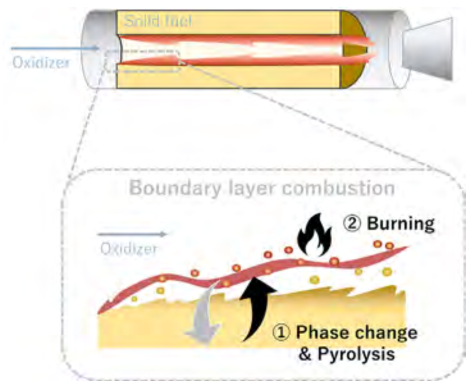
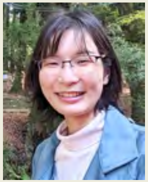
Combustion Mechanisms of Hydrocarbon-based Solid Fuels for Hybrid Rockets

Rocket engines are used in rockets for transporting people and goods into space and in various other applications. Sounding rockets conduct observations and experiments while flying ballistically over the Earth, and thrusters are used for space probes that navigate through space. **Hybrid rockets**, which use **hydrocarbon-based polymer** materials as solid fuel, are being researched and developed worldwide as a safe and low-cost replacement for conventional rocket systems. My research field is the **combustion** of the solid fuels used in hybrid rockets, and my research is aimed at elucidating the combustion mechanism of hydrocarbon fuels that burn in the extreme environments with high temperature and high pressure inside rocket engines. Just as ice changes to water and then to steam when heated, solid fuels derived from polymeric materials undergo a phase change and pyrolysis when burned. To elucidate each phenomenon, we are conducting research using knowledge from various fields such as analytical chemistry and combustion engineering.



Hybrid rockets using hydrocarbon-based polymeric materials as solid fuel undergo a phase change and pyrolysis phenomena on the burning surface.

About Researcher



BANNO Ayana, Ph.D.

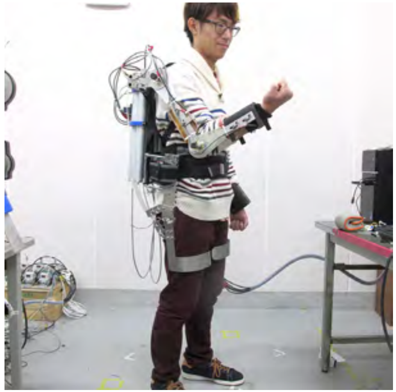
Ph.D., 2022, Chiba Institute of Technology

WEB ≫ https://ds.cc.yamaguchi-u.ac.jp/~w3nainen/

Control Technology Helps Human and Machine to Work Better

Control is an engineering art which not only serves for modern, high quality manufacturing but also enables human and machine to collaborate in a better fashion. Together with the recent developments of computing technology, now control can be deployed almost everywhere we wish to, and we aim to fully utilize it to establish a highly sophisticated relationship between humans and machines. Our research activities in this field include 1) **development of a powered exoskeleton** working in phase with human motion, 2) **biorhythmic signal analysis for system integration**, and 3) development of a human machine interface using an out-of-head sound localization and binaural robotic audition system.

We also put our continuous efforts into the development of control technologies that include 4) **modeling and compensation of rate-dependent hysteresis** of a piezo-ceramic actuator and 5) motion control of a bicycle. Control technology, together with ubiquitous computing power, accelerates the integration and improvement of systems, and we are interested in the implementation of system technologies to improve everyday life.



The 2nd prototype of our powered exoskeleton driven by McKibben artificial muscle

About Researcher

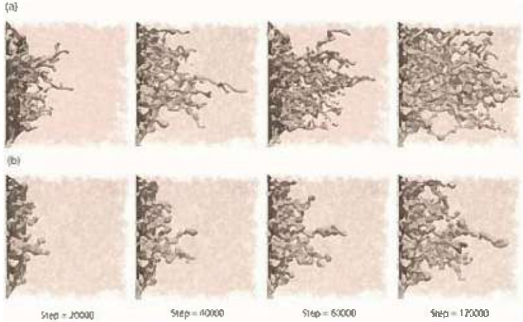
FUJII Fumitake, Ph.D.

