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C. Quan
K. Qian
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F. S. Chau
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Introduction

The 4th International Conference on Experimental Mechanics (ICEM 2009), in conjunction with the 8th Asian Conference on Experimental Mechanics (ACEM8), was successfully held from 18–20 November 2009 at Holiday Inn Atrium Hotel, Singapore. The conference was attended by 256 delegates from 21 countries.

The conference program included three keynote and 19 invited presentations given by eminent experts in their respective fields. Professor Kyung-Suk Kim of Brown University (USA) delivered a lecture entitled "Hybrid multi-scale experiments and high performance computing for cross-scale engineering of nano and microstructures." Professor Masaaki Sato of Tohoku University (Japan) presented the second keynote lecture, entitled "Mechanobiology of endothelial cell and the cytoskeletons." The third keynote lecture was presented by Professor Shulian Zhang of Tsinghua University (China) on "Nano-scale measurement instruments based on new principle in lasers." The 19 invited presentations were given by experts from Belgium, China, Germany, Japan, Singapore, Turkey, UK, and USA.

Apart from the above, 233 papers were presented in 32 oral sessions and 66 papers were presented in nine poster sessions. The Students with Experts Lunch provided a chance to promote personal and professional growth through networking, and provided students with a better perspective of their research. This conference covered eight thematic topics ranging from traditional solid mechanics to fluid mechanics and dynamics to the more current micro and nano mechanics, biomechanics and smart structures and non-destructive testing (NDT). There were six special sessions; two each in Experimental Solid Mechanics and Hybrid Methods & Image Processing, and one each in Non-Destructive Testing & Smart Structures and Commercialization of Research.

We take this opportunity to thank all speakers and authors for contributing to the success of the conference, the members of the international advisory committee for their assistance and enthusiastic support, the session chairs, our sponsors, and the organizing committee for ensuring the efficient execution of the conference program.

C. Quan
Chair, Scientific Program Committee, ICEM2009

Group photo of delegates at the opening ceremony

Keynote Speakers Abstracts

Kyung-Suk KIM
Brown University, USA

Title: Hybrid Multi Scale Experiments and High Performance Computing for Cross Scale Engineering of Nano and Microstructures

In the past decade, the engineering community has begun to develop and enhance the capabilities of technological devices and systems based on nano and microstructures. New discoveries and new inventions are emerging in cross-scale engineering of nano and microstructures, hybridizing supercomputing simulations and scale-bridging experiments. Examples of recent developments in hybrid experiments will include a nano pyramid flattening experiment to study size-scaling of plastic deformation in nanoscale asperities for understanding and controlling the wear and fatigue degradation that occurs between surfaces of engineered materials in contact. The examples will also include ultrasonication experiments which have led to the discovery of a new carbon nanotube scission mechanism caused by ultrasonication, and the ion-beam irradiation growth of nano-porous thin amorphous carbon films on a PDMS compliant substrate, being developed for renewable energy and clean environment technology applications.

