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Visualising the Onset of Meandering Structures in a Small Length Scale Fluidic Junction Using Dye Injections

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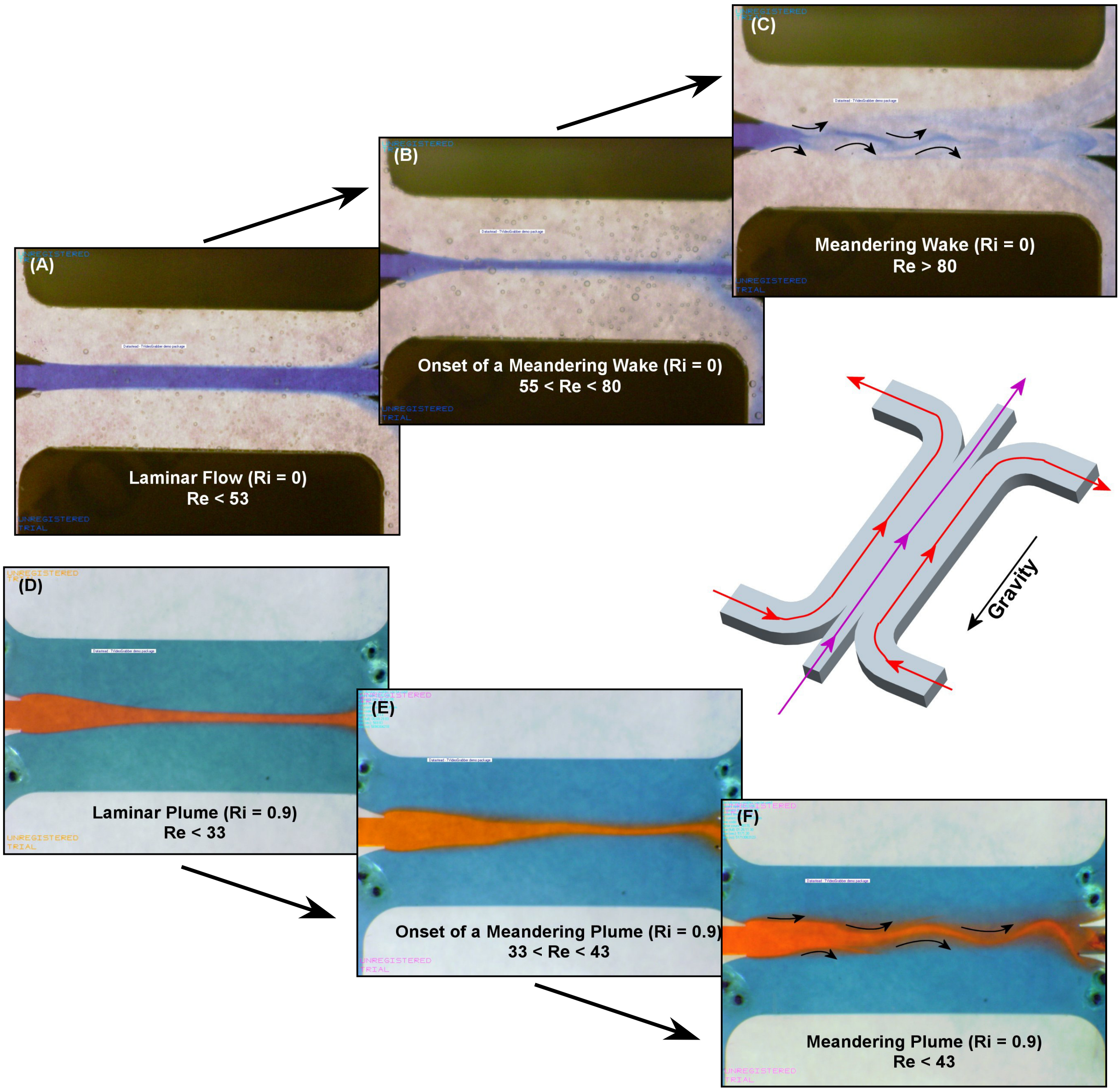

