

PROCEEDINGS OF SPIE

Smart Structures and NDE for Industry 4.0

**Norbert G. Meyendorf
Dan J. Clingman**
Editors

**5–6 March 2018
Denver, Colorado, United States**

Sponsored by
SPIE

Cosponsored by
OZ Optics, Ltd. (United States)
Polytec, Inc. (United States)

Cooperating Organizations
Jet Propulsion Laboratory (United States)
Colorado Photonics Industry Association (United States)

Published by
SPIE

Volume 10602

Proceedings of SPIE 0277-786X, V. 10602

SPIE is an international society advancing an interdisciplinary approach to the science and application of light.

Smart Structures and NDE for Industry 4.0, edited by Norbert G. Meyendorf, Dan J. Clingman, Proc. of SPIE Vol. 10602, 1060201 · © 2018 SPIE · CCC code: 0277-786X/18/\$18 · doi: 10.1117/12.2326430

Proc. of SPIE Vol. 10602 1060201-1

The papers in this volume were part of the technical conference cited on the cover and title page. Papers were selected and subject to review by the editors and conference program committee. Some conference presentations may not be available for publication. Additional papers and presentation recordings may be available online in the SPIE Digital Library at SPIEDigitalLibrary.org.

The papers reflect the work and thoughts of the authors and are published herein as submitted. The publisher is not responsible for the validity of the information or for any outcomes resulting from reliance thereon.

Please use the following format to cite material from these proceedings:

Author(s), "Title of Paper," in *Smart Structures and NDE for Industry 4.0*, edited by Norbert G. Meyendorf, Dan J. Clingman, Proceedings of SPIE Vol. 10602 (SPIE, Bellingham, WA, 2018) Seven-digit Article CID Number.

ISSN: 0277-786X
ISSN: 1996-756X (electronic)

ISBN: 9781510617001
ISBN: 9781510617018 (electronic)

Published by

SPIE

P.O. Box 10, Bellingham, Washington 98227-0010 USA
Telephone +1 360 676 3290 (Pacific Time) · Fax +1 360 647 1445
SPIE.org

Copyright © 2018, Society of Photo-Optical Instrumentation Engineers.

Copying of material in this book for internal or personal use, or for the internal or personal use of specific clients, beyond the fair use provisions granted by the U.S. Copyright Law is authorized by SPIE subject to payment of copying fees. The Transactional Reporting Service base fee for this volume is \$18.00 per article (or portion thereof), which should be paid directly to the Copyright Clearance Center (CCC), 222 Rosewood Drive, Danvers, MA 01923. Payment may also be made electronically through CCC Online at copyright.com. Other copying for republication, resale, advertising or promotion, or any form of systematic or multiple reproduction of any material in this book is prohibited except with permission in writing from the publisher. The CCC fee code is 0277-786X/18/\$18.00.

Printed in the United States of America.

Publication of record for individual papers is online in the SPIE Digital Library.

**SPIE. DIGITAL
LIBRARY**
SPIEDigitalLibrary.org

Paper Numbering: *Proceedings of SPIE* follow an e-First publication model. A unique citation identifier (CID) number is assigned to each article at the time of publication. Utilization of CIDs allows articles to be fully citable as soon as they are published online, and connects the same identifier to all online and print versions of the publication. SPIE uses a seven-digit CID article numbering system structured as follows:

- The first five digits correspond to the SPIE volume number.
- The last two digits indicate publication order within the volume using a Base 36 numbering system employing both numerals and letters. These two-number sets start with 00, 01, 02, 03, 04, 05, 06, 07, 08, 09, 0A, 0B ... 0Z, followed by 10-1Z, 20-2Z, etc. The CID Number appears on each page of the manuscript.