Masaaki SATO
Tohoku University, Japan

Title: Mechanobiology of Endothelial Cell and the Cytoskeletons

Endothelial cells (ECs), lining on the luminal wall of blood vessels, change their morphology and physiological functions due to hemodynamic stimuli. Many of reports have shown that ECs elongate and align to the direction of flow after exposure to physiological levels of wall shear stress (WSS, 1~2 Pa), and such morphological changes of ECs have been thought to influence the functions. However, only a few studies have investigated the effect of wall shear stress gradient (WSSG) on ECs. In my talk I will present morphological responses of ECs under high WSS and high WSSG condition using a T-shaped flow chamber to evaluate the effects of WSSG to ECs. After 24 h exposure to flow, ECs under high WSS (10 Pa) without WSSG condition oriented perpendicular to the flow, whereas ECs at high WSS (10 Pa) with WSSG condition did not cause EC alignment. After 72 h exposure to flow, ECs exposed to WSSG were not polarized whereas ECs at high WSS without WSSG condition orientated and elongated to the direction of flow. These results indicate that a WSSG may suppress orientation of ECs to the flow direction. ECs respond to mechanical stimuli and change their morphology as shown above to be adapting to the mechanical environments. The cytoskeletal structure, mainly actin filaments, also changes the location and the alignment. We have been interested in the roles of cytoskeletons to elucidate the mechanosensing mechanisms. One of the key components to determine cell morphology is stress fiber, bundles of actin filaments, as a structural component. With respect to this, tensile properties of isolated single stress fibers were obtained with in vitro micromanipulation. Preexisting tension in the stress fibers was then evaluated from a combination of their tensile properties and preexisting strain. The result revealed that physiological tension level of the stress fibers was 1-10 nN order of magnitude, which was comparable to that of the traction force applied by adherent cells at their focal adhesion sites. Traction forces were estimated using micropatterned substrates with arrays of micropillars, showing an average of 11.8 nN. This work is supported financially in part by the Grant-in-Aid for Scientific Research (Scientific Research A #17200030 and Specially Promoted Research #20001007) by the Ministry of Education, Culture, Sports, Science and Technology, Japan (MEXT), and the Mitsubishi Foundation.

Shulian ZHANG
Tsinghua University, China

Title: Nano-Scale Measurement Instruments Based on New Principle in Lasers

This paper introduces several nano-scale measurement technologies/instruments based on new physical principles developed in the speaker's group.
Laser Nanometer Ruler, a completely new displacement sensor based on orthogonally polarized HeNe laser cavity tuning. This instrument possesses nano-scale resolution and large measurement range up to tens of mm, as well as the inherent function of trace to the source of light wave without frequency stabilization.

Laser Feedback Nanometer Ruler, another novel displacement sensor based on the orthogonally polarized feedback effect in the HeNe lasers and Nd: YAG laser caused by an extra-cavity 45o wave plate. Its measurement range is up to 150 mm, and the laser beam is very easy to be collimated to the target.

Quasi-common-path Nd: YAG Laser Feedback Interferometers. Working in a totally non-cooperative way this instrument does not require any target mirror/prism as in common interferometers, which makes it capable of characterizing the movement of various objectives such as neuroscience aluminum, neuroscience steel, neuroscience cast iron, glass, and paint surfaces.

Laser Feedback Profiler, a non-contact surface topography measurement instruments based on the feedback effect of the Nd: YAG laser. Due to the super-high sensitivity to the reflected light, it can be used to measure the challenging profile of the transparent (such as glass) surfaces.

The resolution and accuracy of these measurement instruments were gradually enhanced in past 10 years and now have reached nm and sub-nm scopes. We believe that these instruments are able to supplement or partially replace the current sensors.

Abstract for paper 7522-160

Analysis of Broken Accident of FRP Insulator Rod installed in Neutral Section of Electric Railway overhead line

D. Jang, H.-C. Kim, K. Lee, Korea Railroad Research Institute (Korea, Republic of)

The accident of broken insulator rod leads to interruption of moving the subway. We investigate the analysis of analysis of breaking accident of FRP insulator rod installed in neutral section for overhead catenary feeding system. In order to analysis of accident reason, SEM is used to analysis microscopic structure on surface of cross section of broken FRP insulator rod. At the same time, we examine the change of atomic amount on surface of broken accident insulator through EDX analysis. Also, in order to check the mechanical strength, the tensile strength test is conducted. As obtained results, examination of broken insulator from SEM and EDX analysis, the shape of cross section is similar to brittle fracture. From the SEM picture, the resin was damaged by internal discharge and basic resin material, cutting glass fibers were located on the same surface and the surface of cutting glass fiber was smooth. We known that the main ingredients were detected $CaCO_3$, SiO_2 and Al_2O_3 from EDX analysis.

