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MISSION

Offer a Professional newsletter that informs and is informed by international researchers, educators, industrialists, and government officials who are working to advance the field of structural health monitoring.

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Overview of Content

We are pleased to bring you the 4th issue of the SHM newsletter. There are a number of special and invited articles in this issue.

In one article, the winner of the 2008 Structural Health Monitoring Person of Year Award is announced. A summary of the activities of a faculty member at the University of New Mexico is also included in this issue. Then experts within the U.S. Air Force Research Laboratory provide an overview of the structural health monitoring challenges to support Operationally Responsive Space technologies. There are also numerous job opportunities for recent graduates and graduate students to consider. As always, a recent list of structural health monitoring publications and special events are also published in this issue.

Thank you to those who contributed articles to the fourth issue. Our thanks go out to Anthony Deraco, President of DEStech Publications, for his continued support of the newsletter.

Sincerely,

Doug Adams
Managing Editor

EVENTS

Feature Application

Enabling Responsive Space Capability with Structural Health Monitoring

Brandon Arritt and **Capt. Buck Gardenier**
Air Force Research Laboratory, Space Vehicles Directorate, Kirtland AFB, NM

The Department of Defense (DOD) is developing a Responsive Space (RS) capability "focused on the timely satisfaction of the urgent needs of the JFC (Joint Force Commander) and other users." Timely is defined in three-tiers:

Tier 1: Provide the required space-based capability within days from establishing the need with on-orbit assets

Tier 2: Satisfy the warfighter needs within days to weeks with a field-ready, or nearly field-ready capabilities

Tier 3: Deliver an entirely new, or unforeseen capability, within a year

These requirements introduce unique demands. At the Air Force Research Laboratory/Space Vehicles Directorate (AFRL/RV) there are many technology development efforts aimed at enabling modular satellite architectures to increase the responsiveness of satellite assembly and integration. However, all of these efforts are for naught if we are forced to follow the current arduous surety processes, consisting of static load, environmental, dynamic load, and coupled loads analysis. The current tests and analyses procedures that have been developed for conventional satellites take much too long to conform to the timelines of RS. For some satellites, the iterative process of testing and analysis can take over three years[1].

Therefore, AFRL/RV has begun efforts to develop alternative test and analysis procedures which conform to the timelines of RS. Structural Health Monitoring (SHM) technologies will play a pivotal role in the success of these alternative methods. SHM can be used to determine the health of structural components and assess mechanical connections. It can be run in parallel with other ground-based satellite check-out procedures and is amenable to RS timelines. Additionally, unlike traditional testing processes, SHM can pinpoint the location, type, and severity of damage, enabling rapid component swap-out, maintenance action, and go/no-go decisions.

For RS the greatest source of variability between satellite components is the interfaces, which pose the biggest hurdle for failing the current space vehicle surety processes. Therefore, leveraging SHM to insure an RS satellite is assembled in a rapid fashion without being subjected to the time-consumptive and onerous Quality and Assurance (Q&A) processes typical of traditional satellite programs is the primary target of AFRL/RV's current effort. Expedited methods must be developed to ensure the technician fastened a bolt to the specified torque or that a bond-line is acceptable. Furthermore, having the ability to accurately assess the integrity of the connections between satellite components and subsystems will dramatically reduce the variability in any model used to assess the satellite's modal properties. It is anticipated that these SHM-based tests will take a matter of hours and can be conducted while other satellite systems are being checked. This is critical because the truncated timelines of RS dictate that numerous satellite checks be run in parallel. SHM also provides a capability that is not available through other means; if there is a fault, the SHM system will pinpoint the location, type, and severity of the fault. This is helpful in that repair action can be immediate (which may be as simple as tightening a bolt) and focused. Traditional dynamic testing only points to the presence of a fault.

