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

Newsletter

No. 4 E
December 1, 2004

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

Energy Innovation Project

In order to enrich human life, it is increasing necessary not only to deliver stable electric power, but also to provide users with various options for its delivery, such as a stationary small-scale distributed energy systems and mobile energy sources to power communication to devices and patient care equipment.

Future power technologies should also contribute to the safety and security of human society by reducing environmental load due to energy consumption, monitoring living environments, and exploring new natural resources in the ocean and in space.

In this newsletter, some of fundamental researches related to energy and environment are introduced.

Technology for resources recycling

—Toward a sustainable social system—

Recycling Technology

Toyohisa Fujita, Professor
Department of Geosystem Engineering

Energy saving and environmental friendly techniques are being developed in our laboratory. The examples are as follows: electrical disintegration and explosive fragmentation of electric parts, flotation and leaching of rare metals, air separation and triboelectric separation of plastics, magnetic separation, wastewater treatment and soil remediation etc. The purpose is to create a sustainable development of human activity.

Air separator of plastics

Leaching of gold

New crushing and fragmentation

Triboelectric separator

Separated cell phone

Flotation & sink-float separator

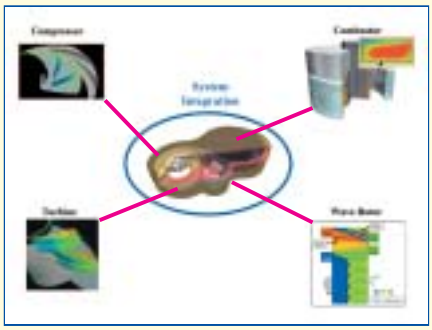
Micro energy conversion system
—Development of innovative mobile power sources—

Innovative Miniature Gas Turbine

Toshio Nagashima, Professor
Department of Aeronautics and Astronautics

Just as we presently enjoy a lap-top computer and cell phones for personal use, our ubiquitous society in the near future would ensure individual management of energy devices for electricity, air conditioning and transport, which all in all could profoundly expand the freedom of our social activities. The battery, though convenient and good in specific output [W/kg], is not satisfactory with respect to specific energy [W-hr/kg] for longer use of the above mobile info-communication devices, not to mention about inadequate application for actuating robots and UAV propulsion. Whilst, the fuel cells, typically DMFC and PEFC, are able to keep continuing use for a longer period, but their specific output may be poor and unsuitable for mobile compactness. Internal combustion engines, which are good in both specific output and energy because of fuel chemical property, are advantageous for miniaturization.

The present research program aims to establish a technical data base for designing further extremes of miniature gas turbine system, that is, thermal, fluid dynamic and structural integrability, as well as the performance prediction and improvement in major components like compressor, turbine and combustor, in addition, newly a wave rotor, that requires more precise and advanced knowledge about non-adiabatic and low Re number flows, fuels and mixing to result in stable micro flame, bearings and seal to sustain over-million rpm rotation, manufacture tolerance, ultra-compact motor and electric generator.



Numerical analysis of each component and system integration

Prototyping of a Very Smallsized Radial Gas Turbine

Chisachi Kato, Professor
Department of Mechanical Engineering

A very small-sized radial gas turbine that installs a several-mm impeller has ten to hundred times greater power as well as energy density than batteries and fuel cells and is therefore expected as a promising candidate for next-generation portable power source for lap-top computers and cell phones. We are developing a very small-sized and high-efficiency radial turbine impeller, one of the key components for such a power source. The shape of the turbine must be restricted to two-dimensional when it is fabricated with MEMS. But, little is known regarding the aerodynamics of a two-dimensional radial turbine. As the first step, we are prototyping radial turbines with 40 mm impeller and measuring their adiabatic efficiencies by air test (figure 2). We are also developing 8 mm radial turbine as shown in figure 3.

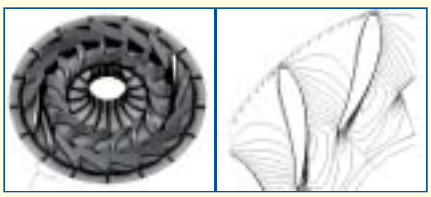


Fig.1 Computationally predicted internal flow in 2-D radial turbine.

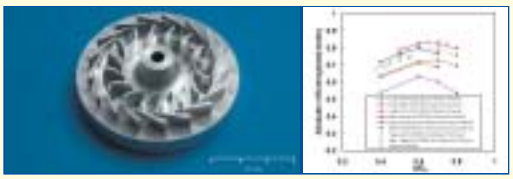


Fig.2 Fabricated 40 mm radial turbine (left) and measured adiabatic efficiencies (right).

