N E W S

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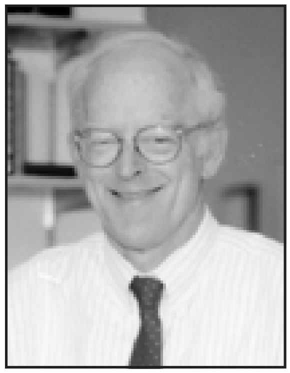
The View from CNDE



R. Bruce Thompson

This is the first in a series of columns, in which I will comment on current directions in nondestructive evaluation and place in that context a number of articles in the newsletter.

This is an exciting time of change for the world, and the technologies that the scientific and engineering communities are developing have become central drivers. This period provides a wonderful opportunity for NDE to help the industrial community, which it was created to serve, in new and exciting ways. We believe that this process will help drive the continued emergence of NDE as a full-fledged engineering discipline, focused on enhancing product reliability and integrated throughout the entire system life cycle— starting with design and proceeding through materials selection, manufacturing, and service. An important goal of CNDE is to play a key role in this evolution and its deployment around the world.

A traditional role of NDE has been its use in the detection of manufacturing defects. However, as we examine the role of nondestructive testing/evaluation in modern structural engineering, the sentiment that “one cannot inspect-in quality, it must be built in” is sometimes heard. This sentiment challenges the role of inspection of finished parts, in which large value has been added by the manufacturing process and NDE is viewed as an added cost by those in management who are concerned with a short-term analysis of returns. However, this change in the view of manufacturing opens many new opportunities for NDE measurements during the product development and manufacturing processes. The article on the application of NDE in powder metallurgy describes a recent workshop devoted to exploring such possibilities.

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The 25th QNDE Review Looks at the 21st Century

The 1998 Review of Progress in Quantitative Nondestructive Evaluation (QNDE), the 25th in the series, was held at Snowbird Ski and Summer Resort in Snowbird, Utah, from July 19–24. An international technical audience of approximately 400, representing academia, industry, and government, participated in the Review where nearly 360 verbal and poster presentations were made.

John Malone, PhD and director of the Research and Technology Group at NASA-Langley, delivered the keynote address. In this address entitled, “The Intelligent Synthesis Environment (ISE): A NASA Concept for the Engineering Design of Aerospace Systems in the Twenty-First Century,” he described a vision of the way in which complex engineering systems of the future will be developed. A central feature of the vision is that the system will be simulated from cradle-to-grave in a virtual reality environment. The simulation will include the total life cycle of the system, including conceptual design, detailed design (including NDE requirements), manufacturing, maintenance, repair, and final disposal. Malone pointed out that this radical culture change is needed to maximize economics in system development that accrue from technology integration and predictable performance and system reliability. He noted specific ways in which new QNDE technologies will benefit from the ISE approach and, conversely, ways that ISE can benefit from ongoing and future QNDE activities.

Two excellent plenary speakers provided talks that highlighted likely NDE specifics of the ISE approach described in the keynote lecture. Jean Bussiere, PhD, of the Industrial Research Institute in Quebec, Canada, gave an excellent talk entitled, “Sensors for the Intelligent Processing of Common Materials.” In this talk, he reviewed new NDE sensors that have

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Another key role in the maturation of NDE is the use of mathematical models of the inspection process in conjunction with other engineering models, such as those based on fracture mechanics, to allow an analysis of the reliability of structural systems during design. The article on ARDAMA describes a new, multi-university program aimed at the application of these ideas to ensuring the reliability of the fatigue life of girth welds in deep offshore risers.

As applications of NDE throughout the lifetimes of major structural systems are developed, there is a constant need to improve the understanding of the measurement principles that form the foundation for such applications. Articles on new advances in the modeling of tip-diffracted ultrasonic signals and suppression of artifacts in X-ray xerography provide examples of some of our recent accomplishments in this area.

As the use of NDE becomes more widespread and the need to integrate it with other technologies to solve systems problems becomes more pervasive, we believe that the development of improved educational offerings assumes an increasingly high priority. Articles on web-based instruction and an NDE Engineering Information Day provide a snapshot of some recent efforts at CNDE in this direction.

The globalization of finance, business, and R&D also has important implications for NDE. For example, as businesses expand their manufacturing activities to emerging countries, it is essential that the skill bases and practices of NDE become more uniform. To facilitate these objectives, we have recently been involved in the formation of a World Federation of NDE Centers, as is described in the corresponding article. We believe that this can nucleate an improved level of communication in the research and educational activities around the world that will be in concert with the demands of the globalization process.

Since the measurement techniques used in NDE have much in common with those employed in other fields of science and technology, there is much to be gained by an exchange of experiences. As an example, we have included an article describing the application of microwave techniques to the characterization of moisture in clouds, an important component of climate modeling.

The NDE community is saddened by the loss of one of its leaders, Christopher M. Fortunko, PhD, who made many contributions to the evolution of the field. I personally view this with considerable sorrow, having worked with Chris in various capacities for over twenty years. His insistence on adherence to the rigorous principles of measurement science, his concern for technology transfer, and his great intensity have all led to significant advances in the field. Chris was recently honored by being named a Fellow of CNDE for “outstanding leadership in applying the principles of quantitative measurement science to NDE standards and reliability.” Some of his contributions are summarized in a brief article, which draws heavily from the thoughts of Harry McHenry of the National Institute of Standards and Technology.

An important landmark in the evolution of quantitative NDE was the 25th anniversary of the Review of Progress in QNDE, held this past summer in Snowbird, Utah. Donald O. Thompson, founding director of CNDE and a co-organizer of the meeting, offers a summary of some of its highlights. Also included is the call for papers for the 26th Review of Progress in QNDE, to be held in Montreal, Canada, on July 25–30, 1999.

This is an exciting time of change for NDE. Please feel free to contact me with ideas on how CNDE can contribute to the rapid advances that are resulting

R. Bruce Thompson

REVIEW/*continued from page 1*

been developed in recent years with emphasis on those that can be customized for specific projects at a reasonable cost. The basis of such systems is the availability of new sensors that diagnose the state of the process, including material behavior and microstructure, and software to plan sequences of events to ensure that good products are produced. These sensors rely on ultrasonic, optical, thermal, and other techniques suitable for harsh environments. Clearly, such sensors form a key ingredient in any ISE approach to product design and development.

A second likely ingredient of an ISE approach was presented by Robert Shannon of Westinghouse Science and Technology Center in his plenary talk entitled, "Intelligent Design for NDE–An Engineering Challenge." Shannon discussed highlights of major advances made in recent years using NDE model-based simulations to assure design for inspectability and more quantitative life cycle predictions. He pointed out that steps are currently being taken to include NDE in the designer's "tool kit" through new simulation capabilities. Shannon provided an excellent summary, noting examples of the beneficial uses of NDE simulations in both product design and in fulfilling component service needs. Both plenary speakers provided ample substance for the vision described in the keynote lecture.

A number of technical sessions should be noted for both the advances made and the high technical interest shown. These include organized sessions in ultrasonic guided waves, NDE of infrastructure, acoustic emission, NDE/biomedical applications, laser ultrasonics and applications, NDE simulations, and thermal wave NDE. These sessions were organized to highlight both the active research problems and early applications of the technologies being developed. The proceedings contain additional detail.