The current approach of AFRL/RV is to focus on the unique aspects of RS, thus maximizing the results from our investment in SHM technologies. For this reason, initial emphasis has been placed on developing systems and methodologies with the necessary flexibility to accommodate the RS paradigm. Development of that configuration flexible system has fallen into two distinct thrusts: developing a flexible SHM system architecture and developing flexible detection methodologies that do not require baselines captured on "pristine," physically identical samples. A robust SHM capability for RS will require a system that is able to detect damage and out-of-spec conditions on satellites with a near limitless variety of configurations. The envisioned system will frequently be asked to detect flaws and damage on configurations it has never been taught. Although SHM for responsive space is clearly a very difficult problem, it is important to note a couple of considerations to show that the problem may not be intractable.

These considerations include:

1. The SHM system will only need to determine the region of damage, and not the specific location. Current satellite testing methods do not lend themselves to locating the source of the problem, so any directing on the part of the SHM system is of great benefit.
2. Specifically for mechanical connections, bolts will likely either be fully torqued or not torqued at all. RS is likely to drive standard interfaces, with standard bolt torques, to ease the assembly process.

Currently, several technology efforts are in progress to leverage SHM technologies for responsive space. First, Acellent Technologies, of Sunnyvale, CA has been tasked with developing a SHM architecture that will work independent of the satellite's configuration. Acellent's system utilizes a network of distributed piezoelectric sensors/actuators embedded on a thin dielectric carrier film called the SMART Layer® to monitor and evaluate the integrity of a structure. A portable diagnostic unit is used to collect and process diagnostic signals obtained from the sensors/actuators during the monitoring process. The signals obtained can then be analyzed to determine the integrity of the structure. Next, Quartus Engineering Incorporated (QEI), in collaboration with the University of California-San Diego (UCSD), is presently developing a SHM capability designed to mitigate the lengthy Q/A certification and testing processes by assessing the integrity of adhesively bonded

and bolted joint assemblies. The QEI/UCSD technology takes an online, data-driven approach to system verification/monitoring of bolted joints, namely, joint connectivity and bolt preload through the use of macro-fiber composite patches (MFC) and novel data processing[2]. Finally, a research team at the New Mexico Institute of Mining and Technology (NMT) is investigating physical properties of structural assemblies that would impact the assessment of a joint's integrity enabling prediction of structural performance and assisting in determining qualification margins for structural envelopes. Current research activities at NMT are focused on the fundamental aspects of joints behavior and utilizing relevant physical parameters for structural integrity assessment.

Structural Health Monitoring is a critical technology for enabling RS. Current methods to assess the satellite's structural surety are not amenable to the short timelines. When a mission is requested, the SHM system must provide input, bounding the uncertainty of the interfaces in the satellite dynamic model. Additionally, the SHM system will be required to validate the assumptions within the model; primarily that the structure is not damaged and assembled according to specifications. SHM systems can also be used to perform periodic checks on the structural components providing feedback on storage condition and component health. SHM may not only help to truncate test requirements, it can also direct rapid repair actions and allows other check-out procedures to be run in parallel. To reach its full potential, the SHM system must be able to detect and assess flaws in complex, multifunctional structures, as well as interrogate numerous mechanical connections. Improving the resolution and reliability of SHM systems may reduce the amount of structural margin that must be built into the structure (translating into reduced mass and cost) because it translates into decreased uncertainty in the dynamic model of the satellite.

References

[1] Sarafin, T.P., P.G. Doukas, "Simplifying the Structural Verification Process to Accommodate Responsive Launch," *Proceedings of the 5th Responsive Space Conference, AIAA-RS5 2007-5003,* April 2007.
[2] Clayton, E. H., et al, "Off-the-shelf modal analysis: Structural health monitoring with motes," *Proceedings of the 24th International Modal Analysis Conference,* 2006

2008 Structural Health Monitoring Person of the Year

Professor T. Kundu

Professor T. Kundu has been named the 2008 Structural Health Monitoring Person of the Year. Professor Kundu received his bachelor degree in Mechanical Engineering from IIT Kharagpur, India. He was the winner of the President Gold Medal for ranking first among all engineering graduates from all disciplines of IIT Kharagpur in 1979. He joined UCLA as a recipient of the University of California Regents' Fellowship**.** There he received the UCLA Engineering Alumni Award in 1981 for his outstanding academic performance. After completing his M.S. and Ph.D. from UCLA he joined the University of Arizona in 1983 as an Assistant Professor and was promoted to full Professor in 1994. From Germany he received the Humboldt Research Prize (the Senior Scientist Award) in 2003 and Humboldt Fellowship in 1989 and 1996. He is a fellow of ASME, ASCE and SPIE.

