1. Visualization of flow structure around two cylinders

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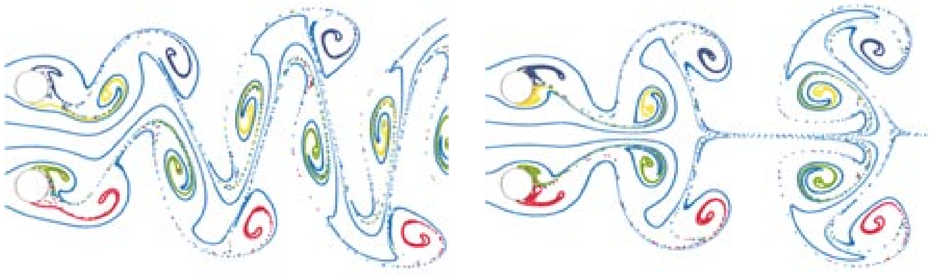
In-phase   Anti-phase

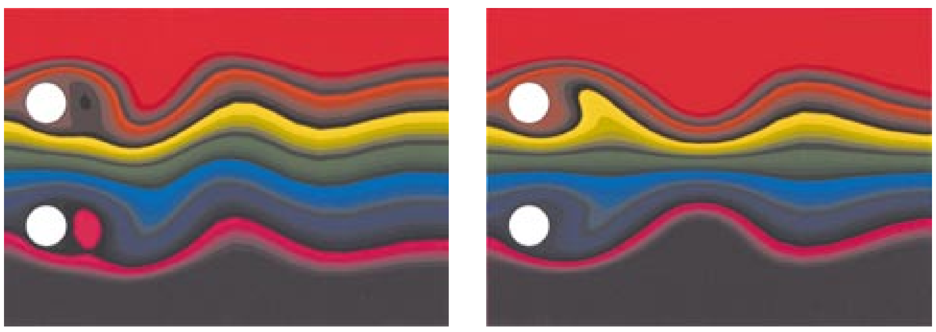


(a-1)   (a-2)

Streakline distribution

(b-1)   (b-2)

Vorticity contours



(c-1)   (c-2)

Streamline distribution

Figures (a) (b) (c) show the results of unsteady computation for two-dimensional flow around circular cylinders using generalized conservation of circulation model. (a-1) (a-2) respectively show the streakline distribution behind two side-by-side cylinders at Re=200 and T/D=3.0, where T and D are the center to center distance between the cylinders and the cylinder diameter, respectively. (b-1) (b-2) show the vorticity contour, and (c-1) (c-2) show the streamline distribution. The studies confirmed that the vortex-shedding synchronization (both in-phase or anti-phase) exist when the gaps between cylinders are in range 2.0<T/D<4.0. It is also noticed that the in-phase flow pattern is the preferred stable mode at Re=200. When no disturbance or only a very small disturbance is introduced into the flow at initial time, it is found that the flow structure will remain in anti-phase state within the range of Re=100 to 2000. However, when a bigger disturbance is introduced, the flow will settle to a stable in-phase pattern after a long time. At Re=3000 and 10000, the anti-phase vortex shedding seems to be the only stable flow pattern.

