The 21st Century COE Program
Mechanical Systems Innovation
The University of Tokyo

Newsletter

No. 11 E
Dec 1, 2006

The 21st Century COE Program
Mechanical Systems Innovation, The University of Tokyo

The 3 years of “Mechanical Systems Innovation” at the University of Tokyo

Three and a half years have already passed since the 21COE program began its research and education activities with the aim of providing improved comfort and secure societies for the diverse people of the world through the creation and application of new knowledge. Through active interactions between the project promoters and Ph.D students, our COE program has implemented cross-disciplinary fusional research activities with focus on energy and biomedical fields, which are indispensable fundamentals for individual life, and also a hyper modeling/simulation field, which supports leading-edge designs of mechanical systems. Now, these activities are yielding remarkable results. Meanwhile, our COE program also makes advancement in the reform of human resource development through industry-government-academia discussions and new educational programs at the graduate school level. Thanks to these efforts, the program has become recognized internationally as the center that makes contributions to achieving the aforementioned goals in the 21st century.

In the Energy Innovation Project, we have disclosed a Japan Energy Vision through industry-academia collaborations with major heavy electric machinery companies with focus on Japan’s energy security. Based on this vision, we have extracted technological issues and implemented several fundamental research projects. In addition, we have launched an Innovative Aerial Robot Project (IARP) for resource exploration and security surveillance. We participated in many activities both within and outside the university such as the Nagoya World Exposition and also organized aerial robot contests for students.

In the Biomedical Innovation Project, we have seen remarkable advancement in the fundamental research of human-friendly medical treatment, namely, non-invasive and low-invasive treatment, and remote medical systems. Integrating the interaction between micro-bubbles and ultrasound into advanced robotics technologies, we are now developing a new integrated system for diagnostic treatment. Furthermore, toward realization and spreading the state-of-the-art medical technologies, such as regenerative medicine, we have studied the effects of mechanical stress at the cell level on cell differentiation, while making progress in development of a micro cell separation device for extracting scarce cells from peripheral blood. These activities played an important part in the establishment of the Department of Bioengineering in 2006.

Nobuhide Kasagi
Program Leader

We have also advanced the hyper modeling and simulation technologies that support the designing of the inventive and cutting-edge mechanical systems mentioned above. Currently, we are developing computational methodologies which accurately analyze the multiscale problems that cover a wide range of issues from the molecular level to the continuum level, and also the multiphysics problems such as the complex mechanical, electromagnetic and chemical phenomena. In addition, we are making progress in simulating overall mechanical systems through large-scale computation and system optimization.

In this issue, we will take a look at some of the research results obtained under this 21COE program.

Energy Innovation Project

Research Initiative for Sustainable Society

Nobuhide Kasagi, Shigehiko Kaneko, Hiroshi Asano, Naoki Shikazono
Department of Mechanical Engineering, School of Engineering

The energy innovation project of the 21COE "Mechanical systems innovation" program is a collaboration between researchers from different departments, and is strongly focusing on relations with industrial world and the society. "Research Initiative for Sustainable Society" is a joint activity with four heavy electric machinery companies and was established in April 2004. In this work, long-term energy strategy and technological road map were discussed. Finally, the vision "Triple 50" was proposed, in which self-sufficiency ratio, fossil fuel dependence, and the energy utilization efficiency were improved to all 50% in 2030. Furthermore, joint symposia with "Holonic energy system (Tokyo Gas chair)", AIST (National Institute of Advanced Industrial Science and Technology) and JHIF (Japan Hydrogen Industrial Forum) were held, which all concluded with great success. Research achievements for biogas heat engines, solid oxide fuel cells and micro high value added energy devices can be noted as successful research topics in the project. Moreover, many COE members are giving lectures of above mentioned topics in "Energy and society" that started as a public course in school of engineering from April, 2006.