Fig.3 8mm turbine rotor with (left) and experimental setup for performance measurement (right).

High-efficiency fuel cell power generation system

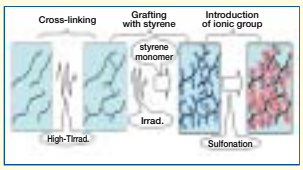
—From development of a new electrolytic film to simulation of heat and fluid flow inside a cell—

Synthesis of Polymer Electrolyte Membrane for PEFC

Takayuki Terai, Professor
Department of Quantum Engineering and System Science

Hydrogen energy system is expected as an secondary energy system, and "fuel cell" is a key technology. We are investigating the improvement of PEFC (Polymer Electrolyte Fuel Cell) , which has some advantages including low operating temperature. In particular, we are developing a new polymer electrolyte membrane, and successfully synthesized a new polymer membrane from cross-linked poly-tetra-fluoroethylene (PTFE) with radiation grafting reaction. It has some advantages such as higher strength, lower swelling for water or methanol, higher proton conductivity and lower fabrication cost than the currently used Nafion membrane. In addition, we simulated the molecular structure of the membrane using the dispersed particle dynamic method and found the the formation of water molecule clusters in the membrane.

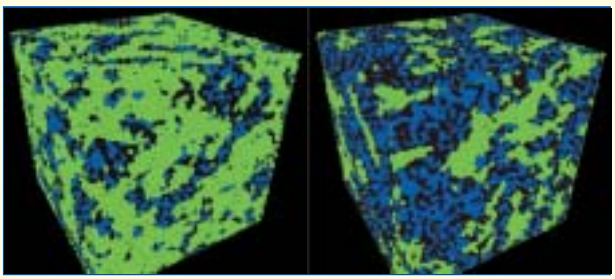
Fabrication of Water Electrolysis Cell using PEFC



Synthesis of PEFC Membrane

Fabrication of MEA

Carbon sheet with Pt catalyst (5cm^2)

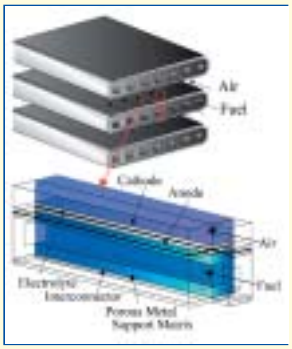


Structure Analysis of the Cross-linked PTFE Electrolyte by the Dispersed Particle Dynamic Method (Water molecule clusters are shown by the blue zones)

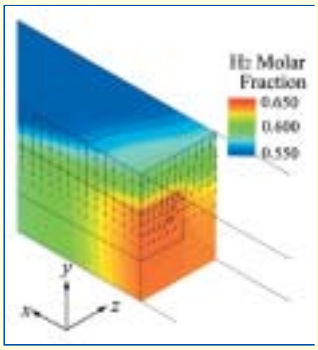
Numerical Simulation of Thermochemical Reaction inside a Fuel Cell

Nobuhide Kasagi, Professor
Department of Mechanical Engineering

Fuel cell is one of the most promising energy conversion processes. Especially, the solid oxide fuel cell (SOFC) is expected to achieve very high efficiency for a wide power output range, and its prospective application extends from large power plants to small-scale distributed generation systems. The objective of this work is to develop high performance SOFC by managing temperature distribution and promoting mass transfer in a cell. The heat and mass transfer as well as electrochemical reactions in the cell are solved simultaneously to predict the performance of the cell. We also try to propose new cell configurations and operating methods to achieve even higher efficiency with this cell and system simulator.



Computational model of the SOFC



Velocity and hydrogen molar fraction profile at the cell inlet

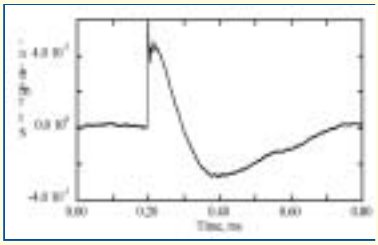
Development of innovative intellectual materials
—Monitoring technologies for ensuring human safety—

Fiber-Optic Sensing

Kazuro Kageyama, Professor
Department of Environmental
and Ocean Engineering

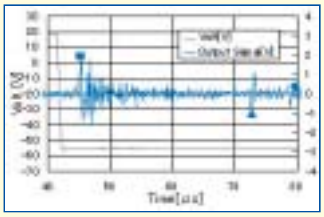
We found a new phenomena in optical fiber; “Doppler Effect in Flexible and Expandable Light Waveguide (DEFEW)”. We and our company have developed a new fiber-optic vibration/acoustic sensor based on the principle.