2.The vortex generation and breaking processes in an impinging round jet*

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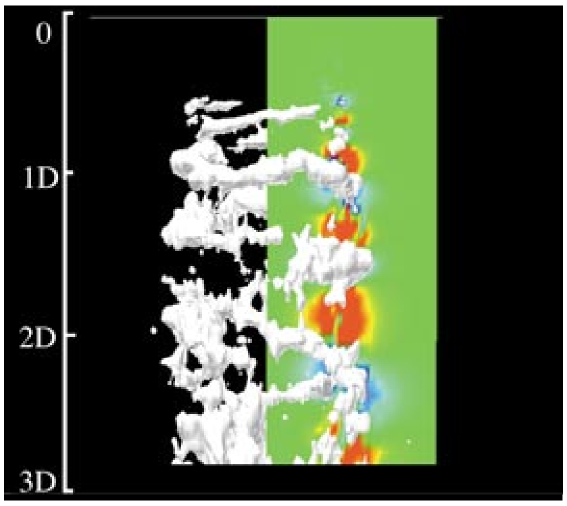
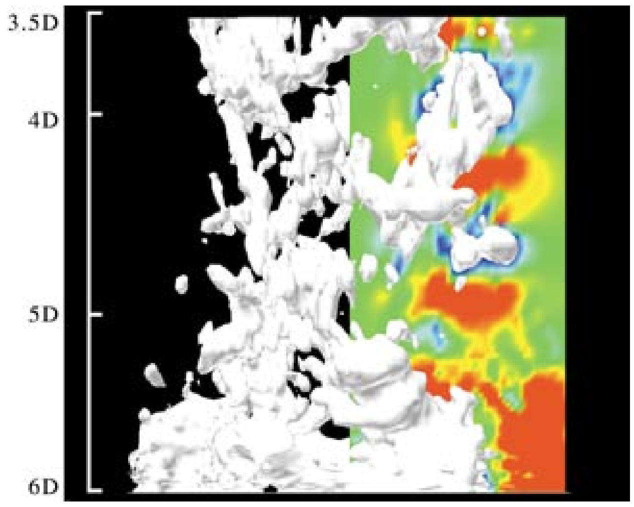


(a) The three-dimensional contour surface of the vortex in the near nozzle edge. White: vortical structures, red; high pressure region, blue: low pressure region, flow direction: top to bottom.



(b) The three-dimensional contour surface of the vortex in the impingement region. White: vortical structures, red; high pressure region, blue: low pressure region.

A direct numerical simulation (DNS) of an impinging round jet into parallel disks (the increment is 6 D) is performed for a Reynolds number of 10000 based on the nozzle exit velocity U_0 and the nozzle diameter (D). The generation of vortex-rings below the nozzle edge can be observed in Fig (a). Figure (b) shows the vortex breaking about half way between the nozzle and the wall. In the impingement region, it is found that the vortex-ring column disappears and another big torus-shaped low pressure region forms in the downstream region. The vortex generation and breaking processes and the generation and elongation processes of the wall-streaks will be considered as the main mechanism of turbulence transition in this flow.

* Satake, S. and Kunugi, T. (1998): Direct Numerical Simulation of an Impinging jet into parallel disks, Int. J. of Numerical methods for Heat & Fluid Flow, Vol. 8, No. 7, pp. 768-780.

