
Handbook of Advanced Nondestructive Evaluation

Nathan Ida • Norbert Meyendorf
Editors

Handbook of Advanced Nondestructive Evaluation

With 949 Figures and 43 Tables

 Springer

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Preface

The Internet of Things (IoT) and the next generation of industrial production (Industry 4.0) encompass the complete networking of all industrial areas. New production techniques as, for example, 3D printing will allow efficient on-time production of low numbers of unique parts. A significant aspect is quality and maintainability of these (sometimes) unique structures and components. Nondestructive evaluation or testing (NDE or NDT) must, necessarily, follow these trends by not only adapting NDE techniques to new technologies but also introducing the capability of cyber systems into the inspection and maintenance processes and anticipating future needs. These new challenges and capabilities will also boost the application of unconventional and new NDE principles to industrial applications.

Industry 4.0 and the ability to tailor individual components to the customer's needs will significantly impact the way we provide nondestructive inspection and evaluation. NDE must be integrated into the production process by networking with processes and production steps during manufacturing. This will result in a paradigm shift in industrial quality management and NDE. Classical concepts based on comparison of multiple similar components and statistical analysis will not be applicable under these conditions, raising the impact of the human factor. Availability of specialists capable of making the right decisions based on NDE results, knowledge about the material and the components, loading conditions, and NDE modeling of NDE experiments will be essential for the future.

This new generation of NDE specialists need to have a broad overview of conventional and new, advanced NDE techniques. A considerable amount of overview literature for common NDE techniques that are usually based on standards is available worldwide. Several organizations offer NDE training classes and certification for inspectors for the standard techniques. Other new methods that may, at present, be in experimental, laboratory stages but have the potential for application for future inspection tasks can only be found in specific scientific journals and, sometimes, may not even be considered as NDE candidates. However, to solve future NDE tasks, the specialist should have a clear understanding of what is possible without going into too many details.

The present book intends to bridge this gap between conventional common sense NDE methods of the present and the past and advanced techniques that provide and guide new opportunities for inspections for the next generation of NDE. As is often

the case, many methods described here have evolved from prior experience and from pressing needs in industrial inspection. The reader will find that the offerings in the present handbook is a healthy mixture of methods that are in limited use, those that are at various stages of development and some that are envisioned for the future.

This handbook is structured on the lines of accepted NDE principles but focuses on advanced methods of measurement or data analysis. It is not the intent of the book to introduce the basics of NDE principles. The exceptional contributions that make up this handbook were made by specialists worldwide working on advanced NDE techniques. The editors are grateful that so many excellent contributions have been submitted and are happy to present this unique overview of advanced NDE techniques. The task of keeping up to date, of course, can never be completed and any attempt at doing so can only be a snapshot of present activities. In this spirit, the online version of the handbook will be updated and enlarged in the future to keep the contents up to date.

We sincerely thank all those involved in the writing, editing, and production of this work.

June 2019

Nathan Ida
Norbert Mayendorf

Contents

Volume 1

Part I Acoustic Techniques	1
1 Physical Basis for Ultrasonic Acoustics	3
Victor Giurgiutiu and Bin Lin	
2 Ultrasonic Wavefield Imaging	43
Jennifer E. Michaels	
3 Acoustic Microscopy	75
Frank Schubert, Martin Barth, Raffael Hipp, and Bernd Köhler	
4 Acoustic Emission	115
Eleni Tsangouri and Dimitrios G. Aggelis	
5 Guided Wave Testing	141
Paul Fromme	
6 Laser-Induced Surface Acoustic Waves for Material Testing	171
Dieter Schneider	
7 The Acousto-elastic Effect and Its Use in NDE	235
Hans-Rüdiger Herzer, Michael Mathias Becker, and Eckhardt Schneider	
8 Nonlinear Acoustics	251
Younho Cho and Weibin Li	
9 Local Acoustic Resonance Spectroscopy	271
Christian U. Grosse, Anne Jüngert, and Philipp Jatzlau	
10 Nonlinear Resonant Acoustic Spectroscopy	295
Bart Van Damme and Koen Van Den Abeele	

