CENTER FOR NDE NEWS

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23rd Annual Review of Progress in Quantitative Nondestructive Evaluation

Biomedical Engineering to be Highlight of Plenary Session

Biomedical diagnostics will be the centerpiece of the plenary session for the 23rd Annual Review of Progress in Quantitative Nondestructive Evaluation (QNDE). The week-long international conference will be held at Bowdoin College, Brunswick, Maine, from July 28 to August 2, 1996. The Review provides an international forum for the presentation and discussion of new results in NDE and related research, highlighting the transfer of new technologies from the biomedical community. Technical emphasis is placed on the fundamentals and early applications of all quantitative measurement modalities. Attention is also given to new results in related technologies that, together with QNDE, may form the building blocks of integrated materials processing and manufacturing sciences.

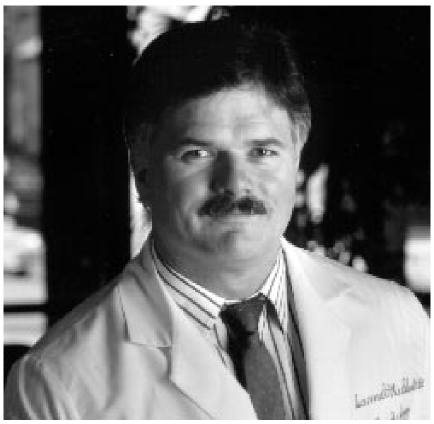
Three outstanding speakers will present lectures on topics in biomedical imaging: Dr. Alan Berson of the National Institutes of Health (NIH); Samuel Wickline, M.D., of the Washington University School of Medicine; and Dr. James Greenleaf of the Mayo Clinic.

Dr. Alan Berson will be the keynote speaker. His address will cover broad issues in the area of cardiac diagnostics, drawing on years of experience in the field. Dr. Berson will discuss questions related to heart, lung, and blood function while showing results of recent research and future research directions.

Dr. Alan Berson

Dr. Berson is a special expert in the Bioengineering Research Group of the Heart Research Program and is a former deputy chief of the Devices and Technology Branch of the Heart and Vascular Diseases Division of the National Heart, Lung, and Blood Institute of the NIH. He has contributed more than 70 research papers to the literature and holds a Ph.D. in physiology and biophysics from Georgetown University, and degrees from George Washington University and City College of New York in engineering science.

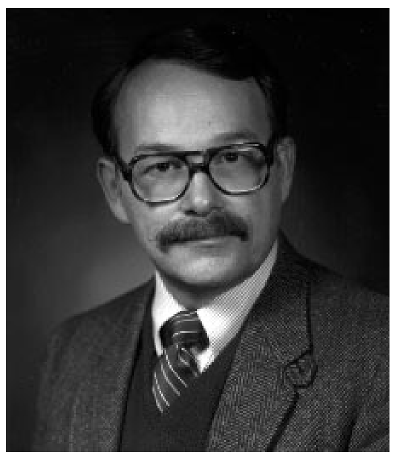
Following Dr. Berson's address, participants at this year's QNDE plenary session will be treated to a special event—a live demonstration of ultrasonic imaging presented by Samuel Wickline, M.D. Using equipment provided by Hewlett-Packard, Doctor Wickline will show two-dimensional ultrasonic B-mode images of the heart, illustrating the standard echocardiographic views. Myocardial wall thickening and valve motion throughout the heart cycle will be demonstrated using various imaging modalities. Doppler-based imaging techniques will be employed to depict blood flow between the heart chambers. Real-time quantitative measurements of cardiac dimensions and parameters related to the assessment of heart function will be demonstrated. The relationship between quantitative clinical assessment of the heart and current research in tissue characterization will be addressed.



Samuel Wickline, M.D.

Doctor Wickline is an associate professor of medicine and chief of cardiology at Jewish Hospital in the Washington University School of Medicine, St. Louis, Missouri, and holds professorial appointments in biomedical engineering and physics. He has authored more than 60 articles and presented over 100 invited conference lectures. Doctor Wickline is a graduate of the University of Hawaii School of Medicine in Honolulu and of Pomona College, Claremont, California. He is a recipient of an Established Investigator Award from the American Heart Association and performs research on contrast agents for ultrasonic and magnetic resonance imaging.