Ph.D., 2002, Tokyo Institute of Technology

WEB ≫ http://ds0n.cc.yamaguchi-u.ac.jp/~ctrl_lab/

Investigations of Complex Fluid Systems using High-Performance Computing Techniques

Our research focuses on the development of high-performance numerical schemes for complex fluid system analyses for fields such as bio-fluid mechanics and hydrological systems. The lattice Boltzmann method (LBM), as a novel computational fluid dynamics scheme, is studied for the accurate modelling of complex flow behaviours. Compared to conventional Navier-Stokes-based solvers, the LBM presents many advantages including simplicity when dealing with complex boundaries and incorporating microscopic physical processes and is easily rendered parallel. Our on-going research topics include 1) multiphase modelling using the phase field concept, 2) fluid-structure interaction modelling with coupled LBM-FEM (finite element method), 3) species and thermal transport modelling with coupled LBM-FVM (finite volume method) and 4) high-performance computing using innovative graphics processor unit parallel techniques. The applications of these developmental schemes include investigations of suspensions of deformable particles, e.g. red blood cells, in microfluidic devices and respiratory airflow characteristics in human airways.



Two-phase flow simulation in a porous medium: (a) injecting fluid with low interfacial tension and (b) injecting fluid with high interfacial tension.

About Researcher

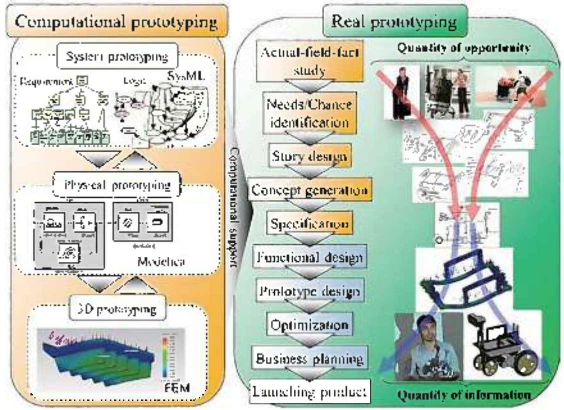
JIANG Fei, Ph.D.

Ph.D., 2013, Kyushu University

WEB ≫ http://www.bme.mech.yamaguchi-u.ac.jp/jiang/

Design Engineering for Creative Prototyping

This research is interested in one question: what factors make someone a creative designer? One conceivable factor is whether the person knows the actual **processes involved in creating new value**, because challenging design is interesting for many people. In order to realize new value, prototyping is effective because there are a huge number of problems, difficulties, and competitors in the world. More and higher quality prototypes **reduce problem solving costs down the road and** manpower to acquire feedback from customers, and allow for design concept improvement.
The figure shows a hypothesis for prototyping processes in this research. The left side shows a **support process, performed by computer**. System prototypes, which include software, sensors, and controlling logics, are assisted by computational definition methodologies and checking algorithms. A prototype which includes multidisciplinary physical phenomena such as mechanical dynamics and electrical / hydraulic system is simulated computationally. Real prototyping processes are assisted by these computational support methodologies. These processes include marketing, functional design, evaluation and optimization, and business planning. The innovative process intermediates mechanical engineering field and MOT (Management of Technology) field.



Prototyping process and computational support methodology for innovation from marketing to business planning.

About Researcher

KOGA Tsuyoshi, Ph.D.

Ph.D., 2005, The University of Tokyo

WEB ≫ http://zairiki.mech.yamaguchi-u.ac.jp/

Psycho-Social Multi-Engineering for IoT in Neuroscience, Education, and Clinical Biology, from Infants to the Elderly

Mental development is diversified over a lifetime through varying environmental processes, the mechanisms of which may be understood and supported by improving the internet of things technology for our own arbitrary self-management. To achieve application to novel functions such as psycho-developmental diagnosis and mental intervention in our social lives, we need a **meta-field networking** under the basic considerations of neurobiological psychiatry and engineering. This study aims to organize multiple scientific fields in real human lives, from babies to adults and the elderly, for the purpose of **human brain evolution**. To compare or understand in different species, generations or situational states, the common metaphase communication tools were crucial for the inclusive analyses. The expression of mental modulation should be described by certain quantic and multiple correlations using computing methodology. Moreover, the acquisition tools should satisfy a stress-free function that usually corresponds to stressfulness in analyzers. We therefore develop demanding points for realizing innovative life technology with interactive perspectives in the thermal physics, space and information sciences, cognitive and genetic biology and social sciences, which will actually create our next generation.