As is the custom of this Review, a special evening session was organized to address current mainline issues in NDE. This meeting was no exception. Tom Siewert, PhD, assisted by Terry Lerch, PhD, of the National Institute of Science and Technology (NIST), led an interesting discussion of "The International Standards System and NDE." The two discussed the International Organization for Standardization (ISO) and its relationships to national standards organizations, ISO 9000 and the system of weld inspection standards that it creates, and technical issues related to revising the standards. The talk and ensuing discussion drew a great deal of interest from the audience.

This year was marked by the passing of three major contributors to QNDE. They were Professor Otto Buck and John Moulder of CNDE and Iowa State University, and Chris Fortunko, PhD, of NIST at Boulder. Special memorial sessions were arranged to honor the memory and contributions of Buck by George Alers, PhD, and of Moulder by Professors Norio Nakagawa and Satish Udpa. These sessions drew on speakers who had collaborated with the honored colleagues in various phases of their research careers. The sessions amply demonstrated the high regard and fondness with which these colleagues are held.

Fortunko passed away suddenly just before the Review. Without adequate time to organize a special memorial session, an extemporaneous tribute to Fortunko took place at the special session on standards, a subject to which he was technically devoted. All three of these contributors will be sorely missed.

The Review is hosted by CNDE and sponsored by QNDE Programs, Inc., with support from the American Society for Nondestructive Testing, U.S. Department of Energy, Federal Aviation Administration, National Aeronautics and Space Administration-Langley, NIST and the National Science Foundation Industry/University Cooperative Research Centers.

–Donald O. Thompson

World Federation of NDE Centers Launched

A formation meeting was held in conjunction with the annual Review of Progress in QNDE to initiate a World Federation of NDE Centers. The idea for the World Federation was conceived by Donald O. Thompson, PhD and former director of CNDE, with colleagues at CNDE in conjunction with members of the Institute of Theoretical and Applied Physics (IITAP), a UNESCO-sponsored institute also located at Iowa State University.

World Federation members pose at CNDE.

Representatives from 13 founding NDE centers in nine countries (Argentina, Belarus, Brazil, China, India, Korea, Russia, South Africa, and Ukraine), in addition to representatives of CNDE and IITAP took part in the meeting. The gathering successfully produced a cooperative working agreement to which all members subscribed and that addressed both administrative matters and technical outlines for the new Federation. Professor Satish Udpa of CNDE accepted the title of permanent secretary of the organization, which will be headquartered at Iowa State within CNDE.

Globalization on many fronts provided common-ground motivation for the various founding members in initiating the Federation. Specific issues included needs fostered by industrial globalization, environmental concerns, population growth, and the easing of world tensions. Uniform NDE technologies and improved people skills are needed on a worldwide basis to support advances in all of these areas.

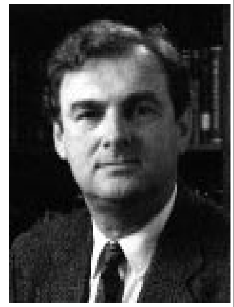
Several objectives were set by the founding members of the Federation that are highly responsive to these motivations. They include: the selection and performance of highly leveraged, collaborative research projects that lead to improved technology and cost-effectiveness in global NDE engineering practice; the development of shared education/training programs that aid the worldwide education and training process in NDE; the pursuit of outreach programs with national and international industries; and the extension of NDE technologies to related applications.

It is expected that attainment of these objectives will provide a number of significant benefits, both to the NDE field and to the participating countries. These include the enhancement of cooperative NDE research efforts in topics that involve global issues such as standards and reliability; the improvement and unification of educational/training capabilities in NDE including the exchange of faculty, students, and other scientific personnel that also enhance local infrastructures; and the efficient integration and extension of individual national NDE efforts into the global economy.

It is the intent of the founding members of the Federation that it be inclusive and that additional centers that are committed to the objective of the organization be admitted. Guidelines regarding this consideration will be available in July 1999. ■

Marking the Passing of Fortunko

A leader in the NDE community for over two decades, Christopher M. Fortunko, PhD, passed away on June 27, 1998. Fortunko made many contributions to NDE, which ranged from his early work on electromagnetic acoustic transducers at the Rockwell International Science Center to his consideration of many problems related to standards and materials characterization at the National Institute of Standards and Technology (NIST) in Boulder, Colorado. The following is the text of a memorial that appeared in *Measurement Science and Technology* (September 1998), as prepared by Harry McHenry, director at the NIST Materials Reliability Division.



Fortunko

> His unique contribution was to bring the discipline and rigor of measurement science to the less orderly world of material testing and nondestructive evaluation (NDE).

In recognition of these and other contributions, Fortunko was named a Distinguished Fellow at CNDE on October 22, 1998. He was honored for “outstanding leadership in applying the principles of quantitative measurement science to NDE standards and reliability.”

Welding, Coatings Alliance Solidifies

CNDE, representing Iowa State University, is one of five institutions that came together to form the Alliance for Research and Development of Advanced Manufactured Assembly (ARDAMA).

The organization is the brain-child of Robert Carnes, research associate at the University of Texas (UT), Austin. As Carnes considered the expertise at UT in electromechanics, he concluded it would be helpful to industry if an organization existed to study and respond to various generic needs related to welding and coatings. After discussions with a colleague, five critical areas were identified: metallurgy and welding engineering, fracture analysis, engineering design and manufacturing, controls, and nondestructive evaluation. He then invited institutions with expertise in those areas to participate. “Of course, CNDE came to mind when we started talking about experts in nondestructive evaluation,” Carnes said.

The complete ARDAMA organization includes: Colorado School of Mines (Center for Welding, Joining, and Coatings Research), The University of Tennessee at Knoxville (Association for Fracture Analysis), Vanderbilt University (Welding Automation Laboratory), UT (Center for Electromechanics), and Iowa State University (CNDE).

From these schools, five members were chosen to be part of the ARDAMA Council. Donald O. Thompson, former CNDE director, represents Iowa State. Other members include David L. Olson, Colorado School of Mines; John D. Landes, University of Tennessee; George E. Cook, Vanderbilt University; and Steven P. Nichols, UT.

“We purposely chose professors that are preeminent in their field,” said Carnes, “but we also chose them for their breadth of experience across fields and the extensive experience of the institutions conducting practical research.”

The experience is central to the goal of the Council, which is to identify significant problems and potential areas for research, consider the problem, and formulate a strategy for its solution. Projects of interest to the Alliance are those that

- exceed the capacity of a single researcher, or even a single academic discipline,
- require a knowledge of fundamentals, as well as practice,
- represent immediate and long-term needs,
- provide immediate and long-term benefits when solved,
- justify a single company- or group-sponsored program,
- qualify for matching funds from government, and
- provide substantial payoff to the industry concerned and the country as a whole.

Although the Council decides which research to consider, other interested parties, particularly industrial representatives, are invited in for discussion. The Council then formalizes a plan for the solution of the problem, including the scope of work, schedules, and budgets. ARDAMA then goes back to industry to locate the necessary funds, which are allocated by the Council to the institutions best able to conduct the investigation. At this point, ARDAMA also takes the plan to interested government agencies for matching funds.

Carnes said this is actually quite a unique approach—generating funding from industry before seeking federal resources.

In fact, ARDAMA’s approach is intended to provide a number of advantages for industrial participants, according to Carnes. These include: having access to a multidisciplinary solution; financial support of only a solution to a specific problem; no facilities support; and completion of the work by accomplished, creative, and cost-effective graduate students. Government agencies working with ARDAMA are also assured of supporting a project with predetermined industrial interest.

