## PROCEEDINGS OF SPIE

# Active and Passive Smart Structures and Integrated Systems XIII

**Alper Erturk** 

**Editors** 

4–7 March 2019 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 SPIF

**Volume 10967** 

Proceedings of SPIE 0277-786X, V. 10967

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

Active and Passive Smart Structures and Integrated Systems XIII, edited by Alper Erturk, Proc. of SPIE Vol. 10967, 1096701 · © 2019 SPIE · CCC code: 0277-786X/19/\$18 · doi: 10.1117/12.2534122

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 Active and Passive Smart Structures and Integrated Systems XIII, edited by Alper Erturk, Proceedings of SPIE Vol. 10967 (SPIE, Bellingham, WA, 2019) Seven-digit Article CID Number.

ISSN: 0277-786X

ISSN: 1996-756X (electronic)

ISBN: 9781510625891

ISBN: 9781510625907 (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 © 2019, 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/19/\$18.00.

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.



**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**

ix Authors Conference Committee χi **ACTIVE AND PASSIVE VIBRATION/NOISE ATTENUATION I** 1096704 Adaptive damping and stiffness control of composite structures: an experimental illustration [10967-1] 1096705 Panel vibration suppression by using piezoelectric damping system [10967-2] 1096706 A sky-ground hook controller for efficiency enhancement of aircraft landing gear with MR **damper** [10967-3] 1096707 Direct adaptive control of non-minimum phase linear distributed parameter models of large flexible structures [10967-4] **METAMATERIALS AND METASTRUCTURES** 1096709 An analytical framework for Kirchhoff plate-type locally resonant piezoelectric metastructures [10967-11] 10967 0A Vibration suppression of metamaterial with local resonators coupled by negative stiffness **springs** [10967-12] 10967 OB Energy harvesting characteristics in metamaterials based on bistable lattices [10967-13] **ENERGY HARVESTING I: NONLINEAR/WIDEBAND** 10967 OF An SECE-based piezoelectric power harvesting induced by rotary magnetic plucking [10967-5] 10967 OG Vibration energy harvesting system with coupled bistable modules [10967-6] 10967 OH Extension of cross-well bandwidths for a bistable oscillator [10967-7] 10967 OJ A bidirectional energy conversion circuit for piezoelectric energy harvesting and vibration exciting purposes [10967-9]

#### ENERGY HARVESTING II: NONLINEAR/WIDEBAND

10967 OK	A passive self-tuning nonlinear resonator with beam-slider structure [10967-17]
10967 OL	Nonlinear dynamic analysis of 1:2 internally resonant V-shaped harvester [10967-18]
10967 OM	Optimized piezoelectric energy harvesters for performance robust operation in periodic vibration environments [10967-19]
10967 ON	Wideband operation of a nonlinear vibration energy harvester with asymmetric restoring force [10967-20]
	ENERGY HARVESTING III: FLUID/ACOUSTIC-STRUCTURE INTERACTION
10967 OP	Power output comparison of side-by-side fluidic harvesters in different types of fractal grid-generated turbulence [10967-22]
10967 OR	Toward synergistic performance of integrated solar-wind hybrid energy harvesting structures [10967-24]
	FLUID-STRUCTURE INTERACTION
10967 OT	Development of a variable-incidence-angle vortex generator for surface contaminated wind-turbine blades [10967-26]
10967 OU	Dynamics of a hybrid wave-current energy converter with a novel power take-off mechanism [10967-27]
10967 OW	Aerodynamic characteristic of the continuous morphing trailing edge [10967-29]
10967 OY	Flutter analysis of a large civil aircraft in case of free-plays and internal failures of morphing wing flaps mechanical systems [10967-31]
10967 OZ	Average power output and the power law: identifying trends in the behavior of fluidic harvesters in grid turbulence [10967-32]
	MORPHING, DEPLOYABLE, AND ORIGAMI STRUCTURES