Figures (A) – (C) and (D) – (F) depict the transition from laminar to meandering flow in the fluidic junction shown schematically. The first set of images, (A) – (C), are captured from isothermal streams merging at the junction (i.e., Richardson number of zero). It is seen that when the Reynolds number of the outer stream reaches approximately 65, a slightly buckled wake is observed. On increasing this value further these buckles are seen to develop into a classical Von Karman Vortex street. The second set of images, (D) – (F), depict a similar transition to a buckled wake for the case of non-isothermal streams (Richardson number of 0.9) merging at the fluidic junction under buoyancy opposing flow conditions. It is observed that the critical Reynolds number to define the transition from a laminar to a meandering wake reduces significantly as the Ri increases from the isothermal case.

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Visualization of Axis-Switching of Elliptical Slot Jets

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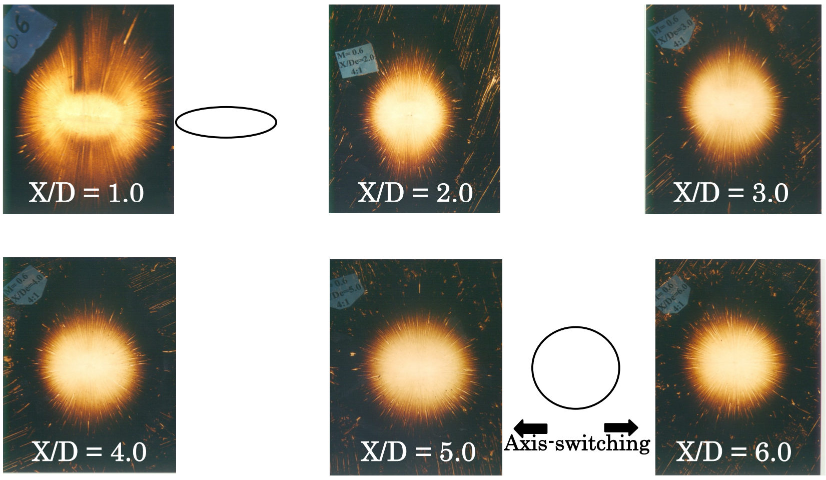
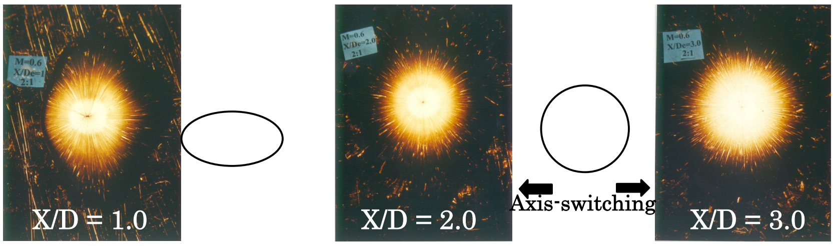


(a) AR = 4



(b) AR = 2

Fig. 1. Surface coating visualization for elliptical jets at Mach 0.6.

Elliptical slot jets of aspect ratio (AR) 2 and 4 were visualized by surface coating technique to understand the physics behind their superiority over circular jets and the influence of aspect ratio on axis-switching phenomenon. The jets were made to impinge on the flat surface of a transparent plate, which was coated with lamp black and pump oil. The plate was kept normal to the jet axis at different axial locations. When the jet impinges on the flat surface of the transparent plate, the surface coating was eroded due to the shearing action. After exposing the coated plate to the jet, it was taken out and the pattern on the plate surface was photographed with a diffused light projected from the uncoated side of the plate. The presence of vortices of various sizes starting from the largest ones at the ends of minor axis and the smallest ones at the major axis ends for Mach 0.6 jet is clearly inferred from the visualization pictures, shown in Fig. 1. For the present aspect ratio elliptical jets at X/D = 1.0, the coating at the minor axis ends are almost intact, indicating that the vortices were large in size, since the large size vortices are good entrainers but poor promoters of mixing. In contrary the small vortices are efficient mixing promoters but weak entrainers. The presence of small vortices is inferred form the significant erosion of the surface coating near the major axis extremities. For the AR 2 jet, axis-switching occurs between X/D = 2 and 3 and for higher AR jet like AR 4, axis-switching occurs between X/D = 5 and 6 (where X is the axial distance from the elliptical slot and D is the equivalent diameter of the elliptical slot). It implies that for AR 2, the entrainment is more compared to AR 4. The visualization pictures demonstrate the generation of vortices from largest to smallest size with continuous variation in their size, owing to the continuous variation of the radius of curvature of the ellipse along its azimuth. These vortices of varying size are responsible for the improved entrainment and enhanced mixing of the elliptical jets compared to circular ones. Among the different aspect ratios tested, AR = 2 is found to be best from jet mixing point of view.

