CAV Review '03

CENTER FOR ACOUSTICS AND VIBRATION

CAV Workshop
May 11 – 12, 2004

This year's conference will be held at the Penn Stater Conference Center and will focus on many of the new research initiatives within the Center.

The program for this year will feature a mix of presenters – our own technical group leaders, our corporate sponsors and our international liaisons. Our graduate students and their advisors associated with the particular CAV technical groups will be available for questions on their research projects. With such a good mix of people, it will be a unique opportunity for all of us to broaden our perspectives on the emerging technologies within and beyond our particular disciplines.

While formal presentations are organized to allow for the exchange of technical information there will be opportunities for informal discussions at a picnic at Shaver's Creek.

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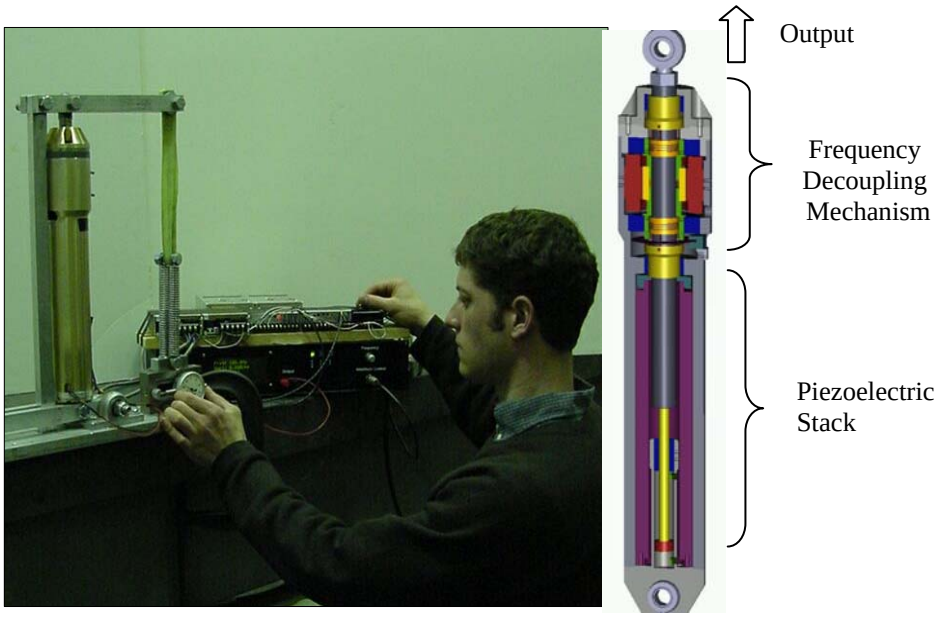

CAV Develops New Piezoelectric Actuator for Lockheed Morphing Aircraft

This has been an exciting year for the Center for Acoustics and Vibration's (CAV) piezoelectric actuator research group. The CAV's latest piezoelectric actuator concept was chosen as a leading smart material actuator concept for the Lockheed Corporation's high profile, Defense Advanced Research Projects Agency (DARPA) funded, Morphing Aircraft Structures (MAS) program. The development of this new actuator for Lockheed's MAS program has come to fruition through a partnership between KCF Technologies (State College), MPC Products Corporation (Chicago), and the CAV.

Lockheed's proposed morphing aircraft will require a smart material actuator to move key components for enabling folding of the aircraft's wings, allowing it to adapt to various flight conditions. The Center's piezo-actuator group, led by Professors Gary Koopmann and George Lesieutre, Ph. D. Candidate Jacob Loverich, and Dr. Jeremy Frank (KCF), developed a novel piezoelectric actuator to move a Leading Edge Flap (LEF) for the aircraft's wing-fold. The development effort involved mathematical modeling and fabricating a number of prototypes to achieve forward and reverse actuation up to the large 1200 lb. force output required by Lockheed's LEF application.

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Lockheed Morphing Aircraft

continued from page 1

The new actuator consists of a piezoelectric stack as the core driving element and a frequency decoupling mechanism that delivers the stacks power output to the load. The operating principle of the actuator is to drive the stack with a high frequency voltage and decouple its high frequency and low displacement motion from the low frequency and high displacement actuation requirements of Lockheed's LEF application.

The success of this actuator project is a result of over 10 years of smart material actuator research at the CAV. The focus is on high power smart material actuation which the CAV began in 2001 with funding from DARPA's Compact Hybrid Actuator Program. Intensive work on this project will continue through 2004, funded by a recent grant of Phase II funding from Lockheed. During Phase II, the actuator's force output and operation control will be improved and the actuator will be integrated into a morphing wing bench-top demonstration. Our group hopes to continue this project into Phase III, where the actuator will be used in a flight-worthy half-scale morphing aircraft. The success of the current actuator and our clear path to even greater improvements point to not only continued successes, but an even greater number of future applications.

Engineered Adaptive Structures IV

The Center for Acoustics and Vibration is organizing a conference on "Engineered Adaptive Structures" to be held in Banff, Canada, July 19 – 23, 2004. The conference will be held at the Banff Conference Center which is in the Canadian Rockies and will be the fourth in a series.

Engineered Adaptive Structures IV focuses on the emerging technologies based on the concept that structures can be engineered to adapt to changing environments. This adaptability is achieved by integrating sensing and actuating devices within the structure together with some form of intelligence for control purposes. While the adaptability is common in the biological world, e.g., changes in the skin color of a chameleon to match its environment, adaptability in engineered structures is still very much an emerging technology. Applications similar to this are due to advances in four major technologies that are continuing to develop rapidly in Asia, Europe, and the USA. These include: development of modern, man-made transduction materials that both sense and actuate, e.g., piezo-ceramics, magnetostrictives, and shape memory alloys; modem digital control and decision theory; and miniaturization of electronic components used with sensors/actuators/controllers techniques for fabricating structures of composite materials with embedded sensors/actuators/controllers

The format for the conference is similar to the previous three with only morning sessions and plenty of time for socializing and informal discussions.