The third plenary speaker, Dr. James Greenleaf, will present exciting new results showing major progress in tissue characterization recently published in *Science* magazine. He will describe a magnetic resonance elastography technique in which shear wave displacements in tissue can be measured quantitatively. The method, pioneered by Dr. Greenleaf and his associates, is being developed as a three-dimensional, quantitative tissue characterization technique that holds promise for the detection and diagnosis of biologic aberrations within the human body.



Dr. James Greenleaf

Dr. Greenleaf is professor of Biophysics and of Medicine at the Mayo Medical School, Rochester, Minnesota. He is also a consultant to the Biodynamics Research Unit of the Department of Physiology and Biophysics, and Cardiovascular Disease and Medicine for the Mayo Foundation. Dr. Greenleaf is an engineering science graduate from the Mayo Graduate School of Medicine and Purdue University. He has published more than 150 articles, edited four books, and holds five patents.

In addition to speakers, the conference will also include nearly 350 talks and posters by a cross-section of researchers and practitioners from industry, research centers, the government, and universities. A Wednesday evening special session will feature an exploratory look at NDE for infrastructure.

The Review of Progress is organized by CNDE in cooperation with the American Society of Nondestructive Testing, the Department of Energy, the Federal Aviation Administration, the National Institute of Standards and Technology, and the National Science Foundation Industry/ University Cooperative Research Centers. Cooperation with other technical societies interested in NDE is encouraged.

For more information about the Review, contact QNDE at 515/294-6770 or http://www.cnde.iastate.edu/qnde/agenda.html on the Internet.

Wednesday Night QNDE Session:

"Aging Infrastructure: The Tip of the Iceberg"

As Dr. Seuss's character "The Cat in the Hat" tells it, "This mess is so big, and so deep and so tall, we cannot pick it up. There is no way at all." In many respects, the problem of the nation's aging infrastructure is aptly put by the well-known children's storyteller.

NDE's first look at infrastructure problems seemed to give a clear picture. Most investigators agreed that cracks and corrosion in steel bridges and concrete structures should have priority. In reality, those problems were already being addressed to some extent. The real problems, however, are so huge that they are difficult to comprehend, by either the technical community or the general public.

Some thorny aspects of the remaining unsolved problems include water flow losses, sewage control, and other basic consequences of neglect. In fact, there has been little NDE research focused on the larger problems. The key to a proper attack on infrastructure problems might be to understand them better, recognize some initial successes, and investigate ways to isolate the more serious problems—a sort of environmental triage.

This year's Wednesday night session at the Review of Progress in QNDE will address these and related issues in its familiar panel discussion format. Dr. Robert Lytton, director of the Center for Infrastructure Engineering at Texas A&M University, will present the invited lecture that will define the problem and set the tone for the evening's discussion. A panel of experts will then be moderated by Dr. Don Bray of Mechanical Engineering at Texas A&M.

The panel will include Dr. Lytton; Dave Goss, an engineer who will describe the approach that a major American city used successfully to solve many of its own infrastructure problems; and Dave Cowfer, a specialist from Westinghouse Savannah River Company, who will discuss the integration of risk-based inspection practices into the treatment of infrastructure problems.

Historically, the QNDE Wednesday night session is a brainstorming meeting dealing with new problem areas. Over the years, topics have included cracks under fasteners in the C-5A, aircraft corrosion, NDE education, federal science policy, uniform life-cycle engineering, aging aircraft, and the Internet and World Wide Web. Last year, a history of Boeing commercial airplanes was the subject of discussion.

ETC Open Forum

The second Engine Titanium Consortium (ETC) Open Forum was held May 8–10, 1996, in San Francisco, California. The meeting was organized by ETC on behalf of the Federal Aviation Administration (FAA) Technical Center and the FAA New England Engine Propeller Directorate.

The Forum's attendance of over 100 represented all segments of the titanium industry, from billet producers to the original engine manufacturers to the airlines. The agenda included technical presentations on fundamental studies, production inspection, probability of detection, contaminated billet study, and inservice inspection.

To open the government/industry/university consortium forum, Mike Bortitz and Al Broz of the FAA presented the agency's perspective. Presenters included the FAA, Iowa State University, General Electric, Pratt & Whitney, West Penn Testing Laboratories, RMI, Wyman-Gordon, Rolls Royce/Allison, and SNECMA. In addition, speakers from Northwest Airlines and United Airlines provided their perspective on the future of engine/aircraft maintenance and essential inspection tools.