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Vortex Entrainment and Separation Using Flow Superposition

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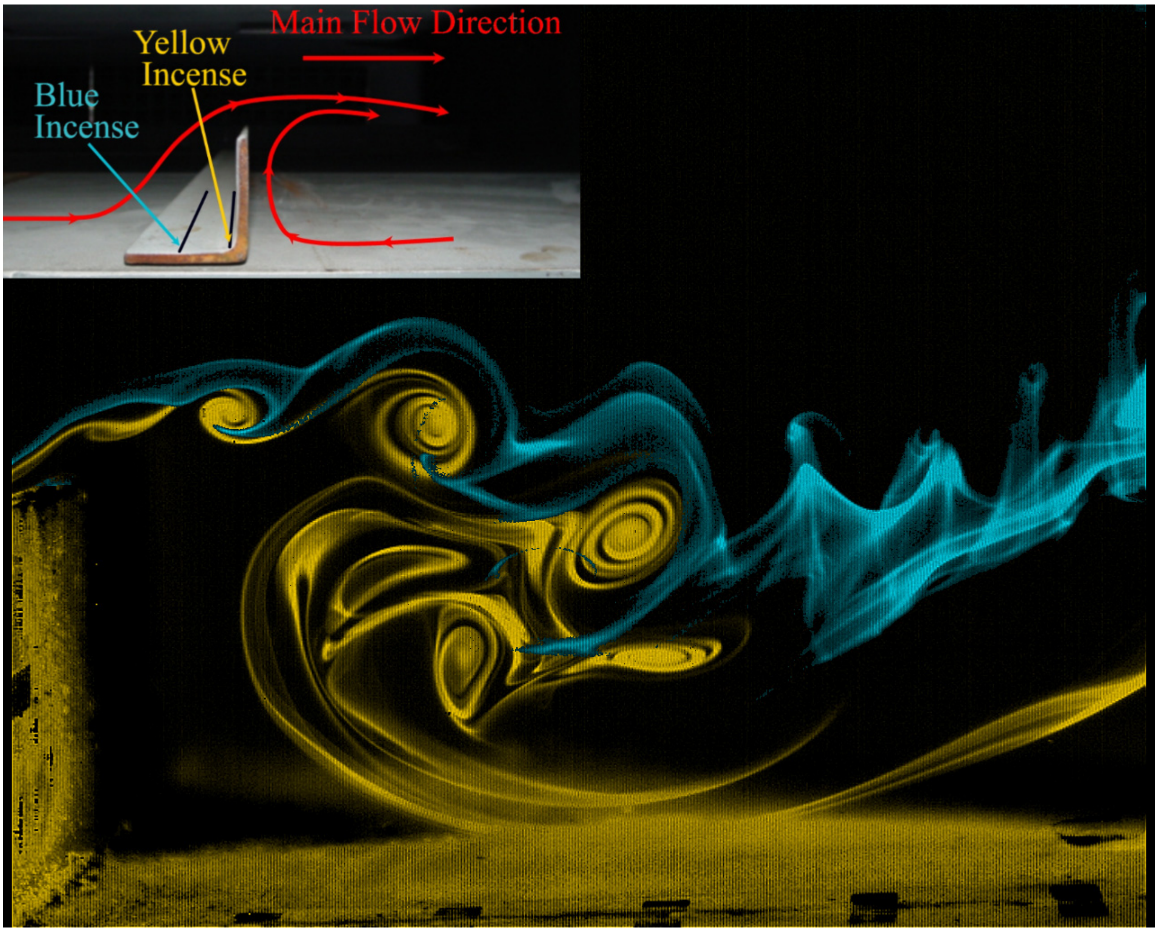