CNDE is currently involved in a project to develop fatigue and inspection criteria for steel catenary (chain) risers, which connect pipelines on the ocean floor to offshore oil and gas production facilities. These risers are susceptible to fatigue at weld sites due to facility motion, as well as wave and current action. Developing an industry-wide fatigue and defect acceptance criterion for these welds is the focus of this project. Scientists at CNDE will assess the reliability of ultrasonics for inspecting these welds. It will also define the steps needed to refine and verify analytical models for evaluating the reliability of the inspection of welds made by state-of-the-art welding methods.

Bruce Thompson, CNDE director, said the project is just one example of the way in which the goals of ARDAMA and CNDE complement each other. “CNDE wants to drive the continued emergence of NDE as a full-fledged engineering discipline focused on enhancing product reliability and integrated throughout the product life cycle. This project allows us to do just that. By working in cooperation with the experts in complementary disciplines from the other universities, we are also able to contribute to the solution of a problem in an important engineering system.”

–Anita Rollins

Advances Made in Modeling Ultrasonic Crack Tip Diffraction

Determining the ultrasonic detectability of unfavorably-oriented cracks is receiving renewed attention in CNDE research. This effort is representative of the center's goal to move measurement simulation to the next level in real-world applicability. The work is being pursued by researcher Ron Roberts with funding from the Design for Inspectability program of the National Institute of Standards and Technology and the Federal Aviation Administration's Engine Titanium Consortium.

A defect such as a crack is favorably oriented when "specular" reflections can be received. Specular reflection refers to wave energy that is reflected like light off a mirror, as if the reflection were emerging from a virtual source behind the reflecting surface. For example, a penny-shaped crack is favorably oriented in a pulse-echo inspection when the incident pulse hits the crack face perpendicular to the direction of wave propagation, thereby reflecting a large signal back to the transducer. In such circumstances, the experiment can be modeled using a simple approach referred to as the Kirchhoff, or physical optics, approximation.

Under this approximation, the vibration of crack surface is assumed locally to be the same as if the incident pulse had encountered an infinitely-wide planar surface. Kirchhoff-based models have proven effective for many important problems, including the detection of favorably-oriented penny-shaped cracks and flat-bottomed holes. In fact, situations when the Kirchhoff approximation is inadequate have been more the exception than the rule in applications addressed to date. For this reason, CNDE's simulation software, such as UTSIM, largely utilizes Kirchhoff-based models.

However, unfavorably-oriented flaws in some cases may be more probable than a favorable orientation. This may be due to alignment with a stress field. An example of an unfavorable orientation is a penny-shaped crack with its face parallel to the direction of incident pulse propagation. The signal received is primarily due to signal scattering by the crack edge rather than the face of the crack. In this case, the Kirchhoff approximation is no longer appropriate, and an alternative approach must be employed to construct a solution.

Little attention, to date, has been paid at CNDE to unfavorable crack orientation, which is the result of priorities in the development of CNDE's simulation capability. Simulation applications have placed more emphasis on issues such as component geometry and its effect on beam focusing using, for example, a favorably-oriented flat bottom hole. Applications occasionally arise that are inappropriate for Kirchhoff-based scattering models, but these situations are addressed on a case-by-case basis using one-time adaptations of more sophisticated modeling tools. Roberts is now developing these more sophisticated models into a generally-applicable simulation tool for routinely handling unfavorably-oriented cracks.

According to Roberts, two strategies must be selected when treating unfavorably-oriented cracks depending on the regime: a low-to-intermediate frequency regime in which the ultrasonic wavelength is comparable to or larger than the length of the crack, and a high-frequency regime in which the wavelength is significantly smaller than the crack.

In the low-to-intermediate frequency regime, Roberts relies on a computational method known as the Boundary Element Method (BEM) to compute scattering. For rigorous study, BEM analysis can be applied on a case-by-case basis to a specific crack geometry. However, since low-to-intermediate frequency scattering is less sensitive to the fine details of a crack's geometry, considering an equivalent flaw of a canonical shape, such as an ellipse of varying aspect ratio, can be used. Results for a variety of such canonical shapes have been archived in a BEM scattering matrix "library" over the past decade by Roberts and others and are readily available.

In the high-frequency regime, BEM analysis becomes time consuming and numerically unstable, so other approaches must be employed. For large cracks with a simple geometry, a theory known as the Geometrical Theory of Diffraction (GTD) is applicable. In this theory, the local plane surface assumption of Kirchhoff theory is replaced by the assumption of a semi-infinite planar crack with a straight edge that locally coincides with the true crack edge. The analytical solution to diffraction by a semi-infinite straight-edged slit is a formidable mathematical problem, according to Roberts, and its solution is relatively new in the time-frame of applied mathematics. A research group at Northwestern University led by Professor J. D. Achenbach, solved the problem around 1980. "I joined this group as a new graduate student at the time this work was going to publication. It has been rewarding to re-visit this work 15 years later," Roberts said.

Recent work uses GTD theory in an algorithm that can be applied to large cracks of arbitrary geometry. "A need existed in our simulation software for an algorithm that could supplement existing Kirchhoff-based computational modules. GTD is configured to be employed when Kirchhoff results are suspect due to an unfavorable crack orientation. The module supplies corrections to the crack tip diffraction signals predicted by Kirchhoff theory," said Roberts.

Results shown in fig.1a demonstrate the accuracy of Kirchhoff theory as a function of crack orientation. A plane compressional wave is assumed incident on a straight-edged, semi-infinite slit as depicted in fig. 1a. A point receiver is located a distance "r" from the crack edge, where $k_T r = 30$, which detects the scattered compressional wavefield. Here $k_T = 2\pi / \lambda_T$ where λ_T is the wavelength of a

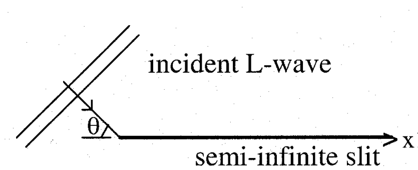


Fig. 1a

TIP DIFFRACTION*/continued on next page*

shearwave. This is a problem for which Achenbach's analytical solution provides an exact answer, and hence provides a good measure of Kirchhoff theory validity. The received scattered field for a plane wave incident at 80 degrees is plotted in fig.1b as calculated by both the exact analytical solution (—) and by the approximate Kirchhoff theory (----). It is seen that Kirchhoff theory is in generally good agreement with the exact theory. Agreement is particularly good at scattered angles in the vicinity of 100 degrees corresponding to a favorable crack orientation. Errors are larger in the 0 to 80 degree range of observation, reaching a maximum of 19 percent at 10 degrees observation. This range of observation represents an unfavorable crack orientation for Kirchhoff theory.

