
Handbook of Advanced Nondestructive Evaluation

Nathan Ida • Norbert Meyendorf
Editors

Handbook of Advanced Nondestructive Evaluation

With 949 Figures and 43 Tables

 Springer

Editors

Nathan Ida
Department of Electrical and Computer
Engineering
The University of Akron
Akron, OH, USA

Norbert Meyendorf
Center for Nondestructive Evaluation
Iowa State University Center for
Nondestructive Evaluation
Ames, IA, USA

ISBN 978-3-319-26552-0 ISBN 978-3-319-26553-7 (eBook)
ISBN 978-3-319-30122-8 (print and electronic bundle)
<https://doi.org/10.1007/978-3-319-26553-7>

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The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

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

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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.

Contributors

Koen Van Den Abeele Physics, Kulak Kortrijk Campus, Kortrijk, Belgium

Dimitrios G. Aggelis Department of Mechanics of Materials and Constructions (MeMC), Vrije Universiteit Brussel (VUB), Brussels, Belgium

Portia Banerjee SGT Inc., NASA Ames Research Center, Mountain View, CA, USA

Javad Baqersad Department of Mechanical Engineering, Kettering University, Flint, MI, USA

Martin Barth Ultrasonic Sensors and Methods, Fraunhofer IKTS, Dresden, Germany

Michael Mathias Becker Fraunhofer Institute for Nondestructive Testing IZFP, Saarbrücken, Germany

Hartmut Brauer Technische Universitaet Ilmenau, Ilmenau, Germany

Helmut Budzier Institute of Solid State Electronics, Technische Universität Dresden, Dresden, Germany

Sergei Chakhlov School of Non-Destructive Testing and Security, Tomsk Polytechnic University, Tomsk, Russia

Jian Chen School of Optical-Electrical and Computer Engineering, University of Shanghai for Science and Technology, Shanghai, China

Zhenmao Chen State Key Laboratory for Strength and Vibration of Mechanical Structures Shaanxi ERC for NDT and Structural Integrity Evaluation School of Aerospace, Xi'an Jiaotong University, Xian, China

Luca Chiari Department of Applied Chemistry and Biotechnology, Graduate School of Engineering, Chiba University, Chiba, Japan

Younho Cho School of Mechanical Engineering, Pusan National University, Busan, South Korea

J. Darrell Comins School of Physics, Materials Physics Research Institute and DST-NRF Centre of Excellence in Strong Materials, University of the Witwatersrand, Johannesburg, South Africa

Hongbo Cong Department of Chemical and Biomolecular Engineering, Corrosion Engineering Program, The University of Akron, Akron, OH, USA

Victor Hugo C. de Albuquerque Programa de Pós Graduação em Informática Aplicada, Universidade de Fortaleza (UNIFOR), Fortaleza, Ceará, Brazil

Yiming Deng NDE Laboratory, Department of Electrical and Computer Engineering, Michigan State University, East Lansing, MI, USA

Marco Endrizzi University College London, London, UK

Rudolph M. Erasmus School of Physics, Materials Physics Research Institute and DST-NRF Centre of Excellence in Strong Materials, University of the Witwatersrand, Johannesburg, South Africa

Microscopy and Microanalysis Unit, University of the Witwatersrand, Johannesburg, South Africa

Arthur G. Every School of Physics, University of the Witwatersrand, Johannesburg, South Africa

Agnes Eydam Institute of Solid State Electronics, Technische Universität Dresden, Dresden, Germany

Paul Fromme Department of Mechanical Engineering, UCL, London, UK

Theobald O. J. Fuchs Fraunhofer EZRT, Fürth, Germany

Masanori Fujinami Department of Applied Chemistry and Biotechnology, Graduate School of Engineering, Chiba University, Chiba, Japan

Tobias Gaul Fraunhofer Institute for Ceramic Technologies and Systems IKTS, Dresden, Germany

Gerald Gerlach Institute of Solid State Electronics, Technische Universität Dresden, Dresden, Germany

Victor Giurgiutiu University of South Carolina, Columbia, SC, USA

Jonas Golde Clinical Sensing and Monitoring, Anesthesiology and Intensive Care Medicine, Faculty of Medicine Carl Gustav Carus, TU Dresden, Dresden, Germany