Energy・Trilemma
- Self-sufficiency ratio
- Use efficiency
- Dependence rate of fossil fuel

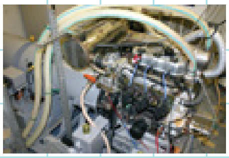
→

Energy Systems Innovation
- Fusion and Harmony (Large-scale and centralized, Individual dispersion
- Renewable Energy/Dispersion Energy
- Creation for new energy machine

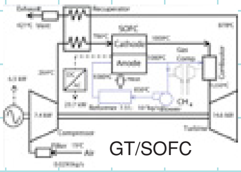
■ Holonic Energy Systems　Prof. Asano
Quantification of Distributed Energy Resource

■ Acceptable Biomass Fuel (Gas Engine, Gas Turbine)　Prof. Kaneko
Low calorie, Composition change

■ Micro gas turbine/Solid oxide fuel cell hybrid system　Prof. Kasagi
High thermal efficiency (> 60 %) Energy diversity



Bio gas engine

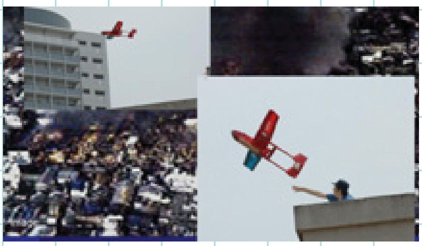


Hybrid system block diagram

Innovative Arial Robot Project

Shinji Suzuki, Kazuro Kageyama, Nobuo Takeda, Keiji Kawachi, Hideaki Murayama
Department of Mechanical Engineering, Department of Environmental & Ocean Engineering, School of Engineering

IARP (Innovative Aerial Robot Project) is a collaborative effort between the university and other public and private organizations. The project is organized within the framework of the COE program called "Mechanical Systems Innovation." We developed a series of small sized unmanned aerial vehicles in time for display at the NEDO Prototype Robot Exhibition held in June last year as a part of the Expo 2005 Aichi Japan. The developed aerial robots are small and lightweight, suitable for airborne imagery in emergency operation. We have been conducting flight experiments to explore their use for such purposes. For disaster-related applications, we have been participating in the emergency drill in Nagata Ward, Kobe along with MELCO and the University of Kyoto for two consecutive years since 2005. We flight-tested our robots for airborne imagery in simulated post-earthquake emergency operations. In November 2005, we photographed the reconstruction of former Yamakoshi Village using our robots. For non-time-critical applications, we saw their potential in environment monitoring missions, and conducted such experiments in November 2005 and in June 2006. We succeeded in the aerial imagery of the vegetation over the Yahata Moor using multi-band cameras developed by the Hiroshima Prefectural Forestry Research Center. Our technical development led to the successful autonomous takeoff and landing of the aircraft in April 2005, and we expect to see further expansion in the potential application areas of our systems. Designing, production, and testing of the aircrafts are led by the students. To promote such activities, we organized "The 1st National Indoor Aerial Robot Student Competition" in Ota Ward in January 2006. Twenty-two teams from ten universities and technical colleges participated in the competition, and a team from our university won the first prize in the airplane category. We would like to hold this competition every year, and we hope that it will evolve into a competition of international scope. The aircrafts that we exhibited at the expo is on display at the Engineering Building No. 11. It is expected to be in display until next summer. You are welcome to pay a visit and have a look at them.



Test Flight at emergency drill in Nagata Ward, Kobe

Success in Full Automatic Flight (2006.4)

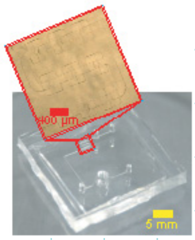
The 1st National Indoor Aerial Robot Student Competition at Oota Industry Plaza

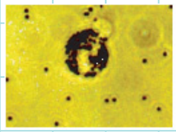
Biomedical Innovation Project

Micro-Cell-Processing System

Nobuhide Kasagi, Takashi Ushida, Yuji Suzuki, Naoki Shikazono, Katsuko Furukawa
Department of Mechanical Engineering, School of Engineering

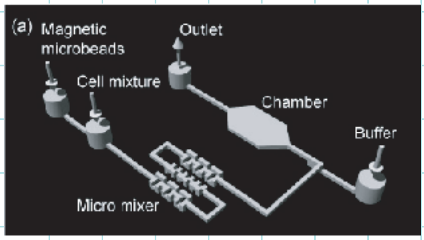
Regenerative medicine, a novel approach to regenerate damaged tissues has been recognized as a promising methodology, using potential capabilities of stem cells such as mesenchymal stem cells. However, technologies capable to separate stem cells from heterogeneous cell mixture, have not been established at clinical application levels. For that purpose, we have been developing a micro-cell-processing system, which can realize to separate stem cells from a small volume of cell suspension under flow conditions, by combining the following two kinds of approach: cone-plate-type rheometer and antibody-patterned surfaces with thermo-sensitive gel; MEMS-based micro-mixer and magnetic separator of target cells specifically bound to magnetic beads with antigen-antibody interaction.