3. Active Jet Control with an Array of Electromagnetic Flap Actuators*

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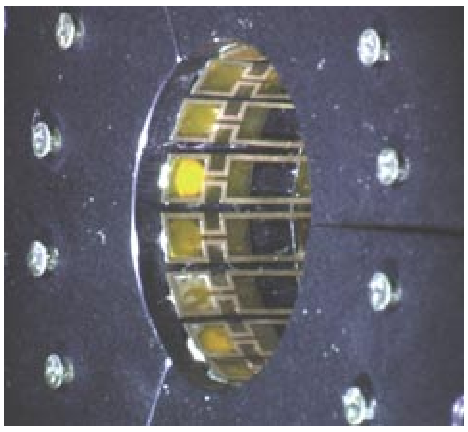
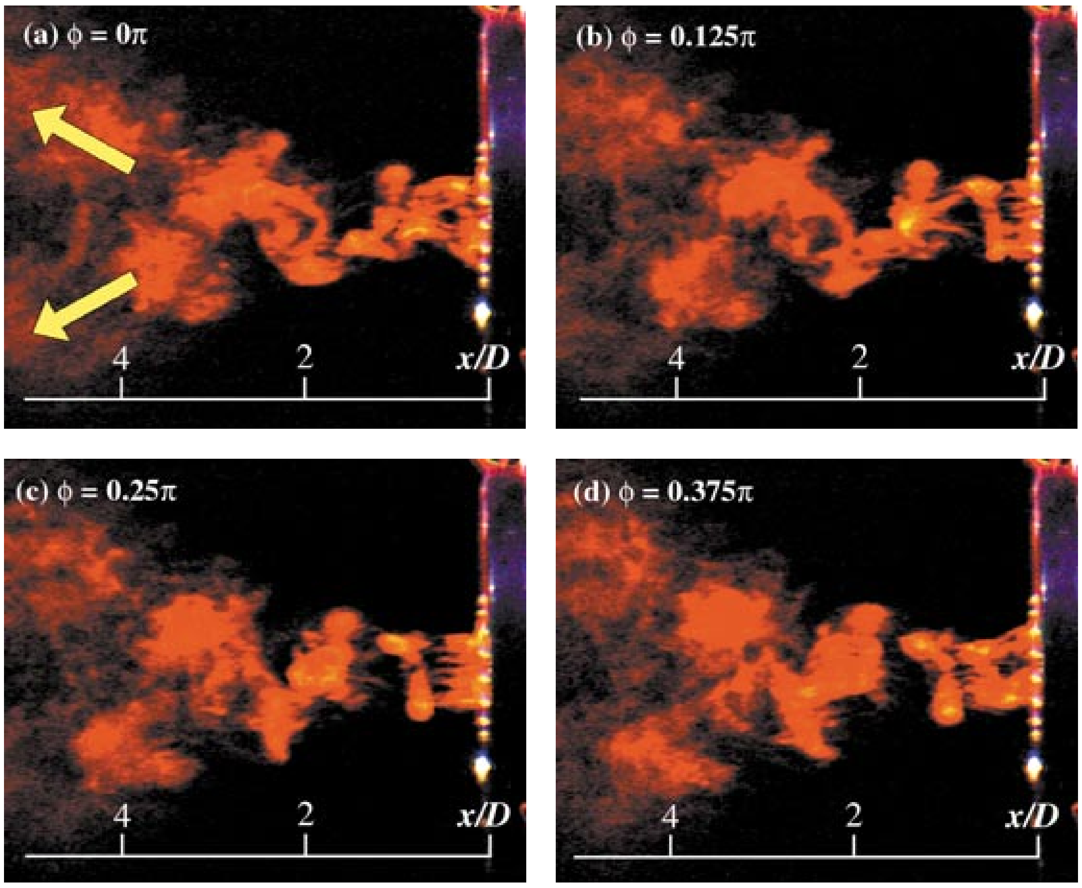


1. Perspective view of the nozzle exit (ID = 20 mm) with 18 flap actuators.

In an attempt of active control of turbulent flow with an aid of MEMS (Microelectromechanical Systems) devices, a novel axisymmetric jet nozzle equipped with a row of miniature electromagnetic flap actuators on its circular lip (Fig. 1) is developed for jet control. By applying PC-controlled driving signal to each flap, the evolution of eddy structures in the jet shear layer is modified. When each half cluster of the 18 flaps are driven out of phase (Alternative Mode), the jet bifurcates clearly into two branches owing to the mutual interaction between alternatively inclined vortex rings (Fig. 2), and mixing is significantly enhanced in the plane of bifurcation. The present control scheme is very effective, since it requires only a small amount of control input; the mechanical power input to the fluid by these actuators is by two orders of magnitude smaller than the propulsive power of the jet.



2. Successive flow visualization images of the bifurcating jet produced by the Alternative Mode control: Alternatively inclined and bent vortex rings are shed and transported into two different directions by their mutual interaction.

* Suzuki, H., Kasagi, N., and Suzuki, Y. (1999) : Manipulation of a Round Jet with Electromagnetic Flap Acutators, Proc. IEEE Int. Conf. MEMS ’99, pp. 534-540.