If anyone is interested in attending this conference please contact Karen Thal at 814-863-1673 of by email (kjt3@psu.edu).

Corporate Membership

Corporate membership in the CAV offers opportunities for collaborative technology development and transfer through the interactions of people from academia, industry, and government. Membership also entitles a representative to participate in the CAV's annual Technology Transfer Workshop, participation in a corporate recruiting program, and a consultation visit with Penn State researchers.

If you are interested in becoming a corporate member of the Center for Acoustics and Vibration and would like more information please contact Dr. Gary H, Koopmann, Director of the CAV at 814-865-2761 or by email at ghk@kirkof.psu.edu

Corporate Members and Representatives

Adapco – Thomas Chyczewski
Bettis Atomic Power Lab – Larry Corr
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Electric Boat – Gary Cooper
Lockheed Martin – Martin Pollack
Lord Corporation – Steve Southward
Northrop Grumman – Allen Lockyer
Trane Company – George Wan
United Technologies Research Center – Rebecca Bryant
York International – Robert Stabley

International Liaisons and Representatives

ISVR (U.K.) – Phillip Nelson
DLR (Germany) – Wolfgang Neise
CIRA (Italy) – Antonio Concillio

CAV Members Receive Awards

Kon-Well Wang, PSES Premier Research Award
Timothy Simpson, PSES Outstanding Research Award
Jacob Loverich, Alumni Association Dissertation Award
Jason Hines, Mideast Region American Helicopter Society Lichten Competition
Michael Philen, SPIE 10th International Symposium Best Student Paper Award (2nd Place)

We invite you to visit our web site at: http://kirkof.psu.edu

TECHNICAL RESEARCH GROUP HIGHLIGHTS

Acoustics Characterization of Materials

Bernhard R. Tittmann, Group Leader
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The defining purpose of the Engineering and Nanostructure Characterization Center is to teach and engage in research for materials characterization, wave mechanics, and nondestructive evaluation with an emphasis on nanotechnology.

Title: Precise Ultrasonic Measurement of Plate Movement Inside a Water-Filled Pressure Chamber
Sponsor: Bechtel Plant Mach. Inc. /DRS Power and Control Technologies.
Description: Design, construct and test of ultrasonic system to measure plate movement with temperature comparisons of 40 to 160 degrees New software(LabView) and signal processing. Accuracy achieved 0.0001 inch. Students

Title: Ultrasonic Technique for In-situ Monitoring Analysis
Sponsor: Bettis Bechtel. Inc West Mifflin, PA
Description: Development of miniature High Temperature Ultrasonic Transducer for In-Sit Monitoring in a Hostile Environment
Students: James Seliga, Spring 2004
Thesis: "Ultrasonic Technique for In-situ Monitoring Analysis"

Title: Ultrasonic Array for monitoring corrosion, dimensional changes, geometry changes and cracking of metal components in a Hostile Environment.
Sponsor: Bechtel Power Plant Machinery
Description: Simulation, design and testing of Ultrasonic Array for High Temperature Applications. .
Students: Kara Oliver, Spring 2004
Thesis: "Ultrasonic Array for Monitoring at High Temperature and Pressure"

Title: "Nuclear Acoustic Resonance for the Detection of Fissile Material"
Sponsor: Lawrence Livermore National Lab.
Description: Ultrasonic Excitation of Nuclear and Electron Spin Simultaneously for obtaining signature of nuclei in metallics.
Students: George Maillios, Spring 2004

Title: "Non-Lethal Weapons Related Studies in Living Cells"
Sponsor: Applied Research Laboratory/ University of New Hampshire
Description: Ultrasonic Atomic Force Microscopy and Scanning Acoustic Microscopy for the Imaging of in-vivo cells during application of heat and shock waves.
Students: Derek Doroski, Spring 2004
Thesis: "Scanning Acoustic Microscopy of In-Vivo Cells subjected to Shock"
Anne Ebert, Spring 2004
Thesis: "The Elastic Properties of Hamster Kidney Cells Evaluated by Atomic Force Microscopy"

Active Structures

George Lesieutre, Group Leader
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Dr. Mary Frecker and her students in the Engineering Design & Optimization Group (EDOG) are pursuing a number of active structures projects. The Life Sciences Greenhouse of Central PA is supporting research on design of multifunctional instruments for ophthalmic surgery (student: Katie Powell). NIH is supporting the development of new electroactive polymer materials along with modeling of their nonlinear mechanical and electromechanical behavior. These models are used in the design and optimization of devices such as blood pumps and innovative surgical instruments (students: Nakhiah Goulbourne and Eunice Yang). AFOSR sponsors research into the optimal simultaneous design of smart material actuators, coupling structures, and drive electronics (student: Terrence Johnson). The National Rotorcraft Technology Center is supporting the design an actively-conformable rotor airfoil that can change its shape (thickness and camber) as it traverses around the azimuth (postdoc: Phuriwat Anusonti-Inthra, student: Andrew Nissly, with Dr. Gandhi). DARPA has supported research into optimal design of tendon-actuated morphing aircraft structures (student: Smita Bharti, with Dr. Lesieutre).