Christian U. Grosse Center for Building Materials, Chair of Non-destructive Testing, Technical University of Munich, München, Germany

Wolfgang R. Habel Department of Non-Destructive Testing, Division of Fibre Optic Sensors, BAM Federal Institute for Materials Research and Testing (formerly), Berlin, Germany

Xiaoyan Han Department of Electrical and Computer Engineering, Wayne State University, Detroit, MI, USA

Randolf Hanke Fraunhofer IZFP, Saarbrücken, Germany

Christoph Heinzl University of Applied Sciences Upper Austria, Wels, Austria

Hans-Rüdiger Herzer Fraunhofer Institute for Nondestructive Testing IZFP, Saarbrücken, Germany

Henning Heuer Systems for Testing and Analysis, Fraunhofer IKTS, Dresden, Germany

Susanne Hillmann Accredited Test Lab, Fraunhofer IKTS, Dresden, Germany

Raffael Hipp Ultrasonic Sensors and Methods, Fraunhofer IKTS, Dresden, Germany

Nathan Ida Department of Electrical and Computer Engineering, The University of Akron, Akron, OH, USA

Philipp Jatzlau Center for Building Materials, Non-destructive Testing, Technical University of Munich, München, Germany

Cherdpong Jomdecha State Key Laboratory for Strength and Vibration of Mechanical Structures Shaanxi ERC for NDT and Structural Integrity Evaluation School of Aerospace, Xi'an Jiaotong University, Xian, China

Joachim Jonuscheit Fraunhofer Institute for Industrial Mathematics ITWM, Kaiserslautern, Germany

Anne Jüngert University of Stuttgart, Stuttgart, Germany

Johann Kastner University of Applied Sciences Upper Austria, Wels, Austria

Lars Kirsten Clinical Sensoring and Monitoring, Anesthesiology and Intensive Care Medicine, Faculty of Medicine Carl Gustav Carus, TU Dresden, Dresden, Germany

Edmund Koch Clinical Sensoring and Monitoring, Anesthesiology and Intensive Care Medicine, Faculty of Medicine Carl Gustav Carus, TU Dresden, Dresden, Germany

Bernd Köhler Accredited NDT Test Lab, Fraunhofer IKTS, Dresden, Germany

Junrui Li Optical Laboratory, Department of Mechanical Engineering, Oakland University, Rochester, MI, USA

Shengxi Li Department of Chemical and Biomolecular Engineering, Corrosion Engineering Program, The University of Akron, Akron, OH, USA

Weibin Li School of Aerospace Engineering, Xiamen University, Xiamen, China

Uwe Lieske Fraunhofer Institute for Ceramic Technologies and Systems IKTS, Dresden, Germany

Bin Lin Department of Mechanical Engineering, University of South Carolina, Columbia, SC, USA

X. Lucas Travassos Federal University of Santa Catarina, Joinville/Florianopolis, Brazil

Sheridan Mayo CSIRO Manufacturing, Clayton, VIC, Australia

Jennifer E. Michaels School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, GA, USA

Udo Netzelmann Fraunhofer-Institute for Nondestructive Testing IZFP, Saarbrücken, Germany

Christopher Niezrecki Department of Mechanical Engineering, University of Massachusetts Lowell, Lowell, MA, USA

Anna Pakula Warsaw University of Technology, Warsaw, Poland

Mario Fernandez Pantoja Universidad de Granada, Granada, Spain

Krzysztof Patorski Department of Mechatronics, Institute of Micromechanics and Photonics, Warsaw University of Technology, Warsaw, Poland

Vivek T. Rathod NDE Laboratory, Department of Electrical and Computer Engineering, Michigan State University, East Lansing, MI, USA

Guglielmo Rubinacci Department of Electrical Engineering and Information Technology, Università degli Studi di Napoli Federico II, Napoli, Italy

Alessandro Sabato Department of Mechanical Engineering, University of Massachusetts Lowell, Lowell, MA, USA

Ali Sadr School of Electrical Engineering, Iran University of Science and Technology (IUST), Narmak, Tehran, Iran