	ACTIVE AND PASSIVE VIBRATION/NOISE ATTENUATION II
10967 16	Minimizing deceleration for drop-induced shock systems using magnetorheological energy absorber [10967-40]
	ENERGY HARVESTING IV: GENERAL
10967 19	Investigation of various cantilever configurations for piezoelectric energy harvesting under rotational motion [10967-43]
10967 1A	Ring energy harvester using cylinder shape change [10967-44]
10967 1C	Possibilities of using flexoelectric effect for energy harvesting applications [10967-46]
10967 1D	Analysis of a triboelectric energy harvester for total knee replacements under gait loading [10967-47]
10967 1E	Analytical solutions for a broadband concurrent aeroelastic and base vibratory energy harvester [10967-97]
	ACOUSTICS AND WAVE PROPAGATION
10967 1G	Standing-to-traveling wave transition in piezoelectric thermoacoustic energy harvesters (SPIE Best Student Paper Award) [10967-50]
10967 1J	A computational study of vibration delocalization in cyclic structures using adaptive stiffness elements [10967-53]
10967 1K	Wave propagation in auxetic mechanical metamaterial: Bloch formalism for various boundary conditions [10967-54]
	MAGNETORHEOLOGICAL DEVICES AND SYSTEMS
10967 1L	Magnetorheological bypass valve design for a semi-active inerter [10967-55]
10967 1N	Speed control of rotary shaft at different loading torque using MR clutch [10967-57]
10967 1Q	Development of a 3D haptic spherical master manipulator based on MRF actuators [10967-60]

#### MODELING AND ANALYSIS OF SMART STRUCTURES

10967 1R	An alternate numerical treatment for nonlinear PDE models of piezoelectric laminates
10967 IS	Representation of a multi-electrodes piezoelectric transformer by experimental extraction of its electric parameters [10967-62]
10967 1T	Shape prediction of a composite wing panel under the action of an SMA wire and an MFC bimorph [10967-63]
	MAGNETOSTRICTIVE, MAGNETOELECTRIC, AND MAGNETORHEOLOGICAL DEVICES
10967 1W	Finite element formulation for analysis of unsymmetric magnetoelectric laminated plates [10967-66]
	SHAPE MEMORY ALLOYS
10967 20	Dynamics of focused ultrasound actuated shape memory polymers [10967-70]
	ENERGY HARVESTING V: GENERAL
10967 24	Generalized modeling and analysis of piezoelectric vibration energy harvesters [10967-75]
10967 25	An arc-shaped electromagnetic energy harvester for ultra-low frequency vibrations and swing motions [10967-76]
10967 26	Improvement on impedance model of electromagnetic energy harvesting systems [10967-77]
	SENSING, ACTUATION, AND DIAGNOSTICS
10967 28	Structural compatibility of thin film sensors embedded in a composite laminate [10967-79]
10967 2A	Piezoelectric wafer active sensors for sensing acoustic emission due to crack rubbing/clapping [10967-81]
10967 2B	A smart sensor for the measurements of strain and vibrations: a work in progress [10967-82]
10967 2D	Nonlinear characterization of piezoelectric patches and piezoelectric stacks from vibrations of
	piezo-actuated structures [10967-84]

109672E Design and modeling of surface bondable piezoelectric stack actuators for actuation of large **structures** [10967-85] **ENERGY HARVESTING VI: GENERAL** 109672F Tuning, power, and efficiency of piezoelectric vibration energy harvesters [10967-86] Study of piezo embedded negative mass metamaterial using generalized Bloch theorem for 109672G energy harvesting system [10967-87] The fatigue behavior study of micro piezoelectric energy harvester under different working 109672H temperature [10967-88] 1096721 Study of split ring metamaterial with simultaneous wave guiding and energy harvesting **capability** [10967-99] **POSTER SESSION** 109672J Modelling and active control aiming at enhancing the sound transmission loss of thin partition panels [10967-89] 10967 2N A self-powered nonlinear wideband vibration energy harvester with high-energy response stabilization control [10967-93] 1096720 Active mass damper using phase and amplitude of mean field of oscillators [10967-94] 10967 2P Design and development of a miniaturized mechanically and magnetically-sprung electromagnetic nonlinear energy harvester [10967-95]