Name: Phuriwat Anusonti-Inthra, Post-doctoral assistant
Title: Design of a Conformable Rotor Airfoil
Summary: The goal of this project is to design an actively conformable rotor airfoil that can change its shape as it traverses around the azimuth for vibration control. Smart materials-based actuation is used to actively adapt to conditions for both the advancing tip and the retreating side in high speed flight. New topology optimization methods are being developed for piezoelectric actuation systems to handle the tradeoff between trailing edge deflection under actuation and stiffness under airloads. Ongoing work includes build and test of a demonstration prototype.
Sponsor: NRTC/Penn State Rotorcraft Center
Collaborator: Dr. Farhan Ghandi

Name: Smita Bharti, Ph.D. expected spring 2005
Title: Optimal Design of Morphing Aircraft Structures
Summary: The project involves optimal design of tendon-actuated compliant cellular truss structures for morphing aircraft. New design methodologies are being developed to optimize truss members, tendons and actuators within the wing structure. Shape changes in span and cross-section of wings are being considered.
Sponsor: DARPA
Collaborator: Dr. George Lesieutre

Name: Nakhiah Goulbourne, Ph.D. expected spring 2005
Title: Design and Modeling of an Innovative Electroactive Polymer Blood Pump
Summary: The current focus is on modeling the nonlinear mechanical and electromechanical behavior of dielectric elastomer materials. A dielectric elastomer membrane may be used as both a blood sac and motive element in a blood pumps, similar to the natural heart. Future work includes

optimization of the membrane for variable compliance.
Sponsor: NIH Bioengineering Research Partnership
Collaborators: Dr. Eric Mockensturm, Dr. Qiming Zhang, Dr. Alan Snyder (Bioengineering)

Name: Terrence Johnson, Ph.D. expected spring 2006
Title: Optimal Design of Electronically Integrated Smart Actuators
Summary: The focus of this project is on optimally designing smart material actuators, coupling structures, and drive electronics simultaneously. Currently actuators, structures, and electronics can be optimized independently, but when they are coupled together the resulting actuator system may be sub-optimal. Basic research is being conducted to understand the coupling relationships between the actuator and the drive electronics. A dynamic topology optimization method has also been developed to design the actuator and structure simultaneously; this method is currently being integrated with a dynamic model of the drive electronics.
Sponsor: Air Force Office of Scientific Research
Collaborators: Dr. Doug Lindner and Dr. Zafer Gurdal (Virginia Tech)

Name: Andrew Nissly, Ph.D. expected Spring 2007
Title: Design of a Conformable Rotor Airfoil
Summary: The goal of this project is to design an actively conformable rotor airfoil that can change its shape as it traverses around the azimuth for vibration control. Smart materials-based actuation is used to actively adapt to conditions for both the advancing tip and the retreating side in high speed flight. New topology optimization methods are being developed for piezoelectric actuation systems to handle the tradeoff between trailing edge deflection under actuation and stiffness under airloads. Ongoing work includes build and test of a demonstration prototype.
Sponsor: NRTC/Penn State Rotorcraft Center
Collaborator: Dr. Farhan Ghandi

Name: Eunice Yang, Ph.D. expected spring 2006
Title: Design and Modeling of Electroactive Polymer Actuators
Summary: The current focus is on modeling the nonlinear mechanical and electromechanical behavior of dielectric elastomer materials. A dielectric elastomer annulus has been modeled analytically and prototype actuators are currently being tested. It is envisioned that such an actuator may be used as a pumping device for drug delivery or other biomedical applications. Future work includes modeling and optimization of other hollow actuators.
Sponsor: NIH Bioengineering Research Partnership
Collaborators: Dr. Eric Mockensturm, Dr. Qiming Zhang, Dr. Alan Snyder (Bioengineering)

Name: Katie Powell, M.S. expected 2005
Title: Design of Multifunctional Mechanisms for Ophthalmic Surgery
Summary: The goal of this project is to optimally design multifunctional instruments which can be used to perform more than one task, thus reducing instrument exchange time and reducing the risk of retinal tears in ophthalmic procedures. Target instruments are on the order of 0.5 mm in diameter and require microfabrication. Prototype instruments are currently being fabricated and evaluated.
Sponsor: Life Sciences Greenhouse of Central PA
Collaborator: Dr. Randy Haluck (Dept. of Surgery), Dr. Kim Neely (Dept. of Ophthalmology), Alcon Manufacturing Ltd.

Dr. Michael Grissom, postdoctoral researcher for Professor Christopher Rahn is building an electroactive polymer actuator for the Clemson Manipulation project funded by DARPA.

Current efforts in Dr. Chris Rahn's Mechatronics Research Laboratory are directed towards: contact sensors for marine environments, biologically inspired robotic manipulators, and MEMS actuators. The Navy is supporting work on the development of mechanical imagers for shape measurement in the surf-zone for mine detection. DARPA is supporting the development of soft robot manipulators that have robust dexterity for follow-the-leader teleoperation and whole arm manipulation. In collaboration with the Department of Electrical Engineering, micron sized actuators are being modeled, fabricated, and tested for MEMS applications.