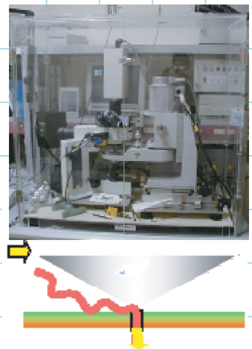


Cell attached with antibody-conjugated magnetic beads

antibody-patterned surfaces with thermo-sensitive gel



Micro-mixer cell separation system



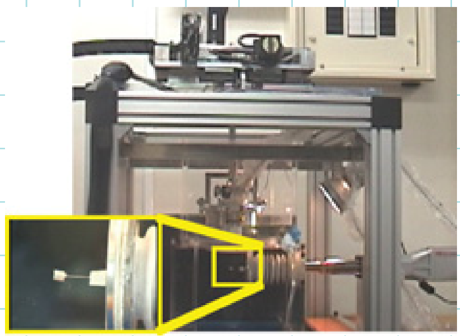
Cone-plate cell separation system

Non-Invasive Ultrasound Diagnosis and Treatment System

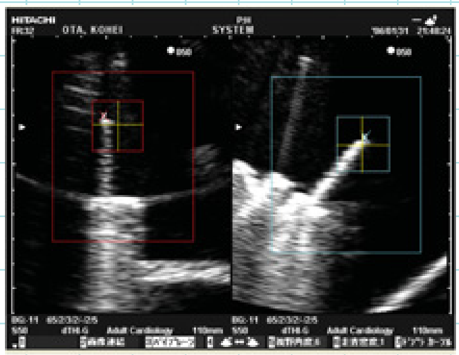
Yoichiro Matsumoto, Mamoru Mitsuishi
Department of Mechanical Engineering & Department of Engineering Synthesis, School of Engineering

It is possible to selectively diagnose and treat an abnormal body part noninvasively using HIFU (High Intensity Focused Ultrasound). The method is presented as an alternative to current surgical methods, such as conventional abdominal surgery and endoscopic surgery, and a number of new research studies have been reported in the area. The fundamental principle of CCL (Cavitation Control Lithotripsy) is that high frequency ultrasonic waves (3 MHz) produce micro-bubbles and lower frequency ultrasonic waves (550 kHz) erode the targeted renal stone. The renal stone is crushed by the energy generated by cavitation. One of the features of the method is that the debris particles from the renal stone are small enough to be safe for neighboring organs. One of the main problems with conventional HIFU systems is that they cannot compensate for the motion of internal structures caused by breathing, thereby increasing the ultrasound exposure of the peripheral organs of the patient and the workload on the surgeon. Therefore, it is desirable to control the focus of the ultrasound irradiation to follow the movement of the body parts under treatment as they move during respiration. To overcome this problem, an integrated system is proposed for non-invasive ultrasound diagnosis and treatment. In the system, the motion of the affected part is compensated by tracking it in the stereo ultrasound images.

The concept of the proposed system is to treat the cancer region or stone, such as a renal calculus, utilizing focused ultrasound without injuring the healthy tissues (skin, muscles, organs, etc.) of the patient, by tracking the affected part. The authors have implemented a prototype system, which tracks an artificial renal stone. In addition, the following experiment was conducted to crush a stone. The stone was moved in correspondence with the recorded input motion pattern of a real human kidney produced by respiration. In this test, it was found necessary to enhance the tracking performance from 2 mm to the sub-millimeter range to obtain a better result. In the future, the authors are planning to conduct clinical tests, including the treatment of various types of cancers.



Overview of the non-invasive ultrasound diagnosis and treatment system



Motion tracking of a model stone using the ultrasound image

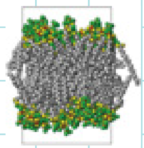
Hyper Modeling / Simulation Project

Multiscale analysis of microcirculatory system

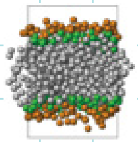
Yoichiro Matsumoto Department of Mechanical Engineering, School of Engineering

We are aiming at developing a technology to simulate human blood circulation by making progress in multiscale analyses which cover from molecular-level transportations into cells through biomembrane to continuum level fluid-structure coupling between blood flow and dispersed bodies.