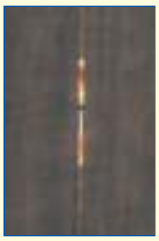
DEFEW sensor has very wide frequency range and extremely high sensitivity and applicable to structural health monitoring such as bridges, buildings, airplanes, underground structure, energy related plants, etc, by measuring and analyzing AE and vibrations.



Elastic wave emitted by fiber breakage

Sensor under the elevated temperature



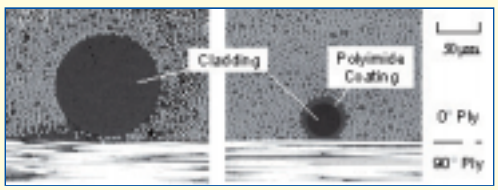


Impact by
electric discharge

Structural Health Monitoring of Advanced Composite Structure System

Nobuo Takeda, Professor
Department of Aeronautics
and Astronautics

Advanced composites have been extensively used especially in recent aerospace structures. For such applications, a structural health monitoring (SHM) system is highly required to detect the damage type, location and size, and to judge the structural integrity in real time. We have been developing a small-diameter optical fiber and its FBG (fiber Bragg grating) sensor which is 1/3 in diameter of a conventional optical fiber. Embedment into a CFRP composite structure and its impact damage monitoring were successfully shown in our composite fuselage demonstrator test. Further development is underway for real applications to next-generation civil aircraft. Moreover, CFRP structures and SHM system are also necessary in space structures, such as CFRP cryogenic tanks for reusable launch rockets and satellite structures. We have been providing some important academic contributions to the technological development with our unique ideas.



Uncoated normal
FBG sensor
Cladding:ϕ125μm

Polyimide-coated
small-diameter
Fbg sensor
Cladding:ϕ40μm
Polyimide Coating:ϕ52μm

Wireless Onboard system

Exploration natural resources and use of space energy
—In search of unknown energy resources—

See-bed Resources Exploration

Tamaki Ura, Professor
Department of Environmental
and Ocean Engineering

Since 1984, Ura laboratory, Institute of Industrial Science, the University of Tokyo is continuing R&D activities of the Autonomous Underwater Vehicles (AUVs).

AUV “r2D4”, completed in July 2003, is the latest version of the ocean-cruising type AUV of our group, major missions of which are automatized investigation of ocean resources and undersea singular regions, such as hydrothermal vents. Since its launch, “r2D4” has already completed a few undersea missions, e.g., full autonomous survey of Rota underwater volcano, located at Mariana back-arc basin within Mid-west Pacific.

In May 2005, “r2D4” is planned to be deployed at Myojinsho off Izu-Ogasawara Islands. As the result of this mission, numerous valuable information about deep sea hydrothermal vents are hopefully to be obtained, which are known to have close relation with undersea earthquakes and volcanic activities.

AUV “R-One Robot”

AUV “Tri-Dog1”

AUV “r2D4”
under deep sea mission

A Snapshot of the plume issuing from a hydrothermal vent at Rota - taken by “r2D4” fully autonomously

Rota undersea volcano and survey trajectory by “r2D4”

Nano-Satellites

Shinichi Nakasuka, Professor
Department of Aeronautics
and Astronautics

We have been studying nano-scale satellites of 0.5kg to 5kg. We launched the world smallest satellite named “CubeSat” (1kg, 10cm cubic) successfully in June 2003, which has been operated on orbit for more than one and half year. Besides, 350ml juice-can sized satellite “CanSats” have been developed. While the national space development seems to come to dead-end because of enormous cost (several million US $ per satellite) and extremely long development time (3-5 years), we are pursuing much lower development cost and much shorter development time for satellites in order to open novel ways of space utilization. Nano-Satellites require different architecture, different ways of achieving certain functions and different players from those for conventional satellites. We are carrying out joint satellite projects with Higashi-Osaka small companies to realize a novel satellite concept “PETSAT,” studying how to deploy small satellite into a large one on orbit, and developing nano-scale Earth observation system suited for nano-satellites. Hand-made nano-satellites are also providing us with excellent material for practical space engineering education, and its tremendous effects not only on technological training but also on project management training for large scaled project has been observed.