#### **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.

Ahmed, Hossain, 21 Ali, Shaikh Faruque, 1T Ameduri, Salvatore, 11 Amoroso, Francesco, OY Arena, Maurizio, 11 Arockiaraian, A., 1T, 1W Arrieta, Andres F., OB Bai, Xian-Xu, 16 Balas, Mark J., 07 Banarjee, Arnab, 1K, 2G Banerjee, Sourav, 21 Baro, Simone, 2J Bhargava, A., 20

Bhattacharya, Bishakh, 1K, 2G Bhuiyan, Md Yeasin, 2A Bryant, Matthew, OR Buiochi, Flávio, 2J Butaud, P., 04 Cai, Wen, 0M Callanan, Jesse, 1G Campos-Ferreira, Andres, 2B

Cha, Youngsu, 1A Chae, Eun Jung, 0W Chang, H. C., 0F Chattoraj, Anwesha, 1K Chen, Bang-fuh, OU Chen, C. T., 2H Chen, S. A., 19 Chen, Shuo, OU Chevallier, G., 04

Chiappazzi, Nicholas, OP, OZ

Chien, J. T., 2H Choi, Seung-Bok, 06 Concilio, Antonio, 0Y, 11 Costa, François, 1S Danesh-Yazdi, Amir H., OP, OZ Danzi, Francesco, OL

Das, Raj, OA Deng, Yiming, 28 Diep, Bao Tri, 1N Dimino, Ignazio, 0Y, 11 Dorin, Patrick, 0G Dwivedi, Ankur, 2G Erturk, Alper, 09 Fan, Kangqi, 25 Ferko, Kevin, OP, OZ Foltête, E., 04 Frost, Susan A., 07 Gao, Yiming, 26

Gibert, James M., 0L Giurgiutiu, Victor, 2A Gong, Jiawei, OP, OZ Gopalakrishnan, S., 2D, 2E

Gupta, Vivek, 1K Han, Chulhee, 06 Han, Jae-Hung, OT Han, Jong-Seob, OT Harne, Ryan L., 0M Henneberg, Alexander, 1C

Hongu, J., 2O Hsieh, T. T., OF, 19 Hu, Guobiao, 0A Huang, P. H., OF

Hwang, Myungwon, OB

lba, D., 20

Ibrahim, Alwathiqbellah, 1D Indaleeb, Mustahseen M., 21

Inman, Daniel J., 0H Jeannin, T., 04 Jiang, Boxi, OU Joodaky, Amin, OL Joseph, E., 04 Joseph, Roshan, 2A Kandagal, S. B., 2D Kang, Byung-Hyuk, 06 Kauffman, Jeffrey L., 1J Khenner, Mikhail, 1R Kim, Ho-Hyun, OT Kim, Ho-Young, OT Kim, Jinki, 0G Kim, Yeunhee, 1A

Kuo, Y. C., 2H Lan, Chunbo, 0A Le, Dai Hiep, 1N, 1Q Le, Duc Thang, 1N Lee, Andrew J., 0H Li, Xiaofan, 0U Liang, Junrui, 0J, 24, 26 Liao, Wei-Hsin, OJ Liao, Yabin, 24, 2F Lin, S. C., 2H

Lozoya-Santos, Jorge de-J., 2B

Mace, Brian R., OK Martinez, Thomas, 1S Masuda, Arata, 0N, 2N, 2P Mazzoleni, Nicholas, OR