United Airlines sponsored a tour of the maintenance facility at the San Francisco airport. As part of the tour, the ETC portable scanner, which is currently in a beta site test at United, was demonstrated to attendees.

Eddy Current Scanner Could Mean Safer Aging Aircraft

McClellan [Air Force Base] could be among the first aviation facilities to apply a new nondestructive inspection (NDI) technology to the Air Force inventory of aging aircraft, NDI manager Al Rogel said.

[Recently,] Iowa State University researcher Jay Bieber demonstrated a prototype of a pulsed eddy current scanner system to scientists and technicians at McClellan's Science and Engineering Laboratory. The prototype, if successful, could be manufactured for use by the Air Force and civilian aviation inspection facilities.

Currently, McClellan's NDI facility uses conventional manual eddy current inspection methods to inspect aircraft components for cracks and corrosion. The eddy current inspection method uses an electromagnetic field induced in the component being inspected. This labor-intensive procedure involves a technician running an eddy current probe similar to a ball-point pen or pencil along the surface of the part being inspected.

"Imagine running a pencil eraser along the fuselage of a KC-135," Rogel said. That is what the eddy current inspection method currently requires.

As the manual eddy current probe is moved across the surface of the component, inspection waveform data is displayed on the eddy current instrument. The inspector then must analyze and interpret the phase-angle changes to determine if there are structural weaknesses that would effect the serviceability of the part. The inspector then sketches the defective area on the component with a grease pencil.

Iowa State University researcher Jay Bieber, left, and Danny Anderson, an engineer at McClellan's Science and Engineering Laboratory, troubleshoot the new pulsed eddy scanner.

The new device uses a probe mounted on an X-Y flatbed scanner, which is attached to the aircraft by suction cups. The scanner moves the probe back and forth along the surface being inspected, transmitting data to a portable computer. An image of the scanned area is then displayed on the computer screen for analysis with specialized software. The scanner, Rogel said, also would allow storage of the inspection data that currently is not possible.

In addition, the pulsed eddy current produced by the new device would allow technicians to inspect several layers of metal simultaneously. Currently, technicians are limited to inspecting one layer at a time. To inspect between overlapped joints—sheets of metal riveted together and bonded by adhesive—technicians must scan the component several times, adjusting the level of penetration by varying the frequency of the eddy current. Imagine running a pencil eraser along the fuselage of a KC-135 not once but three times. The new scanner, which shows not just the image of the damage but how deep or in which layer the damage is located, obviates the need for multiple scans of the same area.

The aging of workhorse aircraft like the KC-135—not scheduled for replacement until 2040—will make technologies like pulsed eddy current increasingly important, Rogel said. The manufacturing techniques used in the 1960s, when the KC-135 was built, make it vulnerable to corrosion between overlap joints. Moisture intrusion between sheets of metal can lead to corrosion, weakening reinforcing adhesives and placing stress on rivets and spot welds, which can cause the rivet holes or spot welds to crack. While labor-intensive methods like the manual eddy current inspection technique were adequate when the KC-135 was young and inspection areas were small, the workload for the inspection facilities will increase as the aircraft age and the size of the areas requiring inspection grow, Rogel said.

The scanner was developed at Iowa State University's Center for Nondestructive Evaluation, with funds from the Federal Aviation Administration and the Air Force Office of Scientific Research. At Iowa State, the scanner has been used to inspect the wing spars of the university's commuter aircraft, Bieber said. The scanner, if developed from the prototype, will have applications for the Air Force's KC-135 and A-10, and for aging civilian commuter aircraft.

"This is something we're excited about," Rogel said. "We'd like to see it used throughout the Air Force."

Reprinted with permission from Space Maker, McClellan Air Force Base.

Center Developing Air-Coupled Testing Technology

Although liquids or rubbers are the media most often used to couple ultrasonic waves in nondestructive evaluation applications, these are not the only choices. Researchers at CNDE are investigating air as a couplant for ultrasonic tests. The density and lower sound velocity of air seem to make air an inappropriate ultrasonic couplant, according to Dale Chimenti, a CNDE senior scientist and professor in Iowa State University's Department of Aerospace Engineering and Engineering Mechanics. Now, in measurements at CNDE supported by the Federal Aviation Administration Center for Aviation Systems Reliability, Chimenti and his collaborators have demonstrated air-coupled ultrasonic C-scans and materials characterization of composites at frequencies of 0.5 to 1.2 MHz.

