Research topics

- Elucidating and establishing prediction method for Mode II fatigue crack propagation in damage accumulation mode.
- Elucidation of failure mode transition mechanism in metal fatigue and its application to active control design.
- Development of parts strength theory, taking fatigue strength design of a material that has undergone material change due to processing, as an example.
- Development of fatigue crack closure evaluation method for rational fatigue design of new materials.
- Development of rational manufacturing process and safety design method of machine elements fabricated by 3D printer.
- Research on the mechanism of metal fatigue under hydrogen environment.

Dislocation substructure analysis using latest equipment

Failure analysis of the machine elements fabricated by 3D printer

Fatigue crack closure phenomena analysis

Mechanical equivalence simulation of crack and hardness

Elucidation of fatigue crack propagation by damage accumulation mode

To seek machine safety and relief by making full use of multi-scale mechanics

Prof. Hiroshi Noguchi, Assoc. Prof. Shigeru Hamada
Machine Elements and Design Engineering Laboratory

- Yoshinori SAWAE, Professor
- Tetsuo Yamaguchi, Associate Professor
- Takehiro MORITA, Assistant Professor

- Basic studies for establishing design guideline of machine elements used in various applications, from medical devices to machine components in hydrogen energy systems.
- Tribology in biomedical engineering field is one of the main research target.

- Wear of prosthetic joint materials
- Biotribology for functional cartilage tissue engineering
- Biomimetic design based on microstructure of gecko finger
- Mathematical model for crack propagation and fatigue fracture in gels

- Structural optimization for dental implant
- Interfacial fracture and non-linear rheology of adhesive
- Wear of polymer seals in high pressure hydrogen
Structural Materials Research Lab.
Prof. Toda, Assoc. Prof. Takakuwa, Assist. Prof. Hirayama

The world’s largest synchrotron radiation facility (SPring-8)

Research Center for HYDROGEN Industrial Use and Storage (HYDROGENIUS)

Innovative Materials Assessment × Strength Design

Elucidating genuine fracture process by in-situ observation and optimizing the strength design of structures
Current researches include characterizing the fatigue behavior of high strength Mg and Ti alloys in such a way that the relationship between microstructure and mechanical properties will be elucidated at all scales especially from microscopic to atomic scale.

“Cumulative damage” at LPSO/Mg interface

Selective variant growth of precipitates

Initiation and propagation of small cracks
Flow control systems lab.

Prof. Satoshi Watanabe
Associate Prof. Shin-ichi. Tsuda
Assistant Prof. Yusuke Katayama

Internal flow in fluid machinery and related fluid flow phenomena

**Pumps and flow instability**
- R&D of contra-rotating axial flow pump
- Cavitation instabilities of inducer
- Unsteady flow/fluid forces in multi-stage pump

**Utilization of natural flow resources**
- Darriues-type hydro-turbine for low head flow

**Cavitation**
- Unsteady cavitation around hydrofoil/cascade
- Thermal effect of cavitation
- Cavitation in automotive torque converter

**Liquid-vapor interface and bubbles**
- Characteristics of evaporation/condensation process
- Bubble formation process in liquid rocket fuel

**Field experiment of Darriues turbine**

**Cavitation surge in space rocket inducer**

**Cavitating hydrofoil**

**Molecular simulations on interface and bubbles**

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**Molecular simulations on interface and bubbles**
Fluids Engineering Science Lab.

CFD analysis of complex internal flows
- Unsteady 3-D vortex flows
- Rotating stall inception
- EFD/CFD hybrid analysis

Analysis of gas flows in turbomachinery

Development of wind-lens wind turbine
- 3-D aerodynamic design
- Matching of wind-lens body and turbine blades

Mechanism of aerodynamic noise
- Noise reduction of fans

Development of imaging measurement technique
- Pressure Sensitive Paint (PSP)
- Particle Image Velocimetry (PIV)
**Research topics**