Part II Optical Techniques	325
11 Surface Brillouin Scattering	327
Arthur G. Every and J. Darrell Comins	
12 Interferometric Methods in NDE	361
Krzysztof Patorski and Maciej Trusiak	
13 Shearography	383
Lianxiang Yang and Junrui Li	
14 White Light Interferometry	421
Joanna Schmit and Anna Pakuła	
15 Optical Coherence Tomography for NDE	469
Jonas Golde, Lars Kirsten, Christian Schnabel, Julia Walther, and Edmund Koch	
16 Ellipsometry	513
Jian Chen and Qiwen Zhan	
17 Raman Scattering	541
Rudolph M. Erasmus and J. Darrell Comins	
18 Optical Fiber Methods in Nondestructive Evaluation	595
Wolfgang R. Habel	
Part III Electromagnetic Techniques	643
19 Eddy Current Testing	645
Zhenmao Chen, Cherdpong Jomdecha, and Shejuan Xie	
20 High-Frequency Eddy Current Techniques	729
Susanne Hillmann, Martin H. Schulze, and Henning Heuer	
21 Eddy Current Tomography	757
Antonello Tamburrino and Guglielmo Rubinacci	
22 Motion-Induced Eddy Current Testing	781
Hartmut Brauer and Marek Ziolkowski	
23 Low Field Methods (GMR, Hall Probes, etc.)	827
Vivek T. Rathod, Portia Banerjee, and Yiming Deng	
24 Micromagnetic Materials Characterization	881
Klaus Szielasko and Ralf Tschuncky	
25 Electrochemical Techniques, Impedance, and Spectroscopy	899
Shengxi Li, Qixin Zhou, and Hongbo Cong	

Volume 2

Part IV Electromagnetic Microwave and Millimeter-Wave Techniques 927

26 Microwave and Millimeter Wave Nondestructive Testing and Evaluation 929
 Nathan Ida

27 Terahertz Techniques in NDE 967
 Joachim Jonuscheit

28 Ground Penetrating Radar 987
 X. Lucas Travassos and Mario Fernandez Pantoja

Part V X-Ray Techniques 1025

29 Processing of X-Ray Images 1027
 Sergei Chakhlov

30 X-Ray Phase Contrast Methods 1053
 Sheridan Mayo and Marco Endrizzi

31 X-Ray Tomography 1095
 Johann Kastner and Christoph Heinzl

32 3D X-Ray Tomography: Basics and Latest Developments 1167
 Theobald O. J. Fuchs and Randolf Hanke

33 Grazing Incidence X-Ray Reflectivity and Scattering 1181
 Brian K. Tanner

Part VI Particle Methods 1215

34 Neutron Radiography and Tomography 1217
 Wolfgang Treimer

35 Positron Annihilation 1301
 Luca Chiari and Masanori Fujinami

Part VII Thermal Techniques 1347

36 Physical Basics of Thermal Techniques of Nondestructive Evaluation 1349
 Vladimir P. Vavilov

37 Passive Thermography, Thermal Imaging 1371
 Helmut Budzier and Gerald Gerlach

38	Active Thermography	1401
	Helmut Budzier and Gerald Gerlach	
39	Thermal Wave Techniques	1419
	Gunnar Suchanek, Agnes Eydam, and Gerald Gerlach	
40	Sonothermic Techniques in Nondestructive Evaluation	1479
	Xiaoyan Han	
41	Induction Thermography of Surface Defects	1497
	Udo Netzelmann	
Part VIII	Special Techniques for Signal and Data Analysis	1523
42	Signal Processing for NDE	1525
	Masoud Vejdannik, Ali Sadr, Victor Hugo C. de Albuquerque, and João Manuel R. S. Tavares	
43	Digital Image Correlation Techniques for NDE and SHM	1545
	Christopher Niezrecki, Javad Baqersad, and Alessandro Sabato	
44	Structural Health Monitoring	1591
	Bianca Weihnacht, Uwe Lieske, Tobias Gaul, and Kilian Tschöke	
Index	1609