The Internet of Things (IoT) realizes human mental and physical evolution based on diverse / integrated sciences.

About Researcher

KOSHIBA Mamiko, Ph.D.

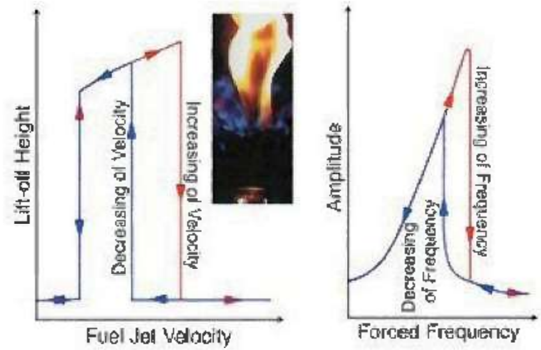
Ph.D., 2005, Tokyo University of Agriculture and Technology
Bachelor of Musical Performance (Piano)

WEB ≫ https://researchmap.jp/7000010297?lang=en

Investigation of Similarity between Different Systems

Our research into the behavior of a lifted flame fueled by propane on a bluff-body burner under the airflow dominant condition, with a higher annular airflow velocity and a lower central fuel jet velocity, reveals the appearance of the hysteresis phenomenon in the lift-off height of the flame, depends on fuel jet velocity history. It is quite interesting that the hysteretic behavior of the lift-off height is similar to that of the amplitude in "Mode Jumping", which occurs as a nonlinear resonance in nonlinear oscillatory systems, which characteristically experience natural frequency increases as oscillatory amplitude increases.

The interest of my study is to find, through experiments, **the similarity between seemingly quite different systems** such as combustion and the aforementioned oscillation, and to consider the reasons why they look similar through **analytical models and numerical simulation**. Such an investigation will give new insight into the phenomena and **another method to control systems**.



Lift-off height vs. fuel jet velocity and oscillatory amplitude in "mode jumping" (the photo shows an example of lifted flame)

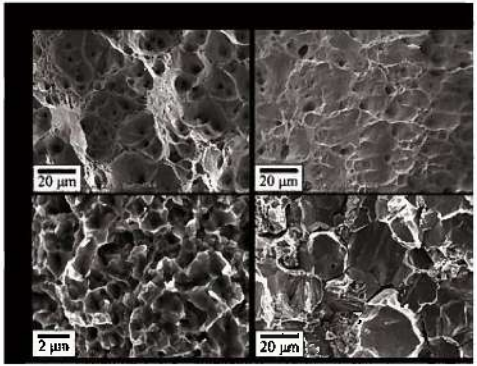
About Researcher

KUNITSUGU Koji, Ph.D.

Ph.D., 2008, Yamaguchi University

Effects of microstructure control and hydrogen on the mechanical properties of steels

I work on the effects of hydrogen on the **properties of steels**, with a focus on metallurgy. In this field, austenitic stainless steels are regarded as less susceptible to hydrogen, but they have relatively low strength. To reduce the cost of high-pressure hydrogen gas infrastructure, high-strength steels are required. In this context, high-strength steels with low susceptibility to **hydrogen-induced degradation** are needed. However, high-strength low-alloy steels are very sensitive to such degradations. I have used ultra-grain refinement of austenitic stainless steels to increase the strength and retain a good compatibility with hydrogen. **Controlling the microstructure** only is not enough, and modifying the chemical composition will also greatly affect the steel's response to hydrogen. Carbides or nitrides increase strength and can also increase the resistance to crack propagation, and as such, microstructure combined with composition control will be my next step on this issue.