Contract Name: 3D Contact Sensing for Mine Detection in Surfzone Environments
Contract Sponsor: Office of Naval Research
Description: The Navy is supporting the development of whisker contact sensors to be mounted on underwater crawlers for mine detection.
Students: Tyler Clements (MS - 2004) "Design and Implementation of a 3D Whisker Sensor", Haiyu Zhao (PhD - 2005) "Modeling and Control of Distributed Structural Elements"

TECHNICAL RESEARCH GROUP HIGHLIGHTS

Contract Name: Soft Robot Manipulators
Contract Sponsor: DARPA
Description: DARPA is supporting the development of novel robotic manipulators that are biologically inspired by elephant trunks and squid tentacles.
Students: Mike Pritts (MS-2005) "Air Muscle Robotic Arm", Arun Srininvasan "Modeling of EAP Actuators"

Contract Name: MEMS Actuators
Contract Sponsor: National Science Foundation
Description: Development of microactuators for MEMS applications.
Student: Jongpil Cheong (PhD - 2005) "Modeling and Fabrication of MEMS Actuators"

Contract Name: Aerostat Design and Manufacturing Program
Contract Sponsor: Army Missile Defense Agency
Description: Development of flight dynamic models that predict stresses in aerostats.
Students: Anthony Docimo (MS - 2003) "Aerostat Flight Dynamic Model" and Keith Stanney (MS - 2003) "Gust Loading on Aerostats"

Professor George Lesieutre and his students are pursuing a number of projects in vibration control and active structures. DARPA is sponsoring a new effort in reconfigurable aircraft structures. The National Rotorcraft Technology Center is supporting three projects. The first aims to develop layered fluid-elastic isolation mounts to reduce interior noise; the second, to develop blade-embedded vibration absorbers to stabilize ground resonance instability without the use of lag dampers; and the third, to actively deploy tiny trailing-edge devices to improve blade performance. Other areas of research includes: Navy-sponsored work in particle dampers; the development of high power density piezoelectric motors ; and self-powered piezoelectric energy harvesting systems .

Title: Layered Fluid-Elastic Isolation to Reduce Rotorcraft Interior Noise
Sponsor: NASA / Army National Rotorcraft Technology Center
Summary: Develop layered isolators to reduce noise transmission from helicopter gearboxes to fuselage. Focus on frequency range from 500 to 2000 Hz. Consider the use of integral fluidic vibration absorbers.
Collaborator: Dr. Edward Smith
Post-Doc: Joseph Szefi (Ph.D. August 2003)

Title: Blade-Embedded Inertial Dampers
Sponsor: NASA / Army National Rotorcraft Technology Center
Summary: Assess feasibility of blade-embedded vibration absorbers to stabilize ground resonance instability without the use of lag dampers.
Collaborator: Dr. Edward Smith
Student: Jason Petrie
M.S. expected: August 2004

Title: Miniature Trailing Edge Effectors for Rotorcraft Applications
Sponsor: NASA / Army National Rotorcraft Technology Center
Summary: Address the use of MITEs for stall alleviation, flight control, and vibration reduction. Consider performance and actuation.
Collaborator: Dr. Mark Maughmer
Student: Michael Kinzel
M.S. expected: August 2004

Title: Morphing Aircraft Structures
Sponsor: NASA LaRC / DARPA
Summary: Develop and demonstrate concepts for reconfiguring flight vehicle structures: primary structure, skin, and actuation. These must be capable of carrying realistic loads and not be substantially heavier than structures that perform similar functions today.
Collaborator: Dr. Mary Frecker
Student: Deepak Ramrakhyani
Ph.D. expected: May 2005 (“Tendon Actuated Compliant Cellular Truss”)

Title: Particle Dampers for Naval Applications
Sponsor: NAVSEA
Summary: Develop experimental database to elucidate the physics of particle dampers. Develop useful design models.
Collaborators: Dr. Gary Koopmann, Dr. Steve Hambric
Student: Michael Yang (Ph.D. August 2003)

Title: Design Analysis of the Nonlinear Behavior of Particle Impact Dampers
Summary: Establish design parameters that result in high damping, damping that is insensitive to modest changes in the operating conditions.
Student: Sanjiv Ramachandran
M.S. expected: August 2004

Title: A hybrid active/passive clamping piezoelectric actuator
Sponsor: Lockheed / DARPA
Summary: Develop a light, high power actuator for application to a morphing UAV. A new hybrid active/passive clamping piezoelectric actuator is the focus. This research effort involves actuator modeling, fabricating prototype actuators, and experimental testing.
Collaborator: Dr. Gary Koopmann (PI)
Student: Jacob Loverich
Ph.D. expected: August, 2004

Title: Self-Powered Energy Harvesting System for Wireless Health Monitoring
Sponsor: ONR
Summary: Develop self-powered energy harvesting system for wireless health monitoring. Consider MEMS implementations.
Collaborators: Dr. Heath Hofmann, Dr. Qiming Zhang

TECHNICAL RESEARCH GROUP HIGHLIGHTS

Pictured here is Dr. Dean Capone, the newest member to the CAV Technical Group Leaders. He directs the Flow Induced Noise Control group.

Flow Induced Noise Control

Dr. Dean Capone, Group Leader
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The mission of the Flow-Induced Noise Group of the Center for Acoustics and Vibration is the understanding and control of acoustic noise and structural vibration induced by fluid flow. A summary of the accomplishments of the members of the Flow-Induced Technical Group is presented below.

In September 2003, Dr. Gerald C. Lauchle attended the International Fan Noise Conference in Senlis, France. He was on the scientific committee of this meeting and presented two invited papers.[1,2] One paper showed that screens shaped like a pancake placed on the inlet side of a motorized impeller alter the turbulence structure entering the rotating blades in a favorable manner. The overall broadband noise radiation was reduced by as much as 5 dB with very little degradation of fan performance. This research was initiated under the sponsorship of Nortel Networks, Ottawa, Canada. A second paper at this conference summarized the turbomachine turbulence ingestion noise model developed as part of the Acoustics doctoral dissertation by Joe Gavin of Electric Boat Corp. This new unsteady force and noise model accounts for the anisotropic nature of the type of turbulence found in turbulent boundary layers. The model is best suited for marine propulsors that are mounted on the stern of the vehicle where the boundary layer of the vehicle gets sucked into the rotating blades. An application of the new model to rotor blades with various degrees of rake and skew was then presented at the International Mechanical Engineering Congress held in November in Washington, DC.[3] Dr. Gavin, who was a former CAV student member, organized a special session related to flow noise modeling and measurement at this Congress.