- CHF enhancement of a large heated surface using Honeycomb Porous Plate
- Development of high-temperature heat pump systems using supercritical pressure fluids
- Evaluation of heat transfer and flow resistance of flow boiling in mini-channels to develop high performance heat pump systems
- Study on heat and mass transfer of adsorption/desorption desiccant materials used for air conditioning, refrigeration and heat pump systems operating with low-grade waste heat

- Experiments and simulation analyses on heat transfer and pressure drop of flow boiling inside mini-channels for a heat exchanger of next generation air conditioning

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**Supercritical pressure fluid**

- Huge change of thermo physical properties of supercritical pressure fluids

**Nano-scale porous adsorbent**

- Equilibrium amount of adsorbed water

**Experiments and simulation analyses on thermal-hydraulics of supercritical pressure fluids for high-temperature heat pumps**

**Measurements of static and dynamic vapor adsorption phenomena in adsorbent materials**
**Pursuit of principle and technologies in combustion**

### Our Goals
- Thermal efficiency (Energy saving)
- Environmental feasibility (Low carbonization, Low hazardous substances emission)
- Fuel diversification (Cost reduction, Energy security)

### Our Targets
- Propulsive devices (Automobile engines, Supersonic aircraft engines, etc.)
- Energy devices (Industrial gas turbines, etc.)
- Gas combustion, Liquid fuel (spray) combustion, Supersonic combustion, etc.

### Our Themes
- Experiment and simulation for understanding physics, developing new concept, etc.
- Engine combustion, Direct injection combustion, Engine knock, Hydrogen combustion, PM(soot) formation, Syngas combustion, Supersonic combustion, etc.

### Laser visualization of flame
- Exp of hydrogen combustion
- EXP of PM formation
- CFD on turbulent flame
- CFD on engine
- CFD on supersonic combustion

**Experimental study using advanced laser diagnostics**

**Simulation study using massive parallel computer**
Research topics

- Enhancement of ignition and burning rate of lean mixtures by Pulsed Flame Jet
- Ignition timing control of Homogeneous Charge Compression Ignition Combustion by Pulsed Flame Jet
- Study on combustion phenomena in engines with visualized rotary engine
- Study on vaporization, spontaneous ignition and combustion of fuel sprays
- Improvement of spark ignition of lean mixtures in a fast gas flow
- Numerical simulation of spray combustion

New concept of internal combustion engines

- Ignition timing control of HCCI combustion by Pulsed Flame Jet
- Gasoline engines
- Rapid compression machine
- Improvement of spark ignition
- Numerical simulation
- Detailed mechanism of combustion phenomena

- Spray combustion
- Diesel engines
- Gas turbine engines
Research Topics

- Effect of high pressure torsion on material thermal transport properties
- Measurement of thermophysical properties of nano materials by laser flash Raman spectroscopy
- Nanoscale solid-liquid-vapor interfacial phenomena
- Behavior and heat transfer of micro droplets impinging on high temperature solid solid surfaces

Development of Si thermoelectric

Coloring with critical protein light. Near the critical point of CO2 (31.0 °C, 7.4 MPa)

Laser system for thermophysical property measurement
**Research Objective:**
- Development of next generation adsorption cooling and refrigeration systems

**Main research fields:**
- Elucidation of adsorption characterization
- Ionic liquid based composite adsorbents
- Porous characterization using AFM technique
- Thermodynamic analysis of adsorption cycles
- Optimum design guidelines for high performance adsorption chiller

**Identified pore statistics:**
- Total projected area: 2.27 μm²
- Total area covered by pore: 44.44%
- Mean pore size: 72 nm

**CVVP experimental apparatus for adsorption characteristics measurements.**

**Adsorption cooling cycles using Maxsorb III (90 wt.%) + Poly[VBTA][Ala] (10 wt.%) + ethanol (solid line) and Maxsorb/ethanol (dashed line) pairs at evaporator, adsorption and desorption temperatures of 7, 30 and 80°C, respectively.**
Vibration and Acoustics Lab.

Research topics

- Active noise control in 3-dimensional sound field.
- Large scale acoustic analysis using lumped mass model.
- Vibration damping.
- Evaluating and detecting softness of human body.