Fracture surfaces of uncharged and hydrogen-charged steels with different grain sizes

About Researcher

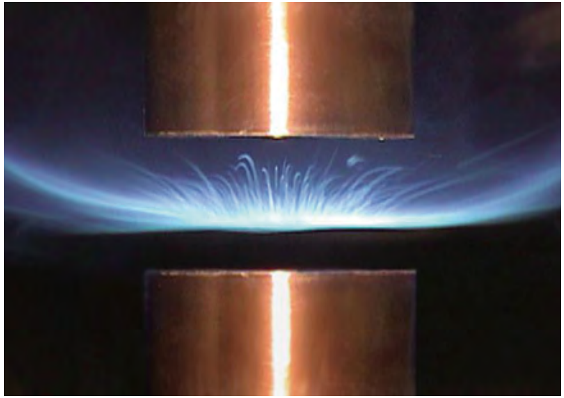
Arnaud MACADRÉ, Ph.D.

Ph.D., 2011, Kyushu University

Fundamental and Applied Research of Spray Combustion: From Jet Engines to Microcombustors

Spray combustion is widely utilized in combustors with liquid fuels such as aircraft jet engines and diesel engines. The spray is a group of numerous fine fuel droplets. In order to realize more stable and efficient combustion of liquid fuels, we have to better understand the behavior of fuel droplets in the turbulent flow field, the interaction between fuel droplets during combustion, and the interaction between fuel droplets and chemical reactions.

My research group has elucidated mechanisms of spray combustion from fundamental aspects using microgravity environments aboard the International Space Station and in a drop facility and original model burners as shown in the figure at right. We have also studied liquid fuel atomization for jet engines and **combustion/noise characteristics improvement** in diesel engines. We recently developed a unique technique to realize spray combustion inside a tube of a few millimeters in diameter. Such a **liquid-fueled microcombustor** could supply much higher energy to portable devices than lithium-ion batteries. Maybe your future cell phone will use spray combustion!!



A model burner with fuel spray in counterflow to elucidate the spray combustion mechanism

About Researcher

MIKAMI Masato, Ph.D.

Ph.D., 1995, The University of Tokyo

WEB ≫ https://ds.cc.yamaguchi-u.ac.jp/~w3nainen/index_en.html

Using MEMS Technology to Create Connections between Mechanical Systems and Organisms in Nano/Micro Scales

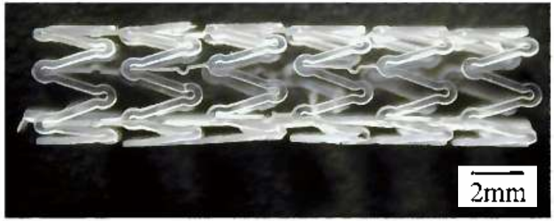
Our research concerns the connection of mechanical systems and organisms using **MEMS technology**. Our interest is focused on the structure and physical phenomena at work, especially the structure and function of organisms, in nano/micro scale. In our laboratory, **nano/micro mechanical devices** are developed by replicating or imitating **organism functions** through the use of **biomaterials**. We also develop nano/micro fabrication technologies, sometimes through the use of biomaterials, to realize novel nano/micro devices. The developed micro devices are applied to the characterization and operation of cells and to minimally invasive treatment, etc.
Major research projects are as follows:

1) Development of micromechanical devices for stimulation or characterization of cells: The micro devices have micro flexible stretchable platforms where living cells adhere.

2) Development of bioabsorbable scaffolds (bioabsorbable stent) made of PLA: These scaffolds utilize a micro latching mechanism.

3) Development of microactuator to drive micromechanical devices: We are currently developing electrostatic microactuators powered by the collaboration between electrostatic and elastic energies/forces.

4) Development of a nano/microfabrication technology for biomaterials including PLA (polylactic acid), collagen, etc.: We have developed a cylindrical RIE technology that can produce a polymer stent structure without causing thermal damage.



Stent structure made using cylindrical RIE Technology from a polypropylene tube with an outside diameter of 4.4 mm

About Researcher

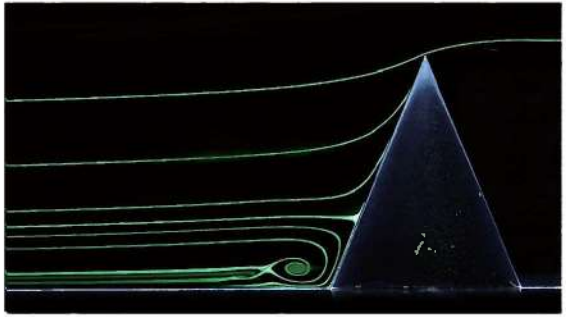
MINAMI Kazuyuki, Dr.Eng.

