



in Quantitative Nondestructive Evaluation Review of Progress in Quantitative Nondestructive Evaluation, Volume 27 9th Annual Review of Progress in Quantitative Nondestructive Evaluation Review of Progress in Quantitative Nondestructive Evaluation Review of Progress in Quantitative Nondestructive Evaluation Review of Progress in Quantitative Nondestructive Evaluation Review of Progress in Quantitative Nondestructive Evaluation Review of Progress in Quantitative Nondestructive Evaluation Review of Progress in Quantitative Nondestructive Evaluation Review of Progress in Quantitative Nondestructive Evaluation, Volume 20 Review of Progress in Quantitative Nondestructive Evaluation, Volume 22

This volume (Parts A and B) contains edited papers presented at the annual Review of Progress in Quantitative Nondestructive Evaluation held at the Fort Magruder Inn, Williamsburg, Virginia, June 23-28, 1985. The Review was organized and sponsored by the Center for NDE at Iowa State University and the Ames Laboratory of the U.S. Department of Energy, in cooperation with the Office of Basic Energy Sciences, USDOE, and the Materials Laboratory at Wright-Patterson Air Force Base. In addition, the NASA-Langley Research Center and the College of William and Mary provided valuable assistance with local arrangements. Approximately 340 attendees, representing various government agencies, industry, and universities, participated in the technical presentations, poster sessions, and discussions. The interchange of technical information in NDE research and engineering represented by this Review is certainly one of the most comprehensive in the field. In order to present the reader with a more useful document, we have chosen to organize the symposium papers in these Proceedings by subject rather than by the order of presentation at the Review. This arrangement has been realized by selecting topical subject headings many are new or revised for this year -- under which the large majority of papers would reasonably fall. These categories cover a broad spectrum of research in NDE and encompass activities from fundamental work to early engineering applications. The following paragraphs capsulize some of the research presented in these Proceedings. Perhaps the largest symposium held annually in the area of quantitative nondestructive evaluation is the one which resulted in this book. The 1981 Review of Progress in Quantitative Nondestructive Evaluation (NDE) was held August 2-7 at the University of Colorado in Boulder. While the review was sponsored by the Materials Laboratory of the Air Force Wright Aeronautical Laboratories and the Defense Advanced Research Projects Agency as part of their sponsored research conducted through the Ames Laboratory of the U.S. Department of Energy, nearly 300 attendees, representing other government agencies and the industrial and university communities as well, participated in the technical presentations, poster sessions and discussions. The program emphasized various areas of interest in quantitative NDE, including topics

related to the development of quantitative ultrasonic and eddy current techniques, other emerging techniques, considerations of improvements needed in the probability of flaw detection, and engineering applications which follow from technology transfer of research results. An example of this transfer is the utilization of the Born inversion algorithm for flaw sizing. The keynote address, "NDE--A Key to Enhanced Productivity," was delivered by Dr. Norman Tallan, Chief Scientist at the Air Force Materials Laboratory. Dr. Tallan's presentation concerned the importance and potential pay-off of moving the NDE inspection procedure forward to provide in-process inspection and control for manufacturing. This step requires the utilization of concepts and research pursued in quantitative NDE activities and the initiation of other key steps. In the current volume, consisting of Parts A and B, edited versions of most of the papers presented at the annual Review of Progress in Quantitative Nondestructive Evaluation held at Bowdoin College, Brunswick, Maine on July 28-August 2, 1991 have been collected. The Review was organized by the Center for NDE at Iowa State University and the Ames Laboratory of the USDOE in cooperation with a number of organizations including the Air Force Materials Directorate, Wright Laboratory, Wright Patterson Air Force Base, the American Society for Nondestructive Testing, the Center for NDE at Johns Hopkins University, Department of Energy, Federal Aviation Administration, National Institute of Standards and Technology, National Science Foundation Industry/University Cooperative Research Centers, and the Office of Naval Research. The 1991 Review of Progress in QNDE was attended by approximately 450 participants from the US and many foreign countries who presented over 360 papers. Divided into 36 sessions, with as many as four sessions running concurrently, the meeting covered all phases of NDE development from basic research to engineering applications and all methods of inspection science from acoustics to x-rays. Over the past ten years, the participants of the Review have seen it grow into one of the largest and most significant gatherings of NDE researchers and engineers anywhere in the world. By sharing their work at this conference, they deserve much credit for its success. This series provides a comprehensive review of the latest research results in quantitative nondestructive evaluation (NDE). Part A of Volume 21 details the development of nondestructive evaluation techniques. Part B addresses advances in materials characterization, new applications, and reliability. Annotation Provides a comprehensive review of the latest research results in quantitative nondestructive evaluation (NDE). Leading investigators working in government agencies, major industries, and universities present a broad spectrum of work extending from basic research to early engineering applications. This volume (Parts A and B) contains the edited papers presented at the annual Review of Progress in Quantitative Nondestructive Evaluation held at the University of California - San Diego, La Jolla, CA, on August 1-5, 1988. The Review was organized by the Center for NDE at Iowa State