In addition, former Acoustics Ph.D. graduate and CAV student member, Walter Kargus IV, attended this ASME Congress and presented a paper on an experiment that localized the region and mechanism of aeroacoustic radiation from the flow of a turbulent boundary layer over a rearward-facing step.[4] Dr. Kargus is now with Johnson Electric in Plymouth, MI.

Lauchle and Acoustics doctoral candidate James McConnell continue to conduct flow noise research on underwater vector and dyadic sensors. In September 2003 Mr. McConnell completed a comprehensive set of flow noise experiments at a Navy test facility in Crane, IN. A single component inertial intensity sensor was towed over a range of speeds typical of those encountered in underwater surveillance work. The sensor simultaneously listened for a low-level sound signal generated by a fixed source located some distance away in the large lake. The speed only needed to reach about 0.25 knot before the velocity sensor channel of the intensity probe (intensity is the product of acoustic pressure and acoustic particle velocity) became saturated with spurious turbulence-induced force fluctuations. The remote source could not be detected at this and higher speeds using either the directional velocity channel or the omni-directional hydrophone channel. However, the cross spectrum between these two channels is the intensity, and with that processing the source was easily detectable even at the maximum flow speed of ½ knot. This work was presented as an invited paper at the Austin Meeting of the Acoustical Society of America in November 2003.[5]

Dr. Timothy A. Brungart and Mr. Steven D. Young are studying the noise associated with ventilated cavities formed over high-speed undersea vehicles. The Office of Naval Research supports their effort.

Drs. Brungart and Timothy E. McDevitt are studying the noise radiated by integrated motor propulsors used in undersea vehicles. Integrated motor propulsors incorporate the electric motor rotor used to power the propulsor into the hydrodynamic rotor used to propel the vehicle.

Drs. Brungart and Dean E. Capone are investigating methods for reducing the turbulence ingestion noise for turbomachinery. In-air testing of a noise-reducing concept was conducted in 2003 and in-water testing of the concept will be conducted in 2004.

Dr. Fan Hwang, Mr. Bill Bonness and Dr. Steve Hambric have completed an investigation on the modeling of structural excitations by low speed turbulent boundary layer flows.[6] This work critically examines various spectral models, both wave vector-frequency spectra and cross-spectra. These models are examined in terms of their theoretical consistency and the ability to predict the pressure spectra measured by flush-mounted hydrophones of various size and location on buoyantly propelled vehicles. This investigation results in recommending a comprehensive wave vector-frequency spectral model, which is consistent with the theory and the measured data available in the literature.

TECHNICAL RESEARCH GROUP HIGHLIGHTS

1. Lauchle, G. C. Effect of Inlet Turbulators on Backward-Curved Impeller Noise. *Proc. of Fan Noise 2003*, 2nd. International Symposium CD/ROM, Senlis, France (2003).

2. Gavin, J. R., G. C. Lauchle. Broadband Forces Caused by Anisotropic Turbulence Entering a Turbomachinery Rotor. *Proc. of Fan Noise 2003*, 2nd. International Symposium CD/ROM, Senlis, France (2003).

3. Gavin, J. R., P. D. Lysak, M. L. Jonson, G. C. Lauchle. Benefits of Rake and Skew for Turbulence Ingestion Noise. *Proc. of the 2003 Inter. Mech. Eng. Conf. and Expo.*, **IMECE-44385**, pp 1-7 (2003).

4. Kargus, W. A., IV, G. C. Lauchle. Acoustic Radiation from Separated Boundary-Layer Flow over a Rearward-Facing Step on a Flat Panel. *Proc. of the 2003 Inter. Mech. Eng. Conf. and Expo.*, **IMECE-43546**, pp 1-9 (2003).

5. McConnell, J. A., G. C. Lauchle. Flow-Induced Noise on a Pressure-Acceleration Underwater Acoustic Intensity Probe (Invited). 146th Meeting of Acoust. Soc. Am., Austin, TX [*J. Acoust. Soc. Am.* **114**, Pt.2, 2362 (2003)].

6. Hwang, Y. F., Bonness, W. K., and Hambric, S. A., "On Modeling of Structural Excitations By Low Speed Turbulent Boundary Layer Flows," ARL Technical Report 03-008 (2003).

Machinery Prognostics & Condition Monitoring Technical Group

Dr. Amulya Garga, Group Leader

The Machinery Prognostics and Condition Monitoring Technical Group is focused on methodologies and technologies for accurate and reliable assessment of equipment condition and predicting remaining useful life in machinery. The benefits of this research are reduced maintenance expenditures and improved system safety.