He has supervised 25 Ph.D. students, 15 MS students and published over 100 journal papers, over 200 technical papers, 2 textbooks and edited 4 research monographs and 14 conference proceedings. Three of his co-authored papers received best paper awards from the SPIE and ASME. Since 2007 he authored 1 text book (Fundamentals of Fracture Mechanics), edited 2 research monographs (DPSM for Modeling Engineering Problems, Advanced Ultrasonic Methods for Material and Structure Inspection), two SPIE conference proceedings on structural health monitoring, and published 12 journal papers. Main focus of his research is ultrasonic nondestructive evaluation and structural health monitoring applied to Engineering and Biological Materials. He is the Chairman of the yearly SPIE conference on Health Monitoring of Structural and Biological Systems held in March, every year.

Dr. Kundu has served as the Chairman of the ASME NDE Engineering Division from 2003 to 2005. He has been serving as the Associate Editor of the ASME Journal of Pressure Vessel Technology since 2006 and Structural Health Monitoring: An International Journal since 2008. From 2001 to 2006 he served on the editorial advisory board of the International Journal of Geomechanics and International Journal for Numerical and Analytical Methods in Geomechanics from 1998 to 2001. As an invited professor and/or scientist he has spent between 1 month and 3 years in each of the following departments at the foreign institutes in Germany, France, Sweden, Switzerland, Denmark and Russia. These are Department of Biology, J. W. Goethe University, Frankfurt, Germany, Department of Experimental Physics, University of Leipzig, Germany, Electrical Engineering Department, Ecole Normale Superieure de Cachan, France, Laboratory of Mechanics and Physics, University of Bordeaux, France, Mechanical Engineering Department, University of Technology, Compiegne, France, Civil Engineering Department, EPFL, Swiss Federal Institute of Technology, Lausanne, Switzerland, Department of Mechanics, Chalmers University of Technology, Gothenberg, Sweden, Semienov Institute of Chemical Physics, Russian Academy of Science, Moscow and Aarhus University Medical School, Denmark. These invitations are the true testament of the interdisciplinary nature of Dr. Kundu's research that has a global appeal.

OPPORTUNITIES

Student Opportunities

Job Opportunities
D. E. Adams

Please send in your list of job and educational opportunities for undergraduate and graduate students. Here are a few of the current opportunities:

Experimentalist – Damage Science of Composite Materials

A research position is available immediately within National Aeronautics Space administration.

Email address: Edward.H.Glaessgen@nasa.gov

Structural Health Monitoring

A postdoctoral position is available immediately in the area of Structural Health Monitoring and Damage Prognosis at Arizona State University.

URL: http://www.fulton.asu.edu/~murishm/

Starting Date: January 2009

Email address: kay.vasley@asu.edu

Adaptive Intelligent Materials and Systems (AIMS) Center

A postdoctoral position is available immediately in the Adaptive Intelligent Materials and Systems (AIMS) Center, Arizona State University.