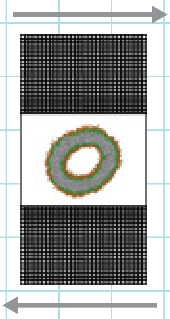
Molecular-scale phenomena have much effect on membrane transportation and physical properties of membrane. Therefore, we investigated lipid bilayers using molecular simulation methods such as the Molecular Dynamics (MD) method, Coarse-Grained Molecular Dynamics (CGMD) method, and Dissipative Particle Dynamics (DPD) method. We also employed MD-continuum hybrid simulation which couples atomistic simulation and continuum simulation and enables us to investigate meso- or macro-scale phenomena while retaining molecular-scale resolution near membrane. At a continuum scale, deformation and interaction of dispersed bodies such as red blood cells play an important role in the flow structure in a microcirculation. A coupled fluid-structure analysis between blood flow and dispersed bodies was conducted using Immersed-boundary method. We treated a Red blood cell and a giant vesicle (GV) as dispersed body and investigated the motion in a simple shear flow. Our scheme was validated through the comparison with the experiments. Moreover, we succeeded in simulating the dispersed bodies to pass through a microchannel with their shapes largely deformed.



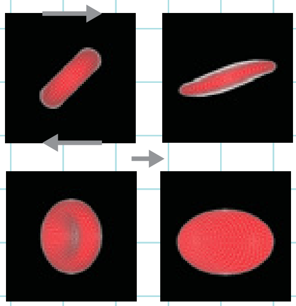
MD simulation of lipid bilayer



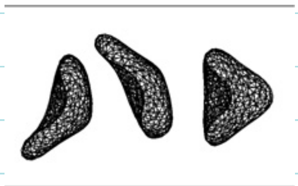
CGMD simulation of lipid bilayer



CGMD-continuum hybrid simulation of a lipid bilayer vesicle



Continuum simulation of a red blood cell in a simple shear flow



Continuum simulation of GVs in a microchannel

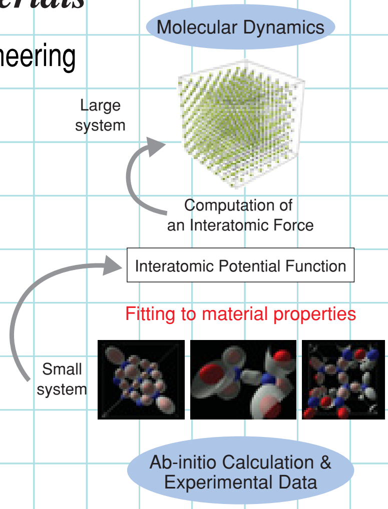
Multiscale analysis of mechanical properties of materials

Shinsuke Sakai Department of Mechanical Engineering, School of Engineering

The interatomic interaction is given in the Classical Molecular Dynamics Method as interatomic potential function. Although the interatomic potential function is normally determined for reproducing experimental values and the results of electronic state calculation, there is still no generic developing method established. Under the current research, we developed a 3-level method for the creation of interatomic potential function as follows:

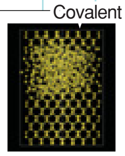
1. Determine the function form that indicates the binding conditions well.
2. Use robustness and properties for calculation purpose as add-in data.
3. Optimize through global method.

We developed a method consisting of the above three phases, improved the Tersoff potential, developed the interatomic potential that recreates the melting-point of silicon, developed the binary potential for Si-B system, and reproduced the diffusion of borons in silicon. We also created the binary ZrNi-EAM potential and succeeded in recreating the radial distribution function of the Zr70Ni30 amorphous structure.



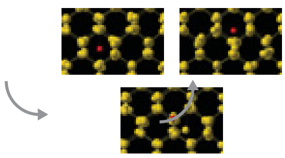
Application to the Covalent and Metallic Systems

Covalent System



Solid/Liquid equilibrium interface system with 1024 Si atoms

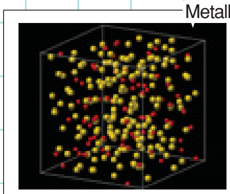
Reproduce a melting point of Si



Kick-out mechanism of Si atom in Si-B system

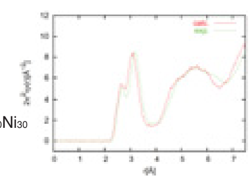
Reproduce a boron diffusion in Si

Metallic System



Reproduce a $Zr_{70}Ni_{30}$ Amorphous Structure

181 Zr atoms
75 Ni atoms
Amorphous $Zr_{70}Ni_{30}$



Radial Distribution Function of Amorphous $Zr_{70}Ni_{30}$

Developing Smart Composite Structures for Application to the Next-generation Japanese-Made Aircraft is My Dream.