Contents

v	<i>Authors</i>
vii	<i>Conference Committee</i>

KEYNOTE SESSION

10602 02	Using smart materials to solve new challenges in the automotive industry [10602-5]
----------	---

SMART STRUCTURES AND NDE FOR INDUSTRY 4.0: INTRODUCTION

10602 04	On the value of information for Industry 4.0 [10602-2]
----------	---

SMART STRUCTURES AND NDE FOR INDUSTRY 4.0

10602 05	Application of the actor model to large scale NDE data analysis [10602-3]
10602 06	A data-driven approach of load monitoring on laminated composite plates using support vector machine [10602-32]

ACQUISITION AND ANALYSIS OF LARGE AMOUNT OF DATA (BIG DATA)

10602 07	Soil-pipe interaction modeling for pipe behavior prediction with super learning based methods [10602-6]
10602 09	Feature recognition and detection for ancient architecture based on machine vision [10602-8]

NEW APPLICATIONS FOR SMART STRUCTURES AND MATERIALS FOR INDUSTRY 4.0

10602 0B	Bulk-wave ultrasonic propagation imagers [10602-11]
----------	--

SMART STRUCTURES AND ADDITIVE MANUFACTURING

10602 0C	Feasibility study of an active soft catheter actuated by SMA wires [10602-12]
----------	--

REAL-TIME MONITORING AND SMART NDE

10602 0I	A new class of high-G and long-duration shock testing machines [10602-18]
----------	--

- 10602 OJ **Development of magneto-rheological fluid (MRF) based clutch for output torque control of AC motors** [10602-19]

APPLICATION OF SMART STRUCTURES AND MATERIALS

- 10602 OL **Tile based rigidization surface parametric design study** [10602-21]
- 10602 OM **Near DC force measurement using PVDF sensors** [10602-22]
- 10602 ON **The output power improvement and durability with different shape of MEMS piezoelectric energy harvester** [10602-23]
- 10602 OO **Piezoelectric-based self-powered electronic adjustable impulse switches** [10602-24]

POSTER SESSION

- 10602 OQ **Metrological assurance and traceability for Industry 4.0 and additive manufacturing in Ukraine** [10602-26]
- 10602 OR **Conductive ink print on PA66 gear for manufacturing condition monitoring sensors** [10602-27]
- 10602 OS **Computational modeling of colorimetric primary transducer for metrological assurance in additive manufacturing** [10602-28]
- 10602 OU **Image-based corrosion recognition for ship steel structures** [10602-30]

Authors

Numbers in the index correspond to the last two digits of the seven-digit citation identifier (CID) article numbering system used in Proceedings of SPIE. The first five digits reflect the volume number. Base 36 numbering is employed for the last two digits and indicates the order of articles within the volume. Numbers start with 00, 01, 02, 03, 04, 05, 06, 07, 08, 09, 0A, 0B...0Z, followed by 10-1Z, 20-2Z, etc.

Abbas, Syed Haider, 0B	Tardiff, Janice, 02
Brei, Diann, 0L	Wang, Niannian, 09
Chen, C. T., 0N	Wu, W. J., 0N
Coughlin, Chris, 05	Yang, Yang, 0U
Dapino, Marcelo J., 0M	Yao, Yuan, 0U
Do, H. M. Hieu, 0J	Zhao, Peng, 09
Fekrmandi, H., 06	Zhao, Xuefeng, 09, 0U
Fu, Y. H., 0N	Zou, Zheng, 09
Futagawa, S., 0R	
Gath, Kerrie K., 02	
Giner Munoz, Laura, 0L	
Gwon, Y. S., 06	
Headings, Leon M., 0M	
Hu, Yafei, 07	
Iba, D., 0R	
Iizuka, T., 0R	
Kamimoto, T., 0R	
Karimi, Saeed, 0C	
Kim, Wonhee, 0L	
Konh, Bardia, 0C	
Kwok, Philip, 0O	
Le, D. Thang, 0J	
Lee, Jung-Ryul, 0B	
Li, Eric, 07	
Li, Shengyuan, 0U	
Lin, S. C., 0N	
Liu, Huan, 07	
Liu, Zheng, 07	
Luntz, Jonathan, 0L	
Ma, Yucong, 0U	
Maranville, Clay, 02	
Masuda, A., 0R	
Miller, Scott, 0C	
Miura, N., 0R	
Moriwaki, I., 0R	
Nakamura, M., 0R	
Neyezhmakov, Pavel, 0Q	
Nguyen, N. Diep, 0J	
Nguyen, Q. Hung, 0J	
Nguyen, V. Quoc, 0J	
Omenzetter, Piotr, 04	
Peng, Xiang, 07	
Prokopov, Alexander, 0Q	
Ramanathan, Arun Kumar, 0M	
Rastegar, Jahangir, 0I, 0O	
Shi, Fang, 07	
Skliarov, Vladimir, 0Q, 0S	
Sone, A., 0R	
Tang, W. H., 0N	