Dr. Amulya Garga spent the summer at NAVAIR, Naval Air Station, Patuxent River, MD as an ASEE Senior Faculty Fellow. He and his student, Jason Hines, worked with the IMD-HUMS data collection and analysis on various helicopters. During the last year, Jeff Banks and his colleagues performed a top degraded assessment for the Light Armored Vehicle (LAV). Dr. Karl Reichard and Jeff Banks have been working with the U.S. Army to develop advanced condition monitoring strategies and techniques for the HEMTT truck. Later this year, ARL will be installing a health monitoring system on the HEMTT truck's hydraulics system. Jeff Banks and Brian Murphy have been developing computer models of HEMTT hydraulic system that will be used in the development of diagnostic and prognostic algorithms and for the implementation of model-based health monitoring techniques. Dr. Jim Kozlowski has been improving the hardware and software for battery state-of-charge estimation. He and Chris Rogan are leading efforts to implement battery diagnostics and prognostics on a variety of platforms including the HEMTT truck, an unmanned ground vehicle and for man portable radios. Mitch Lebold and a team of engineers and PSU faculty have been developing shaft crack detection and monitoring techniques for application in the nuclear power industry through sponsorship by the Electrical Power Research Institute. Karl Reichard, Mark Turner and Jason Estep are working with RLW, Inc. of State College, PA to develop and demonstrate health monitoring technology for cranes in commercial and government shipyards. These are some of the projects in the Complex Systems Monitoring and Automation Department, which develops, demonstrates, inserts and transfers new technologies to monitor and control the health and operation of mechanical, electrical, and electrochemical systems to DoD, other government and industrial customers. Dr. David Swanson is leading the development of intelligent sensor networks based monitoring of system condition for various applications, including mechanical systems. A key aspect of the unattended monitoring is a low cost, wireless, data acquisition system developed and improved over the last few years at the Applied Research Laboratory.

Jason Hines is graduating in August 2004 with an M.S. in Mechanical Engineering. In his thesis he studied the problem of comparing the performance of time synchronous averaging for dramatically improving the signal to noise ratio for signals from specific components in complex gearboxes, including planetary gearboxes. The health features developed for fault classification are significantly more accurate and reliable. This research has won Jason Hines the Mideast region American Helicopter Society Lichten Competition this year. This enters him in the national competition. Gaurav Puri graduated with a B.S. in Electrical Engineering in December 2003. His senior thesis focused on battery state-of-health estimation with artificial neural networks. Since his graduation he has been working as an engineer with the Systems and Automation Division at the Applied Research Laboratory at Penn State.

Propagation and Radiation Technical Group

Dr. Victor Sparrow, Group Leader
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The propagation and radiation group has had another successful year. A number of projects are now ongoing related to propagation in air, although the number had been decreased a few years back. New projects are planned regarding the new FAA/NASA PARTNER Center of Excellence in Aircraft Noise and Emission in which Penn State is a participating university, and those projects will be coming online in the next few years. Some selected current projects include:

TECHNICAL RESEARCH GROUP HIGHLIGHTS

Title: Nonlinear Propagation of Jet Noise
Sponsor: Strategic Environmental Research and Development Program and Wyle Laboratories
Summary: Develop computer algorithms to accurately predict the nonlinear propagation of jet noise from supersonic jets of interest to the DoD.
Student: Kent L. Gee
Collaborators: Dr. Victor Sparrow, Dr. Dennis McLaughlin, Dr. Philip Morris

Title: Modeling and Assessment of Near Field Blast Noise
Sponsor: US Army Engineer Research and Development Center – CERL
Summary: Determine the high frequency content surrounding blast events to provide input to biologists on whether the hearing of bats can be harmed by Army training.
Student: Alexandra Loubeau
Collaborators: Dr. Victor Sparrow

Title: Optimized Hyperthermia Treatment of Prostate Cancer Using a Novel Intracavity Ultrasound Array
Sponsor: US Army Medical Research and materiel Command
Summary: Develop improved array, electronics, and insonification methodology to improve the treatment of cancer of the prostate using ultrasound heating.
Student: Osama Al-Bataineh
Collaborators: Dr. Nadine Smith, Dr. Robert Keolian, Dr. Tom Gabrielson

Designing Quiet Structures (ME597) students, (l-r) Andrew Kankey, Mike Pritts, and Lee Gorny discuss results of their recent project at the technical group luncheon for the Quiet Product Design group.

Quiet Product Design

Dr. Gary Koopmann, Group Leader
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Faculty Affiliates: Dr. Ashok Belegundu
Dr. Weicheng Chen

Visitors: Dr. E. Nishida, Tokyo, Japan
Professor Yang Xiang, Yuhan University, China
Professor Koorosh Naghshineh, University of Western Michigan

Several projects are in progress that build on the computer programs developed by former Ph.D. Students, Michael Grissom's program 'Optimal Acoustic Design' and John Fahnline's program POWER. During April of this year, Professor Koopmann and former PSU student Dr. Jeremy Frank, (now President of KCF Technologies) gave a week long graduate level course to 15 aerospace students at the University of Naples, Italy. The course was organized by a former visiting scholar to Penn State, Francesco Marulo, a professor of Aeronautical Engineering at Naples and was held in a computer classroom allowing students to optimally design a vibrating shell structure for minimum sound power radiation. The Quiet Product Design Group is beginning two new industrial projects that will apply the quiet structure design strategy to both new and existing machines.

Bradley Biehl, a graduate student in our design group, completed his thesis by designing a quiet and highly compact actuator unit for morphing a flow control surface using an integrated ultrasonic motor concept. The prototype is now being replicated for an Applied Research Laboratory project. Bradley accepted a field engineering post with Air Products in Louisiana.