From a technical standpoint, the major obstacle in air-coupled ultrasonics is the availability of transducers that can produce and sense very high frequency pressure waves in the air. Piezoelectric transducer materials, such as quartz, are best suited to generating waves in solids since they have both large stiffness and high density. However, this combination is poorly matched to move the volume of air needed to create high-amplitude pressure waves suitable for air-coupled ultrasonic inspections.

A recent advance in this technology is the development of high frequency foil transducers, an extension of the "tweeter" concept found in stereo speakers. For MHz applications, however, the foils must be much thinner and closer to a ground plane in order to function efficiently. In the air-coupled transducers, it is the charge separation between the foil and the ground plane that causes its "drumhead" to flex, producing comparatively large air displacements. A further advantage is that the foils are reciprocal devices, functioning both as generators and detectors of air-coupled ultrasound. A bias voltage of a few hundred volts is needed for operation.

To increase the efficiency of the coupling, CNDE researchers carefully constructed a measurement model of the test geometry to maximize sound energy insertion into the sample, according to Chimenti. In plate-like test samples, this is the equivalent of generating guided waves in the plates. Evidence of guided waves, seen as complex voltage versus frequency and angle, is routinely recorded and analyzed. This forms the major portion of the experimental data. By using the results of detailed voltage calculations for two-transducer measurements, the geometric aspects of the measurement can be accounted for and the material elastic property information contained in the data extracted with remarkably high resolution. C-scans to detect defects have also been carried out.

Applications of this technology are foreseen in large-scale composite inspection, as well as manufacturing inspections of material that cannot be touched by water, such as composite prepreg. Further work will consist of solving problems inherent in reduction of the method to practice.

Neural Networks Help Automate Inspection

Since the early 1980s, neural networks have developed as a strategy to mimic the architecture and information processing of the human brain. Scientists are attempting to copy the brain's approach by making computers that can learn and generalize from prior experiences.

Work at CNDE will bring the benefits of this research field to nondestructive evaluation. Lalita Udpa, associate professor of electrical engineering at Iowa State University and CNDE scientist, has worked for almost a decade to apply neural nets in classifying signals obtained in nondestructive inspection (NDI) applications.

The neural nets work addresses a problem inherent to NDI: large volumes of signals have to be interpreted accurately to determine the presence or absence of a flaw in an object. When performed manually, analyzing the data can lead to operator fatigue, resulting in an incorrect interpretation of data. Automated signal classification systems can provide consistent signal characterization.

Udpa, an expert in this field, explores the applications of neural nets to address data interpretation challenges represented by a variety of testing modalities. The technique was used with eddy current inspection of nuclear facility steam generator tubes in work sponsored by the Electric Power Research Institute (EPRI). Ultrasonic inspection of welds in boiling water reactor tubing for an EPRI project is also receiving neural nets treatment. Neural net-based signal analysis software is being integrated into a commercial aircraft wheel inspection system in a project supported by the Federal Aviation Administration. In addition, neural net systems developed at ISU are being used by gas pipeline inspection companies to classify magnetic flux leakage data obtained from inspecting thousands of miles of transmission gas pipeline. Several of the systems are being evaluated at industrial beta sites, including AlliedSignal and Vetco Pipelines, Inc.

Modern digital computers outperform the human brain at number crunching and numerical computation. However, human beings excel at solving cognitive problems, such as face recognition and processing of contextual information. Neural networks are an attempt to duplicate this cognitive problem solving capability. "However, we are still not even close to human performance," said Udpa.

In its current form, neural nets are essentially massively parallel, densely interconnected computational elements, or neurons. Each neuron performs a weighted sum of its inputs and passes the result through a nonlinear activation to produce an output. The functionality of the network is established by estimating the connection weights. During the training phase, an appropriate learning algorithm is used to estimate the interconnection weights such that error in the network performance is minimized. Once the network is trained, it can be used to classify unknown field signals.