4. PIV Measurement of Internal Structure of Diesel Fuel Spray

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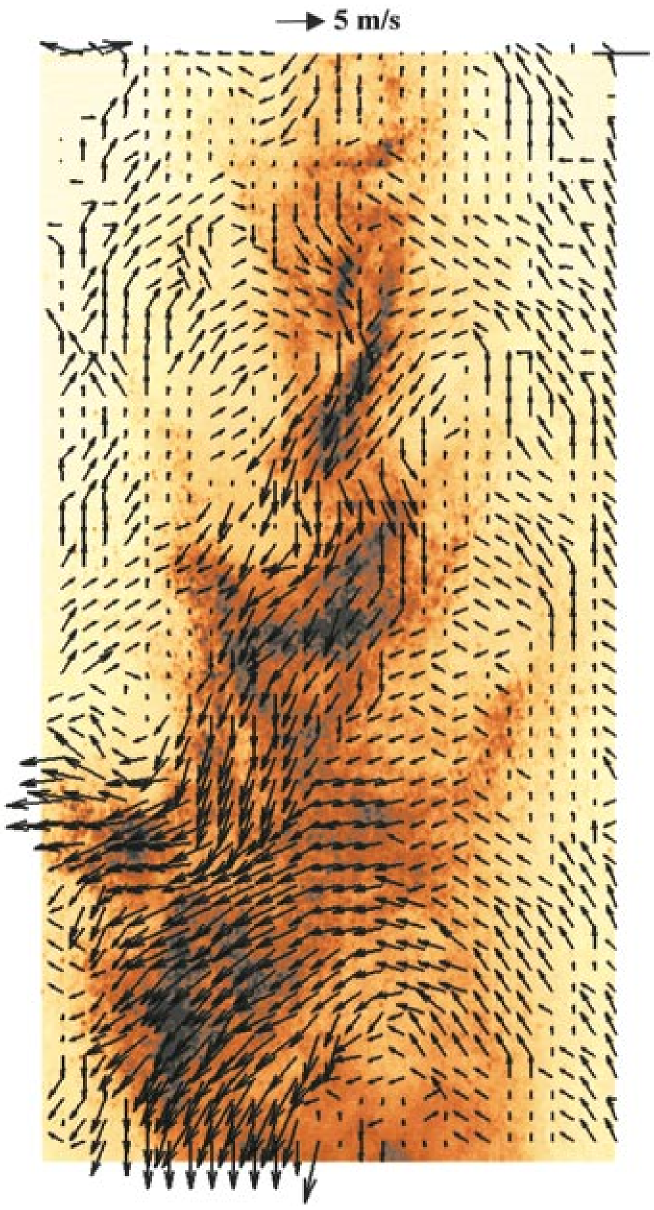
(a) LIF image of diesel fuel spray.



(b) PIV result and internal structures, uniform convection velocity, 2.0 m/s, subtracted from axial velocity component.

(c) Pseudo-vorticity distribution.

Internal structures of diesel fuel spray injected from a single hole nozzle at high injection pressure are visualized using a LIF technique with Rhodamine B ($C_{28}H_{31}ClN_2O_3$) as fluorescent dye. Double-pulsed Nd:YAG laser beams, 532 nm in wavelength and 200 mJ in pulse energy, shaped into a 0.3 mm thick sheet of light are used to excite the dye, which emits fluorescence centered on 590 nm. Large-scale internal structures, known as 'branch-like structures', of atomized fuel droplets are seen in Fig. 1(a), which is acquired at 4.0 ms after the injection made at an injection pressure of 50 MPa in N_2-gas atmosphere pressurized to 2.0 MPa. A corresponding PIV result obtained from doubly pulsed LIF spray images separated at 8 μs is shown in Fig. 1(b), which reveals the existence of active vortical motions of atomized fuel droplets. Note that uniform convection velocity, 2.0 m/s, is subtracted from the axial velocity component in this figure. As highlighted in the pseudo-vorticity distribution in Fig. 1(c), those active vortical motions are associated with the large-scale internal structures, which appear to be responsible for the mixing between fuel and surrounding gas.