The photograph illustrates transient airflow over a fence. The flow was acquired within a two-dimensional aircraft nacelle simulator. This simulator is 0.23 m high and 1.83 m wide (0.75 ft and 6.00 ft respectively). Smoke was produced from burning incense sticks and illuminated with a 1000 W tungsten light. Images were acquired at 240 frames per second using a high-speed digital camera. The image is a combination of two synchronized visualizations taken at two different times and superimposed. The color was added using video editing software in order to differentiate the two separate visualizations. The yellow colored smoke was generated using incense sticks placed at the upstream corner of the fence. The blue colored smoke originated from incense sticks placed approximately 1.27 cm (0.50 in) upstream of the fence.

The two superimposed images show entrainment of outside fluid (blue) into the shear layer vortices, which form in the recirculation region.

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Visualization of a Car Mirror Wake

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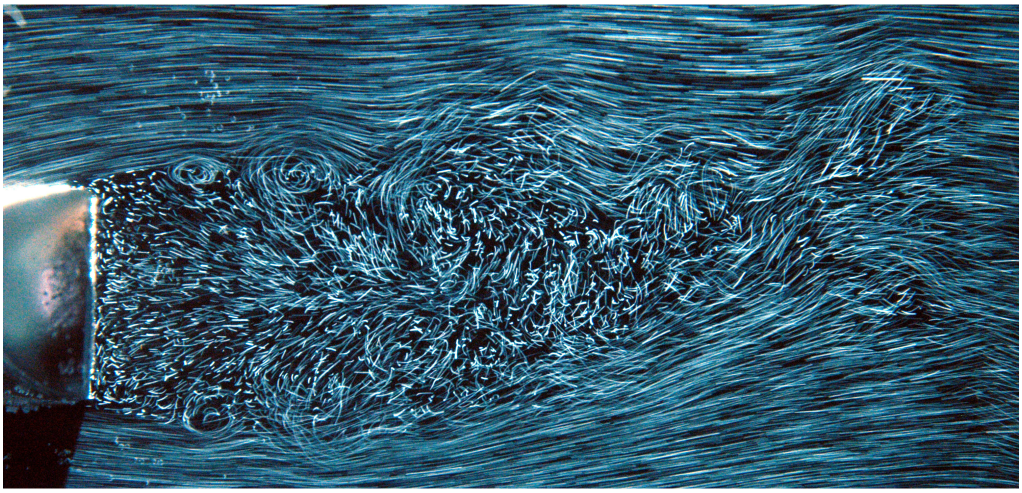

Fig. 1. Flow visualization of side view.