Submission ID : ICEMA00038-00052

Presentation Type : Contributed Oral
Topic/Symposium : (C08) NDTSS: Automation of NDT procedures
Keywords : Nondestructive; Algorithm; Measurement

Blind Eddy Current Sorting: A Case Study

Shyamsunder **Baskaran**
IQC Advanced Inspection Solutions, Chennai, India

Eddy Current Testing is a indirect measurement based test that can be used for flaw detection, conductivity and magnetic permeability measurements. It is used in the manufacturing industry for ensuring that the finished product meets specifications, a process that is called "sorting". Being an indirect method, the technique requires calibration with reference standards. In this case study a procedure deployed to identify good parts in a mixed batch of “good”s and “unknown”s in the absence of reference standards is presented. The procedure makes use of prior statistical knowledge and established statistical tools such as the k-Nearest Neighbour (kNN) to provide a heuristic that helps us isolate a reference standard from the mixed population.

An overview of eddy current testing for segregation and the deployed statistical methods are presented. The procedure is then developed from a statistics perspective. The procedure is applied on actual industrial data and the results are presented.

Submission ID : ICEMA00160-00369

Presentation Type : Contributed Poster
Topic/Symposium : (E05) BLS: Mechanobiology
Keywords : Biomechanical; Mechanobiology; Cell

Suppression of Bone Resorption using Fluid Shear Stress and Neurotransmitter

Ji Hyun **Kwag**; Byung Gwan **Kim**; Kyung Hwan **Kim**; Chi Hyun **Kim**
Department of Biomedical Engineering, College of Health Science, Wonju, South Korea

Oscillatory fluid flow-induced shear stress suppresses bone resorption by regulation of the receptor activator of NF-kB ligand (RANKL) and osteoprotegerin (OPG) signaling. Neurotransmitters such as calcitonin-gene related peptide (CGRP) and vasoactive intestinal peptide (VIP) are present in bone tissue and may have the potential to interact with mechanical signal-induced bone remodeling. In this study, we quantified the effects of the neurotransmitters and/or mechanical loading on the suppression of bone resorptive activities. MC3T3-E1 pre-osteoblasts were subcultured on glass slides and placed in custom-built sterile parallel plate flow chambers under sterile conditions. Oscillatory fluid flow-induced shear stress of maximum ±1 Pa was applied for 1 hr. RANKL and OPG gene expression and protein synthesis were quantified using real-time RT-PCR and ELISA. CGRP and VIP suppressed RANKL and increased OPG protein release. Similar results were obtained with fluid flow-induced shear stress. Combined neurotransmitter and fluid flow-induced shear stress did not further enhance the changes. Results from this study suggest that the bone resorptive aspect of bone balance may be regulated similarly by neurotransmitter and mechanical loading through RANKL and OPG signaling. However, further in vitro and in vivo studies need to be performed to fully understand this mechanism.

Submission ID : ICEMA00253-00389

Presentation Type : Contributed Oral
Topic/Symposium : (D06) MNM: Micro and nano-metrology
Keywords : AFM; Biochips; Biosensors

Quantitatively Characterize the Structure, Surface Properties, and Dynamics of MEMS Device

Wanxin **Sun**
Veeco Asia Pte Ltd, Singapore

MEMS devices have been extensively used in a variety of applications, ranging from inkjet printer, accelerometer in consumable electronics, to biomedical sensing. With increasing demand on functionalities of MEMS devices, the scale of integration has increased significantly over the past a few years. With the shrinkage in dimension and increased complexity, the accuracy in fabrication and surface treatments become critical factors affecting the final performance of the devices. In this report, we review applications of different techniques on the measurements of dimensions in XYZ, surface roughness, mechanical properties, electric properties, and surface hydrophobicity with nanometer resolution. The challenges and feasibility of measurements under controlled environment, e.g. in vacuum, or liquid, are also discussed in this report. Besides these static properties, the dynamics of motion devices affect their applications directly. At the end of this report, we discuss the dynamic characterization of motion in 3D with nanometer accuracy, for example in-plane, out-of-plane motion in hundreds of KHz.