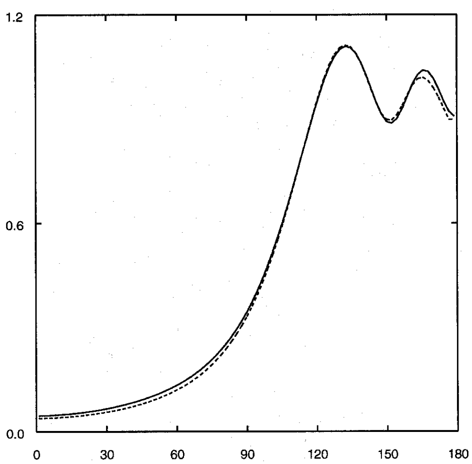


Fig. 1b

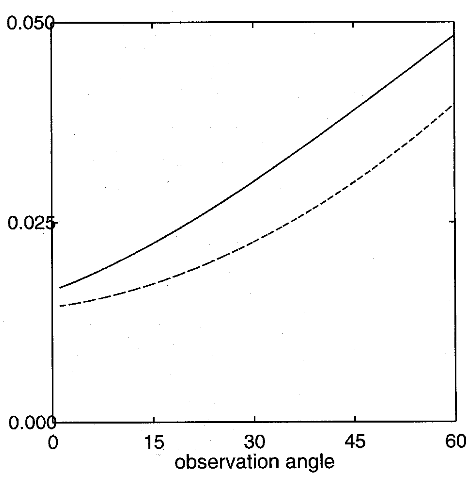


Fig. 1c

Fig. 1c plots similar results for a 30 degree incidence angle. Data is plotted for angles near the backscatter direction, ranging from 0 to 60 degrees. In this case, the error in the Kirchhoff prediction (----) approaches 30 percent at 30 degrees observation. It is mentioned that errors approach 100 percent at 0 degree incidence, for which Kirchhoff theory predicts no scattered signal. It is this type of error that the supplemental GTD computational module is intended to correct.

The modeling of scattering by a curved crack edge seeks to use the straight-edged crack solution in an appropriate approximate fashion. GTD theory, as previously implemented by Achenbach and others, seeks to identify points on the crack edge that significantly contribute to the received signal. These strongly contributing points are known as "points of stationary phase," referring to special local mathematical properties of the wave field, or as "flash points."

Flash points are easily demonstrated by viewing a wedding band on a table top with a single light bulb located behind you: the two bright spots seen on the top edge of the band are the flash points. At each flash point, GTD theory in essence replaces the curved crack edge with a tangent semi-infinite straight-edged crack, along with appropriate factors to account for the actual edge curvature. GTD theory identifies all flash points on the edge of a crack, analyzes the contribution of each flash point to the received signal, and sums these contributions to produce the final result.

Application of GTD flash point analysis is straightforward for simple crack edge geometry, such as a circle or an ellipse. Problems can arise, however, when the crack edge geometry displays certain seemingly benign characteristics. For example, two hypothetical crack edges are

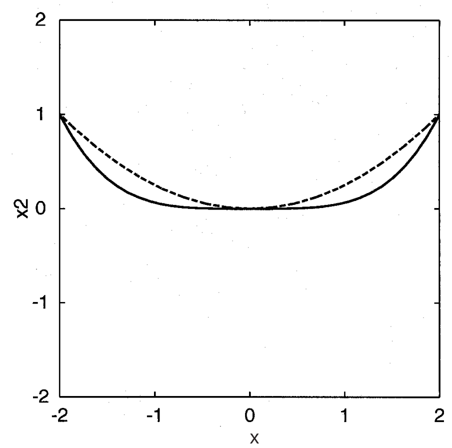


Fig. 2

plotted in fig.2, generated by the equation $y = a\,x^2 / 4 + (1-a)\,x^4 / 16$, where the parameter "a" controls the shape of the crack edge. Crack edge geometry is compared for a=1 (----) and a=0 (–). Consider the case of an incident ultrasonic pulse propagating in the positive "y" (upward) direction. In the high-frequency regime of interest, leading order GTD flash point theory has been shown to accurately predict responses in the case of a=1, whereas in the case of a=0 the theory fails completely, predicting an infinite response. Technically, this failure is due to an infinite radius of curvature at the bottom of the a=0 curve, leading to a singular amplitude in the underlying stationary phase asymptotic analysis. Failure at such seemingly insignificant points presents a serious problem when attempting to implement GTD in a tool for application to arbitrary crack edge geometry. While approaches for analytic treatment of such failures are known, practical implementation of these approaches leads to an unwieldy, ad-hoc algorithm prone to unexpected behaviors.

To develop an approach that overcomes the unwieldy-ness of prior GTD applications, Roberts developed an algorithm that replaces local flash point analysis with an explicit numerical integration around the crack perimeter. In cases studied thus far, his new algorithm functions robustly, giving excellent agreement with GTD flash point analysis in cases where the analysis is known to be

TIP DIFFRACTION*/continued on page 15*

Making X-rays Usable for Layer-Specific Defect Detection

Traditional X-rays are extremely functional when the goal is to determine information about the complete object being analyzed. However, isolating information from only one of several layers, such as those in circuit boards or on aircraft skin, presents a challenge.

Using laminography, a method that visualizes a plane within a three-dimensional object based on multiple X-ray images, information from only one layer can be obtained. However, separating the desired data from unwanted artifacts, or images from other planes, is still difficult. CNDE scientist John Basart, and graduate assistants Han-Chi Hsieh and Sobia Hayee, are looking at ways to make X-ray layer imaging a realistic option for defect detection.

With funding from NASA Langley Research Center, the team is developing a software program that can accurately identify background information and eliminate it from the final laminographic image. The process begins with making conventional radiographs with various relative positions between the sample, the X-ray source, and the detector. In the initial experiment, two metallic grids attached to a foam core constituted the object to be scanned.

The system used for evaluation involves a scanning X-ray source and eight detectors placed at different angles above the object. Higher contrast images and a better signal-to-noise ratio are obtained using this method than when using a single detector. Fig. 1 shows one of the raw images obtained. However, despite these improvements, the raw radiographs still do not have adequate signal-to-noise ratio. It is necessary to clean up this noise in the radiographs before using the edge-detection and feature-extraction processes that are an integral part of laminography.

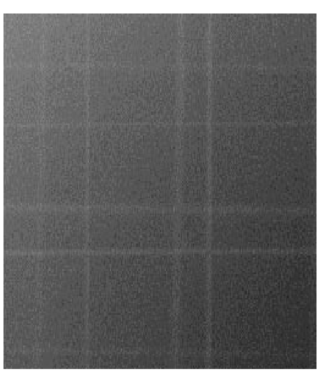


Fig. 1

As a result, a pre-processing stage is required to determine the relative positions of the source, object, and detectors. With stationary detectors and X-ray sources, the acquired relative positions can be determined and used repeatedly. To determine the relative positions, two features from two different focal planes are identified in each radiograph and their relative positions are recorded. A straight line can then be drawn using these two features, and a reference point can be generated from each line for every radiograph. By aligning these reference points, a laminograph can be made for the focal plane corresponding to the reference points.

However due to this alignment, or averaging, process, relatively strong features at another plane may still be visible after the laminographic process, and the presence of these artifacts may cause incorrect human interpretation. To successfully remove the artifacts depends on being able to describe features of the various planes. So before the laminograph is made, the aligned radiographs are processed by a low-pass filter to blur the image and reduce noise. This noise reduction is not easily seen when viewing the radiograph, but it is obvious when looking at the one-dimensional plots presented in fig. 2. The plot of the raw radiograph in the top image is much noisier than the image that has been subjected to a low-pass filter (bottom image). This process is accomplished via a computer program in the frequency domain, and the resulting image is then converted back to the spatial domain. Because this blurring can effect the edge of a desired feature, this activity must be closely monitored to avoid misclassification.