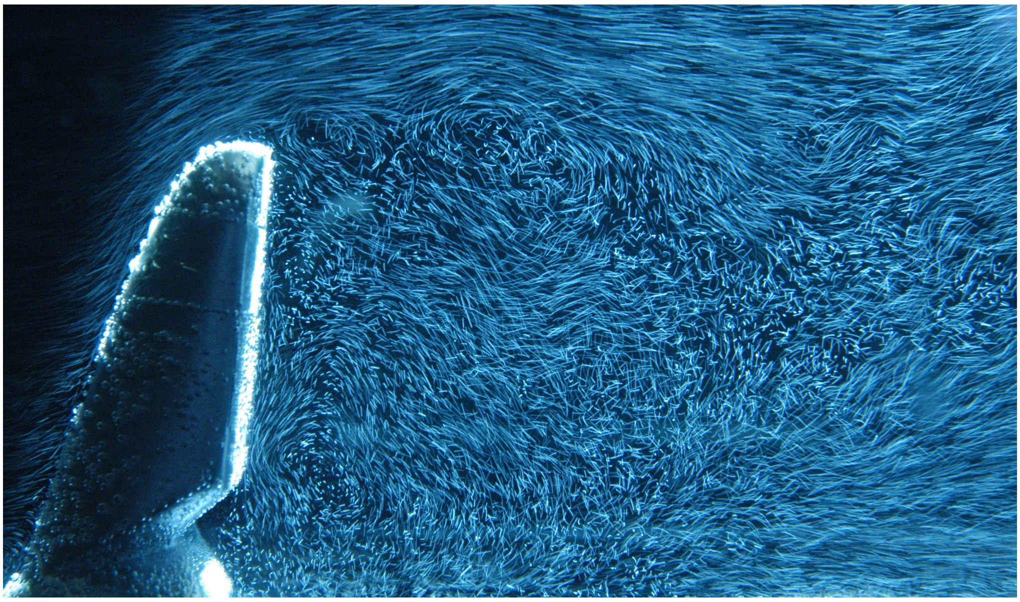

Fig. 2. Flow visualization of plane view.

The flow structures around externally mounted vehicle mirror were visualized at a Reynolds number of 125,000 by using solid tracers. Figure 1 shows the flow visualization photograph of the side view around the mirror. The image clearly reveals that two vortex streets in the anti-symmetric or inphase mode are produced by two sides of the mirror edge due to the anti-symmetrical mirror. The separation bubble or the region of the reverse flow behind the mirror is also observed. Two vortex streets gradually grow up downstream, however, behind the region of the reverse flow the oscillation of large vortices is formed. The flow visualization photograph of the plan view is shown in Fig. 2. In this case, besides a large separation region, two evident vortex regions are found in this separation region. One is located between the separation bubble and the free stream (i.e. in shear layer), which are produced by the tip of the mirror. The other is located near the root of the mirror where a shedding vortex occurs.