University and the Ames Laboratory of the U. S. Department of Energy in cooperation with the Air Force Materials Laboratory, the Office of Basic Energy Sciences, USDOE, the Office of Naval Research, the NASA-Langley Research Center, and The Metallurgical Society (TMS). With a total of over 450 participants from the US and nine foreign countries who presented a record 325 papers, this conference has grown into the largest, most significant gathering of NDE researchers and engineers anywhere in the West. The meeting was divided into 36 sessions with as many as four sessions running concurrently. All stages of NDE development from basic research investigations to early engineering applications and all methods of inspection science from ultrasonics to x-ray tomography were covered. Following a pattern now familiar to regular attendees of the Review and readers of the Proceedings, the editors have organized the papers in the Proceedings according to topical subject headings rather than the original order of presentation. This rearrangement yields a more user friendly reference work. Part A of the Proceedings treats NDE technique development whereas Part B is organized around the theme of materials. This volume (Parts A and B) contains edited papers presented at the annual Review of Progress in Quantitative Nondestructive Evaluation held at the Fort Magruder Inn, Williamsburg, Virginia, June 23-28, 1985. The Review was organized and sponsored by the Center for NDE at Iowa State University and the Ames Laboratory of the U.S. Department of Energy, in cooperation with the Office of Basic Energy Sciences, USDOE, and the Materials Laboratory at Wright-Patterson Air Force Base. In addition, the NASA-Langley Research Center and the College of William and Mary provided valuable assistance with local arrangements. Approximately 340 attendees, representing various government agencies, industry, and universities, participated in the technical presentations, poster sessions, and discussions. The interchange of technical information in NDE research and engineering represented by this Review is certainly one of the most comprehensive in the field. In order to present the reader with a more useful document, we have chosen to organize the symposium papers in these Proceedings by subject rather than by the order of presentation at the Review. This arrangement has been realized by selecting topical subject headings many are new or revised for this year -- under which the large majority of papers would reasonably fall. These categories cover a broad spectrum of research in NDE and encompass activities from fundamental work to early engineering applications. The following paragraphs capsule some of the research presented in these Proceedings. These Proceedings, consisting of Parts A and B, contain the edited versions of most of the papers presented at the annual Review of Progress in Quantitative Nondestructive Evaluation held at the University of Washington, Seattle on July 30 to August 4, 1995. The Review was organized by the Center for NDE at Iowa State University, in cooperation with the Ames Laboratory of the USDOE, the American Society of Nondestructive Testing, the Department of