5. Direct Numerical Simulation of Hydrogen-Air Turbulent Premixed Flames

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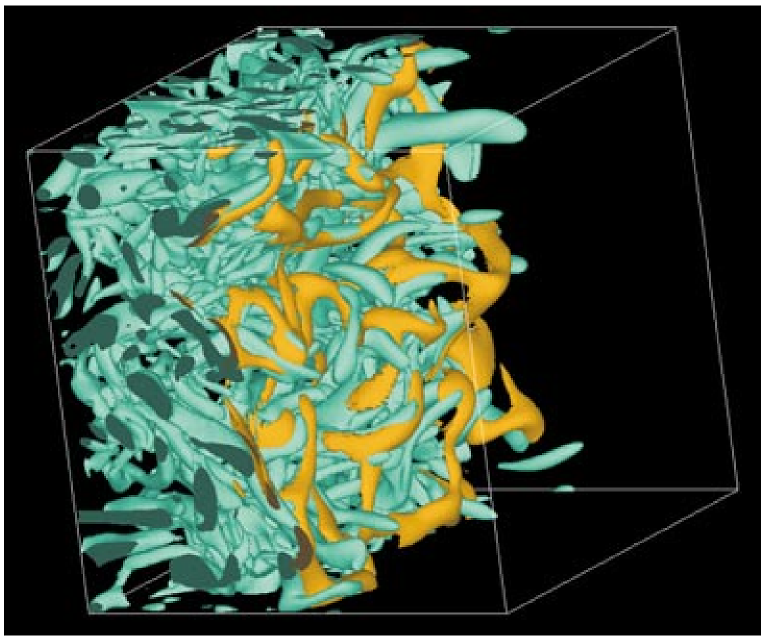
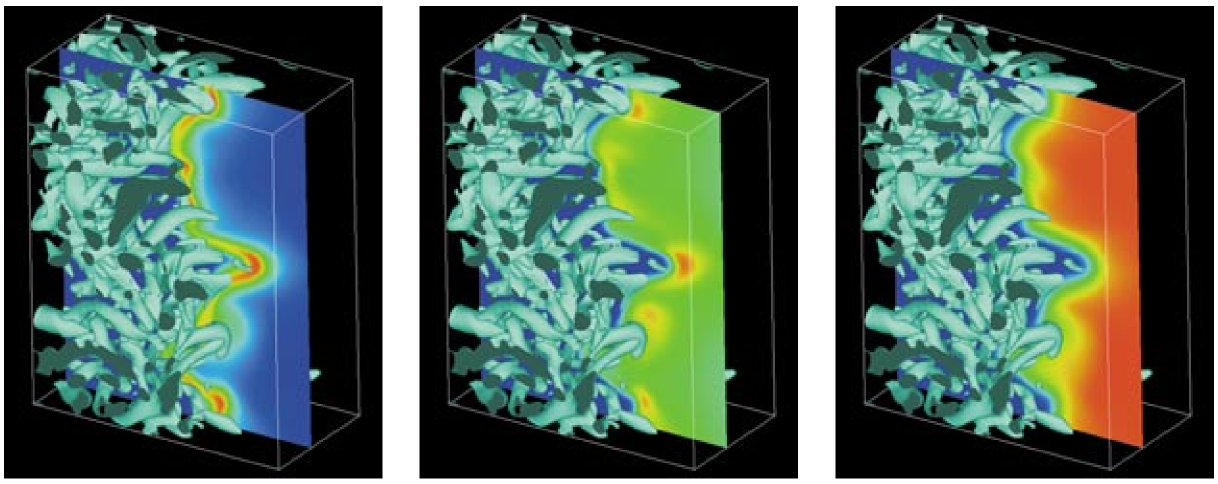


Figure 1 Coherent fine scale eddies in unburnt turbulence (green) and high heat release rate region (yellow) in a hydrogen-air turbulent premixed flame.



(a) Heat release rate (b) O atom (c) OH radical

Figure 2 Modification of local flame structure due to coherent fine scale eddies in turbulence.