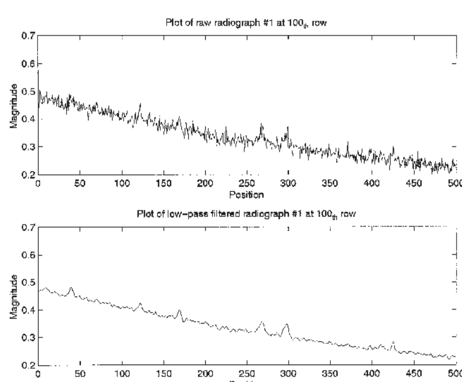


Fig. 2

After features of the focal plane of choice are acquired, a binary feature is used to reduce artifacts. The slope of the filtered radiographs is calculated and the gray-scale image converted to a binary image using a variable threshold method. The threshold value of a given pixel is determined by examining the global mean and local variance. By using these threshold values, a binary image can be obtained that describes the boundaries of all features in each radiograph (see fig. 3). Although the binary edge images have much misclassified information due to random noise, these errors are taken care of at the next step, which is feature extraction.

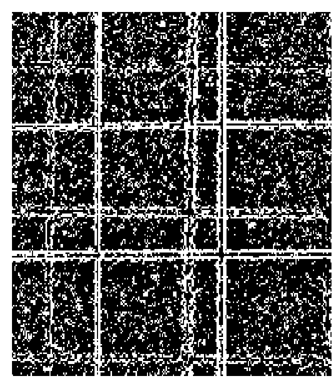


Fig. 3

Laminography depends on identifying features that agree with one another in position, and the team found early on that comparing just three or four edge images

X-RAY*/continued on page 11*

Liljegren Returns

The popping and exploding that Jim Liljegren heard on July 4, 1998, didn't come from fireworks.

It came from arctic ice being crushed beneath the hull of an icebreaker that was carrying Liljegren toward the solid footing of the North American mainland for the first time in eight weeks — two weeks past his scheduled June 23 departure date.

The ice pack surrounding the ship where he had been stationed was cracking and melting, making it impossible for the scheduled plane to land safely. He was forced to wait until a second icebreaker, the *Polar Sea*, could pick him up along with the 13 scientists and 18 crewmen due to leave with him. "It was hard not knowing when we would be able to leave," he says. "But it was wonderful to see all of the things you'd read about or modeled actually occurring. It was fantastic."

Liljegren, a CNDE and Ames Laboratory researcher, was one of several scientists from throughout the world who volunteered for a six-week shift aboard the *Des Groseilliers*, a Canadian icebreaker intentionally frozen into the arctic ice pack for 13 months to study polar climate conditions. The *Des Groseilliers'* mission is at the heart of a five-year climate study funded by the National Science Foundation (NSF) and the Office of Naval Research. Data collected during the mission will be used to improve the accuracy of climate models in order to make better predictions of how global warming might affect the Earth's climate.

Polar data is crucial; most of the sun's heat strikes the Earth at the equator and is then carried toward the poles where it dissipates back into space. Unless the models contain accurate information on the interactions of water, air, and ice at the poles, their predictions will be faulty. Prior to the *Des Groseilliers* mission, it had been more than 100 years since the last long-term study of the arctic climate.

Liljegren's involvement with climate research began seven years ago when the U.S. Department of Energy (DOE) was looking for volunteers for its Atmospheric Radiation Measurement (ARM) program, which studies the role played by clouds in maintaining a balance between incoming heat from the sun and outgoing heat radiating from Earth. Liljegren, then a mechanical engineer at Pacific Northwest National Laboratory in eastern Washington, was intrigued.

He began working with ARM's microwave radiometers, sensitive radio receivers tuned to the frequencies at which water vapor and liquid water emit tiny amounts of energy. The strength of the signals indicates the amount of water vapor in the atmosphere and liquid water in clouds. Clouds play a critical role in climate models and in the ongoing debate over global warming. Liljegren notes that although carbon dioxide is the trigger for the so-called "greenhouse effect," water vapor is the controlling factor in the phenomenon.

"Doubling the carbon dioxide concentrations produces only a slight warming in the Earth's atmosphere, but because most of the Earth is covered with water, this warming will cause more water to evaporate into the air," he says. "Water vapor blocks heat from escaping to space, so this causes additional warming, which causes additional evaporation, and so on.

"But sooner or later, water vapor condenses into clouds, which are made of liquid-water droplets or ice crystals or both. Liquid-water clouds are very effective at keeping heat from escaping Earth's surface, but they also tend to cool the planet."

For now, scientists don't know whether an increased cloud cover would enable the Earth's climate to balance itself or cause atmospheric temperatures to escalate. To gather the needed cloud data from a variety of longitudes, ARM has radiometers at three strategic sites: the Great Plains in Kansas and Oklahoma; the equatorial region near New Guinea; and at Barrow, Alaska.

When the NSF began planning an in-depth study of the arctic climate, they wanted ARM to participate. The study is known as the Surface Heat Budget of the Arctic Ocean, or SHEBA. As part of the overall five-year SHEBA project, one year would be spent on the ice pack gathering polar climate data, and the next four years would be spent analyzing the data and applying the findings to climate models.

Among the instruments ARM sent to the SHEBA site was a microwave radiometer, which made Liljegren eligible for a six-week shift. Even though cold temperatures aren't his favorite ("I put on a sweater when the air conditioner is on," he says with a laugh), he eagerly signed on.

He wanted a shift in the late spring/early summer when the sun was up continuously so that he could see the clouds that the radiometer was measuring. Fortunately for him, that also meant relatively warmer temperatures and a better chance of spotting polar bears that might be lurking near the ship.

On May 11, he traveled to Barrow, located on the northernmost tip of Alaska. From there, he boarded a Twin Otter plane along with a fresh rotation of scientists and crewmen and a load of supplies. The plane flew to the SHEBA site every three weeks for personnel exchanges and supply drops, and was the sole source of transportation between the ice camp and the mainland.

During the two-hour plane flight, Liljegren was struck by the vastness of the ice pack. "You get this sense of smallness because the ice seems to go on forever," he says. "You realize how very hostile the environment is."

LILJEGREN*/continued on next page*

LILJEGREN/*continued from previous page*

Life in the Arctic took some getting used to. Because the sun never set and because there was so much to learn at first, Liljegren sometimes found himself staying up for 20–22 hours straight. He gradually developed a routine so that he'd know when to sleep. Each day, he would check the data recorded during the night by the various ARM instruments and then physically inspect each instrument to clear moisture from the lenses, re-level the stands that shifted in the melting ice, and make sure they were positioned properly to track the sun. He also helped other SHEBA scientists, sometimes standing guard for polar bears while the researchers checked their instruments on the ice.

Venturing onto the ice was never an easy task. Though temperatures seldom rose above freezing, the wind chill made it as cold as 40 degrees below zero. "You couldn't just take a little walk around the ship," Liljegren recalls. "First, you had to dress appropriately, then you had to check out a radio and a gun, and you had to let the bridge know where you were going and stay in contact with them. At first it seemed a little burdensome, but you had to take reasonable precautions to be safe."

Fog and snow frequently shrouded the ice pack, making it difficult for scientists to see the ship from the instrument sites—and making it difficult to spot an approaching polar bear. There were no polar bear attacks, although seven bears were sighted during a two-week period in late May to early June. Anytime a bear got within 1,000 meters of the ship, crewmen set out on either snowmobiles or the helicopter to chase it away. With the scientific staff spending several hours each day out on the ice, a hungry bear would have posed a real threat. By keeping the bears clear of the SHEBA site, neither the bears nor the group members were harmed.

A different kind of danger gurgled beneath their feet. The ice pack melted more rapidly than expected. Large cracks, known as leads, fractured the ice floe. Near the end of May the crew tied the ship to large mooring posts that had been driven into the outlying ice—a precaution designed to secure the ship and keep the ice from shifting as it started to break up. By mid-June, the ice immediately around the *Des Groseilliers'* hull had melted, allowing the ship to float within the ice pack.