Energy, the National Institute of Standards and Technology, the Federal Aviation Administration, the National Science Foundation Industry/University Cooperative Research Centers, and the Working Group in Quantitative NDE. This year's Review of Progress in QNDE was attended by approximately 450 participants from the US and many foreign countries who presented over 375 papers. The meeting was divided into 36 sessions with as many as four sessions running concurrently. The Review covered all phases of NDE research and development from fundamental investigations to engineering applications or inspection systems, and it included many important methods of inspection science from acoustics to x-rays. In the last several years, the Review has stabilized at about its current size. Most participants seem to agree it is large enough to permit a full-scale overview of the latest developments but still small enough to retain the collegial atmosphere which has marked the Review since its inception. The Proceedings are structured in a format to reflect the organization of the Review itself, producing a more logical organization for both the meeting and the present volume. In this volume (parts 1 and 2) are contained the edited papers presented at the annual Review of Progress in Quantitative NDE held at the University of California, San Diego, August 1-6, 1982. This Review, possibly the most comprehensive annual symposium emphasizing both ongoing research and applications in quantitative NDE, was sponsored by the Center for Advanced NDE at the Ames Laboratory of the U. S. Department of Energy in cooperation with the Materials Laboratory of the Air Force Wright Aeronautical Laboratories and the Defense Advanced Research Projects Agency. Over 300 attendees representing various government agencies and the industrial and university communities participated in the technical presentations, poster sessions, and discussions. The symposium benefited from the insight of two keynote speakers, Dr. Harris Burte of the Materials Laboratory, AFWAL, and Mr. Ward Rummel of the Martin Marietta Corporation, who presented complementary messages. Dr. Burte pointed out the need to identify "windows" to serve as guides for focusing NDE research. The "window" concept may be thought of as an opportunity for the application of NDE technology to an important problem and, through this application, to identify knowledge gaps which must be filled by generic research. This concept simultaneously provides a mechanism for the solution of a direct application problem and a set of strong guidelines for generic research directions. Mr. Rummel called attention to the value of "lessons learned" from var. This series provides a comprehensive review of the latest research results in quantitative nondestructive evaluation (NDE). Leading investigators working in government agencies, major industries, and universities present a broad spectrum of work extending from basic research to early engineering applications. Papers cover recent developments in essentially all measuring techniques and their applications to flaw detection and structural reliability. These Proceedings, consisting of Parts A and B, contain the edited

versions of most of the papers presented at the annual Review of Progress in Quantitative Nondestructive Evaluation held at Snowmass Village, Colorado, on July 31 to August 4, 1994. The Review was organized by the Center for NDE at Iowa State University, in cooperation with the Ames Laboratory of the US DOE, the Materials Directorate of the Wright Laboratory, Wright-Patterson Air Force Base, the American Society of Nondestructive Testing, the Department of Energy, the National Institute of Standards and Technology, the Federal Aviation Administration, the National Science Foundation Industry/University Cooperative Research Centers, and the Working Group in Quantitative NDE. This year's Review of Progress in QNDE was attended by approximately 450 participants from the U.S. and many foreign countries who presented over 360 papers. The meeting was divided into 36 sessions, with as many as four sessions running concurrently. The Review covered all phases of NDE research and development from fundamental investigations to engineering applications or inspection systems, and it included many important methods of inspection science from acoustics to x-rays. In the last eight to ten years, the Review has stabilized at about its current size, which most participants seem to agree is large enough to permit a full-scale overview of the latest developments, but still small enough to retain the collegial atmosphere which has marked the Review since its inception. These proceedings provide the latest research and development papers in nondestructive evaluation (NDE) and its applications to flaw detection, material properties, NDE, and structural reliability. The papers are prepared by internationally known researchers and are reviewed by qualified scientists. Papers cover recent developments in essentially all measuring techniques (ultrasonics, electromagnetic, x-rays, thermal, acoustic emission, etc.) And their applications to flaw detection and structural reliability. This volume (parts A and B) contains the edited papers presented at the annual Review of Progress in Quantitative NDE held at the University of California, San Diego, July 8-13, 1984. We have chosen to organize the papers by subject, an arrangement that we feel to be more useful for a reference volume than the order of paper presentation at the Review. To do this, topical subject headings have been selected under which the large majority of papers reasonably fall. These categories cover a broad spectrum of research in NDE and encompass activities from fundamental work to early engineering applications. The scope and depth of the Review may be easily assessed by examination of the Table of Contents. The Review was sponsored by the Center for Advanced NDE at the Ames Laboratory of the U.S. Dept. of Energy in cooperation with the Office of Basic Energy Sciences, USDOE, the Materials Laboratory at Wright-Patterson AFB, and the Naval Sea Systems Command. Approximately 300 attendees representing various government agencies, industry, and universities participated in the technical presentations, poster sessions, and discussions. This Review, possibly the most comprehensive annual symposium in NDE, provides a valuable forum for the