CanSat

CubeSat

CubeSat and
Captured Earth Image

PRISM: 5kg Earth
Observation Satellite

Panel Extension Satellite “PETSAT”

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 Human and Society, Institute of Industrial Science

Takayuki Terai
Professor, Department of Quantum Engineering and System Science, School of Engineering

Kazuo Kageyama
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Nobuo Takeda
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Toyoshisa Fujita
Professor, Department of Geosystem Engineering, School of Engineering

Biomedical innovation

Mamoru Mitsuishi
Professor, Department of Engineering Synthesis, School of Engineering

Masao Washizu
Professor, Department of Mechanical Engineering, School of Engineering

Masayuki Nakao
Professor, Department of Engineering Synthesis, School of Engineering

Teruo Fujii
Associate Professor, Department of Environmental and Ocean Engieering, Institute of Industrial Science

Hyper modeling / simulation

Masahiro Shoji
Professor emeritus, Department of Mechanical Engineering, School of Engineering

Yoichiro Matsumoto
Professor, Department of Mechanical Engineering, School of Engineering

Takafumi Fujita
Professor, Department of Information and System, 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

Specially appointed members

Kensuke Tsuchiya
Specially Appointed Research Associate, International Research and Education Center for Mechanical Systems Innovation, School of Engineering

Yosuke Hasegawa
Specially Appointed Research Associate, International Research and Education Center for Mechanical Systems Innovation, School of Engineering

Advisory Committee

Advisory Committeemen

Koutaro Inoue	Senior Fellow, Japan Science and Technology Agency	Yoshitsugu Kimura	Chair, President, Kagawa University
Noboru Kikuchi	Professor, The University of Michigan	Tetsuya Tateishi	Professor, Tokyo Denki University

Activities of Mechanical Systems Innovation Program (scheduled)

〈Open Seminars〉

◎FY2004-8th Seminar
Date : September 10, 2004
Venue : Lecture Room No.226, Faculty of Engineering Bldg.7, Hongo Campus
Speaker : Prof. Seung Jin Song (Department of Mechanical and Aeronautical Engineering, Seoul National University)
Subject : Rotor Dynamics in Turbomachinery

◎FY2004-9th Seminar
Date : September 28, 2004
Venue : Lecture Room No.27, Faculty of Engineering Bldg.2, Hongo Campus
Speaker : Prof. Ahmed F. Ghoniem (Department of Mechanical Engineering, Massachusetts Institute of Technology)
Subject : Combustion Dynamics and Control: Mechanisms, Simulations, Modeling and Design

◎FY2004-10th Seminar
Date : November 9, 2004
Venue : Conference Room No.1, Institute of Industrial Science, Komaba Campus
Speaker : Dr. Wolfgang Fritzsche (Department Biotechnical Microsystems, Institute for Technology Jena)
Subject : Bridging Molecular Constructs with the Macroscopic World: Concepts Based on a Combination of Biomolecular Self Organization and Microsystem Technology

◎FY2004-11th Seminar
Date : November 11, 2004
Venue : Lecture Room No.84, Faculty of Engineering Bldg.8, Hongo Campus
Speaker : Dr. Wolfgang Fritzsche (Department Biotechnical Microsystems, Institute for Technology Jena)
Subject : Bridging Molecular Constructs with the Macroscopic World: Concepts Based on a Combination of Biomolecular Self Organization and Microsystem Technology

◎FY2004-12th Seminar
Date : November 22, 2004
Venue : Lecture Room No.226, Faculty of Engineering Bldg.8, Hongo Campus
Speaker : Dr. Sivaram Arepalli (NASA-Johnson Space Center)
Subject : Single Wall Carbon Nanotube Research at NASA-Johnson Space Center

◎FY2004-13th Seminar
Date : December 3, 2004
Venue : Seminar Room No.2, Faculty of Engineering Bldg.2, Hongo Campus
Speaker : Dr. Christopher Hebling (Fraunhofer Institute for Solar Energy Systems)
Subject : Micro Energy Technology by means of Micro Fuel Cells, Device Integrated Solar Cells, Thermophotovoltaics and Laser Power Transmission

◎FY2004-14th Seminar
Date : December 13, 2004
Venue : Lecture room No.226, Faculty of Engineering Bldg.8, Hongo Campus
Speaker : Dr. Peigang Deng (Department of Mechanical Engineering, The Hong Kong University of Science and Technology)
Subject : Micro Bubble Actuator for DNA Hybridization Enhancement

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December 1, 2004
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