1. Role of Flow Visualization in the Development of UNICORN

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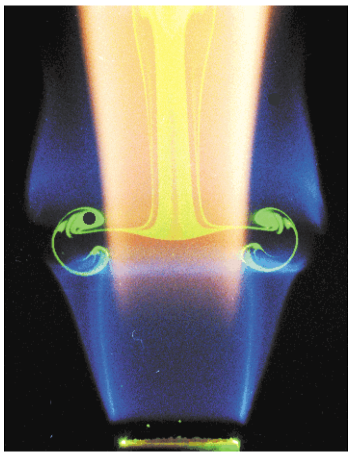


Figure 1 (a)

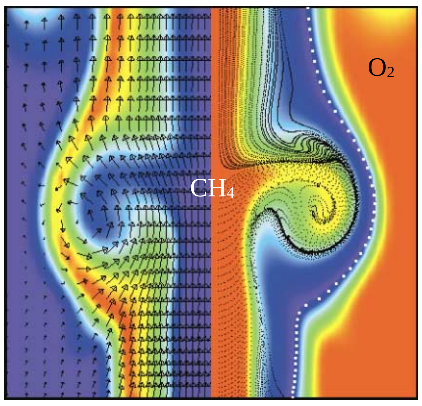
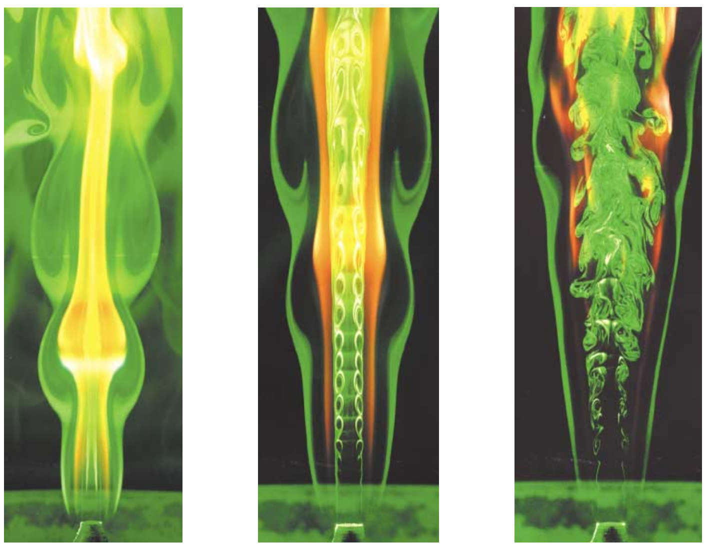


Figure 1 (b)

Interaction of a vortex and a flame surface is studied experimentally and numerically. A vortex is created within a laminar jet diffusion flame by driving the fuel jet at 30 Hz using a loud speaker. Phase-locked Reactive-Mie-Scattering visualization at 10 ms after the firing of the vortex is shown in Fig. (a). The vortex structures have a dark green-yellow appearance, while the flame image is indicated by yellow and blue. Visualization of the computed vortex-flame interaction is shown in Fig. (b), with an iso-temperature plot on the left side and the iso-concentration plots of fuel and oxygen separated by the peak-temperature surface (white dots) on the right. The instantaneous particle field is superimposed on the right-hand side of the image, and the velocity field is superimposed on the left-hand side.



Laminar Transitional Near Turbulent

Figure 2

Detailed information on the mixing and transport processes that occur within and around jet flames is obtained for the development of gas-turbine-combustion models such as UNICORN. The three methane flames shown here have an annulus-air velocity of 0.15 m/s. The fuel-jet velocity is varied to obtain cold-flow exit plane Reynolds Numbers of 408, 1867, and 5834 for the laminar, transitional, and near-turbulent flames, respectively. The flow structures are visualized using the Reactive-Mie-Scattering technique in which the light sheet is formed with a Nd:YAG laser. The green scattered light from TiO_2 particles is captured with a 10-ns laser pulse, and the yellow flame is captured with a 2-ms shutter opening.