Dr.Eng., 1994, Tohoku University

Experimental and Numerical Approach to Turbulence Control in Engineering

My main interest research into the **fundamental structure of turbulent shear flows and its control**. People currently face various turbulent flows such as jets, duct flows, and wakes. We want to manage these turbulent flows, namely noise reduction, enhancement of diffusion, and drag reduction. We must understand the key structures involved in these phenomena using ideas and tools invented in the laboratory. Of particular focus is our continued development of experimental and numerical tools to find new aspects to turbulent flows. Some of the typical research being conducted now in the laboratory are as follows:

1) Universality of log law in wall bounded shear flows under various conditions, pressure gradients, and wall roughness.
2) Development tools for experimental investigation to measure wall shear stress, velocity, and pressure.
3) Application of numerical simulation to some turbulent flows in practical situations in engineering.
4) Investigation of structure in complex turbulent flows behind obstacles using PIV or LDV measurement techniques.



Flow approaching an obstacle placed on a wall. A horseshoe vortex appears at the foot of the obstacle.

About Researcher

MOCHIZUKI Shinsuke, Dr.Eng.

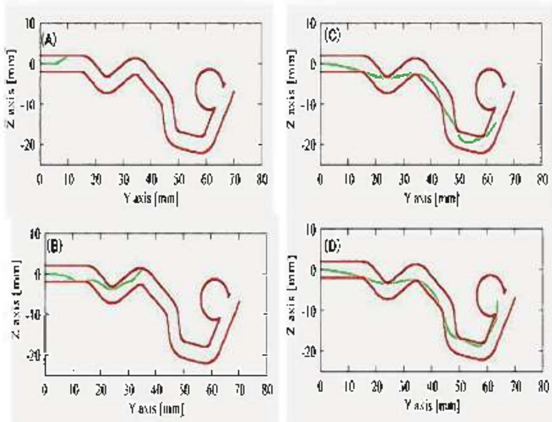
M.Eng. 1986, Yamaguchi University

Development of Low-Invasive Medical Devices

Our lab has been investigating **low-invasive medical devices** such as an intravascular treatment devices and have a primary interest in bone and joint mechanics. Our goal is to provide effective medical devices in the field of intravascular treatment and orthopedics. Achieving this goal, however, will also require a fundamental knowledge of human normal tissue and diseased tissue. We therefore often design original measuring devices to estimate these tissues.

Our lab has two teams, one of which has been researching the behavior of guidewires or catheters, which are used in **intravascular treatment**. The behavior of these wire-like devices is also interesting from the view of mechanical engineering. We have been studying the effect of contact force between the guidewire/catheter and vessel walls on the behavior of these devices in intravascular treatment. Numerical simulation is primarily used in such research.

The other team focuses on bone and joint mechanics and the mechanism of **osteoarthritis** (OA), in particular. Since cartilage degeneration is considered to be one of the causes of OA, we have developed the intra-joint ultrasonic probe and measured human cartilage in collaboration with orthopedic surgeons.



Snapshots of guidewire simulation in the delivery (insertion) process

About Researcher

MORI Koji, Ph.D.

Ph.D., 2001, Kyoto University

WEB ≫ http://mina.mech.yamaguchi-u.ac.jp/

Development of an Integrated Measurement-Treatment Device

Cerebral stroke and myocardial infarction are caused when clots cannot be dissolved within several hours after they are formed. One area of our research is the measurement of the solubility of blood clots in vivo. information that is very important for the doctor to ascertain the status of clot dissolution in an operation.

Our research interest involves the development of an **integrated measurement-treatment device** (Right image) to attack the blood clot and control the treatment method depending on the measurement results. Our proposed stirrer is made of a simple structure with an embedded piezo-cell in order to achieving high stirring performance via mechanical vibration. It is well known that the piezo-cell has both an actuator and sensor function. Techniques for propagating energy while observing the state of the device are expected to have various uses.