Conference Committee

Symposium Chairs

Tribikram Kundu, The University of Arizona (United States)
Gregory W. Reich, Air Force Research Laboratory (United States)

Symposium Co-chairs

Zoubeida Ounaies, The Pennsylvania State University (United States)
Hoon Sohn, KAIST (Korea, Republic of)

Conference Chair

Norbert G. Meyendorf, Iowa State University of Science and
Technology (United States)

Conference Co-chair

Dan J. Clingman, Boeing Research and Technology (United States)

Conference Program Committee

Steven R. Anton, Tennessee Technological University (United States)
Diann E. Brei, University of Michigan (United States)
Peter C. Chen, NASA Goddard Space Flight Center (United States)
Marcelo Dapino, The Ohio State University (United States)
Kevin M. Farinholt, Luna Innovations Inc. (United States)
Xiao-Yan Gong, Medical Implant Mechanics LLC (United States)
Steven F. Griffin, The Boeing Company (United States)
Nancy L. Johnson, General Motors Company (United States)
Jayanth N. Kudva, NextGen Aeronautics, Inc. (United States)
Amrita Kumar, Acellent Technologies, Inc. (United States)
Jay Lee, University of Cincinnati (United States)
Jung-Ryul Lee, KAIST (Korea, Republic of)
Donald J. Leo, The University of Georgia (United States)
Zheng Liu, The University of British Columbia Okanagan (Canada)
Geoffrey P. McKnight, HRL Labs., LLC (United States)
Tobias Melz, Fraunhofer-Institut für Betriebsfestigkeit und
Systemzuverlässigkeit (Germany)
Christopher Niezrecki, University of Massachusetts Lowell
(United States)
Gyuhae Park, Chonnam National University (Korea, Republic of)
W. Lance Richards, Armstrong Flight Research Center (United States)

Janet M. Sater, Institute for Defense Analyses (United States)
Edward V. White, The Boeing Company (United States)
Christian Wunderlich, Fraunhofer-IKTS CMD (Germany)

Session Chairs

Keynote Session

Piotr Omenzetter, University of Aberdeen (United Kingdom)

Smart Structures and NDE for Industry 4.0: Introduction

Norbert G. Meyendorf, Iowa State University of Science and Technology (United States)

Saveri Pal, Iowa State University of Science and Technology (United States)

Smart Structures and NDE for Industry 4.0

Norbert G. Meyendorf, Iowa State University of Science and Technology (United States)

Saveri Pal, Iowa State University of Science and Technology (United States)

Acquisition and Analysis of Large Amount of Data (Big Data)

Piotr Omenzetter, University of Aberdeen (United Kingdom)

New Applications for Smart Structures and Materials for Industry 4.0

Kerrie Gath, Ford Motor Company (United States)

Smart Structures and Additive Manufacturing

Norbert G. Meyendorf, Iowa State University of Science and Technology (United States)

Real-Time Monitoring and Smart NDE

Dan J. Clingman, Boeing Research and Technology (United States)

Application of Smart Structures and Materials

Dan J. Clingman, Boeing Research and Technology (United States)