Completed projects
Title: Sound Evaluation and Noise Reduction of Shop-Vac Products.
Sponsor: Shop Vac Corporation, Williamsport, PA
PIs: Dr. E. Nishida and Professor Gary Koopmann

Projects in Progress
Title: Compressor Noise and Vibration Mitigation Using Acoustic Design Optimization Strategies
Sponsor: Copeland Corporation, Sidney, Ohio
PIs: Dr. E. Nishida, Professor Gary Koopmann, and Dr. Weicheng Chen

Title: Investigation of a Piezo-Driven Material Transport Unit
Sponsor: FMC Technologies, Inc. Homer City, PA
PIs: Dr. Weicheng Chen and Professor Gary Koopmann

Graduate Students:
Dongjai Lee, Ph.D expected Fall 2004
Thesis Subject: Reducing transmission loss of vibrating surfaces covered with contiguous, optimally-tuned tiles that act both as tuned absorbers and weak radiators.
Sponsor: Penn State Mechanical & Nuclear Engineering Department
Advisors: Professor Gary Koopmann and Professor Ashok Belegundu

TECHNICAL RESEARCH GROUP HIGHLIGHTS

Brian Zellers, Ph.D. expected Summer 2005
Thesis Topic: Topological Optimization of Radiating Surfaces. In this study, a highly efficient acoustic superposition program is being developed that incorporates changes in a machine's geometry as an acoustic design variable.
Sponsor: Office of Naval Research
Advisors: Professor Koopmann and Professor Frank Archibald

Lee Gorny, MS expected Summer 2005
Thesis Topic: Use of Fluid Excited Resonators to Control Blade Tones of Axial Fans. In this study, several tuned resonators are mounted on the shroud of an axial fan. The shroud is perforated near the tip of the fan blades to allow communication with each resonator that in turn generates a tone in antiphase to the blade tone.
Sponsor: Weiss Fellowship and E&F Fellowship, Applied Research Laboratory
Advisors: Professor Gary Koopmann and Dr. Dean Capone

Andrew Kankey, MS expected Summer 2005
Thesis Topic: Study of Inverse Methods to Characterize the Structural Acoustic Coupling of Submerged Structures. In this study, the use of piezo actuators is investigated to examine reciprocity phenomenon in structural acoustic systems.
Sponsor: US Navy
Advisors: Professor Gary Koopmann, Dr. Steven Hambric and Dr. John Fahnline

Rotorcraft Acoustics and Dynamics Group

Ed Smith, Group Leader
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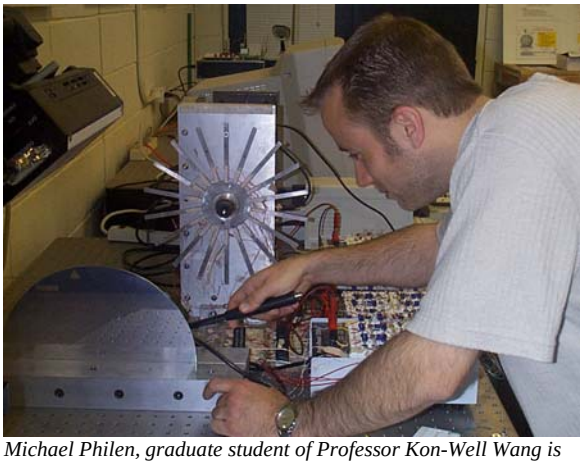
The past year in CAV's Rotorcraft Acoustics and Dynamics Group was marked by a combination of technical research breakthroughs, and continued development of new experimental and computational facilities to be used for ongoing research work and class instruction.

The Rotorcraft Center continues to be a model of multidisciplinary and collegial interactions, involving 17 faculty members, approximately 30 graduate students, and 6 undergraduate research assistants from Aerospace, Mechanical, Engineering Science and Mechanics, and the Applied Research Laboratory. Annual research volume was again at the $2,000,000 mark – representing a healthy leverage of the $600K core award from NRTC. Research projects sponsored by the Army Research Office (equipment upgrades, vibration control), Piasecki Aircraft (compound helicopters), Bell Helicopters (Fluidlastic dampers), Boeing Helicopters and Sikorksy Aircraft (senior design projects), NASA (active control of drivelines, optimal design of low-weight rotor systems), Lord Corporation (embedded blade lag dampers, high frequency gearbox isolation mounts), NSF (rotor wake simulation), and NREL (acoustical simulation of wind turbine blades) were all active this past year. Check out our Rotorcraft Center Webpage for additional details on our ongoing research programs. (http://www.psu.edu/dept/rcoe/).

Major steps towards the development of our new model scale rotor test facility were realized this past year. Led by Profs. Camci and Smith, our Boeing-donated test stand now has a refurbished drive system, and will soon feature icing capabilities and a fully instrumented rotor head. Our new driveline dynamics testbed is up and working as well. This unique facility features a modular flexible driveline, active magnetic bearings, metallic or flexible matrix composite driveshafts, as well as host of instrumentation control hardware. Our new rotorcraft flight simulation research facility is also nearing completion and our capabilities for rotorcraft UAV flight research continue to grow.

Finally, our students and faculty continue to gain recognition for excellence in research, scholarship, and teaching. We had three Vertical Flight Foundation Scholarship Winners, a Regional Lichten Award Winner, and Prof. McCormick received the prestigious honor of the AHS Nikolsky Lectureship Award for life achievement in Rotorcraft Technology.



Michael Philen, graduate student of Professor Kon-Well Wang is testing small scale adaptive mirror using piezoceramic actuators for shape and vibration control.

Structural Vibration and Acoustics Group

Kon-Well Wang, Group Leader
kwwang@psu.edu

During the 2003 Spring Workshop, the Structural Vibration and Acoustics Group has highlighted a couple of research programs, these include projects in the Structural Dynamics and Controls Lab (Professor Kon-Well Wang) and the Applied Research Lab Structural Acoustic Program (Dr. Steve Hambric).

TECHNICAL RESEARCH GROUP HIGHLIGHTS

During the past year, the Structural Vibration and Acoustics Group has organized two group meetings with seminars presented by Professor Samir Nayfeh from MIT in Fall 2003 and by Professor Eric Mockensturm fro**m** Penn State in Spring 2004. Dr. Nayfeh's talk was on vibration suppression by dynamic interaction with low-density, low-wave-speed media. Dr. Mockensturm's presentation was on carbon nanotube modeling. The seminars have attracted many audiences and have stimulated some very good discussions.