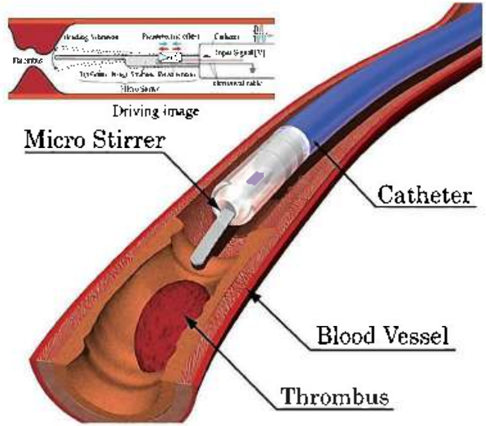


Image of the integrated measurement-treatment device that contains a piezo-cell and simple structure

About Researcher

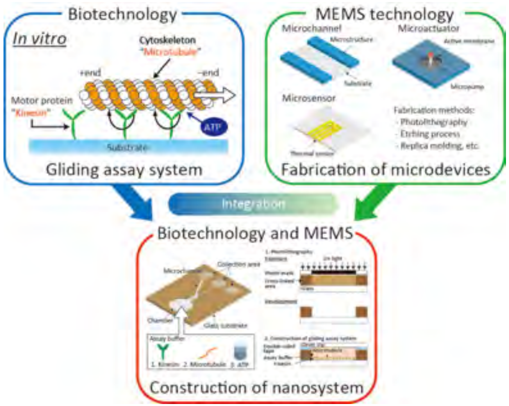
MORITA Minoru, Ph.D.

Ph.D., 2008, Yamaguchi University

WEB ≫ http://web.cc.yamaguchi-u.ac.jp/~mechatro/Eng/index-e.htm

Velocity Control of Microtubules Using a Micro Device in Vitro

Our research interest is in nanosystems using integration of Micro Electro Mechanical Systems (**MEMS**) and motor proteins.
A motor protein, **kinesin**, plays key roles in intracellular transport by moving on a cytoskeleton—**microtubules**, specifically—*in vivo*. Reconstructed *in vitro* systems have been studied because kinesin-microtubule systems act as nano-scale actuators due to their size (several dozen nanometers). A gliding assay system, in which microtubule is propelled by kinesin coated on a substrate, has been widely used *in vitro* for nano-scale applications. One challenging factor concerning gliding assay systems is controlling the velocity of gliding microtubules as their velocity is constant without external factors.
Research now underway in our laboratory is focused on controlling the velocity of microtubules using a micro device. The device is fabricated using MEMS techniques such as photolithography,etching, and replica molding. A major method in experiments for proteins is fluorescent observation using an optical microscopy.
We also leverage numerical analysis to understand the physics observed in experiments.



Our research concept

About Researcher

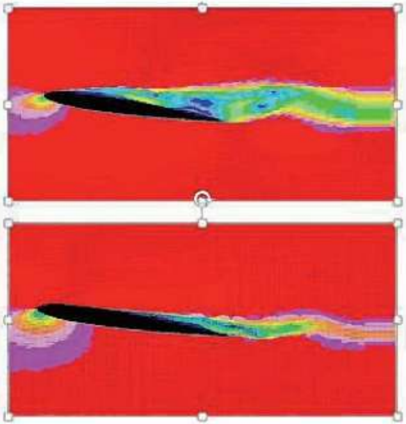
NAKAHARA Tasuku, Ph.D.

Ph.D., 2015, Kyoto University

WEB ≫ http://mems.mech.yamaguchi-u.ac.jp/

Flow Control Using Plasma Synthetic Jet Actuators for Micro UAV

We must precisely understand fluid flow characteristics in order to improve the fuel efficiency of things such as automobiles, airplanes, and turbo-machineries. In order to understand certain flow fields, experiments using wind-tunnels or **numerical simulations** using computers are commonly utilized. Since both experiments and simulations come with advantages and disadvantages, our laboratory consists of two groups, one focused on experiments and one on simulations. In that way, researchers who mainly conduct experiments using **hot-wire velocimetry can compete with researchers** who mainly conduct simulations. This also allows both groups to quickly reference in-house experimental and simulation data. For example, in series of studies on **plasma synthetic jet actuators** (PSJA), we examined their effectiveness through wind-tunnel experiments then studied the fluid mechanics of corresponding flow fields through numerical simulations. Although studies on PSJA have been drawing interest in recent years as a device for flow control, our laboratory has concentrated on this subject since 2003 and has been working to apply this technology to Micro Observatory UAVs.