Submission ID : ICEMA00251-00391

Presentation Type : Contributed Oral
Topic/Symposium : (A06) ESM: Nondestructive testing evaluation and fault detection
Keywords : Techniques; Analysis; Nondestructive

Column Test-rig Facility for Column Scanning Studies

Rasif **Mohd Zain**; Roslan **Yahya**
Industrial Technology Division, Malaysian Nuclear Agency, Selangor, Malaysia

Distillation columns are considered as one of the most critical components in oil and gas plants. The plant performance depends on the ability of these columns to function as intended. Defective columns may lead to serious consequences to the plant operation, and hence the quality of product. In order to perform any inspection techniques to distillation column for NDT practitioner, the best facility was designed when the adjustable defeats of distillation column test rig has been developed. The paper discussed the development and the function of this facility.

Submission ID : ICEMA00277-00522

Presentation Type : Invited Oral
Topic/Symposium : (A05) ESM: Whole-field distribution analysis of displacement & strain
Keywords : MEMS; Displacements; Measurement

Two Grating-based Methods for Deformation Evaluation of MEMS

Zhanwei **Liu**[1;5]; Huimin **Xie**[2]; Changzhi **Gu**[3]; Yonggang **Meng**[4]; Jianxin **Gao**[5]
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3. Institute of Physics, Chinese Academic of Science, Beijing, China
4. Department of Precision Instrument and Mechanology, Tsinghua University, Beijing, China
5. TWI (The Welding Institute), Cambridge, United Kingdom

Quantitative evaluation of the structure deformation of MEMS is of importance for the design and functional control of Microsystems. In this investigation, a geometric phase analysis technique and digital phase moiré method based on gratings are developed to meet the deformation evaluation requirement of MEMS. The geometric phase analysis technique is performed on the basis of regular gratings, instead of natural atom lattice. The regular gratings with a pitch of range from micrometer to nanometer will be directly fabricated on the measured surface of MEMS devices by using a Focus Ion Beam (FIB). Phase information can be obtained from Bragg filtered images after Fast Fourier Transform (FFT) and Inverse Fast Fourier Transform (IFFT) of SEM scanning images. And then in-plane displacements field and local strain field related to the phase information will be evaluated. The digital phase moiré method is performed by the superimposition of the SEM images of specimen gratings and the digital reference grating designed. Four steps phase shifting technique is used to provide a high sensitivity for deformation measurement. Gaussian blur algorithm will be applied to getting rid of the details of both the specimen and reference gratings in resulting digital moiré. Obtained results show that both the two techniques can be well applied to the deformation measurement with nanometer sensitivity and stiction force estimation of a MEMS device.

Submission ID : ICEMA00329-00527

Presentation Type : Contributed Oral
Topic/Symposium : (A05) ESM: Whole-field distribution analysis of displacement & strain
Keywords : Displacements; Microscopy; Moiré

Recent Progress on the Full Filed Deformation Measurement in Micro/nano-scale Using Grating Techniques

Huimin **Xie**[1]; Kishimoto **Satoshi**[2]; Asundi **Anand**[3]; Fulong **Dai**[1]
1. AML, School of Aerospace, Tsinghua University, China
2. National Institute for Materials Science, Japan
3. School of AME, Nanyang Technological University, Singapore

The micro-electronic devices are greatly promoted with the rapid development of electronics industry. The study on the reliability of the micro-electronic devices is the foundation of designing novel electronic products, and the relative research has drawn great attention of the researchers. From the experiment aspect, the difficulty comes from the minute size of the measured object, whose deformation is hard to be measured using the traditional moiré technique.

In this study, the development of micro-moiré methods is introduced; grid phase analysis method under high resolution microscopes and the relative application to analysis of mechanics behavior of the micro-electronic devices are discussed. The successful results show that the methods have a good potential in the full field deformation analysis in micro-and nano-scale.