According to Udpa, she and her team of researchers, including other faculty and several ISU graduate students, will continue to address the problems that remain. One of the major challenges is the development of a preprocessing scheme that compensates for variations produced by changes in scanning speed, operating frequencies, drifts in instrument gain, and other test parameters. Data compression strategies that identify and extract important features in the signal, yet allow the algorithm to work faster and more accurately, are a challenge as well. The concept of neural networks offers exciting possibilities, but the field is "very much in its infancy," according to Udpa.

Evaluating the Probability of Detecting Defects

The challenge: To determine the probability of finding a flaw that is never the same shape, size, or distance from the surface; a flaw that can send back a variety of signals depending on the placement and design of testing equipment. R. Bruce Thompson, associate director of CNDE, and Iowa State University, AlliedSignal, General Electric, and Pratt & Whitney are developing a methodology to help meet this testing challenge.

All disciplines have standards or measurement techniques to assess the reliability of a process. Thompson and his colleagues are using probability of detection (POD), an engineering measure of the proportion of flaws that a process is likely to detect, to determine how reliably various inspection techniques detect hard alpha inclusions in titanium alloys. Hard alpha inclusions are a POD challenge since the defects are subsurface and of varying shape. Titanium alloy also creates ultrasonic noise that can mask the signal resulting from a flaw. With funding from the Federal Aviation Administration, the POD work will allow comparison of various inspection techniques. This will also enable the aircraft community to determine how best to detect hard alpha inclusions and other defect types in new components, and make risk and life management decisions in older components.

With the new methodology, a determination is made of the distribution of noise in flaw free materials and of signal plus noise in flawed material. From these distributions, predicting the POD and other relevant quantities, such as the probability of false alarms, is possible. The methodology permits the combining of empirical experimental information and physical information obtained from the inspection process. A key element of the approach is the use of measurement models developed at CNDE, which assist in simulating the inspection data. The physical insight permits POD generalization to other systems.

Existing methodologies, such as the development of representative sample sets for performing inspections, are difficult to apply to hard alpha inclusions because they are subsurface defects of complex morphology, according to Thompson. Application of existing methodologies are often very costly and deal unsatisfactorily with false calls. “A desirable methodology would incorporate field experience, provide estimates for the effects of changes in procedures without requiring new sample sets and experiments each time, permit comparison and qualification of systems, and provide engineering feedback to managers,” said Thompson.

The new methodology takes into account these desires. The Engine Titanium Consortium (ETC) is interested in the work as it focuses on why detection results change and what introduces the variability.

To date, the methodology has been applied to simply shaped defects such as flat-bottomed holes and synthetic hard alpha inclusions. Work with ETC is under way to use the methodology to gain increased understanding of the POD of a number of naturally occurring hard alpha inclusions found in a contaminated billet.

More CNDE News Highlights

Research Excellence Award to AEEM Ph.D.

Rick Hale, a senior project engineer at McDonnell-Douglas in St. Louis, Missouri, received a Research Excellence Award from Iowa State University for his Ph.D. dissertation, "Ultrasonic Nondestructive Evaluation Techniques and the Effects of Fiber Architecture on Mechanical Performance in Multidirectionally Reinforced Textile Composites." Hale's thesis was directed by Daniel Adams, assistant professor of Aerospace Engineering and Engineering Mechanics, and David Hsu, ISU adjunct professor and CNDE senior scientist. Hale, who took a leave of absence to complete his Ph.D. work at ISU, graduated in December 1995.

Team Wins Model of Excellence Award

Members of a team that worked on DC-9 wing box inspection recently received the McDonnell-Douglas Aerospace (MDA) Model of Excellence Award.

The team was nominated by Dwight Wilson, manager of nondestructive testing at Douglas Aircraft in Longbeach, California, and selected by the MDA Executive Business Council. The award recognizes "individuals and teams who champion change for the enterprise, achieve exceptional quality improvements, and enhance Excellence in MDA products." The team developed, documented and received approval from the Federal Aviation Administration for an ultrasonic technology that reduced inspection labor hours by 85–94 percent using service bulletin estimates and airline calculations. The technology also reduced inspection costs by $1 million. Members of the team were flown to St. Louis for a recognition dinner with McDonnell-Douglas officials on April 26. Team members include:

Jan D. Achenbach, Northwestern University
Glenn Andrew, Science Application International Corporation (SAIC)
Mike Ashbaugh, SAIC
Don Hagemaier, Advanced Transport Aircraft Development NDE group, Douglas Aircraft Corporation
Gerardo M. Hueto, Douglas Aircraft Corporation
Bill Jappe, Advanced Transport Aircraft Development NDE group, Douglas Aircraft Corporation
Greg Kark, Advanced Transport Aircraft Development NDE group, Douglas Aircraft Corporation
Igor N. Komsky, Northwestern University
Greg Linke, Northwest Airlines
David G. Moore, Airworthiness Assurance NDE Validation Center
Jeff Register, Northwest Airlines
Al Steinberg, Douglas Aircraft Corporation

Graduates Leave University with NDE Experience

CNDE, in cooperation with several academic colleges at Iowa State University, educates and trains new scientists who will lead future efforts in NDE and related disciplines.

This year, 48 ISU students are involved in NDE research at CNDE in pursuit of advanced degrees while contributing significantly to the Center's leading edge NDE research. A number of graduates will be mentioned on the following pages, both from this year and those from previous years who have not received recognition here. These students received the rigorous training necessary to lead future research and management programs in NDE and related disciplines. In honor of their dedication and to showcase their research, an abstract of each student's dissertation or thesis is included.

Jane Johnson

Ph.D. 1995
Aerospace Engineering and Engineering Mechanics

"Development of an Acoustic Microscope to Measure Residual Stress via Ultrasonic Rayleigh Wave Velocity Measurements"

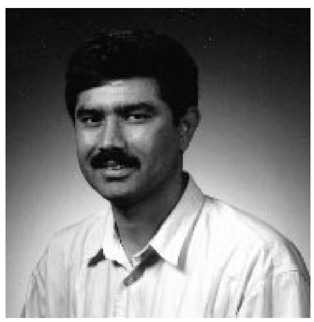
High stress in a crucial instrument part can cause failure. Stress detection is one of the aims of nondestructive testing. The velocity change of acoustic waves can be used to detect stress in a material. An acoustic microscope is an instrument that induces and detects acoustic waves and, in one mode of operation, is able to measure the velocity of acoustic surface waves. It does this over a very small area and is capable of high spatial resolution.

One of the challenges in the measurement of stress is the achievement of high spatial resolution. Since the stress induced velocity shifts are generally small (~0.01%), the required precision of time and distance measurements can be quite high for the short propagation distances required for high spatial resolution. The goal of this dissertation is to measure residual stress via the acoustic wave velocity with spatial resolution on the order of one millimeter or less.

There are many types of acoustic waves. The type of interest here is surface waves known as Rayleigh waves. The velocity of these waves is determined by time and distance measurements. The high precision necessary leads to many complications in the measurements. These are described and, for a few cases, overcome.

The sound velocity in a material can be used to describe material characteristics other than stress. The instrument was used to measure the velocity of Lamb waves on freestanding diamond films. The possibility of using these velocity measurements as a method of characterizing the diamond films is explored. Attempts at using the acoustic microscope on a variety of materials with a large range of Rayleigh wave velocities led to the discovery of surface waves following the second and third front surface reflections between the lens and the surface of the sample. The explanation of these surface waves and their uses are described.

Velocity measurements were made on a sample of silicon carbide during loading in an attempt to measure applied stress. Shifts in the velocity were observed but were not reproducible. The problems with these measurements are described and some possible causes given.



Jahangir Kayani

Ph.D. 1996
Electrical Engineering

"Development and Application of Spread-Spectrum Ultrasonic Evaluation Technique"

The problem of ultrasonic nondestructive evaluation (NDE) is viewed as the acoustic-impulse-response estimation and characterization problem. It is compared with an analogous problem from the field of radio communications, namely radio-detection and ranging (radar). Based on the well-known, spread-spectrum principles from the communications field, a new approach to the acoustic-impulse-response estimation is investigated.

This new approach to ultrasonic NDE, called Spread-Spectrum Ultrasonic Evaluation (SSUE), results from the acoustic-impulse-response estimates, which have a very large dynamic range and high signal-to-noise ratio. The measured acoustic-impulse-response is, therefore, much more sensitive to very small changes in the acoustic characteristics of the test specimen when compared with the conventional techniques.

