

PROCEEDINGS OF SPIE

***Nondestructive Characterization
and Monitoring of Advanced
Materials, Aerospace, Civil
Infrastructure, and
Transportation XVI***

H. Felix Wu
Andrew L. Gyekenyesi
Peter J. Shull
Tzuyang Yu
Editors

7-9 March 2022
Long Beach, California, United States

4-10 April 2022
ONLINE

Sponsored and Published by
SPIE

Volume 12047

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 SPIDigitalLibrary.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 *Nondestructive Characterization and Monitoring of Advanced Materials, Aerospace, Civil Infrastructure, and Transportation XVI*, edited by H. Felix Wu, Andrew L. Gyekenyesi, Peter J. Shull, Tzuyang Yu, Proc. of SPIE 12047, Seven-digit Article CID Number (DD/MM/YYYY); (DOI URL).

ISSN: 0277-786X

ISSN: 1996-756X (electronic)

ISBN: 9781510649699

ISBN: 9781510649705 (electronic)

Published by

SPIE

P.O. Box 10, Bellingham, Washington 98227-0010 USA

Telephone +1 360 676 3290 (Pacific Time)

SPIE.org

Copyright © 2022 Society of Photo-Optical Instrumentation Engineers (SPIE).

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 fees. To obtain permission to use and share articles in this volume, visit Copyright Clearance Center 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.

Printed in the United States of America by Curran Associates, Inc., under license from SPIE.

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

**SPIE. DIGITAL
LIBRARY**

SPIDigitalLibrary.org

Paper Numbering: A unique citation identifier (CID) number is assigned to each article in the Proceedings of SPIE 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

vii *Conference Committee*

SHM/NDE OF ADVANCED MATERIALS I

- 12047 02 **Carrera unified formulation (CUF) for the analysis of disbonds in single lap joints (SLJ)** [12047-76]
- 12047 03 **Non-destructive evaluation of damage detection in hybrid basalt/flax fibres-polypropylene composites** [12047-2]
- 12047 04 **Thermosonics: electrostatic transducer based air-coupled ultrasonics and thermography for NDE of carbon fibre reinforced polymer materials** [12047-3]

SHM/NDE OF ADVANCED MATERIALS II

- 12047 05 **Volumetric nondestructive evaluation for damage in carbon fiber reinforced polymer panels subjected to artificial lightning strikes** [12047-5]
- 12047 06 **Design and application of an engineered composite patch toward crack damage mitigation on stainless steel plates** [12047-6]
- 12047 07 **Understanding the elastic, plastic, and damage features in fracturing of self-reinforced thermoplastic composites via non-destructive digital imaging correlation** [12047-8]
- 12047 08 **Non-destructive testing applications for in-service FRP reinforced/strengthened concrete bridge elements** [12047-9]

SHM/NDE TOOLS DEVELOPMENT FOR AUTOMOTIVE AND AEROSPACE COMPONENTS AND SYSTEMS

- 12047 09 **Nonlinear ultrasonic inspection of cohesive failure in adhesive due to contaminants in the manufacturing process** [12047-10]
- 12047 0A **Thermosonics: array-based, air-coupled ultrasonics and thermography for NDE of carbon fibre reinforced polymer materials** [12047-11]
- 12047 0B **Developments in Gd₂O₃ based pixelated-metallic aperture arrays** [12047-12]
- 12047 0C **Integrating robust feature detection methodology with in-house DIC for identification and correlation of natural patterns on large structures** [12047-13]
- 12047 0D **Damage detection using two-stage compressive sensing** [12047-14]

12047 OE **Finite difference 3D model for structural health monitoring of single lap joints** [12047-15]

MULTIFUNCTIONAL COMPOSITE MATERIALS AND STRUCTURES FOR AUTOMOTIVE APPLICATIONS I

12047 OF **Multifunctional fiber-reinforced composites for passive sensing and energy harvesting with enhanced mechanical performance** [12047-16]