timely exchange of technical information. A few highlights of the Review are summarized in the following paragraphs. These Proceedings, consisting of Parts A and B, contain the edited versions of most of the papers presented at the annual Review of Progress in Quantitative Nondestructive Evaluation held at the University of California San Diego, in La Jolla, California on July 19- July 24, 1992. The Review was organized by the Center for NDE at Iowa State University and the Ames Laboratory of the USDOE in cooperation with a number of organizations including the Air Force Wright Laboratory Materials Directorate, the American Society for Nondestructive Testing, the Center for NDE at Johns Hopkins University, the Department of Energy, the Federal Aviation Administration, the National Institute of Standards and Technology, the National Science Foundation Industry/University Cooperative Research Centers, and the Working Group in Quantitative NDE. This year's Review of Progress in QNDE was attended by approximately 475 participants from the U. S. and many foreign countries who presented over 380 papers. With such a large volume of work to review, the meeting was divided into 36 sessions with as many as four sessions running concurrently. The Review covered all phases of NDE research and development from fundamental investigations to engineering applications or inspection systems, and it included all methods of inspection science from acoustics to x-rays. During the last twenty years, the participants of the Review have contributed to its steady growth. Thanks to their efforts, the Review is today one of the largest and most significant gatherings of NDE researchers and engineers anywhere in the world. Proceedings of the Thirteenth Symposium on Quantitative Nondestructive Evaluation held in Brunswick, Maine, August 1-6, 1993 It has been shown both experimentally {2} and theoretically {2,3} that surface skimming SH waves propagating along symmetry axes of the texture have velocities that differ in proportion to the magnitude of any stress that lies along one of the symmetry axes. Specifically, the stress is directly proportional to the relative velocity difference through the equation 
$$v_i - v_k = \frac{2G}{v_k} \epsilon_{ik} \quad (I)$$
 where  $\epsilon_{ik}$  is the stress in the direction  $i$ ,  $G$  is the shear modulus and  $v_k$  is the velocity of an SH wave propagating in the  $i$  direction and polarized in the  $k$  direction. This rather simple relationship is particularly useful because the constant of proportionality involves only the well known shear modulus and the velocity term can be measured directly by observing the transit time shift when a transmitter-receiver pair of SH wave transducers are rotated through 90 degrees on the surface of the part. Experimentally, Equation (I) was tested on the web of railroad rails which had been loaded by a 200,000 pound mechanical testing machine {1}. The method of exciting and detecting the necessary surface skimming SH waves used electromagnetic acoustic transducers (EMATs) that operated through a magnetostrictive mechanism at high magnetic fields {4}. Wave velocities parallel and perpendicular to the axis of the rail on the web differed by

the amount predicted by Equation (I) to an absolute accuracy of 30 percent in the worst case. This volume (Parts A and B) contains the edited papers presented at the annual Review of Progress in Quantitative Nondestructive Evaluation held at the University of California - San Diego, La Jolla, CA, on August 1-5, 1988. The Review was organized by the Center for NDE at Iowa State University and the Ames Laboratory of the U. S. Department of Energy in cooperation with the Air Force Materials Laboratory, the Office of Basic Energy Sciences, USDOE, the Office of Naval Research, the NASA-Langley Research Center, and The Metallurgical Society (TMS). With a total of over 450 participants from the US and nine foreign countries who presented a record 325 papers, this conference has grown into the largest, most significant gathering of NDE researchers and engineers anywhere in the West. The meeting was divided into 36 sessions with as many as four sessions running concurrently. All stages of NDE development from basic research investigations to early engineering applications and all methods of inspection science from ultrasonics to x-ray tomography were covered. Following a pattern now familiar to regular attendees of the Review and readers of the Proceedings, the editors have organized the papers in the Proceedings according to topical subject headings rather than the original order of presentation. This rearrangement yields a more user friendly reference work. Part A of the Proceedings treats NDE technique development whereas Part B is organized around the theme of materials. These Proceedings, consisting of Parts A and B, contain the edited versions of most of the papers presented at the annual Review of Progress in Quantitative Nondestructive Evaluation held at University of San Diego, San Diego, CA, on July 27 to August 1, 1997. The Review was organized by the Center for NDE at Iowa State University, in cooperation with the Ames Laboratory of the USDOE, the American Society of Nondestructive Testing, the National Institute of Standards and Technology, the Federal Aviation Administration, and the National Science Foundation Industry/University Cooperative Research Centers. This year's Review of Progress in QNDE was attended by approximately 370 participants from the US and many foreign countries who presented a total of approximately 350 papers. As usual, the meeting was divided into 36 sessions with four sessions running concurrently. The Review covered all phases of NDE research and development from fundamental investigations to engineering applications and inspection systems, and methods of inspection science from acoustics to x-rays. The Review continues to experience some fluctuations in size, mostly under pressure from a decrease in funding for NDE research at the US Federal level, but increased participation from foreign laboratories has more than made up the difference. The Review is ideally sized to permit a full-scale overview of the latest developments in a collegial atmosphere that most participants favor. The opening plenary session this year concentrated on advances in imaging technologies and methodologies that have been made in