SSUE employs a carefully tailored, pseudorandom transmit waveform and correlation processing at the receiver. A comprehensive analysis of the various alternatives for the optimum waveform and correlation receiver design is carried out. The optimized system is implemented in the hardware and its performance compared with the theoretically predicted results. The effectiveness of the SSUE technique is verified through a number of different experiments representing various practical NDE situations.

Terry Lerch

Ph.D. 1996
Aerospace Engineering and Engineering Mechanics

"Ultrasonic Transducer Characterization and Transducer Beam Modeling for Applications in Nondestructive Evaluation."

In this work, analytic models have been developed for two different nondestructive evaluation (NDE) applications: the characterization of spherically focused ultrasonic immersion transducers, and the prediction of the radiated wave fields of a variety of commonly used ultrasonic transducers.

When a spherically focused probe is correctly and completely characterized, its corresponding theoretical model can accurately predict the experimentally measured structure of its incident wave field. A new and efficient method for completely characterizing a spherically focused transducer and its accompanying measurement system is described. Predicted responses that make use of this method are shown to correspond very well to measured responses for a number of different commercial transducers.

The ultrasonic beam modeling work is divided into three parts. First, the problem of a planar piston ultrasonic transducer radiating at oblique incidence through a planar fluid-solid interface is studied, and two new types of beam models representing this problem are developed—a surface integral model and a boundary diffraction wave (BDW) paraxial model. The less restrictive surface integral model is used to test the validity of the BDW paraxial model, particularly in the near field and at different angles of incidence. Second, a new edge element method for numerically evaluating a variety of ultrasonic transducer beam models has been developed. This edge element model, which uses a local Fraunhofer approximation, is shown to be able to predict the wave fields of a focused probe in water and of a planar probe radiating into water through a planar fluid-solid interface with the accuracy equal to that of the surface integral models while also being considerably more efficient. Third, and finally, a complete elastodynamic model of an ultrasonic angle beam shear wave transducer is also presented. This model is evaluated by the edge element method, and various transmitted mode contributions are compared with those predicted by a simpler fluid-solid model.

Anita Ousley

Ph.D. 1995
Education

"A Study of the Attitudes of Faculty and DEOs at Iowa State University Toward Deming's Principles of Total Quality Improvement (TQI)"

Recent issues facing higher education have created uncertainty over the traditional philosophies underlying higher education administration. As a result, some institutions are investigating Total Quality Improvement (TQI) as an alternative teaching and administrative practice. However, TQI implementation efforts sometimes fail due to poor attitudes of faculty and other employees toward the philosophy and toward change in general. This study investigates the attitudes of faculty and Department Executive Officers (DEOs) at Iowa State University toward some aspects of TQI by identifying possible group differences between DEOs and faculty and between/among faculty subgroups. To achieve the objectives, an instrument was developed by the researcher based on some issues more often raised in the literature regarding TQI and higher education. The Total Quality Improvement Attitude Scale was mailed to a sample of 436 faculty members and the total population of 59 DEOs with appointments at ISU during the Spring semester of 1994. Usable questionnaires were received from 262 (60%) faculty members and 45 (76%) DEOs.

The results of this study are first reported on an item-by-item basis and then on factors extracted from the data. The results of the item-by-item analysis reveal several significant differences between faculty and DEOs and among faculty across academic rank, gender, college of appointment, tenure, and length of time as a faculty member. Results of the factor analysis yield significant differences across academic rank, college of appointment, and length of time as a faculty member. The findings of this study can be used both within and beyond the concept of TQI. The research yields information regarding the views of faculty toward controversial topics that may be useful in evaluating programs, policies, goals, and priorities of the university. The findings also can be beneficial in providing a better understanding of the campus culture and attitudes of campus subgroups.

Naveen Bohra

M.S. 1996
Electrical & Computer Engineering

"Development of a Novel Scanning System for Aircraft Engine Components"

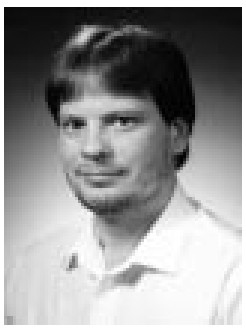
The development of a reliable eddy current inspection system to detect cracks in aircraft structures such as an engine turbine disc poses serious difficulties. Detection of cracks close to an edge using conventional eddy current techniques is difficult owing to the significant background signal from the edge. This thesis deals with the development of a reliable inspection or scanning system using a novel technique based on the eddy current method. The scanning system performs well in detecting surface cracks existing close to the edges of the engine disk slots. Experiments were conducted on electro-discharge machined (EDM) notches in the vicinity of an edge using a differential probe. The scanning system was tested by making scans on different specimens such as bolt-hole and grooved specimens.