Joanna Schmit 4D Technology, Tucson, AZ, USA

Christian Schnabel Clinical Sensing and Monitoring, Anesthesiology and Intensive Care Medicine, Faculty of Medicine Carl Gustav Carus, TU Dresden, Dresden, Germany

Dieter Schneider Fraunhofer Institute for Material and Beam Technology (IWS), Dresden, Germany

Eckhardt Schneider Fraunhofer Institute for Nondestructive Testing IZFP, Saarbrücken, Germany

Frank Schubert Ultrasonic Sensors and Methods, Fraunhofer IKTS, Dresden, Germany

Martin H. Schulze Eddy Current Methods, Fraunhofer IKTS, Dresden, Germany

Gunnar Suchaneck Institute of Solid State Electronics, Technische Universität Dresden, Dresden, Germany

Klaus Szielasko Fraunhofer Institute for Nondestructive Testing IZFP, Saarbrücken, Germany

Antonello Tamburrino Department of Electrical and Information Engineering, Università degli Studi di Cassino e del Lazio Meridionale, Cassino, Italy

Department of Electrical and Computer Engineering, Michigan State University, East Lansing, MI, USA

Brian K. Tanner Department of Physics, Durham University, Durham, UK

João Manuel R. S. Tavares Instituto de Ciência e Inovação em Engenharia Mecânica e Engenharia Industrial, Faculdade de Engenharia, Universidade do Porto, Porto, Portugal

Wolfgang Treimer Department Mathematics-Physics-Chemistry, University of Applied Sciences Beuth Hochschule für Technik Berlin, Berlin, Germany

Maciej Trusiak Department of Mechatronics, Institute of Micromechanics and Photonics, Warsaw University of Technology, Warsaw, Poland

Eleni Tsangouri Department of Mechanics of Materials and Constructions (MeMC), Vrije Universiteit Brussel (VUB), Brussels, Belgium

Kilian Tschöke Fraunhofer Institute for Ceramic Technologies and Systems IKTS, Dresden, Germany

Ralf Tschuncky Fraunhofer Institute for Nondestructive Testing IZFP, Saarbrücken, Germany

Bart Van Damme Empa, Swiss Federal Laboratories for Materials Science and Technology, Dübendorf, Switzerland

Vladimir P. Vavilov Tomsk Polytechnic University, Tomsk, Russia

Masoud Vejdannik School of Electrical Engineering, Iran University of Science and Technology (IUST), Narmak, Tehran, Iran

Julia Walther Clinical Sensing and Monitoring, Anesthesiology and Intensive Care Medicine, Faculty of Medicine Carl Gustav Carus, TU Dresden, Dresden, Germany

Bianca Weihnacht Fraunhofer Institute for Ceramic Technologies and Systems IKTS, Dresden, Germany

Shejuan Xie State Key Laboratory for Strength and Vibration of Mechanical Structures Shaanxi ERC for NDT and Structural Integrity Evaluation School of Aerospace, Xi'an Jiaotong University, Xian, China

Lianxiang Yang Optical Laboratory, Department of Mechanical Engineering, Oakland University, Rochester, MI, USA

Qiwen Zhan School of Optical-Electrical and Computer Engineering, University of Shanghai for Science and Technology, Shanghai, China

Department of Electro-Optics and Photonics, University of Dayton, Dayton, OH, USA

Qixin Zhou Department of Chemical and Biomolecular Engineering, Corrosion Engineering Program, The University of Akron, Akron, OH, USA

Marek Ziolkowski Technische Universitaet Ilmenau, Ilmenau, Germany
West Pomeranian University of Technology Szczecin, Szczecin, Poland

Handbook of Modern Non-Destructive Testing broadens the scope from traditional books on the subject. In addition to classical, emerging and exotic methods of evaluation, the book will also cover the use of NDT techniques in other fields, such as archaeology or resource exploration. With contributions from experts in all areas of the field, the reader will find balanced coverage of a variety of testing methods, with no bias against or endorsements of any particular method. X-ray imaging is a widely used technique for nondestructive testing (NDT) and evaluation (NDE), for a detailed coverage of this application field refer to [1]. Images reveal spatial variations of object density, material and shape. X-ray imaging and computed tomography for engineering applications.