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

Newsletter

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

No.2E
October 1, 2004

Hyper Modeling and Simulation Project

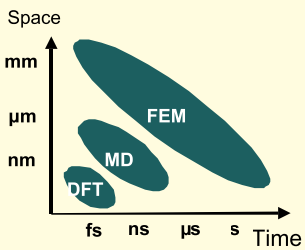
To cultivate and create various kinds of future technologies to better human life, it is indispensable to establish powerful design methodologies incorporating high performance simulations that accurately model the complex multi-scale and multi-physics phenomena that occur internal and external to real mechanical systems.
Such engineering methodologies must be developed based on a hierarchy from quantum to continuum mechanics, and advanced modeling should be promoted for micro and nano scale fundamental processes, physics and chemistry at interfaces between different phases, nonlinear multi-scale and biochemical phenomena, and so forth.
In this letter, researches related to modeling and simulation which provide the foundation for future mechanical systems are introduced.

Establishment and enhancement of multi-physics and multi-scale analysis methods ~Construction of a hierarchical dynamical system from quantum mechanics to continuum mechanics~

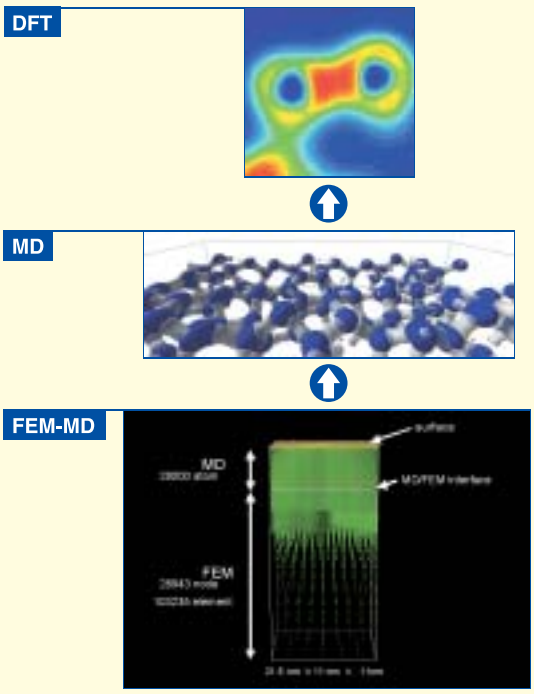
Multi-scale Analysis for Mechanical Properties of Materials

Shinsuke Sakai, Professor
Department of Mechanical Engineering

Our group pays attention to the multi-scale analysis for the mechanical properties of solid, which covers the density functional theory (DFT), molecular dynamics simulation (MD) and finite element method (FEM). The left figures illustrate the multi-scale analysis for the surface of silicon. Since the electron-level defects affect the macroscopic properties such as intrinsic stress and elastic constants, microscopic investigation is indispensable.



Spatio-temporal scales and numerical methodologies



Multi-scale analysis for the surface of silicon

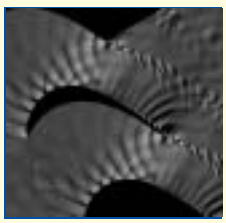
High performance simulations of complex phenomena
~Coupled fluid-structural analysis ~

Prediction of Internal Flows of Turbomachinery

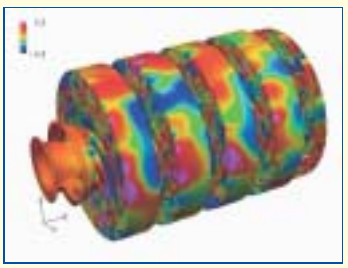
Chisachi Kato, Professor
Department of Mechanical Engineering

Reynolds-Average Navier-Stokes Simulation (RANS) that is most widely used for the prediction of internal flows of turbomachinery, has essential limitations in terms of its computational accuracy and is not applicable to the predictions of the unsteady turbulent flows. We therefore applied Large Eddy Simulation (LES) to the predictions of internal flows of turbomechinery. This has enabled accurate predictions of flows with large separation, transitional flows and flow-induced noise.

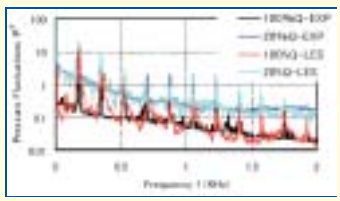
Computed large-scale recirculating eddies in impellers' inlet



Computation of transitional flow in a turbine cascade



Predicted surface-pressure fluctuation for a multi-stage centrifugal pump



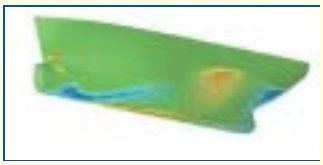
Comparisons of pressure-fluctuation spectra with measurements

Motion Simulation for Ships in Waves of Very High Amplitude

Hideaki Miyata, Professor
Department of Environmental and Ocean Engineering

Ships are designed with the postulation that they may encounter waves of 30m amplitude in their whole life of about 20 years. On the other hand, it is very usual for them to encounter waves higher than 10m in one to several years, and it is often the case that they receive structural damage at some portion of the ships hull. In these heavily rough sea conditions a variety of nonlinear phenomena take place, such as ship slamming, generation of wave impact pressure, heavy wave breaking, and so on. Because it has been so far difficult to realize and understand the structure and mechanism of these extremely nonlinear phenomena, the design of the hull structure from the strength stand-point of view is based on experience and simplified models.
The present simulator makes use of the finite-volume method and the density function, and going to succeed in the realization of the strongly nonlinear phenomena. Since the accuracy in the pressure prediction is on the satisfactory level, this simulator is used in the practical design process at ship design offices.