Numerical simulations on flow around NACA0012 airfoil. PSJA is on in the upper image and off in the lower image

About Researcher

OGAWARA Kakuji, Eng.Sc.Dr.

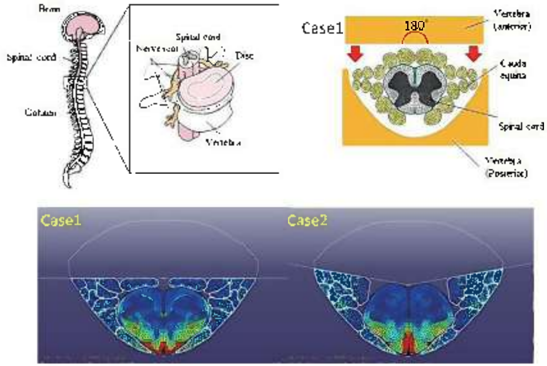
Eng.Sc.Dr., Columbia University in New York City

Stress-Strain Analysis of Human Spinal Column and Spinal Cord under Impact Compressive Loading

Our research interest is in simulating human body mechanics under impact loading, mainly using the **finite element method**. We are currently focused on stress-strain analyses of the **spinal column** in compression fractures, and of the **spinal cord** when compressed due to ossification of the posterior longitudinal ligament or to fractured bone. In addition, we are trying to enhance creep and/or fatigue life of polymers such as **PLA** and **UHMWPE** for artificial joint and bone fixation screws/plates using forging.

Our current research is as follows:

1) Analyses of damage caused by compression of spinal the cord and cauda equina in the thoracolumbar junction. 2) Simulating the behavior of the human spinal column with compressive fracture under impact compressive loading. 3) Investigating the stress-strain response of brain tissue, and simulating the behavior of the brain under anterior impact loading. 4) Investigating the anisotropy of the stress-strain response in the spinal cord by tensile and compression tests. 5) Effect of forging and shape recovery on creep strength of PLLA. 6) Enhancement of wear resistance of UHMWPE for artificial joints using forging.



Influence of the shape of the anterior vertebra on equivalent stress distribution in the spinal cord and cauda equina

About Researcher

OHGI Junji, Ph.D.

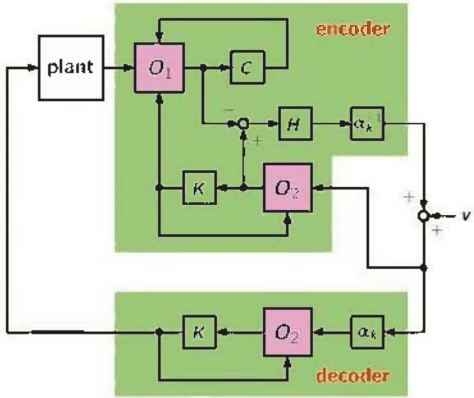
Ph.D., 2000, Yamaguchi University

Dynamical Systems Control with High-Efficiency Data Processing

Our recent research interest is focused on the following themes in the field of control engineering.

Unification of Control and Communication: Modern mechanical systems controlled over communication links must be reliably operated under various uncertainties due to real-time data interaction. Our goal is to provide the optimal control strategy that minimizes the data rate required for satisfying control specifications. We take an information-theoretic approach based on generalized entropy to analyze the trade-off between control and communication performances. The results elucidate limitations concerning bit rate and signal-to-noise ratio for the systems disturbed by signals with bounded amplitude, despite their mathematical intractability.

Model Reduction Based on New Criteria: Model reduction is a way of simplifying mathematical expressions of dynamical systems to reduce the high computational cost required to control large-scale systems. We provide a new method to extract important components of the variables fundamentally contributing to enhancing optimal control performance. The method is based on a new index for evaluating the degree of performance degradation due to simplifying control law.