Mir, Fariha, 21

Miyata, Yusuke, ON, 2P

Morales-Menendez, Ruben, 2B

Mukherjee, Aghna, 1T

Nguyen, Duy Hung, 1Q

Nguyen, Ngoc Diep, 1Q

Nguyen, Quoc Hung, 1N, 1Q

Nguyen, Vien Quoc, 1N

Nouh, Mostafa, 1G

Okina, Fabio T. A., 2J

Ouisse, M., 04

Özer, Ahmet Özkan, 1R

Parker, Robert G., 0U

Pecora, Rosario, 0Y, 11

Peng, K., 20

Pillonnet, Gaël, 1S

Ramírez-Mendoza, Ricardo A., 2B

Rathod, Vivek T., 28

Renault, D., 04

Ripamonti, Francesco, 2J

Rodriguez, Andres M., 1J

Ruzzene, Massimo, 09

Sadoulet-Reboul, E., 04

Schwesinger, Norbert, 1C

Seyfert, Lars, 1C

Shahab, S., 20

Shih, W. T., 2H

Shivashankar, P., 2D, 2E

Shu, Y. C., 0F, 19

Sims, Neil, 1L

Song, Jae-Bok, 1A

Su, Pyae, 0W

Sudersan, S., 1W

Sugino, Christopher, 09

Sundersan, S., 1W

Suzuki, Shunji, 05

Tan, Qinxue, 25

Tang, Hong, 26

Tang, Lihua, 0A, 0K, 25

Tipuric, Matthew, 1L

Towfighian, Shahrzad, 1D

Truong, Thuy Duy, 1N, 1Q

Tudon-Martinez, Juan Carlos, 2B

Ushiki, So, ON, 2N, 2P

Vargas-Martinez, Adriana, 2B

Vasic, Dejan, 1S

Verdin, B., 04

Wada, T., 20

Wagg, David, 1L

Wang, Jiahua, 0J

Wang, K. W., 0G

Willing, Ryan, 1D

Wu, W. J., 2H

Xiong, Liuyang, OK

Xiong, Qiuchi, 0U

Xu, Jiawen, 0A

Yamaguchi, Toshizumi, 05

Yamomo, Geofrey, 1D

Yang, Sen, 16

Yang, Tiejun, OK

Yu, Liuding, 0K

Zhao, Bao, OJ

Zhao, Feng, 0N, 2P Zhao, Liya, 1E Zhong, Wei-Min, 16 Zuo, Lei, 0U

Χ

### **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

Alper Erturk, Georgia Institute of Technology (United States)

Conference Co-chair

Jae-Hung Han, KAIST (Korea, Republic of)

Conference Program Committee

**Mehdi Ahmadian**, Virginia Polytechnic Institute and State University (United States)

**Steven R. Anton**, Tennessee Technological University (United States)

Hiroshi Asanuma, Chiba University (Japan)

**Diann E. Brei**, University of Michigan (United States)

Matthew Bryant, North Carolina State University (United States)

Gregory P. Carman, University of California, Los Angeles (United States)

**Eun Jung Chae**, California State University, Long Beach (United States)

Seung-Bok Choi, Inha University (Korea, Republic of)

Carlos De Marqui Jr., Universidad de São Paulo (Brazil)

Alison B. Flatau, University of Maryland, College Park (United States)

Mehrdad N. Ghasemi-Nejhad, University of Hawai'i (United States)

**Victor Giurgiutiu**, University of South Carolina (United States)

Nam Seo Goo, Konkuk University (Korea, Republic of)

Faramarz Gordaninejad, University of Nevada, Reno (United States)

Nakhiah C. Goulbourne, University of Michigan (United States)

**Ryan L. Harne**, The Ohio State University (United States)

Daniel J. Inman, University of Michigan (United States)

**Hyung-Jo Jung**, KAIST (Korea, Republic of)

M. Amin Karami, University at Buffalo (United States)

Jung-Ryul Lee, KAIST (Korea, Republic of)

**Soobum Lee**, University of Maryland, Baltimore County (United States)

Junrui Liang, ShanghaiTech University (China)