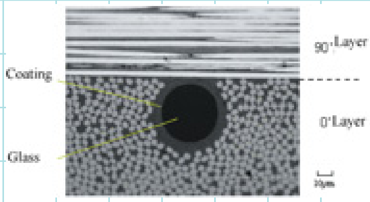
Professor Nobuo Takeda
Department of Advanced Energy, Graduate School of Frontier Sciences
Additional Post: Department of Aeronautics and Astronautics,
School of Engineering
(University of Tokyo)

• Developing composite material structures with embedded small-diameter fiber optic sensors.

Aircrafts require light and strong materials. CFRP (carbon-fiber reinforced plastics) with excellent properties are being extensively used to replace metals for the fuselage and wings of aircrafts in service in the next 2 or 3 years.

My research is concerned with smart material systems able to carry out self-monitoring of damages and self-repairs, hoping to apply such material systems in aircrafts or satellites.

We have developed unique small-diameter optic fibers measuring 40 μm in diameter, one-third of the usual one, and are the first in the world to have succeeded in embedding these fibers in CFRP. When equidistant gratings are inscribed into the core of the glass optic fibers, light signals with a certain wavelength are reflected and bounced back. This can be used as strain sensor called FBG (fiber Bragg grating) by analyzing the wavelength of this light and measuring the strain in the Bragg grating. Furthermore, the CFRP do not weaken in strength even with this type of FBG optic sensors embedded in CFRP structures.



CFRP laminate with embedded small-diameter fiber optic sensors.

• Constant search for originality in my research.

I decided to become a researcher after I saw the live broadcast of the launch of Apollo 11, when I was in my second year of senior high school. I had wanted to become a detective up to when I was in junior high, but gave up the idea because I was afraid of the sight of blood.

I knew I was not gifted and would be better being a research engineer than a scientist, and have since been working on advanced composite materials research. In the course of that I began asking myself constantly what the originality of my research is.

I wish for the young generation to always think about the originality of their own research. While today we can look up anything quickly on the Internet, I am concerned that many young people may be misled by the information they have obtained and forget to use their own thinking. It is vital for a researcher to come up with his or her own unique story and to explain it for others to understand.

To this end, language skills will also be essential. I myself have also spent a fortune in my younger days to acquire the English language as a skill, and I found the repeated shadowing method being the most effective.

When no ideas come to mind we can always turn to nature for inspiration. For instance, the reinforcing fibers of the bamboo to protect the branch are mainly distributed at the edges than in the middles burdened with weight when the bamboo is bent. Such amazing property of natural elements can unexpectedly offer hints.

I find reading a great way to refresh my mind during my one-hour one-way commute. A recent book of interest is “The Da Vinci Code”. The mystery books by the author Michael Connelly, a fellow student from The University of Florida, are my favorite. If I have free time then I go to the cinemas on Sundays. My favorites are of course detective films.

While looking at research works by other professors within the COE program on “Mechanical Systems Innovation”, I am hoping to also obtain cooperation from them. The root of my current research can be traced back to the time I spent at the Research Center for Advanced Science and Technology of the University of Tokyo, where I was located next door to Professor Hotate, a researcher on fiber optic sensors. Discussing ideas with researchers from different fields is a great stimulation, and can sometimes create new research fields.

Perhaps in about 10 years we might see the smart composite material systems we are developing now being used on next-generation aircrafts. About 35% of Boeing 787 parts now being produced are made by Japanese companies and are mostly made of composite materials. Our ambitious goal in the near future is to apply our systems to Japanese-made aircrafts.

<Profile>

Completed master in Aeronautics and Astronautics at the School of Engineering, University of Tokyo, in 1977. Entered Ph.D program in the same year. Entered Ph.D program in Engineering Mechanics at the University of Florida in 1978 and was later awarded his PhD title there. Returned to the Ph.D program at the University of Tokyo and received his PhD title in engineering. His experiences include working as researcher at the Takasaki Laboratory of the Japan Atomic Energy Research Institute, associate professor at Kyushu University (Applied Elasticity Division within the Research Institute for Applied Mechanics), associate professor at the University of Tokyo (Area of Robotics Material, Advanced Material Department at the Research Center for Advanced Science and Technology). Assumed current position in 1998.