2. Benard-Marangoni Convection Patterns by Infrared Thermography

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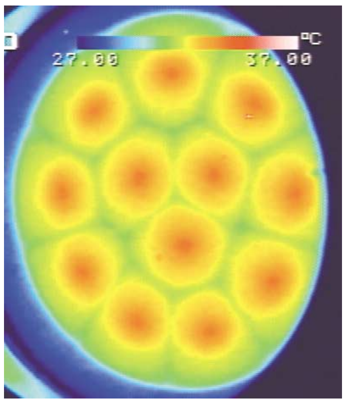
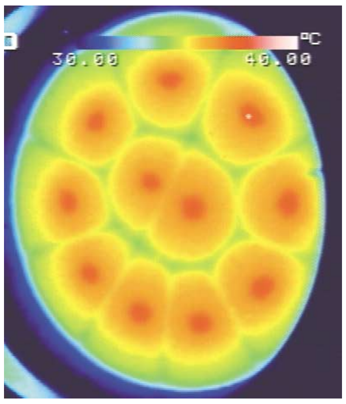


(a)



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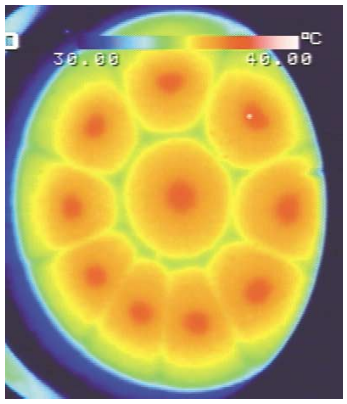
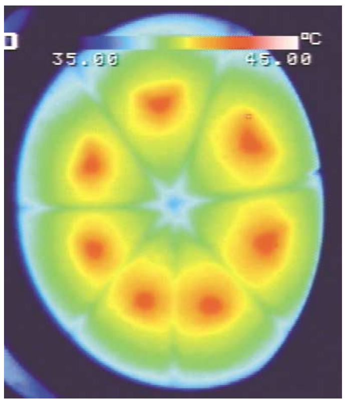
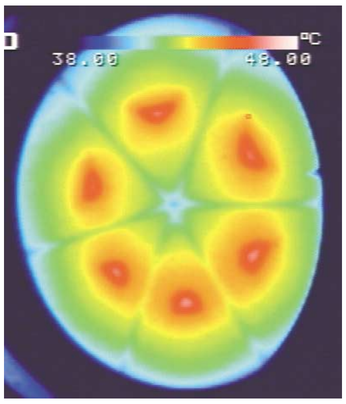


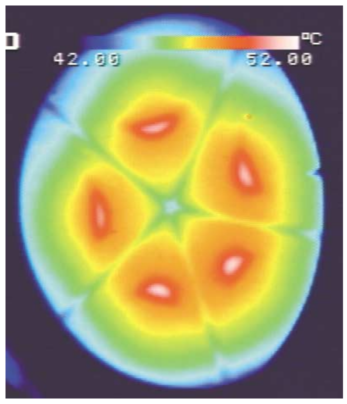
(c)



(d)



(e)



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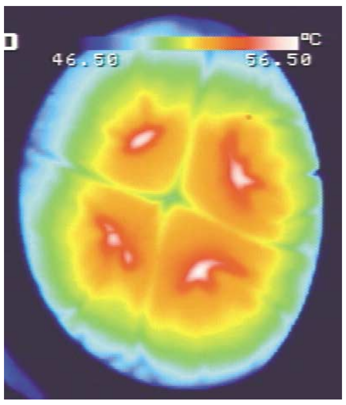
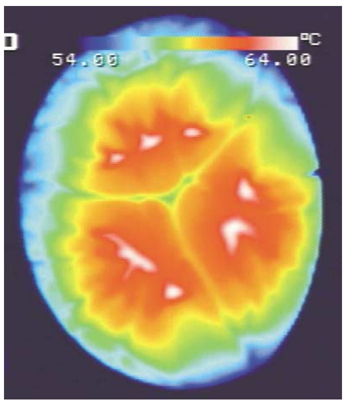


(g)



(h)

These figures show interfacial temperature fields in a Benard-Marangoni convection with a 5mm silicone oil layer, Pr = 206, Biot number L = 2.52, obtained by infrared thermography. Pattern dynamics are observed when the gradient of temperature ΔT_p is increased from ΔT_p = 0ºC to ΔT_p =50ºC. After the onset of convection, a pattern with 3 central cells and 9 peripheral cells are observed (a), after that, a coalescence is observed and only two cells remain in the center part (b), but there occurs a coalescence of the two cells to form one cell (c). As ΔT_p is increased, the size of peripheral cells increases inducing the disappearance of the central cell (d) and number of cells decreases to 3 cells for ΔT_p =45ºC, every one of them contains a pair of cells which coalesce and split as function of time (h).