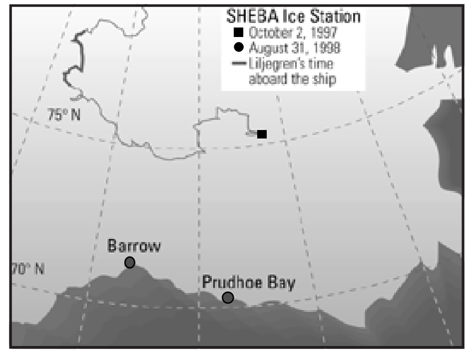
Melt ponds now covered the ice. Ponds with white bottoms indicated that somewhere below the slush was "multi-year ice" that would never completely melt and would support Liljegren's weight as he stepped on it. Darkened melt ponds, however, indicated that the ice was only a few inches thick.

Life inside the ship was less forbidding. His 8-foot by 12-foot cabin was comfortable, and the food was exquisite. The chefs aboard the *Des Groseilliers* whipped up lavish Sunday brunches and hearty meals. The food served its purpose. The grueling work in frigid temperatures was physically exhausting, so the researchers and crew needed to eat well to keep up their energy levels.

The group also made time for fun. Liljegren visited with his counterparts during the ship's bar nights and attended a few theme parties, including a beach party where he showed off a Hawaiian shirt he'd brought along. "Everybody that I worked with was really nice—not just professionally, but personally," he says. "All of the people involved were committed to making it a good experience."

At the weekly SHEBA science meetings, Liljegren listened as his fellow scientists explained their work and how the various elements of the arctic ecosystem worked together. He gained a greater appreciation for the way in which vegetation and animals adapted to the forbidding environment. "The Arctic is prolific in terms of life, although you don't always notice it," he says.

He also managed to find a few moments of solitude. "Every now and then in the evenings, I would go out and just stand on



the bow of the ship and look out because it was so unique to see the sun shining at midnight, reflecting off of the melt ponds. It was amazing, really."

Liljegren says he was pleased with the radiometer's performance at SHEBA and is looking forward to analyzing all of the data. "It looks like it's going to give us a really useful picture of the role of polar clouds and of the radiation transfer through the atmosphere," he says. "Everything worked quite well, so we certainly have the data to move forward."

But even as he moves ahead with his work, he looks back with satisfaction at his time in the Arctic. "It was a very unique experience being in a place where almost no one else has been," Liljegren says. "Working and living there for two months was fantastic."

Current research is funded by the DOE Biological and Environmental Research Office, Environmental Sciences Division, Atmospheric Radiation Measurement Program.

–Susan Dieterle

Call For Papers:

Twenty-sixth Annual Review of Progress in QNDE

Papers are sought for the 26th Annual Review of Progress in Quantitative Nondestructive Evaluation to be held July 25–30, 1999, at the Hotel du Parc, Montreal, Quebec, Canada. The Review will be hosted by CNDE in collaboration with the Industrial Materials Research Institute, National Research Council–Canada. Conference information and forms are available on the following site:

http://www.cnde.iastate.edu/qnde/qnde.html

Verbal and poster sessions will be held that emphasize both the basic science and early engineering developments in quantitative NDE and closely related technologies, such as materials characterization and process control, that utilize quantitative NDE techniques.

Categories of the Review will include advances in:

1. Fundamentals of all QNDE methods (field-flaw interactions and field-property relations, scattering, probability of detection, inverse methods and their application to flaw sizing and property measurement, process models, reliability of measurement and component inspectability)

2. Flaw imaging and reconstruction, image analysis—all techniques

3. Signal processing methods including application of advanced techniques to QNDE

4. Sensors, transducers, and probes for flaw detection, material property measurement, and process control

5. New and emerging QNDE techniques (e.g., NMR)

6. New QNDE instruments and systems

7. QNDE reliability and inspectability

8. Materials characterization (properties, stress, processes, weldments, corrosion, and others)

9. QNDE for advanced materials (composites, electronic materials and devices, ceramics)

10. QNDE of civil structures and materials

11. QNDE in manufacturing, design, and process control

Abstracts:

Prospective authors are requested to prepare a 200-word (or less) abstract. The abstract should be typed and include the title, author(s), and affiliation before the body of the abstract. Abstracts may be submitted by mail, fax, or electronically. Each abstract must have a separate submittal form attached.

Submission information
Electronic: abstracts@cnde.iastate.edu

Fax: 515-294-2367

Mail:
QNDE Programs
Attn.: ABSTRACT ENCLOSED
CNDE; ASC II
Iowa State University
1915 Scholl Road
Ames, IA 50011-3042

Deadline: April 30, 1999

Questions concerning abstracts should be directed to Connie Nessa or Sarah Kallsen at 515-294-9749.

Abstracts will be reviewed by a program committee, and author(s) will be informed by May 21, 1999, of acceptance and whether the presentation will be in a verbal or a poster session for the Review.

Proceedings will be published as a hardbound volume. Details of manuscript preparation will be sent at the time of notification of acceptance of the abstract. Manuscripts are due on September 1, 1999. ■

X-RAY*/continued from page 8*

was sufficient, rather than using all eight. To eliminate misclassification as a result of improper alignment, the team also compared only the most similar images. In order to pick the best images, the correlation coefficient among the binary images is calculated and the image pairs with the highest coefficient are chosen.

The desired features are then obtained by doing a pixel-by-pixel comparison, and a feature exists if its edge is seen at a given pixel in all three binary images. The result of this comparison is the information needed to determine the boundary of features in the focal plane. (See fig. 4)

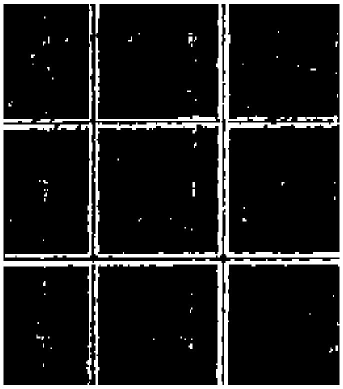


Fig. 4

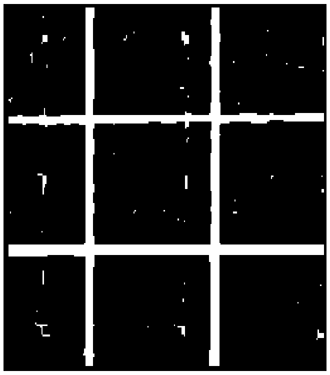


Fig. 5

Mathematical morphology to remove or enhance the information is then used to integrate the various discontinuities and fill in regions between bounded areas.

X-RAY*/continued on next page*

Novel Seminar Looks at NDE and Powder Metallurgy

CNDE staff members assisted in the development, organization, and presentation of a unique seminar that brought together representatives of two industries to exchange information. On July 7–8, 1998, over 40 people attended a seminar in Ames, Iowa, presented under the auspices of the Metal Powder Industries Federation (MPIF).

Organized for MPIF by Dave Utrata of CNDE and Iver Anderson of Ames Laboratory, this seminar is believed to have been unique in that it focused solely on the application of nondestructive methodologies to solve problems germane to the fabrication of powder metal (PM) components. Consisting of several technical presentation sessions as well as a tour of NDE facilities and even a mini trade show, the seminar offered NDE researchers and vendors a chance to discuss specific problems that PM manufacturers encounter. The event also offered both groups an opportunity to learn the vocabulary of each profession while enhancing appreciation for the technical challenges involved in meeting some peculiar inspection needs.