Direct numerical simulation of hydrogen-air turbulent premixed flames propagating in homogeneous isotropic turbulence is conducted to clarify turbulence-flame interaction in turbulent premixed flames. A detailed kinetic mechanism which includes 12 species and 27 elementary reactions is used to represent the H_2-O_2-N_2 reaction in turbulence. Figure 1 shows tube-like coherent fine scale eddies and heat release rate. It is shown that the fine scale structure of turbulent premixed flames is significantly affected by the coherent fine scale eddies in turbulence. Figure 2 shows distributions of heat release rate, O atom and OH radical on a typical cross section with the coherent fine scale eddies. The relatively strong coherent fine scale eddies can survive behind the flame front and they are perpendicular to the flame front where heat release rate increases. Most of the coherent fine scale eddies near the flame front tends to be parallel to the flame front and enhance the chemical reaction.

6. The Structure of Plumes Generated in Unidirectional Solidification Processes

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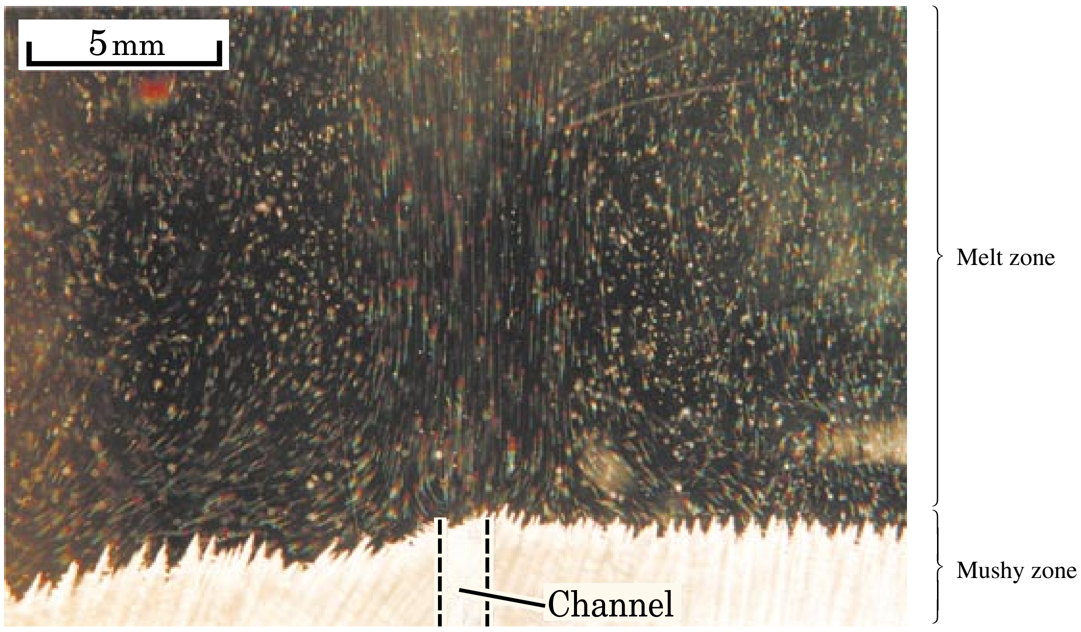

In the unidirectional solidification process of binary metallic alloys from a melt, several channels are formed in localized regions of the mushy layer composed of solid dendritic crystals with liquid in the interstitial spaces, known as freckles leading to the defects of materials. The origin of freckles is related to the onset of plume convection in the mushy zone*. The structure of plume convection emanating from channels in a transparent NH_4Cl-H_2O system analogous to metallic alloy system is visualized by a sequential three color light sheet method which identifies upward and downward flows in the melt. A typical observation after 60min from the start of solidification experiment of a 27wt% of solution is shown on the figure. The flow direction is from red to blue line in each particle path during the exposure time, and thus the plume is found to consist of the upward flow enveloped in the downward flow, which has not been known previously. The central upward flow near the channel exit ranges from 2.6 to 3.8 mm/s during solidification.

* Nishimura, T. and Wakamatsu, M. (1998): Natural convection suppression and crystal growth during unidirectional solidification of a binary system, Trans JSME, Ser. B, 64, pp.1155-1160.