12047 OG **Micromechanics modeling of multifunctional EGaln-polymer composites** [12047-17]

MULTIFUNCTIONAL COMPOSITE MATERIALS AND STRUCTURES FOR AUTOMOTIVE APPLICATIONS II

12047 OH **Discrete and functional carbon nanotubes (Molecular Rebar) for improved tires in transportation** [12047-23]

SHM/NDE MATERIALS CHARACTERIZATION OF ENERGY INFRASTRUCTURE

12047 OI **Physics-informed neural networks for identification of material properties using standing waves** [12047-25]

12047 OJ **Lamb wave focusing by gradient-index phononic crystal lens in layered composites** [12047-26]

12047 OK **Analysis of Lamb wave propagation in cross-ply laminates modeled with homogenized properties of transverse cracked plies** [12047-27]

12047 OL **Evaluation of crack closure by ultrasonic wave transmission** [12047-28]

12047 OM **Aperture effect on Rayleigh wave measurements on cement media** [12047-30]

SHM/NDE TECHNOLOGIES FOR CIVIL INFRASTRUCTURE APPLICATIONS I

12047 ON **Interpretation of synthetic aperture radar images of concrete by combined uses of image parameters** [12047-32]

12047 OO **Investigating the effect of mass redistribution on damping of building models using a shake table and a laser Doppler vibrometer** [12047-33]

12047 OP **The field evaluation of pavement roughness in conjunction of the response-based compact roughness evaluation device** [12047-35]

12047 OQ **Application of dual-frequency GPR for subsurface void detection in culverts** [12047-38]

- 12047 OR **Structural health monitoring of new technology composite highway bridge deck with 100-year design life** [12047-39]
- 12047 OS **Laser Doppler imaging vibrometer for real-time health monitoring of civil infrastructures** [12047-40]

SHM/NDE FOR ADDITIVE MANUFACTURING PROCESSES

- 12047 OT **The numerical model of additive manufactured carbon fiber reinforced polymer under mechanical loading** [12047-41]
- 12047 OU **Characterization of hydrogel structures using video-based vibration analysis** [12047-45]
- 12047 OV **Characterization of anisotropic mechanical properties of polymer composites from a hybrid additive manufacturing-compression molding process using x-ray computer tomography** [12047-46]
- 12047 OW **Detecting thermal crack growth on a large additive manufactured structure using acoustic emission** [12047-47]

SIGNAL/IMAGE PROCESSING AND DENOISING, DATA FUSION/MINING

- 12047 OX **Optimizing the range of a bilateral filter to enhance defects and threads visibility in x-ray radiographic testing** [12047-64]
- 12047 OY **Identifying defects under shadows from a series of thermal images by employing robust principal component analysis and local binary function** [12047-65]
- 12047 OZ **Segmentation of multiple features in carbon fiber reinforced polymers using a convolutional neural network** [12047-67]
- 12047 10 **Acoustic emission source location based on artificial neural network** [12047-68]

SHM/NDE SENSOR DEVELOPMENT, MEMS/NEMS, AND INTELLIGENT TRANSPORTATION SYSTEMS

- 12047 11 **Low-power multi-hop wireless sensor network for vibration monitoring of large structures** [12047-48]
- 12047 12 **Stroboscopic video microscopy with sub-nanometer accuracy for characterizing and monitoring MEMS** [12047-49]
- 12047 13 **Finite element modeling for a flexible transparent piezoelectric surface acoustic wave transducer** [12047-50]
- 12047 14 **Piezoelectric sensor-based 3D modal analysis under shaker derived random excitations** [12047-53]

PREDICTIVE MODELING AND SIMULATION

- 12047 15 **The detection of fatigue crack in thick steel with phase array ultrasonics [12047-58]**
- 12047 16 **Engine rotor health monitoring: an experimental approach to fault detection using a machine fault simulator [12047-60]**
- 12047 18 **Turbofan engine performance simulation study under selected failure scenarios of rotating and hot sections components [12047-62]**

AUTOMATED AND AUTONOMOUS SHM/NDE WITH UNMANNED AERIAL VEHICLES/SYSTEMS

- 12047 19 **Application of machine learning for defect detection in FRP-bonded systems with different defect sizes [12047-57]**

POSTER SESSION

- 12047 1A **Higher order nonlinear acoustics parameters for real-time damage assessment of metallic alloys using laser Doppler vibrometry [12047-63]**
- 12047 1B **Modal identification method based on ESMD and MPM [12047-69]**
- 12047 1C **Flutter boundary prediction method based on CEEMDAN [12047-70]**
- 12047 1D **Operating environment sensing of transmission tower based on deep learning [12047-74]**