URL: http://aims.asu.edu

Starting Date: Fall 2008

Email address: kay.vasley@asu.edu

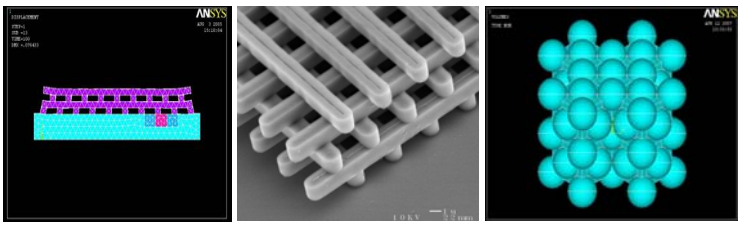
PEOPLE

Meet Professor Mahmoud Reda Taha

Mahmoud Reda Taha has recently been promoted to Associate Professor at the University of New Mexico (UNM) with appointments in the Department of Civil Engineering, The Department of Mechanical Engineering and The Department of Electrical and Computer Engineering. Mahmoud graduated from the University of Calgary, Canada with a PhD in Civil Engineering (2000). Prior to his studies in Calgary, he attended Ain Shams University, Cairo, Egypt where he received his BSc. (1993) and M.Sc. in Structural Engineering (1996).

Professor Taha with his research team at UNM.

Taha's research interests include structural health monitoring (SHM), nano-technology for structural composites and biomechanics. His thrust efforts are focused on developing new sensing technologies and damage detection methods for SHM applications. Taha's SHM research team at UNM was first to introduce fuzzy damage pattern recognition as an alternative to statistical damage pattern recognition realizing the non-crisp boundaries of damage states. His research demonstrated the effectiveness of Theory of Possibility in realizing structural damage and the research team also developed efficient techniques for sensor allocation and operation on long span bridges. During the last three years, Taha's research team successfully developed a remote submicron damage detection technology using photonic bandgap sensors. This development made it possible to quantify damage in composite substrates that are adhered to new sensors by observing the light reflection spectrum of the photonic bandgap sensors. Taha's SHM research activities have been a product of strong collaboration with Sandia National Laboratories and Los Alamos National Laboratory.



(a) (b) (c)

Photonic bandgap sensors for submicron damage detection (a) a model of photonic sensor nano-fabricated above a damaged substrate (b) Scanning electron microscope (SEM) image of the photonic bandgap material (c) a model of inverse opal photonic sensor.

Taha's SHM research team has recently been awarded a grant from the Federal Highway Administration (FHWA) to monitor a reinforced concrete bridge in New Mexico on Interstate I-40 which has been strengthened using advanced composites. The SHM monitoring program aims to identify the structural performance of the bridge post-strengthening. The SHM monitoring system will integrate measurements from the newly installed Fiber Reinforced Polymers (FRP) composites with acceleration measurements from various locations on the bridge surface. SHM software is currently being developed to integrate all monitoring data. In addition, a new algorithm for smart sensor activation for damage tracking developed by Taha's research team will be implemented with the monitoring system. The SHM project is currently on-going and monitoring of the bridge by New Mexico Department of Transportation (NMDOT) will start in 2009.

Reinforced concrete bridge on Interstate I-40 monitored by Taha's research team at UNM. The techniques on smart sensor activation for damage tracking in the SHM field project were developed by Taha's research team.

Taha is interested in attracting undergraduate students for research activities and has introduced some of these technological advances to the undergraduate curriculum at UNM. His research team includes three undergraduate students who are working on nano-technology. In collaboration with colleagues in Mechanical Engineering, Taha was recently awarded a grant by National Science Foundation (NSF) for introducing nano-technology to the undergraduate curriculum as part of Nanotechnology Undergraduate Education (NUE) program in NSF. He has also been involved with a number of colleagues across the country in organizing special sessions on structural health monitoring and is currently guest editing a special issue of International Journal of Smart Structures and Systems on structural health monitoring which will be published in early 2009. In recognition of Taha's research work, he received UNM's Stamm Endowed Lectureship for Outstanding Faculty Performance from the Department of Civil Engineering in 2007. UNM also named Taha with the distinction of UNM Regents' Lecturer. This is the most prestigious honor UNM bestows on junior faculty for research excellence.

RESOURCES

SHM Bookshelf

Journals and Books to Note

JOURNAL

Structural Health Monitoring – An International Journal
Editor-in-Chief: Fu-Kuo Chang, *Stanford University*

Sage Publications, appears quarterly

Structural Health Monitoring is an independent journal devoted to the prompt publication of original papers reporting the results of experimental or theoretical work on any aspect of structural health monitoring. The journal has a broad topical coverage and it serves as a primary reference for the structural health monitoring of aeronautical, mechanical, civil, electrical, and other systems. Manuscripts should be submitted electronically to ijshm@uc.edu. The Journal has recently received a high impact factor of 1.721 meaning it is ranked 7th out of 66 in the engineering, multidisciplinary category and 8th out of 53 in instruments and instrumentation.