Wei-Hsin Liao, The Chinese University of Hong Kong (Hong Kong, China) Zhu Mao, University of Massachusetts Lowell (United States) David L. Mascareñas, Los Alamos National Laboratory (United States) Gyuhae Park, Chonnam National University (Korea, Republic of) Norbert Schwesinger, Technische Universität München (Germany) Shima Shahab, Virginia Polytechnic Institute and State University

(United States)

Yi-Chung Shu, National Taiwan University (Taiwan)

Henry A. Sodano, University of Michigan (United States)

Jiong Tang, University of Connecticut (United States)

Lihua Tang, The University of Auckland (New Zealand)

Serife Tol, University of Michigan (United States)

Dai-Hua Wang, Chongqing University (China)

Kon-Well Wang, University of Michigan (United States)

Ya S. Wang, Stony Brook University (United States)

Norman M. Wereley, University of Maryland, College Park (United States)

Byeng D. Youn, Seoul National University (Korea, Republic of)

Lei Zuo, Virginia Polytechnic Institute and State University (United States)

#### Session Chairs

- Active and Passive Vibration/Noise Attenuation |
  Alper Erturk, Georgia Institute of Technology (United States)
  Jae-Hung Han, KAIST (Korea, Republic of)
- 2 Metamaterials and Metastructures Andres F. Arrieta, Purdue University (United States) James M. Gibert, Purdue University (United States)
- 3 Energy Harvesting I: Nonlinear/Wideband Wei-Hsin Liao, The Chinese University of Hong Kong (Hong Kong, China) Ryan L. Harne, The Ohio State University (United States)
- 4 Energy Harvesting II: Nonlinear/Wideband Serife Tol, University of Michigan (United States) Lihua Tang, The University of Auckland (New Zealand)
- 5 Energy Harvesting III: Fluid/Acoustic-Structure Interaction Matthew J. Bryant, North Carolina State University (United States) Amir H. Danesh-Yazdi, Rose-Hulman Institute of Technology (United States)
- Fluid-Structure Interaction

  Lei Zuo, Virginia Polytechnic Institute and State University (United States)

  Eun Jung Chae, California State University, Long Beach (United States)

- 7 Morphing, Deployable, and Origami Structures
  Ryan L. Harne, The Ohio State University (United States)
  Serife Tol, University of Michigan (United States)
- 8 Active and Passive Vibration/Noise Attenuation II Lei Zuo, Virginia Polytechnic Institute and State University (United States) Jung-Ryul Lee, KAIST (Korea, Republic of)
- 9 Energy Harvesting IV: General Shima Shahab, Virginia Polytechnic Institute and State University (United States) Shahrzad Towfighian, Binghamton University (United States)
- 10A Acoustics and Wave Propagation
   Mostafa A. Nouh, University at Buffalo (United States)
   Jeffrey L. Kauffman, University of Central Florida (United States)
- 10B Magnetorheological Devices and SystemsAlper Erturk, Georgia Institute of Technology (United States)
- 11A Modeling and Analysis of Smart Structures

  Ahmet Ozkan Ozer, Western Kentucky University (United States)

  Francesco Danzi, Politecnico di Torino (United States)
- 11B Magnetostrictive, Magnetoelectric, and Magnetorheological Devices Jae-Hung Han, KAIST (Korea, Republic of)
  Alper Erturk, Georgia Institute of Technology (United States)
- 12A Shape Memory Alloys
   Nam Seo Goo, Konkuk University (Korea, Republic of)
   Shima Shahab, Virginia Polytechnic Institute and State University (United States)
- 12B Energy Harvesting V: GeneralYabin Liao, Penn State Behrend (United States)Francesco Danzi, Politecnico di Torino (United States)
- 13A Sensing, Actuation, and Diagnostics Jung-Ryul Lee, KAIST (Korea, Republic of) Ahmet Ozkan Ozer, Western Kentucky University (United States)
- 13B Energy Harvesting VI: General
   Mariantonieta Gutierrez Soto, University of Kentucky (United States)
   Yabin Liao, Penn State Behrend (United States)