3. Surface flow pathlines between groins visualized by the DMS method

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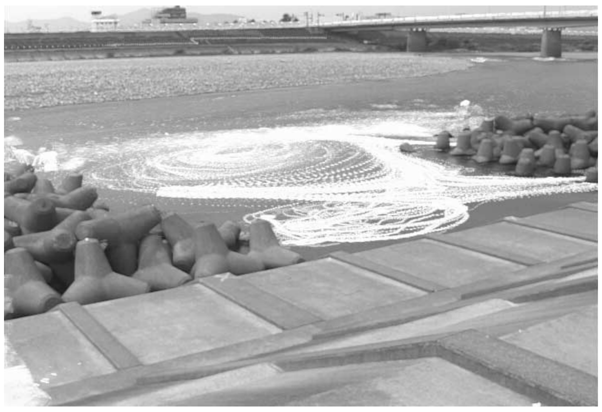
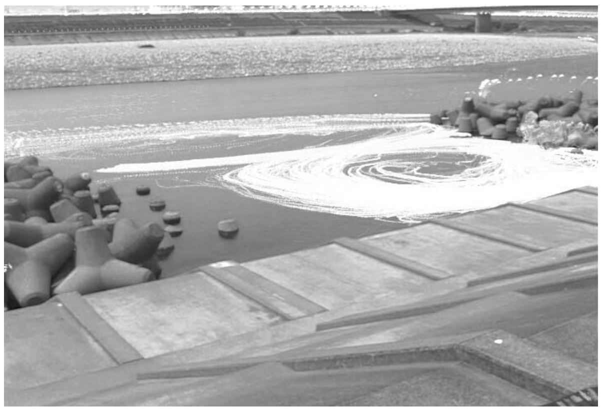


(a) Pathlines between 1st and 2nd groins

(b) Pathlines between 2nd and 3rd groins



(c) Pathlines between 3rd and 4th groins

(d) Pathlines between 4th and 5th groins

These figures show free-surface pathlines for the groin fields of the Nagara River (main flow from right to left). The surface flow is visualized using 5-cm long light pieces made of cornstarch, easily dissolved into water and non-toxic to the river environment. Pathlines are obtained by the Digital Multiple Superposing (DMS) method, i.e. by superposing hundreds of images sampled at time intervals varying from 0.5 to 3.0 seconds. Large-scale flow structure is completely different for each of the groin fields; counterclockwise flow structures are visible in the upstream two fields between 1st and 3rd groins, whereas flows are decelerated in the downstream fields.