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Turbulent Pulsed Jet

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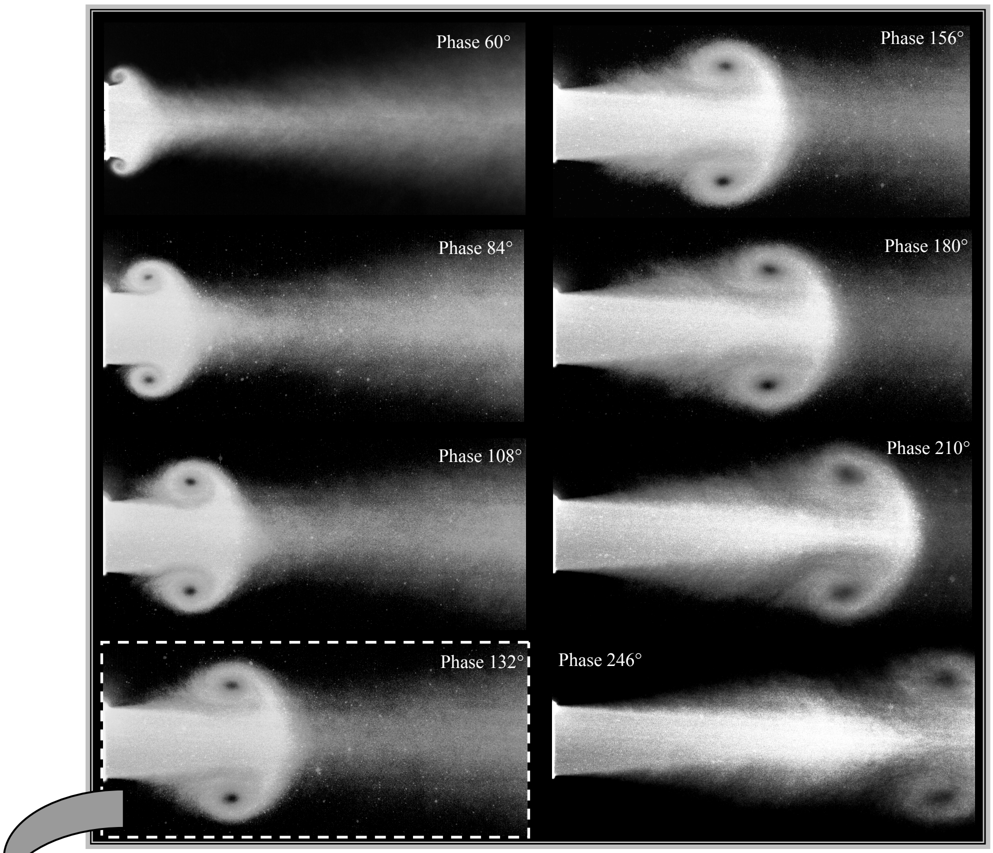
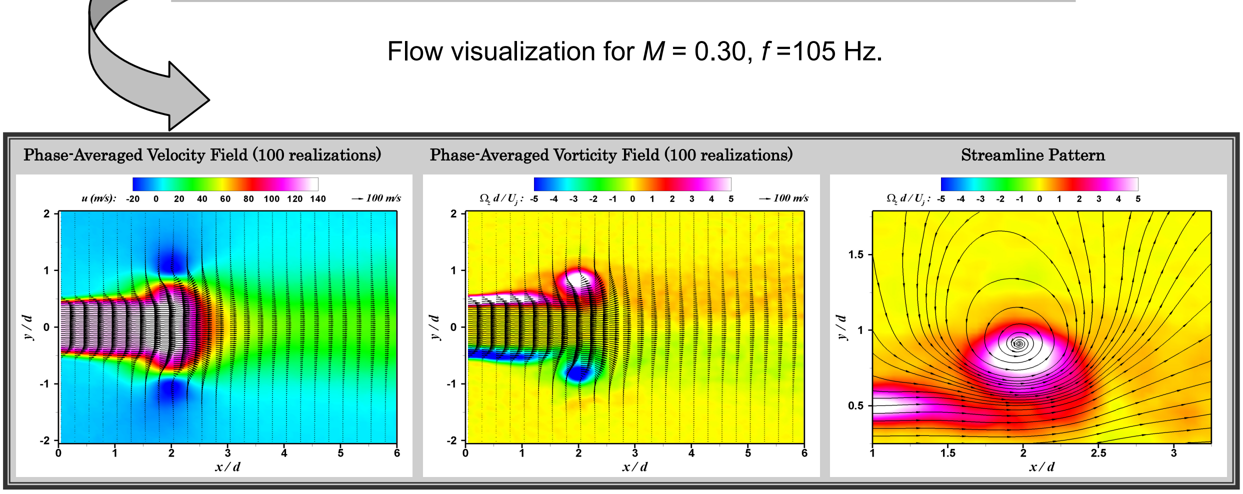


Flow visualization for M = 0.30, f =105 Hz.



A turbulent pulsed jet issuing from an axisymmetric nozzle at an operating Mach number of 0.30 (Re = 3.25 x 10^5) and a pulse frequency of 105 Hz is studied by Particle Image Velocimetry (PIV). The jet, seeded with oil droplets, is illuminated by a laser sheet in the central plane to capture phase-averaged images. The time evolution of the pulsed jet clearly shows a leading vortex ring followed by a trailing jet. The fidelity of the phase-averaged PIV measurements is vividly displayed by the hydrodynamic flow field and the associated vorticity field. The streamline pattern obtained from the velocity field exhibits strong entrainment, with reversed flow, induced by the vortex ring.

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Control of Vortex Shedding from a Hemisphere by Local Suction