BOOKS

Damage Assessment of Structures
Proc. of 7th DAMAS Conf., Turin, Italy, June 2007
Editors: L. Garibaldi, C. Surace, K. Holford, and W. Ostachowicz
Transtech Publications Ltd, Stafa-Zurich, CH, 2007, 710 pages
Also available as Volume 347 of Key Engineering Materials
ISSN 1013-9826, online publ.: http://www.scientific.net

Structural Health Monitoring 2007: *Quantification, Validation, and Implementation*
Proc. 6th Int'l Workshop on Structural Health Monitoring
Editor: Fu-Kuo Chang
ISBN: 978-1-932078-71-8, Two volumes with CD-ROM bound in Vol. 2, 2154p.
DEStech Publications Inc., Lancaster, PA; USA, September 2007

Structural health monitoring and intelligent infrastructure, Vol. 1 and 2
Proc. 2nd Intl. Conf. On Structural health monitoring and intelligent infrastructure
Editors: J P Ou, H Li and Z D Duan
ISBN: 0415396522.
London: Taylor and Francis, 2006, 762p. (Vol.1) and 1762p. (Vol.2)

Health Monitoring of Structural Materials and Components: *Methods with Applications*
Author: Douglas Adams
John Wiley & Sons, Chichester, UK, Hardcover, 512 pages
April 2007
ISBN: 978-0-470-03313-5

Sensing Issues in Civil Structural Health Monitoring

Editor: Farhad Ansari

Summary: This book provides information about the application of Structural Health Monitoring technologies to civil engineering structures including buildings, bridges, tunnels, dams, and pavements. The book is unique as it covers application of a broad spectrum of sensors for monitoring of cracks, deformations, loads, and other types of structural anomalies. The range of sensors covered includes conventional as well as novel sensors such as resistance type strain gauges, PZT, magnetic, fibre optics and smart materials.

The book describes post earthquake structural health monitoring of historic structures such as masonry towers, real time monitoring of modem cable stayed structures and various construction materials including steel, concrete, and fiber reinforced polymer composites (FRP). It covers distributed and multiplexing schemes for monitoring of large structures, data acquisition and processing as well as techniques for interpretation of data. A specific section is dedicated to issues concerning sensor and instrumentation reliability and durability during sensor placement in harsh construction environment, adverse exposure conditions, and long term performance.

ISBN-10: 1402036604, ISBN-13: 978-1402036606, Springer, August 2005, 528 pages.

Fibre Optic Methods for Structural Health Monitoring

Authors: Daniele Inaudi and Branko Glisic

Summary: The book is organised as a step-by-step guide to implementing a monitoring system and includes examples of common structures and their most-frequently monitored parameters and presents a universal method for static structural health monitoring, discusses a variety of different structures including buildings, bridges, dams, tunnels and pipelines; features case studies which describe common problems and offer solutions to those problems; provides advice on establishing mechanical parameters to monitor (including deformations, rotations and displacements) and on placing sensors to achieve monitoring.

ISBN-10: 0-470-06142-1, ISBN-13: 978-0-470-06142-8
John Wiley & Sons, October 2007, 276 pages

Structural Health Monitoring With Piezoelectric Wafer Active Sensors

Author: Victor Giurgiutiu

Summary: Comprehensive textbook to provide background information, theoretical modeling, and experimental examples on the principal technologies involved in SHM. Textbook can be used for both teaching and research. Provides a step by step presentation on how Piezoelectric Wafer Active Sensors (PWAS) are used. Presents underlying theories and experimental techniques to be employed in successful SHM applications. Offers also comprehensive teaching tools (worked examples, experiments, homework problems, and exercises) and an extensive online instructor manual containing lecture plans and homework solutions.