4. Two Phase PIV Measurements inside the Intake Port of an IC-Engine

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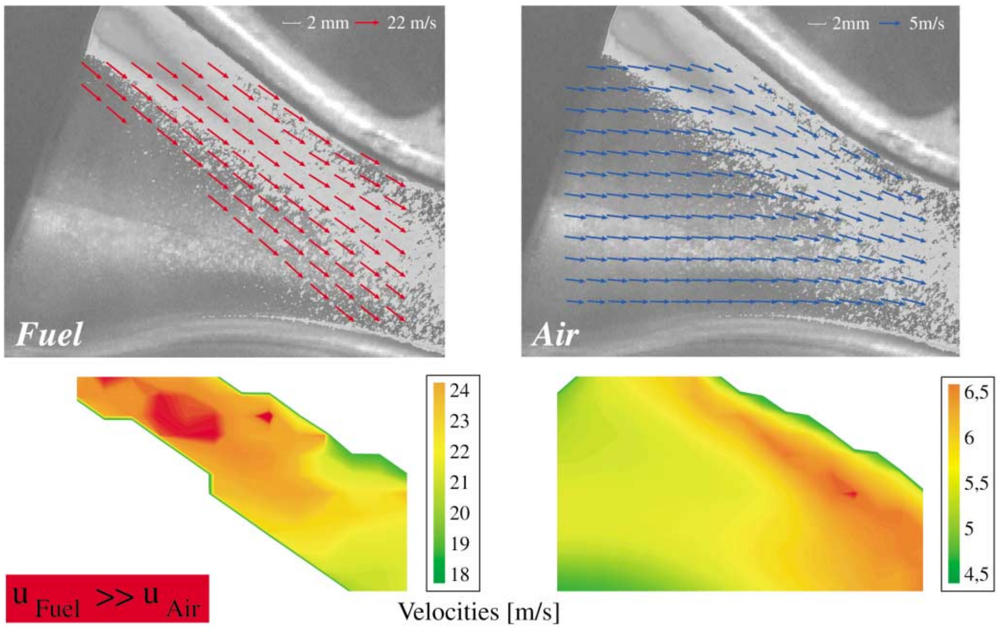
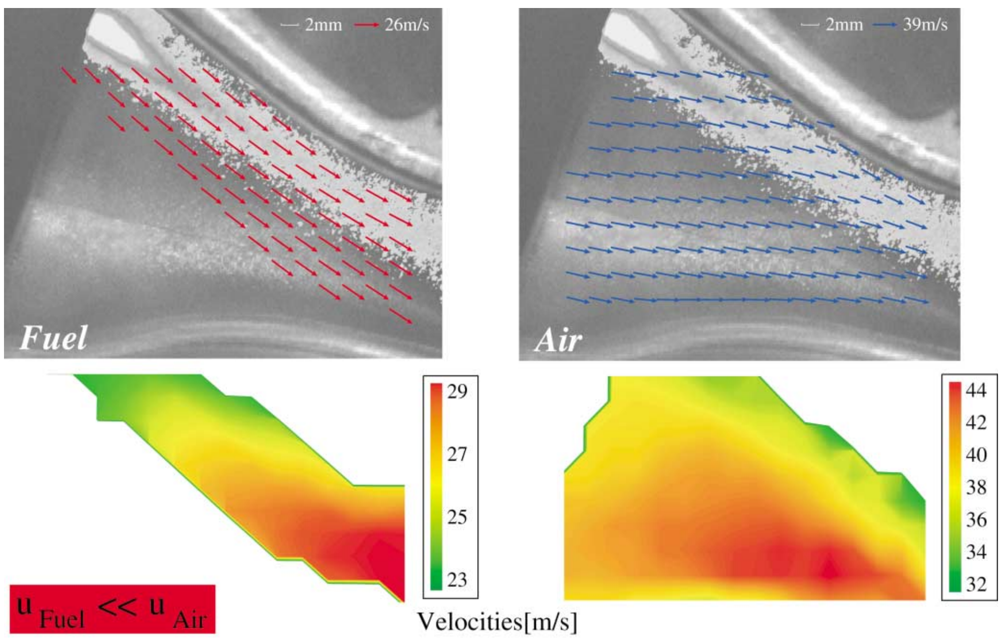


(a) Averaged velocity distributions at 6 m/s initial air velocity



(b) Averaged velocity distributions at 40 m/s initial air velocity

The figures show the interaction of the fuel spray with the intake air flow inside the intake manifold of an SI-engine. A new derivative of the PIV technique was investigated to determine simultaneously the velocity fields of a two phase flow, where the difference in the intensity of the scattered light substantially exceeds the dynamic range of the camera. The technique operates with fluorescent seeding particles and an optical filter to adjust the intensity of the Mie scattered light. The two phases recorded by a single CCD-camera are separated by the difference in correlation intensity. The results show impressively the potential of that measurement technique to study the interaction of the fuel spray with the intake air flow.