- Experiment of Active Noise Control in anechoic chamber
- 3-D lumped mass model
- Sound pressure distribution (example of calculation result)
- Softness sensor for human body
- Magnetic damper
A High-Performance Method of Vibration Analysis for Large-Scale Nonlinear Systems.
Prevention Method for Self-Excited Vibration.
Development of Mechanical Systems Using Self-Synchronized Phenomena.
Vibration Control by Elimination of Natural Frequency Component.
Low Frequency Vibration of a Vibroimpact System
New diagnostic technique using ultrasound wave
Diagnostics technique with instantaneous frequency of ultrasound pulse

Evaluation of adhesive strength of heat seal with instantaneous frequency of ultrasound pulse
Evaluation of slackness using ultrasound pulse wave (simulation and basic experiment)

Vibration analysis of complicated structure

Study for efficient vibration analysis of automobile body structure
Estimation on transfer characteristics of vibration

Mechanism for automatic tuning, signal processing etc.,
Studies on robotic systems and intelligent machines are carried out. Especially, robotics technologies for medical and human assist systems are studied. For details, power-assist robots, perception-assist, human assist systems, rehabilitation systems, human motion simulation, human motion change using vibration stimulation, robotic prosthetic systems such as robotic artificial arms, surgery assist robots, human body characteristics, machine learning are studied to prepare for an aged society.
Analysis of wheelchair’s caregiver

Motion control using human illusions and reflexes

HEALTHCARE ROBOT

Pointing devices for endoscopic procedures

Evaluation of fall slipping

Evaluation of standing stability

Precise control by FES

Flexible Linear Motor

Stable grasping by passively deformable soft finger

Flexible object grasping by ultra-high speed parallel link

SOFT ROBOTICS

Motoji Yamamoto, Prof.
Yasutaka Nakashima, Assoc. Prof.
Ayato Kanada, Koki Honda, Assist. Prof.
• **From human to robotics**
  To realize the advanced motor intelligence of human’s movements in robotics

• **From robotics to human**
  To realize flexible and dexterous robots that can support human’s daily life

Numerical simulation for the musculoskeletal system

High-backdrivable parallel-link manipulator with CVT

Multi-fingered robotic hand
Development of the state-of-the-art manufacturing processes and measuring techniques for the green devices and machine elements

Giga range processing and evaluation

I. Ultra-Precision Manufacturing Technology
   (1) CMP (Chemical Mechanical Polishing) for energy saving device materials
       (SiC, Sapphire, Diamond, Silicon, GaN, Atmosphere controlled CMP machine, Slurry, Polishing pad, Recycling, etc.)
   (2) Ultra-precision manufacturing and performance evaluation (Ultra-high-speed hobbing, Coated tools, etc.)

II. Ultra-Precision Measuring Technology
   (1) Optical measurement & evaluation (Nano particle sizing using fluorescent probe, Ultra-precision defect detection by femtosecond laser, Ultra-high-precision measurement of transmission error, etc.)
   (2) R&D of 3D measurement and testing method (Test and evaluation of high-speed CMM, Gear accuracy evaluation by whole circumference scanning measurement, etc.)

III. R&D of Creative Manufacturing Technique and Machines
     Film formation of organic LED, Conformal coating and Electro spray application for MEMS, Development of high throughput CO₂ capturing system at low temperature, Low power laser processing with surface excitation
Variable approaches to “Manufacturing”

In our laboratory, we develop and analyze new material processing techniques using powders as structure materials, with an aim to revolutionize the process of “Manufacturing”. We process ceramic or metal powders. The outcome of our research is expanded to a wide variety of applications.

Analysis

Numerical analysis of the powder metallurgy process in order to improve precision and functionality of industrial parts.

Examples of time evolution of structures during sintering, applying the Phase Field Method.

Particle deformation analysis during sintering using FEM. Analysis of transitions in bonding behaviors of particles in order to estimate the deformation of sintered products.

Development

“Manufacturing” is carried out by the process development itself. Constant inventions of processes from a new point of view.

Development of high performance piezoelectric materials by the powder rolling process.

