Review of Progress in QUANTITATIVE NONDESTRUCTIVE EVALUATION

Volume 9A

Review of Progress in QUANTITATIVE NONDESTRUCTIVE EVALUATION

Volume 9A

Edited by
Donald O. Thompson
Center for NDE
Ames Laboratory (USDOE)
and Department of Engineering Science and Mechanics
Iowa State University
Ames, Iowa

and
Dale E. Chimenti
Center for NDE
and Department of Materials Science and Engineering
The Johns Hopkins University
Baltimore, Maryland

PLENUM PRESS • NEW YORK AND LONDON

The Library of Congress has cataloged earlier volumes of this title as follows:

Library of Congress Cataloging in Publication Data

Main entry under title:

Review of progress in quantitative nondestructive evaluation.
"Proceedings of the Eighth Air Force/Defense Advanced Research Projects Agency Symposium on Quantitative Nondestructive Evaluation, held August 2-7, 1981, at the University of Colorado, Boulder"—Vol. 1, verso t.p.

"First half of the proceedings of the ninth review of progress in quantitative nondestructive evaluation, held August 1-6, 1982, at the University of California, San Diego, California"—Vol. 2A, t.p. verso.
"Proceedings of the Tenth Annual Review of Progress in Quantitative Nondestructive Evaluation, held August 7-12, 1983, at the University of California, Santa Cruz, California"—Vol. 3, verso CIP t.p.
Includes bibliographical references and index.
1. Nondestructive testing—Congresses. I. Thompson, Donald O. II. Chimenti, Dale E. III. United States. Air Force. IV. Air Force/Defense Advanced Research Projects Agency Symposium on Quantitative Nondestructive Evaluation (8th: 1981: University of Colorado, Boulder) V. United States. Defense Advanced Research Projects Agency.
TA417.2.R48 1982 620.1'127 82-9140

ISBN 0-306-43535-7

First half of the proceedings of the Sixteenth Annual Review of Progress in Quantitative Nondestructive Evaluation, held July 23-28, 1989, in Brunswick, Maine

A Division of Plenum Publishing Corporation
233 Spring Street, New York, N.Y. 10013

Printed in the United States of America

A Continuation Order Plan is available for this series. A continuation order will bring delivery of each new volume immediately upon publication. Volumes are billed only upon actual shipment. For further information please contact the publisher.

PREFACE

This volume (Parts A and B) contains the edited papers presented at the annual Review of Progress in Quantitative Nondestructive Evaluation held at Bowdoin College, Brunswick, ME on July 24-28, 1989. The Review was organized by the Center for Advanced NDE at 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. The statistics for the 1989 Review of Progress in QNDE include a total of over 460 participants from the U. S. and nine foreign countries who presented some 325 papers. Over the years this conference has grown into one of the largest, most significant gatherings of NDE researchers and engineers in the world. The meeting was divided into 35 sessions, with as many as four sessions running concurrently, and covering all stages of NDE development from basic research investigation to early engineering applications and all methods of inspection science from ultrasonics to x-ray tomography.

The Editors have organized the papers in the Proceedings according to topical subject headings, rather than in the original order of presentation. This rearrangement yields a more user-friendly reference work and follows a pattern now familiar to regular attendees of the Review. Some changes in the headings and their subcategories have been introduced to accommodate dynamic evolution of the field, as we observe it. The topical areas selected represent the major centers of gravity in NDE and reasonably subsume all papers in the Proceedings. In the following paragraphs we offer a brief summary of the research presented in each of these topical areas.

The past dozen years have seen major developments in the field of imagery for NDE. Exploiting the well known recognition powers of the human mind, NDE data presented as images are easier to analyze and lead to more reliable defect discrimination than in other representations. Also, large amounts of data, literally megabytes, can be processed for accept/reject decisions very rapidly when configured in image format. With these developments in mind Professor Glen Wade of the University of California, Santa Barbara, gave the plenary session at the Review's inception a sparkling lecture on all aspects of imaging. Calling his keynote address, "Seeing with Light, Sound, Microwaves, X-rays, Gamma Rays, Etc.", he offered the audience many fascinating examples of each of these imaging modalities. From cave drawings to the latest real-time, three-dimensional computer simulation, Professor Wade documented mankind's urge to abstract his world in pictures and to reach beyond the visible to explore the unknown. Following the keynote address a minisymposium on the tools of image processing investigated some specific operations on image data and how these can improve the extraction of information from images.