5. Color Schlieren Photographs of Interaction between Oblique Shock Wave and Boundary Layer on Flat Plate with Bleeding Effect

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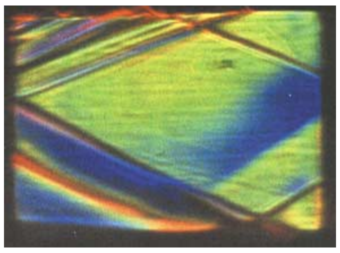
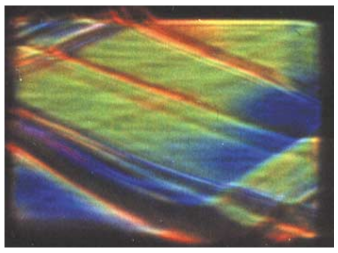

(a) Schlieren photograph (no bleed)


(b) Schlieren photograph

These figures show the CCD color schlieren photograph of interacting flow field of oblique shock wave from right middle side coming from upper two-dimensional wedge and boundary layer developed on the lower flat surface from the leading edge of rectangular intake model of 64(width)×56(height)×280(length)mm^3. The triangle section on the lower surface is the separation zone by shock/boundary layer interaction. Without bleeding of lower surface of Fig.(a), a strong oblique separation shock wave is emitted to the left upper direction and a shock wave by re-attachment of separation flow to the lower surface to the same direction is also emitted. The shock wave system is decayed and deformed if the bleed of boundary layer on flat surface is on. The two shock waves of separation and re-attachment come closer together and the strength of interacting shock waves is attenuated as shown in Fig.(b). Mach number M = 3.0, and bleeding rate is 0.1% of total intake mass flux.

6. Leading-Edge Vortices Visualized by Water Vaporization Method

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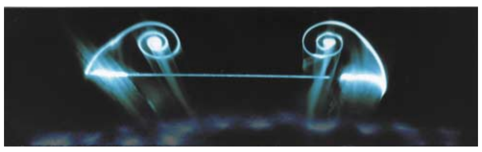
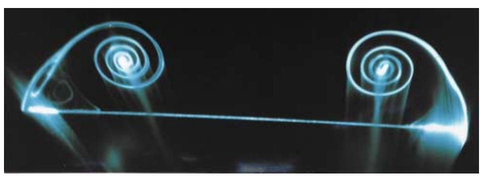
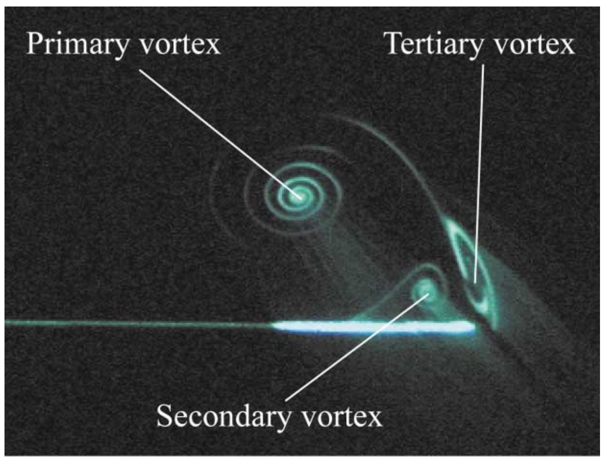
2) *Graduate Student, Graduate School of Engineering, Nagoya University, Japan*


(a) Cross-sectional view of longitudinal vortices at x/c = 0.4, where x is the distance from the apex of delta wing along the centerline.


(b) x/c = 0.6



(c) Close-up view of vortices on a half side at x/c = 0.5

A pair of leading edge vortices are produced by a delta wing placed in a wind tunnel. The flow is made visible by cooling the leading edges using liquid nitrogen to condense water vapor naturally included in airflow. The delta wing model used here has a root chord length, c, of 0.25m and a sweep angle of 76 deg. Measurements were made at an airflow velocity of 2 m/s, i.e. Re = 33,000, and at an attack angle of 20 deg. Primary, secondary, and tertiary vortices are well captured as well as vortex sheets.

