerned with the nonlinear dynamic simulation of complex structures composed of a given number of substructures. Discrete substructures possessing a large number of degrees of freedom, such as those represented by finite-element models, are emphasized. Because present nonlinear simulations are extremely expensive computationally, the object is to limit the expense by drastically reducing the number of degrees of freedom used to represent each substructure. Particular emphasis is placed on the effects of substructure representation on the overall simulation accuracy and on a procedure for improving any substructure's representation at desired steps in the simulation. Multilevel modified Newton-Raphson iteration algorithms are presently under investigation.

Plasticity with Rate-dependent Yield Stress Structural Analysis

A. R. Zak*

University of Illinois

This research program involves the extension of a previously developed finite-element method to handle elastic-viscoplastic material with rate-dependent yield properties. The motivation for this analysis is the number of practical applications to nonmetallic materials which exhibit definite rate effects. The present effort is directed toward developing a finite-element model to handle three-dimensional configurations.

Probabilistic Minimum Weight Analysis

H. H. Hilton*

University of Illinois

An analytical method has been developed for designing structures having a prescribed probability of failure so that the overall weight is minimum. The solution is obtained for structures consisting of components having normal and beta-distributed applied and failure stresses, and is applicable to combined loading conditions. The loading conditions are such that general relations can be used to relate the mean stresses to the cross-sectional area. Weight comparisons with standard design procedures based on the margin of safety concept are made and indicate the possibility of substantial weight savings.

Random Response of Turbine Structures Under Seismic and Turbulent Excitations

Y. K. Lin,* C. Y. R. Hong, W. F. Wu

National Science Foundation, CEE-81-20438

Electricity generated by wind turbines, if well planned, can supplement a significant portion of national needs; therefore, it is important to develop useful and rational design tools for such systems. The present research focuses on the rotor blade assembly, the most important component of a wind turbine. Specifically, probability-based theoretical procedures are being developed, taking into account two natural hazards, the wind turbulence and seismic loads. The goals of investigation include the determination of the motion stability conditions for the rotor blades and the statistical properties of blade response to the random excitations, using progressively more complex structural models.

Random Viscoelastic Material Effects

H. H. Hilton*

University of Illinois

(See also Materials Engineering — Mechanical Behavior)

Analytical studies are presented which extend the elastic-viscoelastic analogies to stochastic processes caused by random linear viscoelastic material properties. Separation of variable as well as integral transform correspondence principles is formulated and discussed in detail. The statistical differential equation of the moment characteristic functional is derived, but rather than solving the highly complex functional equation, the solutions are formulated in terms of the first- and second-order statistical properties. Both Gaussian and beta distributions are considered for the probability density distributions of creep and relaxation functions; and their effectiveness is evaluated.

Recursive Substructuring Algorithms in Structural Dynamics

A. L. Hale*

University of Illinois

(In conjunction with the Department of Civil Engineering)

A model reduction method developed in the past two decades for structural dynamics is known as substructure synthesis. The idea is to regard a complex structure as an assemblage of substructures with each substructure represented by a reduced order mathematical model, and to couple the substructures together so as to form a whole structure. Because the substructuring process is inherently multileveled, recursive solution algorithms arise naturally. For self-adjoint systems, a family of algorithms has been developed to extend the concepts of subspace iteration, developed in the literature for single structures, to structures composed of substructures. Various novel multisubspace recursive procedures presently are being developed.

Stochastic Analysis of Rotor Blade Vibrations

Y. K. Lin,* J. E. Prussing,* J. S. Fuh, T. N. Shiau, M. M. Franke

U.S. Army Research Office, DAAG-29-81-K-0072

By modeling turbulent velocities as random functions of time, stability boundaries have been obtained for a single blade in coupled flap-torsional motion and coupled flap-lag motion in forward flight. Mean and mean square values of structural response variables, as functions of azimuth angle, have also been obtained when the motion is stable. For multiblade systems, a large number of equations must be derived to determine the mean and mean square stability and response statistics. A symbolic manipulation program has been developed to derive these equations on the computer using a FORTRAN V code.

Synthesis of Structural Dynamic Models from Separately Identified Substructure Models

A. L. Hale,* L. A. Bergman,* L. Downey
University of Illinois
(In conjunction with the Department of Civil Engineering)

This work is concerned with synthesizing a number of identified substructure models. The idea is to test each substructure separately and determine substructure models directly from time domain test data. Structural modeling concepts significantly affect the substructure identification and substructure coupling. The effects are being examined in detail.

Theory of Thin-Walled, Orthotropic, Laminated Beams

A. R. Zak*
University of Illinois

The finite-element models being developed applies to general configurations with either open or closed sections and are designed to retain the orthotropic properties in a most general manner for each layer without limitation on a number of layers. The model being developed holds for general geometry sections. Each section is divided into segments. The geometry of the segments can be arranged so as to create any desired open or closed section. Each segment of the section can have a different number of orthotropic material layers, with each layer having its unique orthotropic axes relative to beam coordinates. A set of beam conditions is applied then through the thickness of the segments and the beam section as a whole.

Torsion-bending Flutter of Viscoelastic Wings

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An analysis of subsonic and supersonic torsion-bending flutter, including rotary inertia, shear, and hearing effects, of a time-dependent linear viscoelastic lifting surface consisting of either a Bernoulli-Euler or a Timoshenko beam is formulated using aerodynamic strip theory. Complex moduli models for aluminum are characterized as functions of temperature and frequency by fitting Chebyshev polynomials to actual material experimental data.

The flutter analysis is carried out in the complex plane and a computerized iterative method for the determination of flutter speeds and frequencies is developed. The influence of viscoelastic material properties (storage and loss moduli), temperature, rotary inertia, and shear effects is evaluated.

WIND ENERGY

Utilization of Nocturnal Wind-Energy Maxima

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This research comprises an analytical and experimental investigation of the significance of low-level nocturnal wind maxima for wind-energy conversion in the midwestern United States.

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