Numerical model of a ship in waves of high amplitude



Numerical prediction of waves and pressure distribution around a ship

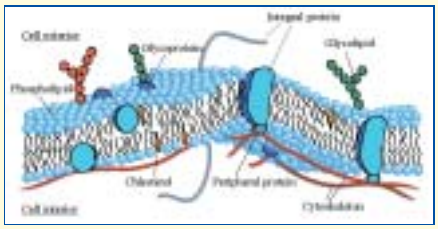
Hyper modeling and simulation for future biomedical innovation ~From molecular analysis of biomedical membrane to biofluidics~

Analysis of Microcirculation System of Blood

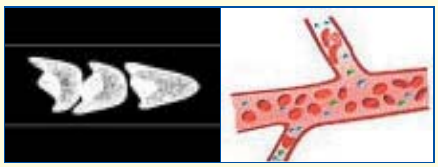
Yoichiro Matsumoto, Professor
Department of Mechanical Engineering

The development of simulation tools for the circulation of blood in the human body is getting more important for the achievement of advanced medical care for cardiovascular diease, cerebrovascular disease, and others, which are becoming increasingly serious problems in the aging society. Especially, the blood flow in capillary vessels plays an important role for many kinds of molecular transfer to/from the surrounding cells. In these flows, the mechanical properties of dispersed bodies such as red blood cells and mass transfer in molecular level are closely related each other. To evaluate the effect of these factors quantitatively and to control them effectively, development of the simulation tool, which can handle the multi-scale physics from the molecular scale to continuum scale, is required. In the present study, we are developing the simulation tool to analyze these kinds of complicated microcirculation systems rationally and accurately.

Multi-scale analysis for the circulation of blood



Molecular analysis of biological membrane



Fluid-structural interaction between dispersed bodies and blood

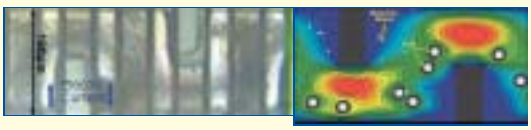
Micro Cell Processing

Nobuhide Kasagi, Professor
Department of Mechanical Engineering

Regenerative medicine is a promising future biomedical technology, in which multipotent stem cells are cultured to proliferate indefinitely or differentiate into various tissues and transplanted to damaged or deficit tissues and/or organs.
Currently, the design methodology as well as prototype development of a miniaturized cell sorting system are being studied with micro fluidic components integrated on a single chip of several square centimeters in order to achieve minimized sample size, fast processing and lower cost.
Specifically, a micro chaotic mixer has been developed, utilizing magnetic force as external perturbations to induce Lagrangian chaos.
Numerical simulation of microscale multiphase fluid flow, including motion of cells with deformation, antigen/antibody reactions at the cell membrane, and magnetic-bead motion under a time-varying magnetic field will lead to a highly integrated design and analysis tool for physical phenomena related to biofluidic processing.

Immunomagnetic cell sorting

Micro immunomagnetic cell sorting



Motions of cells and magnetic beads in a micro chaotic mixer, left figure: experimental result, right figure: numerical result

Program Executive Organization

Project Promoters

Program leader

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Energy innovation

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Hyper modeling / simulation

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Specially appointed members

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

〈Open Seminars〉

◎FY2003-4th Seminar
Date : January 8, 2004
Venue : Lecture Room No.73, Faculty of Engineering Bldg.7, Hongo Campus
Speaker : Dr. Lim Chwee Teck (Division of Bioengineering, Faculty of Engineering, National University of Singapore)
Subject : Nanomechanics of Biological Structures & Biomaterals

◎FY2003-5th Seminar
Date : January 7, 2004
Venue : Conference Room No.1, Institute of Industrial Science, Komaba Campus
Speaker : Dr. Lim Chwee Teck (Division of Bioengineering, Faculty of Engineering, National University of Singapore)
Subject : Nanomechanics of Biological Structure & Biomaterials

◎FY2003-6th Seminar
Date : January 15, 2004
Venue : Lecture Room No.125, Faculty of Engineering Bidg.8, Hongo Campus
Speaker : Prof. Constantine Megaridis (Department of Mechanical and Industrial Engineering, University of Illinois)
Subject : Fluid Transport, Phase Change and Wetting Behavior of Multiphase Fluids inside Carbon Nanotubes

◎FY2003-7th Seminar
Date : February 24, 2004
Venue : Conference Room No.4, Institute of Industrial Science, Komaba Campus
Speaker : Dr. Sander Koster (Institute of Microtechnology, University of Neuchatel)
Subject : Microfluidics: New Tools to Study the Response of Cells to Chemicals

◎FY2003-8th Seminar
Date : March 3, 2004
Venue : Seminar Room No.2, Faculty of Engineering Bldg.2, Hongo Campus
Speaker1 : Dr. Hidenori Otsuka (National Institute for Materials Science)
Subject1 : Control of Interfacial Nano Structure and Spheroid Array
Speaker2 : Prof. Masaharu Takeuchi (Institute of Industrial Science, The University of Tokyo)
Subject2 : Bio Hybrid System
Speaker3 : Dr. Sander Koster (Institute of Microtechnology, University of Neuchatel)
Subject3 : Microfluidics: New Tools to Study the Response of Cells to Chemicals

◎FY2003-9th Seminar
Date : March 19, 2004
Venue : Lecture Room No.73, Faculty of Engineering Bldg.7, Hongo Campus
Speaker : Dr. Peter G. Ifju (Department of Mechanical and Aerospace Engineering, University of Florida)
Subject : Micro Air Vehicle Research at the University of Florida

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