The seminar began with an overview of needs of the PM industry as presented by John Porter of Cincinnati, Inc. Bruce Thompson of CNDE and Bob O'Brien of Hittman Materials & Medical Components provided background on the principles and application of various NDE techniques. This was followed by discussion of the potential and promise of specific inspection methods, including resonant inspection/resonant ultrasonic spectroscopy, ultrasonic velocity measurement, microresistivity testing, various implementations of eddy current testing, and radiographic techniques.

After the overview, other CNDE staff members made presentations. Norio Nakagawa, group leader for eddy current research, discussed the possible applications for pulsed eddy current techniques to PM parts. This talk was highlighted during the later tour with a demonstration by Jay Bieber on hardware developed at CNDE. Simon Huss, a graduate student finishing his work in the radiography group, presented his work on X-ray transmission techniques for density mapping of PM components. He also hosted visitors during the tours by demonstrating equipment in the test bed area at CNDE.

Ongoing work performed by the Iowa Demonstration Laboratory (IDL) involving tests of ferrous and copper PM samples was presented at the seminar in two talks given by Utrata. This work was part of an extensive collaborative effort initiated by Square D Co., a world leader in the manufacturing of electrical systems. The presentations made at the seminar have been posted on the IDL web page, HYPERLINK http://www.cnde.iastate.edu/idl/pm.html. Additional work on this subject was also presented at the 1998 Review of Progress in Quantitative Nondestructive Evaluation. Those proceedings will be published by Plenum in the spring of 1999.

Vendors who participated in the trade show portion of the seminar took full advantage of the facilities at CNDE to set up equipment and provide hands-on demonstrations of their wares on samples supplied by attendees. The list of vendors included: Magnaflux, Dynamic Resonance Systems, i.b.g. NDT Systems, Zetec, and North Star Imaging. Attendees came from throughout the United States and Canada to be part of the event. Arrangements are currently being discussed for a second workshop. ■

***X-RAY**/continued from page 11*

Region-filling is followed by trend removal. Since the intensity of the beam diminishes inversely with the square of the distance between the source and detector, a sloped background exists in each of the radiographs. To compensate for this, the background of each radiograph is removed by fitting a two-dimensional, second order polynomial to the data, and then subtracting the fitted polynomial from the data. This step normalizes the image and is important to the final step: the artifact reduction process. During artifact reduction, features are removed simply by setting their intensities equal to the normalized background. (See fig. 5)

The initial experiment proved the possibility of reducing artifacts successfully, according to Basart. The use of the low-pass filter, as well as the computation time needed to establish variable thresholds and the possibility of using mathematical morphology for edge detection, are among the areas that will be explored in coming months.

"We think this software program has great potential, but we are only in the beginning stages," said Basart. "We will continue to look for ways to move the research forward until we have effective image detection in more complex objects."

–*Anita Rollins*

Web-based NDE/NDT Educational Resources Developed

The concept of students working in teams is now prevalent in elementary and secondary schools, as well as at community colleges and universities. CNDE has also found teaming to be effective in producing educational materials. Through the combined efforts of the interdisciplinary team of Anita Ousley (education), Sam Wormley (electrical engineering), and Brian Larson (materials science and engineering), a set of web-based materials presenting the principles of nondestructive testing and evaluation is being assembled. The goals are two-fold: to foster interest in basic science and mathematics and to promote instruction regarding how fundamental physical principles influence nondestructive evaluation (NDE) results.

These efforts are part of the North Central Collaboration for NDE Education, which began efforts to enhance NDE education in October of 1996 with funding from the National Science Foundation (NSF). Funding has been added to the project from the Iowa Space Grant Consortium. Some of the Collaboration's tasks involve: enhancing nondestructive testing (NDT) education in the two-year programs at community colleges (CC), fostering collaborations between CNDE and the surrounding CCs, and encouraging qualified graduates of CC programs to become engineering students at ISU and advancing NDE-related education and career opportunities. The team developing the educational materials receives input from collaboration members and NDT instructors at Cowley County Community College in Arkansas City, Kansas; Ridgewater College in Hutchinson, Minnesota; Northeast Iowa Community College in Peosta, Iowa; and Southeast Community College in Milford, Nebraska.

The web-based educational materials being developed address two broad audiences. The first audience is late elementary and early middle school youngsters. At this age, students are easily impressed with ideas that can eventually lead to career choices. The goal is to foster interest in basic science and mathematics and to play on the student's natural curiosity asking questions like, "Do you ever wonder why a paper clip is attracted to a magnet? Do you ever wonder what a magnet is?"

Before actual development began, the collaboration members attended workshops provided by Professor E. Ann Thompson and her colleagues at ISU's College of Education. These were designed to help the team better understand how youngsters learn. The approach of tapping natural inquisitiveness and teaching science concepts in an entertaining, interactive way, was emphasized. The collaborators learned that they would need to lead the students through a simple nondestructive testing experiment that relates the science of testing to real things in their lives—things like pop cans and CDs, familiar products of science and technology. It is essential to get students interested in science and engineering at an early stage if they are to become NDT technicians or engineers with NDE training. Even if students don't enter the NDT/NDE field, an increased awareness of the benefits of science and technology may encourage pursuit of other technical careers or contribute to students becoming technically literate members of the electorate.

For the K-12 audience, five areas are planned: capillary action, electricity, magnetism, sound, and X-rays. Each of these represents a fundamental phenomenon whose importance can be illustrated by NDE applications. As of this writing, the magnetism section is completed with much of the section on sound in the stages of applet development. To view the work on-line use: http://www.cnde.iastate.edu/ncce/Intro_K12.html.

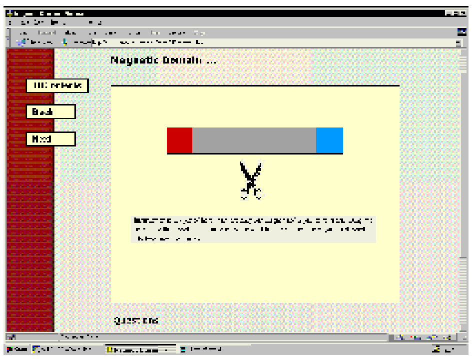


Fig. 1

Fig. 1 shows a Shockwave applet that allows the viewer to cut a magnet into two pieces demonstrating that each piece becomes a new magnet with both a north and south pole. The magnetism section makes use of more than a dozen such applets culminating in a magnetic particle inspection that the viewer performs. There is a discussion section following each experiment done with the Shockwave applets. In addition to interactive applets, there are film clips and talking, animated characters that actually read text in an engaging fashion.

The second audience for the web-based educational material is post-secondary school students. The purpose of the advanced NDE/NDT internet offering being developed is to serve as complementary resource materials for both NDT courses taught at technical schools and CCs and NDE courses offered at universities. The web pages incorporate user-interactive Java applets to engage the students in active learning. The pages are designed to aid in conceptual learning, to reinforce materials provided at the schools, and to serve as working tools to aid students, working technicians, and engineers.

Java applets in six nondestructive technology areas are planned: liquid penetrants, eddy current, magnetic particles, ultrasonics, radiography, and visual inspection. The ultrasonics section has been completed, with work currently in progress on the radiography and eddy current sections. Because of the diverse backgrounds of the students, these web pages attempt to start with very basic information leading up to more advanced material within the pages themselves. The organization of material closely follows areas for level I, II, and III technicians outlined in a Recommended Practice No.