About the Editors



Nathan Ida is currently distinguished professor of Electrical and Computer Engineering at The University of Akron in Akron, Ohio, where he has been since 1985. His current research interests are in the areas of electromagnetic nondestructive testing and evaluation of materials at low and microwave frequencies with particular emphasis on theoretical issues, on all aspects of modeling and simulation and on related issues stemming from research in NDE. Starting with modeling of eddy current and remote field phenomena, and continuing with high frequency methods for microwave NDE, his work now encompasses the broad aspects of computational electromagnetics where he has contributed to both the understanding of the interaction of electromagnetic fields with materials and the development of new methods and tools for numerical modeling and simulation for, and beyond, NDE. Other areas of current interest include electromagnetic wave propagation, theoretical issues in computation, as well as in communications and sensing, especially in low power remote control and wireless sensing. Much of this work has found its way into practice through industrial relations and consulting across industries as diverse as power generation, polymers, steel, medical, and software, spanning the globe. Dr. Ida has published extensively on electromagnetic field computation, parallel and vector algorithms and computation, nondestructive testing of materials, surface impedance boundary conditions, sensing, and others, in over 400 publications. He has written nine books: two on computation of electromagnetic fields (one in its second edition), one on modeling for nondestructive testing, one on nondestructive testing with microwaves, a textbook on engineering

electromagnetics (now in its fourth edition), a textbook on sensing and actuation (now in its second edition), a book on the use of surface impedance boundary conditions, and others, including on ground penetrating radar and industrial sensing based on microwaves. Dr. Ida is a life fellow of the Institute of Electric and Electronics Engineers (IEEE), a fellow of the American Society of Nondestructive Testing (ASNT), a fellow of the Applied Computational Electromagnetics Society (ACES), and a fellow of the Institute of Electronics and Technology (IET). Dr. Ida teaches electromagnetics, antenna theory, electromagnetic compatibility, sensing, and actuation, as well as computational methods and algorithms.

Dr. Ida received his B.Sc. in 1977 and M.S.E.E. in 1979 from the Ben-Gurion University in Israel, and his Ph.D. from Colorado State University in 1983.



Norbert Meyendorf retired in fall 2018 as deputy director of the Center for Nondestructive Evaluation and professor in the Aerospace Engineering department at the Iowa State University in Ames, Iowa. Before joining ISU in 2016 he had several appointment and ranks. The most recent are:

Branch Director at the Fraunhofer Institute for Non-destructive Testing IZFP and later IKTS, director of the International University of Dayton/Fraunhofer Research Center at the School of Engineering at the University of Dayton, organizing collaborative projects between Fraunhofer and University of Dayton, and Program Director of the Master program “Nondestructive Testing, M. Sc. (NDT)” at the Dresden International University (DIU) between 2011 and 2015.

Norbert Meyendorf continues to be active as adjunct professor for micro- and nano-NDE at the University of Dresden and adjunct professor at the Department for Chemical and Materials Engineering, University of Dayton.

He is the author or coauthor of more than 300 peer-reviewed journal articles, contributions to edited proceedings, technical reports, and numerous oral presentations on conferences, meetings, workshops, etc. He is editor in chief of the *Journal of Nondestructive Evaluation* and edited several books and conference proceedings.

His areas of expertise include solid state physics and physical analytics, welding metallurgy, materials testing, nondestructive evaluation (NDE), and structural health monitoring (SHM), for instance.

Since 2001, he has been chairman or co-chairman of several conferences within the SPIE International Symposium on Nondestructive Evaluation for Health Monitoring and Diagnostics and later the Symposium for Smart Structures and NDE. In 2005, 2006, 2012, and 2013, he was chair or co-chair of the whole SPIE Symposium. In 2018 he became fellow of SPIE.

Norbert Meyendorf was founder and chair of two expert committees of the German Society for Non-Destructive Testing (DGZfP), the Expert Committees for “Structural Health Monitoring” and “Materials Diagnostics.” Between 2016 and 2018, he reorganized and directed the ASNT Section Iowa.

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