Notwithstanding the attraction of new materials and methods in NDE, the fundamentals of the basic techniques continue to provide a rich source of important results. The first chapter contains papers on Elastic Wave Scattering and Flaw Sizing and Elastic Wave Propagation, where emphasis on scattering from cracks, in the one case, and waves in

the presence of material anisotropy, in the other, is evident. Papers on Eddy Currents treat detection, inversion, and multifrequency analysis. The final section in this chapter is devoted to X-radiography.

Newer, innovative methods, which have generally received less attention than the older well established techniques, are collected in Chapter 2. These include X-ray Computed Tomography, now recognized as an important new tool, Laser Ultrasonics, which promises to change preconceptions about ultrasound, and Other New Techniques. This last section includes such novelties as NMR imaging and advanced thermal wave detection schemes.

Chapter 3 collects the work presented on signal and image processing with an emphasis on interpretation for purposes of defect detection and characterization. This chapter contains individual sections on Signal Processing and Neural Networks and Image Processing.

All nondestructive measurements or observations include some kind of sensor to detect the probing field and how this field has been altered by interaction with the object of the inspection. Therefore, sensors play a central role in any inspection. Their importance to NDE has long been recognized, and this year we also present an expanded chapter devoted to Probes, Sensors and Inspectability. Papers on Ultrasonic Transducers, Inductive Probes, and Inspectability constitute the major sections of Chapter 4.

Eventually, the fruits of research projects in NDE should find their way to useful application. Chapter 5, which ends Part A of this volume, records those papers dealing with the integration of NDE technology into instruments or complete inspection systems.

Utilizing a division of topics now familiar to readers of earlier volumes, Part A of the Review treats the subject of technique development, whereas Part B is devoted to the theme of materials. At the head of the book in Chapter 6 are collected papers on Electronic and Ceramic Materials. Very interesting recent work can be found there on nondestructive evaluation of electronic materials and devices, an area of growing involvement for NDE researchers since its introduction to the Review in 1984.

In Chapter 7 we have pulled together three types of materials-related papers, unified by the fact that in each case the materials are tailored to fill a specific function. The chapter is therefore entitled Engineered Materials and comprises contributions on Smart Structures, Adhesive Joints, Metal-to-Metal Joints, Properties of Composites, and Defects in Composites. Long a subject of intense interest in the development of aerospace materials, composites present serious challenges to inspection technology. Their singularly high elastic anisotropy can lead to unusual effects when these materials are subjected to ultrasonic inspection.

Responding to an established trend in NDE, the next chapter collects those papers seeking to provide more generalized inspection information, beyond defect location and size. This year, research work on the characterization of materials represents nearly a quarter of the total included in these Proceedings. Chapter 8 is further subdivided into six sections. These cover contributions on Properties, Nonlinear Acoustics, Deformation and Fracture, Acoustoelasticity, Stress and Texture, Ferrous Materials and Methods, and Civil Materials and Structures. As the national infrastructure increasingly needs repair or replacement, assessing its condition and suitability for service nondestructively grows in importance. The last section of Chapter 8 recognizes this interest.

We close the section of contributed papers with a chapter on Manufacturing and Process Control. As the movement to improve US national competitiveness gains momentum it appears clear that to raise product quality and lower costs, we will need to monitor and control the manufacturing process closely at each stage. Nondestructive evaluation and sensor technology will necessarily play a major role in the development of this capability. These papers are collected in Chapter 9.

The Review concludes with the reappearance of a fixture from many previous Reviews, the Wednesday evening Problem Session. Devoted to a single topic and including a small number of speakers, this session as been used to introduce a variety of issues to Review participants and to solicit their ideas in a brain-storming format. This year Mr. Steve Bobo of the FAA spoke to a standing-room-only crowd on the problems facing airlines with the nondestructive inspection of their fleets of aging aircraft. Some of the difficulties are related to inspection equipment, some to personnel training, and the fewest to the inspection circumstance itself. Mr. Bobo indicated to the audience the complex interplay of the technical, sociological, and political issues that a problem of such high national visibility involves.