Flexible micro actuators fabricated by the soft MEMS process.

Applying nanoimprinting lithography for powder processing.

MIM apparatus, which enables mass-production of complex metal products.

Application

The outcome of our research is expanded to a wide variety of applications.

Application of the MIM Process to large size parts. Analytic technology and optimization of process parameters are carried out in order to suppress deformation.

Artificial cilia for the use of micro pumps, which replicates naturally optimized asymmetrical movement or metachronal waves.

An application example of the nanoimprinting process to ceramic materials. Fuel cell electrolyte is processed into a wavy shape in order to improve cell performance.
Heat & Mass Transfer Lab.

Interdisciplinary topics between thermal engineering and bioengineering

- Measurement of fluid thermal conductivity with small samples using a MEMS sensor
  - Scanning electron micrograph of a MEMS sensor

- Measurement of thermal conductivity of biopolymers
  - New method for measuring thermal conductivity

- Experiments and simulation of freezing during cryosurgery
  - Cryosurgery of liver cancer (image)

- Understanding thermal transport through simulation and statistics
  - Molecular simulation of liquid
  - Kyushu University’s supercomputer

- Non-thermal irreversible electroporation to treat tumors
  - Concept of clinical application of irreversible electroporation

- Inhibition of tumor cell division using a weak electric field
  - Difference of dielectrophoretic force distribution depending on cell shape
Abstract

We are elucidating the mechanisms by which the functions of cells and tissues adapt to mechanical environments on the basis of biomechanics. We are also trying to clarify the mechanism and micro- and nanoscopic biotransport. Macroscopic biotransport can be often be analyzed by using a differential equation to model physical phenomena. However, biotransport at much smaller scales (the micro-and nano-scales) is more difficult to model in physical detail. Clarification of the mechanisms of such micro- and nanoscale biotransport will be useful not only in improving our understanding of the mechanisms of disease and the maintenance of stable biological functions, but also for the development of clinical applications such as tissue engineering.
Biomedical Applications

- Researches on Minimally invasive cell therapy
  - Needles injector for medical applications
- Micro/Nano-mechatoronics
  - Evaluation system of Electrically induced bubbles
  - Cell manipulation & measurement utilizing high-speed vision integrated system

Spatiotemporal microfluidics

- Investigation of ultra-fast microfluids
  - “Daily activities” Discussion, Writing Journal, Presentation, Design, Fabrication, Experiment, Analysis
  - “Seamless researches” Fundamentals to Applications
- Microfluidic chips based on MEMS fabrication
- Fabrication technologies for wafer level 3D structures
- Lab on a chip Micro total analysis systems
- On-chip cell manipulations & analyses with high-speed & high-accuracy

Microfabrication/MEMS

- Novel medical devices & applications
- Micro/Nano- mechatronics
  - Evaluation system of Electrically induced bubbles

Interdisciplinary researches on “Bio” “Medical” “Microfluidics (Mech. Eng.)”

Kyushu University, Biomedical Microfluidics Lab.
Research on new Medical Devices based on Robotics

Our research aims at new medical applications based on Robotic technology. Robotic technology includes many elements - mechanism, sensor, control, system integration and etc. We study about these elements to realize further effective medical applications. Find more on http://amd.mech.kyushu-u.ac.jp/

World smallest 2mm robotic surgical manipulator

Hand rehabilitation robot currently tested in clinics

Tele-manipulation system for the orbital space station
**Hydrogen Compatible Materials & Fracture**

**Research topics**

- **Key words**: Interaction between materials and hydrogen, Strength of structural materials, Hydrogen-assisted degradation of materials strength

- **Future high-strength steel**
- **How to safely use H₂**
- **Predict hydrogen embrittlement**

- **Ultrafine Grain Steel**, 1μm grain size
- **Fatigue in High-Pressure Hydrogen**, Backup data for relaxation of regulations
- **Single Crystal Experiment** From ultra-fine grain to single crystal Wide range of interest

**Ultrafine grain steel**

- Austenitic steels is used for hydrogen equipment. But lower strength is the drawback.
- Toughening by grain refinement.
  - Grain size: Several tens of μm → 1μm
- High strength is realized.