O_1: observer for transmission, O_2: observer for reception

Optimal stabilizing control strategy for minimizing the SNR of a channel with bounded-amplitude noise

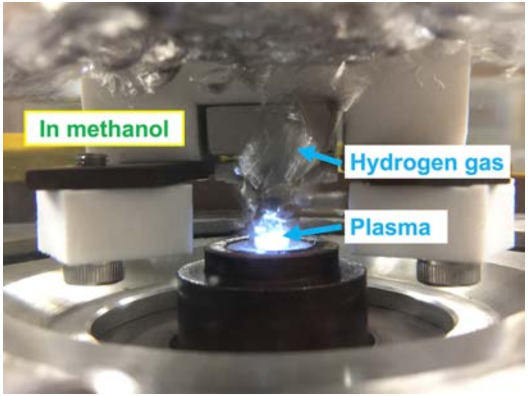
About Researcher

SHINGIN Hidenori, Ph.D.

Ph.D., 2008, Osaka University

Carbon-Neutral Fuel Production Using Plasma

In order to solve global warming, "**carbon-neutral fuel**" which does not emit greenhouse gases such as CO_2 needs to become widespread. **Hydrogen** has received the most attention. However, electrical energy must be consumed to obtain it. This is because most of the hydrogen on the earth exists as compounds such as water and oil, so it is necessary to decompose them in order to obtain pure hydrogen that can be used as fuel. In other words, since energy is consumed to obtain fuel (hydrogen), "how much hydrogen can be recovered using less electrical energy (= energy efficiency)" is important. The "hydrogen production method using **plasma**" I' m researching could be 2 to 5 times more energy efficient than those currently in use, such as water electrolysis and natural gas steam reforming. Previous research has found that to improve energy efficiency, the following two points must be improved: (1) concentrating the plasma energy into the hydrogen production reaction rather than heat diffusion to the surroundings, (2) stabilizing the plasma. Therefore, aiming to realize high-efficiency hydrogen production, I' m researching solutions to these problems.



A photo of producing hydrogen with plasma. A plasma is generated in methanol, which decomposes to produce hydrogen.

About Researcher

SHIRAISHI Ryoya, Dr. Eng.

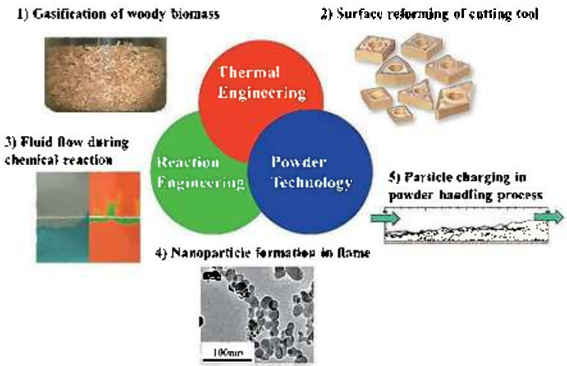
Dr.Eng., 2019, Ehime University

WEB ≫ https://researchmap.jp/r-shiraishi?lang=japanese

Heat and Mass Transfer During Chemical Reactions

Our research interest is in heat and mass transfer during chemical reactions, in addition to related subjects in the field of thermal engineering, reaction engineering, and powder technology. Research now underway in our laboratory is focused on the following 5 subjects:

1) **Biomass gasification** and solidification; 2) surface reforming of cutting tools by thermal chemical vapor deposition; 3) fluid flow during chemical reactions in the liquid phase; 4) nanoparticle formation and temperature measurement in premixed flames; and 5) particle charging in the powder handling process. Subjects 1) to 4) have been investigated experimentally and numerically by taking account of not only heat and mass transfer but also chemical reactions. In particular, **digital laser speckle technic** is utilized to measure refractive index distribution in heat and mass transfer. We are also interested in the phenomena of **particle charging** and liquid bridge force, which cause particle deposition on the walls of equipment in the powder handling process.



Our research concept and related subjects

About Researcher

TANOUE Ken-ichiro, Dr.Eng.

Dr Eng., 1997, Kyusyu University