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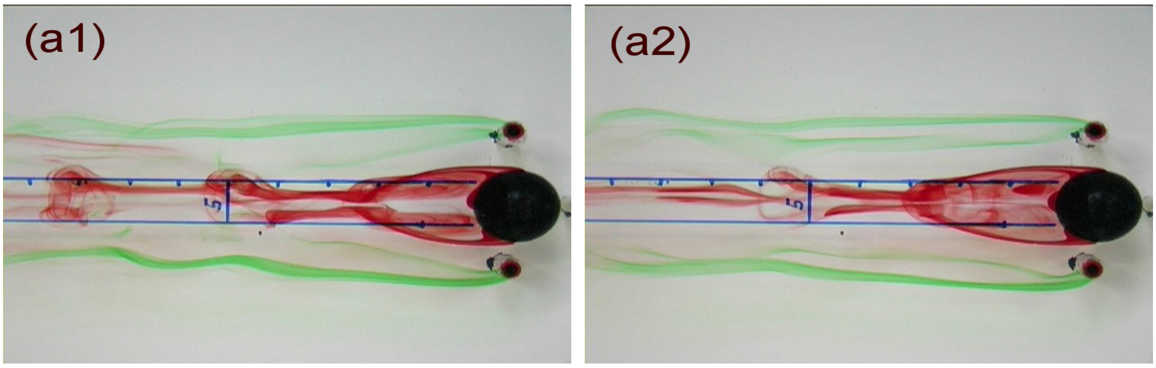

Fig. 1. Wake region of a hemisphere in the laminar boundary layer without suction (left) and with suction (right) at a suction rate of SR = 3.1.

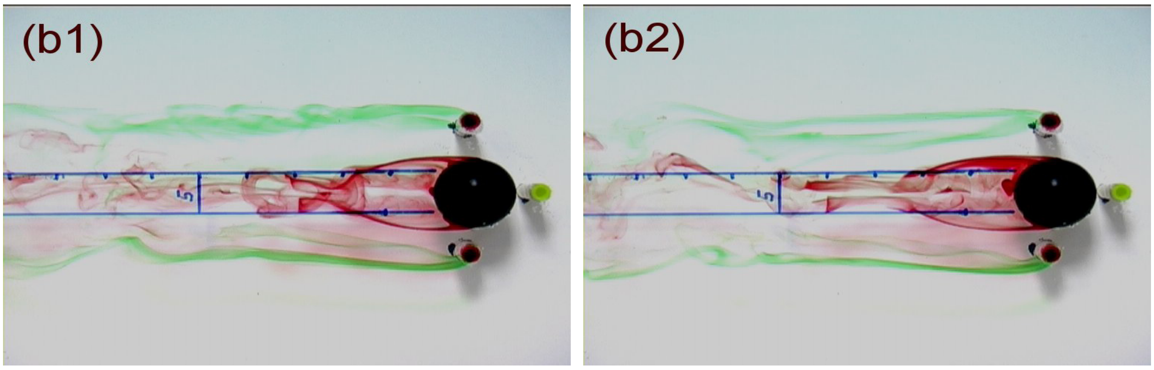

Fig. 2. Wake region of a hemisphere in the laminar boundary layer without suction (left) and with suction (right) at a suction rate of SR = 1.47.

A water channel experiment was carried out to investigate into a possibility of controlling vortex shedding from a hemisphere in the laminar boundary layer. This work was conducted by modifying the necklace vortices around a hemisphere by local wall suction, thereby reducing their interaction with the shedding hairpin vortices. The boundary layer over the test plate was laminar, where the Reynolds numbers based on the distance from the leading edge were 2.7×10^4 and 4.0×10^4 with the freestream velocity of 0.074 m/s and 0.107 m/s, respectively. The corresponding Reynolds numbers based on the diameter of hemisphere were 1.26×10^3 and 1.82×10^3, respectively. We visualised the wake region of a 17 mm diameter hemisphere by colour dye injection, where the baseline flow (left) is compared with a controlled flow by local suction through 2.5 mm diameter hole, 3 mm upstream of the hemisphere (right). It seems that the induction of high speed fluid into the wake region is reduced as the strength of necklace vortices is weakened by suction. As a result, the shedding frequency of hairpin vortices has been reduced by 12.4 % for the suction ratio (defined as a ratio of the suction pressure to the freestream dynamic pressure) SR = 3.1 and by 7 % for SR = 1.47. It was also observed that the local wall suction has extended the wake region of a hemisphere further into downstream. This suggests that the local wall suction has moved the flow separation point into upstream over the hemisphere, thereby increasing the area of wake region.

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