**Fretting fatigue in hydrogen**

- Fatigue + Wear
- Significant reduction in fatigue strength
- How to ensure safety?

**Single Crystal Experiment**

- No predictive model of hydrogen embrittlement.
- Single crystal → Simple slip system
- International collaboration Greece, USA and Japan

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**Questions**

- Effect of hydrogen?
- Fatigue properties?

- Effect of impurities because PEFC need humidity for proton conductivity
- How to achieve safe design of hydrogen equipment

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**Graphs and Diagrams**

- Stress-strain graph for UFG16-10 and SUS316
- Fretting fatigue test results
- Single crystal experiment setup
Studies on Low-Temperature Fuel Cells (PEFCs)
(Electric power units for automotive and portable applications)
- Novel electrocatalysts and alternative materials.
- Cell performance evaluation & simulation studies.

Studies on High-Temperature Fuel Cells (SOFCs)
(High electric efficiency & fuel flexibility)
- Fundamental studies to realize longer durability.
- Evaluation of electrodes.
- Studies on materials / system design principles.

Fundamental Studies on Hydrogen Energy Related Technologies
- Study on hydrogen sensors.
- Fuel cell operation with bio-fuels.

You can learn research and development skills for fuel cells and related technologies!
“Fabrication of materials and cells ⇒ Measurement of cell performance and durability ⇒ Microscopic characterization and various electrochemical / materials analysis”
Fuel cell (FC) is a direct electricity generator from chemical energy of fuel, with high efficiency and low environmental impact. This merit motivates FCs to be used as a main generator in hydrogen energy age. FCs are expected as mobile, vehicle, residential and dispersed power source. Although a part of FCs has been utilized practically, cost, durability and efficiency are still large concern.

Against this backdrop, our laboratory advances globally competitive research and development on FC through mechanical engineering approach with the following keywords:

- Elucidation of mass, heat and charge transfer phenomena
  - Flooding
  - Drying
  - Temperature
  - Thermal analysis
  - Hydrogen solubility in electrolyte membrane

- Development of new proving technique for the elucidation.
  - Measurement of temperature distribution with micro TCs.
  - Tracer method
  - Concentration and current distribution
  - FC diagnostic with impedance measurement

- New proposal based on understanding the phenomena in cell.
  - Repellency optimization of porous layers
  - Advanced channel pattern
  - Feedback control for water management
  - Hydrogen pump

Contact us! kohei@mech.kyushu-u.ac.jp
http://www.mech.kyushu-u.ac.jp/lab/ki07/index.html
Aims and scope

- Elucidate the **fundamental principles** of hydrogen embrittlement.
- Contribute to revisions of **domestic-** and **international-** regulations on material selection and strength design (e.g., design by rule and design by analysis) for components used in high-pressure gaseous hydrogen.
- Find and develop **new structural materials** having higher resistance to hydrogen with lower cost.

Strength properties which is necessary for the strength design of high-pressure hydrogen components

<table>
<thead>
<tr>
<th>Properties</th>
<th>Loading types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatigue crack growth</td>
<td><img src="image" alt="Fatigue Crack Growth" /></td>
</tr>
<tr>
<td>Fracture toughness</td>
<td><img src="image" alt="Fracture Toughness" /></td>
</tr>
<tr>
<td>Tensile fracture</td>
<td><img src="image" alt="Tensile Fracture" /></td>
</tr>
<tr>
<td>Fatigue life</td>
<td><img src="image" alt="Fatigue Life" /></td>
</tr>
</tbody>
</table>

**Keywords:**
Hydrogen Storage, Hydrogen Embrittlement, Fatigue and Fracture, Strength Design, Regulation Review
Machine Design for Energy, Environment and Safety

**Structural design**  
Strength of materials  
Fluid Engineering  
Dynamics, Vibration  
Thermal Engineering  
**Machine Elements**  
Manufacturing  
etc.