ISBN: 978-0-12-088760-6, Academic Press, Burlington, MA
January 2008, 747 pages

Intelligent Fault Diagnosis and Prognosis for Engineering Systems

Authors: George Vachtsevanos, Frank L. Lewis, Michael Roemer, Andrew Hess, and Biqing Wu

Summary: This expert book gives a comprehensive presentation of basic essentials and technologies of fault diagnosis and failure prognosis for condition-based maintenance. Details the interdisciplinary methods required to understand the physics of failure mechanisms in materials, structures, and rotating equipment, and also presents strategies to detect faults or incipient failures and predict the remaining useful life of failing components. Case studies are used throughout the book. Includes state-of-the-art algorithms, methodologies, and contributions including cost-benefit analysis tools and performance assessment techniques.

ISBN: 9780471729990, John Wiley, Hoboken, NJ, 2006

Calendar of Events

Upcoming Conferences

Dynamics Days 2009
January 8−11, 2009, University of California – San Diego, Double Tree Hotel, San Diego, CA, USA

2nd Asia-Pacific Workshop on Structural Health Monitoring
December 2−4, 2008 at Melbourne, Australia
Abstract Deadline March 1, 2008

Smart Structures and Materials & Nondestructive Evaluation and Health Monitoring
San Diego, CA, USA, 8−12 March 2009
Call for Papers will begin May 2008

IMAC XXVII, Conference and Exposition on Structural Dynamics
February 9−12, 2009, Orlando, FL, USA
Abstract Deadline: June 13, 2008.

CONTACT INFORMATION

Please send information for the next newsletter to one of the editors listed below:

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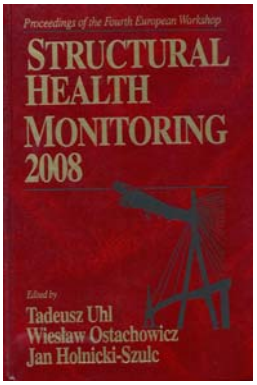
RECENTLY RELEASED: NEW BOOK IN EUROPEAN STRUCTURAL HEALTH SERIES



Structural Health Monitoring 2008

Proceedings of the Fourth European Workshop

Cracow, Poland, July 2-4, 2008

Edited by: **Tadeusz Uhl, Wiesław Ostachowicz** and **Jan Holnicki-Szulc**

Publications Details

ISBN 978-1-932078-94-7
July 2008, 1328 pages
6x9, hardcover,
author index
Price: $289.50

- **Over 180 original presentations on SHM theory, technology, applications**
- **Critical new information on damage detections algorithms, novel sensor strategies and devices, networking, embedding technology**
- **Sponsored by the University of Science and Technology of Krakow, Poland, the Institute of Fluid Flow Machinery, and the Institute of Fundamental Technological Research, of the Polish Academy of Science**

The latest in a series, this book comprises 180 articles representing research from Europe on all phases and system types of structural health monitoring. The volume shows how SHM is applied in emerging technologies, such as wind turbines, as well as in transportation and infrastructure. Information is provided on how SHM enhances the maintenance, safety, and lifecycle of aircraft, ground vehicles, buildings, and industrial machinery.

Sections Include: Keynote Presentations ● SHM Applications—Aerospace Application ● SHM Applications—Rotating Machinery ● SHM Applications—Railways Infrastructures and Vehicles ● SHM Applications—Civil Engineering ● SHM Applications—General Applications ● Sensors-Design and Solutions/Fbg Based Sensors ● Sensors-Design and Solutions/Piezo-Material Based Sensors ● Modelling and Simulation ● Sensors-Design and Solutions/Other Type of Sensors ● Sensors-Design and Solutions/Wireless ● SHM Systems/Guided Ultrasonic Waves ● SHM Systems/Fibre Bragg Grating Based System ● SHM Systems/Vibration Based Methods ● SHM Systems/Damage Detection Algorithms ● SHM Systems/Acoustic Emission Based Systems ● Life Cycle Assessment and Prognosis ● Poster Session

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