7. Image Measurement of Wave Height Distribution around a Ship Hull in Regular Wave

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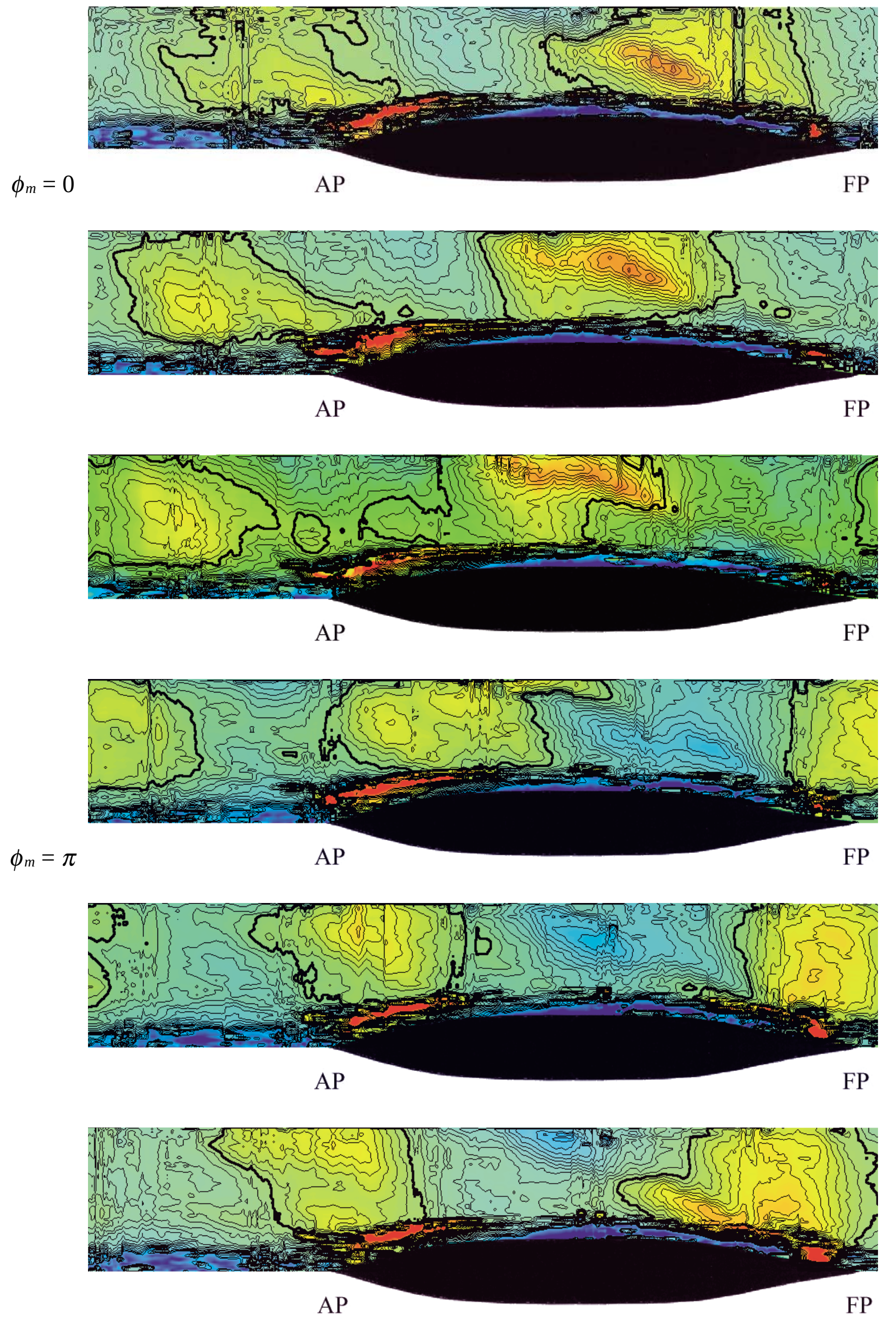

The wave height distribution around ship hull in regular wave is measured using visualized image. The wave profile on a laser light sheet is visualized by the difference of light scattering between air and water. The wave pattern around a ship model in regular wave changes periodically, and the conditional sampling based on the encountering phase of the incident wave and ship gives the wave profile at specified wave phase. The system enables to obtain the wave height distribution in regular wave in practical consuming time for the measurement. The figures show the measured wave height distribution through one period of encountering.