To highlight the research activities, several recent research projects and the graduate students working on the projects are summarized below:

Title: Structural-acoustics of submerged cylindrical shells
Sponsor: ONR
PI: Steven A. Hambric
Students: Ben Doty (M.S. pending), Rob Campbell (Ph.D. pending)

Title: Distributed flow-induced fluctuating forces in ducts
Sponsor: ONR
PI: Steven A. Hambric

Title: Component mode synthesis of fluid-loaded structures
Sponsor: ONR
PI: Steven A. Hambric, John B. Fahnline

Title: Structural-acoustic scattering of electromagnetic pressure fluctuation fields
Sponsor: NAVSEA
PI: Steven A. Hambric

Title: Reduce Order Models for Carbon Nanotube Coolapse
Student: Arash Mahdavi
Support: NSF
Advisor: Eric Mockensturm

Title: The Dynamics of a Belt Wrapped Helically Around a Drum
Student: Jianping Guo
Support: Procter & Gamble
Advisor: Eric Mockensturm

Title: The Dynamics of Systems with One-Way Clutches
Student: Raghavan Balaji
Support: NSF
Advisor: Eric Mockensturm

Title: Design and Modeling of a Novel Motion Amplifier Using Axially Driven Buckling Beam
Student: Jie Jiang
Support: NSF
Advisor: Eric Mockensturm

Title: Design and Modeling of an Innovative Electroactive Polymer Blood Pump
Student: Nakhiah Goulbourne
Sponsor: NIH Bioengineering Research Partnership
Advisors: Dr. Eric Mockensturm, Dr. Qiming Zhang, Dr. Alan Snyder (Bioengineering), and Dr. Mary Frecker

Title: Design and Modeling of Electroactive Polymer Actuators
Student: Eunice Yang
Sponsor: NIH Bioengineering Research Partnership
Advisors: Dr. Eric Mockensturm, Dr. Qiming Zhang, Dr. Alan Snyder (Bioengineering), and Dr. Mary Frecker

Title: Vibration confinement and disturbance rejection through electromechanical synthesis of piezoelectric networks
Sponsor: National Science Foundation
PI: K. W. Wang
Student: Tian-Yau Wu (Ph.D.)

Title: High precision shape control of optical surfaces
Sponsor: Eastman Kodak Corporation
PI: K. W. Wang
Student: Michael Philen (Ph.D.)

Title: Simultaneous vibration isolation and damping control via high authority smart structures
Sponsor: US Army Research Office
PI: K. W. Wang
Students: David Belasco (M.S.), graduated in 2003.

Title: Hydraulic valve dynamics modeling using first-principle-based neural networks for automatic transmission applications
Sponsor: Ford Motor Company
PI: K. W. Wang
Students: Ming Cao (Ph.D.) and Loren DeVries (M.S.), graduated in 2003.
Postdoc Fellow: Ming Cao.

Title: Piezoelectric tailoring with enhanced electromechanical coupling for concurrent vibration control of mistuned periodic structures
Sponsor: Air Force Office of Scientific Research
PI: K. W. Wang
Student: H. Bill Yu (Ph.D.)

Title: High performance damping with carbon nanotube-polymer composites
Sponsor: US Army Research Office
PIs: K. W. Wang and Charles Bakis
Student: Ailin Liu (Ph. D.)

TECHNICAL RESEARCH GROUP HIGHLIGHTS

Title: High authority piezoelectric actuator for rotor vibration control via mechanical resonance and electrical circuit synthesis
Sponsor: National Rotorcraft Technology Center
PIs: K. W. Wang and Ed Smith
Student: Jun-Sik Kim (Ph.D.)

Title: Helicopter driveline with flexible matrix composite shafting and active bearing controls
Sponsor: National Rotorcraft Technology Center
PIs: K. W. Wang and Ed Smith
Student: Bryan Mayrides (M.S.)

Title: Active magnetic bearing control of misaligned high-speed drivelines
Sponsor: NASA Glenn Research Center
PIs: K. W. Wang and Ed Smith
Student: Hans DeSmidt (Ph.D.)

Title: An agent-based negotiation framework for the robust design of active-passive hybrid piezoelectric vibration control networks
Sponsor: National Science Foundation
PIs: K. W. Wang and John Yen
Students: Lijun Jiang (Ph.D.) and Kaivan Kamali (Ph.D.)

Also, recently Dr. Kon-Well Wang (PI) together with a team of colleagues, Dr. Chris Rahn (Mechanical Engineering), Dr. Andrew Zydney (Chemical Engineering), Dr. Sarah Assmann (Biology), Dr. Charles Bakis (Engineering Science and Mechanics), and Dr. Michael Jonson (Applied Research Lab), received a DARPA Research Initiative project entitled "Fibrillar Network Adaptive Structure with Ion Transport Actuation". The objective of this multidisciplinary program is to develop innovative approaches, through exploring a novel combination of innovative ideas inspired by the mechanical, chemical, and electrical properties of plants, for the creation of a high authority adaptive structure system to generate large strains while carrying significant loads.

Visiting Faculty to the CAV

Professor Yang Xiang of China is currently working in the CAV lab at Penn State.

Professor Yang Xiang is currently a visiting researcher at Penn State. Professor Xiang is from the Wuhan University of Technology in Wuhan, Hubu, China. Her area of interest is in marine machinery vibration theory. While Professor Xiang is at Penn State she will be collaborating with Dr. Gary Koopmann in the CAV laboratories.