recent years. Dr. K. Papers presented at the 50th annual meeting of the Society for American Archaeology held in Denver in 1985. This Proceedings contains the edited papers presented at the annual Review of Progress in Quantitative NDE held at the University of California, Santa Cruz, Aug. 7-12, 1983. In it, papers have been arranged topically by chapters and subsections rather than by order of presentation at the Review. The editors believe that this format is preferable as a reference volume. Thus, the Proceedings contains nine chapters and subsections which provide broad coverage of topics of current interest in NDE research and development. The Review was sponsored by the Center for Advanced NDE, Ames Laboratory of the U. S. Department of Energy, in cooperation with the Office of Basic Energy Sciences, USDOE, the Defense Advanced Research Projects Agency, the Materials Laboratory of the Air Force Wright Aeronautical Laboratories, and the Naval Sea Systems Command. Approximately 275 attendees representing various government agencies, industry, and academia participated in the technical presentations, poster sessions, and discussions. This Review, possibly the most comprehensive annual symposium in NDE, emphasizes both basic research and early engineering applications; it provides a valuable forum for the transfer of technical information. Paragraphs given below provide a brief summary of the contents of the Proceedings. Chapter 1 consists of four papers that discuss elements of NDE Reliability and contains the keynote paper given by Dr. J. M. Coffey of the NDT Applications Centre, Central Electricity Generating Board, Manchester, England. In his paper, Dr. This volume (Parts A and B) contains the edited papers presented at the annual Review of Progress in Quantitative Nondestructive Evaluation held at the University of California - San Diego, La Jolla, CA, on August 1-5, 1988. The Review was organized by the Center for NDE at Iowa State University and the Ames Laboratory of the U. S. Department of Energy in cooperation with the Air Force Materials Laboratory, the Office of Basic Energy Sciences, USDOE, the Office of Naval Research, the NASA-Langley Research Center, and The Metallurgical Society (TMS). With a total of over 450 participants from the US and nine foreign countries who presented a record 325 papers, this conference has grown into the largest, most significant gathering of NDE researchers and engineers anywhere in the West. The meeting was divided into 36 sessions with as many as four sessions running concurrently. All stages of NDE development from basic research investigations to early engineering applications and all methods of inspection science from ultrasonics to x-ray tomography were covered. Following a pattern now familiar to regular attendees of the Review and readers of the Proceedings, the editors have organized the papers in the Proceedings according to topical subject headings rather than the original order of presentation. This rearrangement yields a more user friendly reference work. Part A of the Proceedings treats NDE technique development whereas Part B is organized around the theme of materials. It has been shown both experimentally

{2} and theoretically {2,3} that surface skimming SH waves propagating along symmetry axes of the texture have velocities that differ in proportion to the magnitude of any stress that lies along one of the symmetry axes. Specifically, the stress is directly proportional to the relative velocity difference through the equation  $\sigma_{ik} = 2G(V_i - V_k)$  (1) where  $\sigma_{ik}$  is the stress in the direction  $i$ ,  $G$  is the shear modulus and  $V_i$  is the velocity of an SH wave propagating in the  $i$  direction and polarized in the  $k$  direction. This rather simple relationship is particularly useful because the constant of proportionality involves only the well known shear modulus and the velocity term can be measured directly by observing the transit time shift when a transmitter-receiver pair of SH wave transducers are rotated through 90 degrees on the surface of the part. Experimentally, Equation (1) was tested on the web of railroad rails which had been loaded by a 200,000 pound mechanical testing machine [1]. The method of exciting and detecting the necessary surface skimming SH waves used electromagnetic acoustic transducers (EMATs) that operated through a magnetostrictive mechanism at high magnetic fields [4]. Wave velocities parallel and perpendicular to the axis of the rail on the web differed by the amount predicted by Equation (1) to an absolute accuracy of 30 percent in the worst case.

[nieuw.judithslagter.nl](http://nieuw.judithslagter.nl)