WEB*/continued on page 15*

NDE Engineering Information Day Held

Again this year, community college students converged on Ames, Iowa, to learn about the nondestructive evaluation-related educational opportunities at Iowa State University (ISU). Over fifty students participated in "NDE Engineering Information Day '98." This was the third such event sponsored by the National Science Foundation and organized by the North Central Collaboration for Education in NDE (NCCE). The Collaboration teams ISU with Cowley County Community College in Arkansas City, Kansas; Northeast Iowa Community College in Peosta, Iowa; Ridgewater College in Hutchinson, Minnesota and Southeast Community College in Milford, Nebraska. The goal of the collaboration is to improve NDE education and improve articulation between two-year and four-year NDE programs.

The student participants were all currently working to complete two-year nondestructive testing technician training programs at their community colleges and attended the event to explore the possibilities for continuing their education by completing a four-year degree. During the one-day program, speakers provided information about the various engineering degrees available at ISU and the NDE minor in engineering. The minor allows students to obtain an engineering degree and remain focused on the field of NDE. Also discussed were scholarship and internship opportunities and transfer issues.

In addition, the students also had the opportunity to hear about NDE applications in three different industries. The timing of this year's event (the day preceding the fall Industrial/University meeting) made it possible for three of CNDE's industrial sponsors to address the group. Chuck Anderson from Caterpillar, Kevin Smith from Pratt & Whitney, and Robin Clark from Sperry Rail Service provided presentations on the need for and use of NDE in their organizations.

Rick Lopez

"The industrial talks were excellent and, along with the tour of CNDE, were definitely highlights of the day," commented Bruce Crouse, NDT Instructor at Cowley County Community College. "The students really appreciate the insight that the industrial speakers provide about the career fields available to them."

Brian Larson, program manager for the collaboration, said that the objective of the event was to give the students a look at the NDE program at ISU and let them know they have an option to further their education beyond the two-year degree.

"Our intent is not to convince all the students that they must have an engineering degree," said Larson. "Rather, we try very hard to communicate to the students that they have already made good career choices by getting a two-year degree in NDT and that a four-year degree simply expands their career opportunities. We hope that all of the students ended the day feeling positive about their decision to pursue a career in the field of NDE."

Many of the students in the two-year programs have strong academic backgrounds and are definitely capable of obtaining an engineering degree, according to Larson. "Rick Lopez is a great example of how well these transfer students can do in engineering," Larson said. Lopez completed the NDT program at Northeast Iowa Community College before transferring to ISU. He is an NCCE scholarship recipient who found himself on the dean's list several semesters. He graduated in December with a degree in metallurgical engineering. Larson said Lopez will not have trouble finding a job after graduation.

"His strong NDE background, work experience at CNDE, summer internship at Boeing, and engineering degree should make Rick a very attractive candidate for employment," added Larson.

Lopez reports that the transition from community college to the university was not always easy and the first few semesters at ISU were tough. For instance, he had to sacrifice a few summers to take courses to catch up on the math and science requirements he could not get at the community college. But Lopez is pleased with his decision.

"Although getting my engineering degree did require some sacrifice, the overall experience has been very positive and I am glad I made the decision to continue my education," said Lopez. ■

WEB*/continued from page 13*

SNT-TC-1A provided by the American Society for Nondestructive Testing, Inc.

Java applets are incorporated in some pages to help visualize a concept and often serve as a working calculator. The Java applet shown in fig. 2, demonstrates Snell's Law. This is an example of more than a dozen applets incorporated into the ultrasonics pages. To view the work on-line use: http://www.cnde.iastate.edu/ncce/Intro_CC.html. The viewer is able to select material properties via pull-down menus, grab incident or refracted rays with the mouse, and edit numerical fields.

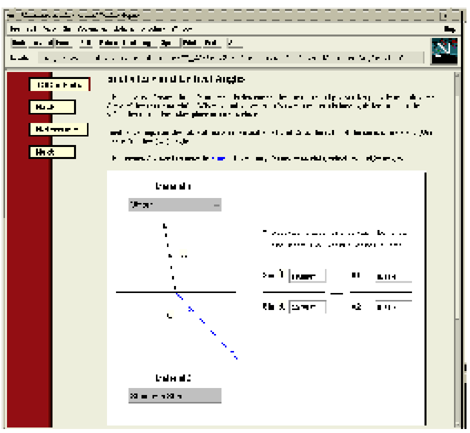


Fig. 2

The three team members are able to bring different levels of expertise, experience, and perspective to the effort. The team believes that, when completed, the applets will serve a broad audience of students learning about NDT/NDE and the basic physical principles behind those inspections. Comments and feedback from readers who have reviewed the applets noted above are strongly encouraged.

–Sam Wormley

TIP DIFFRACTION*/continued from page 7*

valid, while displaying no anomalous behaviors at the previously identified problem points.

As an example, fig. 3 compares the scattered signal strength computed using GTD flash point analysis and Roberts' new algorithm, for incidence on the crack edge geometry referred to in fig.2. The result simulates a 5 MHz, 0.5 in. diameter transducer used in a pulse-echo mode. The transducer's radiation and reception characteristics are modeled by a gaussian beam with 1/e width equal to 10 wavelengths in steel. A unit beam radius is assumed with respect to the coordinates of fig.2. Incidence is oriented parallel to the y-axis in the +y direction. The strength of the 5MHz signal component is plotted in fig. 3 as a function of the crack edge geometry parameter "a." It is seen that for the parabolic crack edge geometry of fig. 2 (a=1), the flash point result (s.p.----) and explicit integral evaluation (exact—) are equal. As parameter "a" approaches zero, the results diverge, with the flash point evaluation approaching an infinite value. More extensive results of preliminary algorithm tests were presented at this past summer's QNDE conference at Snowbird, and will be included in the upcoming conference proceedings.

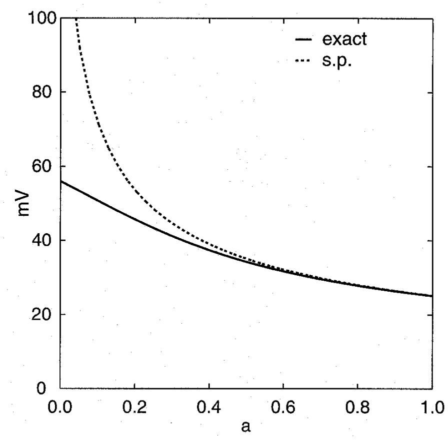


Fig. 3

The current aim of Roberts' work is to extend GTD applicability to large cracks having a more irregular edge geometry. "The new algorithmic implementation of GTD has been shown to be both accurate and robust when the crack edge is arbitrary but smooth, with local radii of curvature sufficiently larger than the wavelength," said Roberts. "The challenge lies in applying the theory when the overall size of the crack is large, but the crack edge geometry has wiggles that are comparable in dimension to the wavelength. I have ideas on how to approach the problem and have implemented these ideas in computational models. The questions currently being examined are: are the results being generated by these models valid, and of course, what to do if they are not?"

Roberts said there is no shortage of ideas, only time to examine them. ■

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We wish to acknowledge with thanks the following agencies and industrial sponsors who have helped to develop the Center through their financial support and technical interests. We hope this newsletter contributes to achieving a common goal–the continued development of both technology and people for NDE as an engineering discipline.

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