As in past years, the organizers of the Review wish to acknowledge the indispensable contributions of several organizations and persons for assistance in the planning and conduct of the Review and in the preparation of these Proceedings. Organizations include the Center for NDE and the Ames Laboratory at Iowa State University and those listed in the first paragraph of the Preface. They are especially indebted to Professor Glen Wade for his memorable keynote lecture and to Dr. W. G. Heller of the Analytical Sciences Corporation (TASC), Professor E. A. Robinson of the University of Tulsa, and Dr. R. J. Wall of the Jet Propulsion Laboratory who delivered the other plenary lectures. A number of people helped to organize specific sessions; this list includes L. Adler (Ohio State University), J. Bussiere (Industrial Materials Research Institute), D. Jiles (Iowa State University), W. Lord (Iowa State University), J. Opsal (Therma-Wave, Inc.), Y. Rajapakse (Office of Naval Research), H. Ringermacher (United Technologies), F. Rizzo (Iowa State University), R. Rogowski (NASA - Langley Research Center), R. Thomas (Wayne State University), K. Wickramasinghe (T. J. Watson Research Center) and T. Yolken (National Institute of Standards & Technology). These sessions contained several invited papers for which the organizers are grateful. The organizers are also indebted to the session chairpersons who managed the sessions and did an excellent job of keeping the Review on time - an especially important and noteworthy achievement in a meeting that contains four concurrent sessions. They are especially indebted to Mrs. Diane Harris who again managed Review logistics, to Ms. Elizabeth Bilyeu and Ms. Diane Miller for their preparation of meeting materials and assistance at the Review, and to Ms. Connie Nessa and Ms. Sarah Jaqua for their devoted efforts in preparing the manuscript of the Proceedings. Finally, the organizers wish to acknowledge the authors who have contributed to the Proceedings. Clearly, these contributions constitute the core of the Proceedings.

Donald O. Thompson
Center for Nondestructive Evaluation
and Ames Laboratory, USDOE
Iowa State University
Ames, Iowa 50011

Dale E. Chimenti
Center for Nondestructive Evaluation
The Johns Hopkins University
Baltimore, MD 21218

CONTENTS

VOLUME 9A

Section C. Eddy Currents

CHAPTER 3. INTERPRETIVE SIGNAL AND IM GE PROCESSING

Section A. Signal Processing and Neural Networks

Section B. Interpretive and Image Processing

SEEING WITH LIGHT, SOUND, MICROWAVES, X-RAYS, GAMMA RAYS, ETC.

Glen Wade

Electrical and Computer Engineering Department
University of California
Santa Barbara, CA 93106

INTRODUCTION

It is common to regard humans as being able to see only with light, but about a hundred years ago at the beginning of the modern era, along came x-rays and sonograms. By now technology has made it possible for us to see in a great many different ways. Important views such as underground pools of oil, tumors in the brain, fine structure in the rings of Saturn, ship wreckage on the bottom of the ocean, cracks in the ice packs of the Arctic, all these views and many more, completely unperceivable one hundred years ago, are available to us now with our technology in astonishing clarity and detail.

Strictly speaking it is not true to say that we used to see only with light, if "seeing" is defined broadly enough. A common dictionary definition for "seeing" is "obtaining a mental image." It is quite accurate to say that we "see" mainly with light by means of our eyes. But we also "see" with sound by means of our ears. In addition, we "see" by means of our senses of smell, taste, and touch.

If we go into a kitchen, our eyes may see a steak frying in a pan. We can close our eyes and easily retain the mental image. We can go into the kitchen blindfolded, and if we hear a sizzle, we may get the same mental image. If we are wearing a blindfold and ear muffs, our nose can still give us the same mental image. If we are blindfolded, ear muffed, and with a clothespin sealing our nostrils, a bite of the steak will elicit the same mental image.

One might still maintain that we see only with light. After all, each of the above mental images was first obtained optically. The odor of steak merely brings back memories of previously constructed light images. If you insist that this is true for all mental images, you must logically conclude that a person born blind will never have any mental images at all, a clearly false conclusion.

Images are generally of either two or three dimensions. But one-dimensional images are no rarity and are highly useful. An example of a one dimensional image is the A-scan of elementary pulse-echo sonar and radar.

What does the act of imaging consist of? Basically there are two steps:

1) gathering image data by means of detectors, and
2) manipulating these data by means of computers (either digital or analog, man-made or natural).

Review of Progress in Quantitative Nondestructive Evaluation, Vol. 9
Edited by D.O. Thompson and D.E. Chimenti
Plenum Press, New York, 1990