Program Executive Organization

Project Promoters

Program leader

Nobuhide Kasagi
Professor, Department of Mechanical Engineering, School of Engineering

Energy innovation

Toshio Nagashima
Professor, Department of Aeronautics and Astronautics, School of Engineering
Chisachi Kato
Professor, Department of Mechanical Engineering, Institute of Industrial Science
Takayuki Terai
Professor, Department of Nuclear Engineering and Management, School of Engineering
Kazuro Kageyama
Professor, Department of Technology Management for Innovation, School of Engineering
Nobuo Takeda
Professor, Department of Advanced Energy, School of Frontier Sciences
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Biomedical innovation

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Professor, Department of Engineering Synthesis, School of Engineering
Teruo Fujii
Associate Professor, Department of Environmental and Ocean Engineering, Institute of Industrial Science
Takashi Ushida
Professor, Center for Disease Biology and Integrative Medicine, School of Faculty of Medicine

Hyper modeling / simulation

Yoichiro Matsumoto
Professor, Department of Mechanical Engineering, School of Engineering
Takafumi Fujita
Professor, Department of Engineering Synthesis, Institute of Industrial Science
Hideaki Miyata
Professor, Department of Environmental and Ocean Engineering, School of Engineering
Shinsuke Sakai
Professor, Department of Mechanical Engineering, School of Engineering
Shinobu Yoshimura
Professor, Department of Quantum Engineering and Systems Science, School of Engineering

Project members

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Yosuke Hasegawa	Project Research Associate, International Research and Education Center for Mechanical Systems Innovation, School of Engineering
Yoshiaki Akematsu	Project Research Associate, International Research and Education Center for Mechanical Systems Innovation, School of Engineering

Advisory Committee

Advisory Committee

Koutaro Inoue	Senior Fellow, Japan Science and Technology Agency
Noboru Kikuchi	Professor, The University of Michigan
Yoshitsugu Kimura	Professor Emeritus, The University of Tokyo
Tetsuya Tateishi	Fellow, National Institute for Material Science

Activities of Mechanical Systems Innovation Program

〈Open Seminars〉

◎**FY2006-1st Seminar**
Date : May 15th, 2006 14:00-16:00
Venue : Conference Room 1, Institute of Industrial Science, Komaba Campus
Subject: : 21st Century COE Mechanical Systems Innovation Open Seminar (IIS NonoBio Seminar/Foreign Researchers Seminar)
Speaker : Dr. Vincent Senez (CNRS/IEMN)
Dr. Taher Saif (University of Illinois at Urbana-Champaign)

◎**FY2006-2nd Seminar**
Date : June 5th, 2006 14:00-15:30
Venue : Lecture Room 72, Faculty of Engineering Bldg.7, Hongo Campus
Subject : Numerical Simulation of Mechanical Behavior of Composite Structures by Parallel Supercomputing Technology
Speaker : Dr. Seung-Jo Kim (Professor, Department of Aerospace Engineering, Seoul National University)

◎**FY2006-3rd Seminar**
Date : July 20th, 2006 14:00-15:30
Venue : Lecture Room 232, Faculty of Engineering Bldg.2, Hongo Campus
Subject : Scale Your Enthusiasm: Designing Nanomaterials
Speaker : Dr. Stephen O'Brien (Associate Professor, Materials Science and Engineering Department ofApplied Physics and Applied Mathematics, Columbia University)

◎**FY2006-4th Seminar**
Date : Sept. 22nd, 2006 10:00-12:00
Venue : Conference Room, Faculty of Engineering Bldg.7, Hongo Campus
Subject : Introducing the Sir Lawrence Wackett Centre for Aerospace Design Technologies
Speaker : Dr. Cees Bil (Associate Professor, Department of Aerospace Engineering, RMIT University)

◎**FY2006-5th Seminar**
Date : Oct. 18th, 2006 15:00-17:00
Venue : Conference Room 2-31A, Faculty of Engineering Bldg.2, Hongo Campus
Subject : On the Non-destructive Determination of the Mechanical Response of Engineering Materials Using Pattern-recognition and Classification Methodology
Speaker : Dr. Y. M. Haddad (Professor, Department of Mechanical Engineering, University of Ottawa)

◎**FY2006-6th Seminar**
Date : Nov. 2nd, 2006 10:30-11:30
Venue : Lecture room 72, Faculty of Engineering Bldg.7, Hongo Campus
Subject : Influence of NDE/SHM on Aircraft Structural Design
Speaker : Dr. Christophe Paget (Airbus UK)

〈Domestic Symposium〉

◎**The 2nd symposium on Holonic Energy Systems**
Date : July 10th, 2006
Venue : Takeda Hall, Takeda Building, Asano Campus

The 21st Century COE Program Mechanical Systems Innovation,Newsletter No.11E

Dec 1, 2006
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