Submission ID : ICEMA00277-00556

Presentation Type : Contributed Oral
Topic/Symposium : (H06) HMIP: Digital image correlation and applications
Keywords : Correlation; Measurement; Thin films

CTE Measurement Using a Novel Deformation Pattern-based Digital Image Correlation

Zhanwei **Liu**; Jianxin **Gao**
TWI (The Welding Institute), Cambridge, United Kingdom

A novel digital image correlation method, deformation pattern based digital image correlation (DPDIC), was proposed for measuring residual stress in conjunction with a hole drilling technique in 2008. This study extends DPDIC to the measurement of the Coefficient of Thermal Expansion (CTE). With DPDIC, intrinsic parameters that represent a particular mechanical behaviour of an object under investigation are used as the direct variables in correlation computation. Here the intrinsic parameter is the CTE. This turns CTE measurement into a purely numerical computational process, i.e. a search of an optimal trial CTE that will maximise the correlation between the original digital image and deformed image (acquired at different temperatures of the test sample) with affine transformation. It leads to the direct output of CTE without the need to manipulate displacement data. Results of CTEs from DPDIC and conventional DIC methods are compared with the actual CTE, showing an improved accuracy. Further applications of DPDIC are expected to include other specific measurement tasks with known deformation patterns, such as the measurement of Poisson's ratio, stress intensity factors, J-integral etc.

Submission ID : ICEMA00383-00687

Presentation Type : Contributed Poster
Topic/Symposium : (A13) ESM: Experimental analysis of mechanical properties
Keywords : Thermography; Fracture; SEM

Damage Characterization in Composite Materials Using Infrared Camera

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The tensile testing was performed on polymer matrix composites, and high-speed infrared camera was used to characterize the damage evolution during the tests. The tensile specimens were prepared from glass fiber reinforced epoxy matrix composite panel. A high-speed infrared (IR) camera was employe d for in-situ monitoring of progressive damages, in terms of surface temperature of composite samples, d uring tensile testing. After tensile testing, the microstructural characterization using scanning electron microscope (SEM) was performed to correlate the mechanical failure mode with thermographic results. In this research, the IR thermography and SEM techniques were use d to facilitate a better understanding of damage evolution and failure mode of polymer matrix composite materials during tensile testing.

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Quantification of Osteoclastic Resorption Pit Volume using AFM

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Bone is regulated by the balance between bone forming osteoblasts and resorbing osteoclasts. Osteoclasts dissolve bone by acidification forming 3D excavations (pits) which lead to bone loss. The conventional tools for analyzing resorption pits are tartrate-resistant acid phosphatase (TRAP) staining and toluidine blue staining. These are qualitative 2D analysis of resorption pits observing TRAP activity, pit number, and multinucleated cell morphology. However, osteoclastic bone resorption occurs in 3D and quantification of the resorption depth is vital in understanding whether a trabecula has been disconnected. Therefore, it is important to quantify the 3D resorption volume which includes area and depth. In this study, we quantified osteoclastic resorption pit volume using atomic force microscope (AFM) and obtained the pit depth (maximum and average), area, and volume. Bone marrow cells were incubated in 25 ng/ml macrophage colony-stimulating factor (M-CSF) and 35 ng/ml receptor activator for nuclear factor κB ligand (RANKL) to differentiate osteoclasts. Dentine discs cultured with osteoclasts for 1, 2, 3 weeks were stained with toluidine blue. AFM was used to scan 3D pit topology and MATLAB was used to calculate volumetric integration. Currently, 1 week results have been obtained where AFM analysis resulted in a 2.5 μm max pit depth and 108,086 μm^3 pit volume after 1 week. We have shown that osteoclastic resorption pit can be quantified 3D using AFM. This technique may be applied in understanding how to maintain bone mass by controlling bone resorption.