Todd Cloutier

M.S. 1994
Aerospace Engineering and Engineering Mechanics

"Experimental and Theoretical Analysis of Elastic Waves Propagating in Cylindrical Shells"

A series of experiments have been performed exploring the propagation of elastic waves in fluid loaded, layered, cylindrical shells. Two commercially available 1 MHz transducers were used to collect time signals. The transducers were positioned at an angle that would excite a Lamb mode in a flat plate of equal thickness. Numerical analysis for all cases was provided through the use of a complex source-point model. Experimental results for unlayered, thick walled (thickness> 10λ), aluminum and stainless steel shells have shown excellent agreement with the numerical analysis. Preliminary results for unlayered thin walled (thickness $<7\lambda$) shells also show good agreement for stainless steel. Future research will involve testing of layered shells for the purpose of locating debonds in the shell-layer interface.



Brent Fischer

M.S. 1996
Aerospace Engineering and Engineering Mechanics

"Interaction of Shear Wave Polarization and Composite Laminate Layup: Experiment and Modeling"

The layup sequence in a composite laminate greatly affects its properties. If one ply is misaligned in the layup sequence, it can result in the part being rejected and discarded. At the present, most manufacturers cut a small coupon from the waste edge and use a microscope to optically verify the ply orientations on critical parts. This can add a substantial cost to the product since the test is both labor intensive and performed after the part is cured. A nondestructive technique that could be used to test the part after curing and require less time than the optical test would be very beneficial, and one that could be performed prior to curing would be extremely desirable. Preliminary tests demonstrated a high probability that the model and tests developed in the author's thesis can be used for characterizing uncured layups as well.

To accomplish this, the author developed, reduced, and implemented a novel ply-by-ply vector decomposition model for composite laminates fabricated from unidirectional plies. A new technique for determining ply orientation errors and sequencing errors in a composite laminate using through transmission of shear waves is also presented. Preliminary studies in possible areas for future research and a novel technique used to graphically display an entire set of received signals as a function of flight and transmitter orientation is also presented.

Clay Maranville

M.S. 1996
Ceramic Engineering & Materials Science and Engineering

"Radiographic Imaging of Ceramic Tape Microstructures"

Efforts to control the microstructures in ceramic tapes through systematic adjustment of the processing parameters have resulted in improved quality and reliability of these parts. However, there is still a critical need for a characterization method which can determine how these processing changes affect the green microstructure. Current methods of gleaning information from green parts are typically destructive, ex-situ, or bulk averaged. Therefore, by developing an x-ray radiographic technique, we are able to determine nondestructively how changes in processing affect the green microstructure. More specifically, we can track individual microstructural defects throughout the casting, drying, and sintering steps to determine how they will affect the final dense part. In addition to the ability of this technique to analyze ceramics, it is general enough to be used in many other fields of research and manufacturing. The steps involved in performing this characterization include magnification radiography using a microfocus generator, digitization of the radiographs using a 14-bit CCD camera, and image processing of the digitized radiographs. From the digitized information, we have been able to detect three types of defect structures in our ceramic tapes: (1) bulk thickness variations of less than 5 percent, (ii) isolated pores as small as 10 microns in diameter, and (iii) hierarchical porosity formed by powder agglomeration. Processing conditions varied, including tape thickness, slurry chemistry, and particle size. Correlations between the defect structure and the imaged microstructure were made that suggest this technique will be a useful process control tool.

Doug Van Otterloo

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"Elastic Property Estimation in Thin Graphite Epoxy Composite Plates Using Ultrasonic Nondestructive Evaluation"

In-plane elastic properties, such as E_1, E_2, υ_{12} and υ_{21} are of interest in composite materials. These properties depend on the fiber orientation. This work is concerned with an inverse method where two measurements of the Lamb wave velocities perpendicular to each other on a composite plate are used in a Simplex Optimization Code to estimate ultrasonically, and an estimate of the theoretical estimate based on the classical composite plate theory is also obtained.

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