**Interior design**  
Fluid Engineering  
Thermal Engineering  
**Machine Elements**  
Human Engineering  
etc.

**Engine design**  
Combustion, Thermal Engineering  
Fuel Cell, Chemistry, Strength  
Dynamics, Vibration, Control,  
Fluid Engineering, Manufacturing  
**Machine Elements**  
Electronics, etc.

**Wheel design**  
Strength of materials  
Dynamics, Vibration  
**Machine Elements**  
 Manufacturing  
Materials  
etc.

**Importance of Machine elements**

**Machine life depends on machine elements!!**  
Bearings, shafts, springs, gears, crews, joints, belts, seals, brakes, their materials, etc.

**Tribology**  
Science and technology of friction, wear and lubrication
- for future interfacial technology

**Research Topics**
- Surface engineering
- Novel lubrication concept
- Soft materials for elements
- Extreme environment
Pool boiling on a wettability-patterned surface

Multiscale observations of phase change phenomena

Heat transfer enhancement by wettability modification

Thermophysical properties of new refrigerants

Condensation on wettability-patterned micropillars

Droplet evaporation and flows

Thermofluid Physics Lab

Professor

Assoc Prof

Y. TAKATA

N. SAKODA

Y. KITA

Reveal **fundamental thermofluid phenomena** at vapor-liquid-solid interfaces
Establish **thermophysical property databases** for new generation refrigerants

**Heat transfer enhancement by wettability modification**

**Thermophysical properties of new refrigerants**

**Multiscale observations of phase change phenomena**

**Droplet evaporation and flows**

Environmental SEM

Condensation on wettability-patterned micropillars

Orejon et al., RSC Advances 6, 2016

Vapor-liquid Equilibrium Measurement Apparatus

Sample

R32 (GWP = 675)

R1234yf (GWP < 1)

Droplet impact on a hot surface

Thermograph of a drying ethanol drop

Controlling internal flows in a drop
The research group studies and develops functional ion-conducting solid materials and their applications in relation to the environment improvement and realization of low-energy society. For the use of sustainable energies, hydrogen is the candidate energy medium: Electricity produced via solar cells, wind mills, and so on can be stored in the form of hydrogen for energy storage and distribution. Hydrogen thus produced will be converted to electricity to use for automobiles, households, industries, etc.

Wind mills → Solar power → Hydrogen → Electricity

No CO₂ emission!

Fuel cells

Fuel-cell-powered houses and automobiles
Advanced Hydrogen Materials Lab.

**Research topics**

- Influence of fillers on hydrogen penetration properties and blister fracture of rubber composites for O-ring exposed to high-pressure hydrogen gas.
- Evaluation of sealing behavior of rubber O-ring in high pressure hydrogen gas.
- Development of rubber materials for diaphragm pump.
- Analyses of polymer materials after high-pressure hydrogen exposure.

**Seal Break**

- Seal breaks after 100MPa, 30°C × 25 cycles

Analyses of mechanism of blister fracture of rubber materials during high-pressure hydrogen exposure

**Fracture**

- High durability rubber materials for O-ring of high-pressure hydrogen gas vessels

**Evaluation of sealing behavior of rubber O-ring in high pressure hydrogen gas**

- High reliability high-pressure hydrogen gas seal design

**Development of high frequency fatigue-resistant rubber materials**

- Long-life diaphragm pump for hydrogen gas

**Analyses of polymer materials by NMR, IR, Raman spectroscopy and measurement of physical properties after high-pressure hydrogen exposure**

**Molecular design guidelines for polymer materials for hydrogen energy system**
Our group has been working on **Fuel Cell Research for Vehicles.** We focus on development of novel electrocatalysts, which play a most important role for fuel cell performance, with following approaches.

- **Encapsulation of Pt into nano-channels** to suppress Pt aggregation, leading to high activity and durability.
- **Graphitization of carbon surface by heat-treatment**, leading to increased tolerance to carbon oxidation.
- **Investigation of electrode degradation at higher temperature operation**.
- **Investigation of degradation mechanism by In-situ SEM**.