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Visualization of Streamwise Vortex Pairs in an Indeterminate Origin (IO) Nozzle Jet

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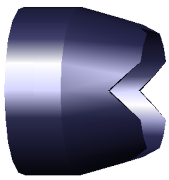
The shape of the indeterminate origin (IO) nozzle, which is a truncated, conical 4-peak nozzle, is shown in Fig. 1.



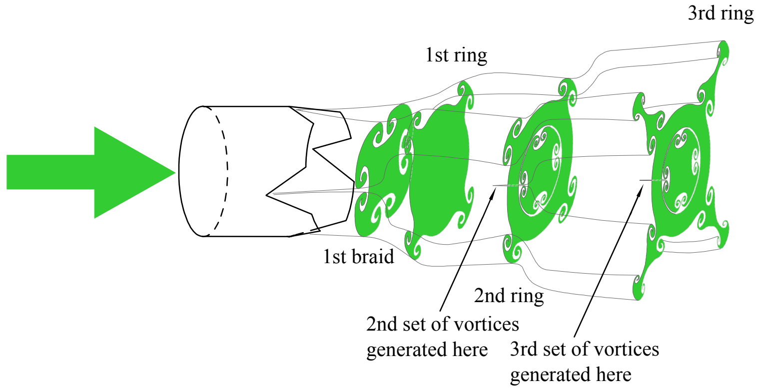


Fig. 1. Geometry of the IO nozzle. Fig. 2. Sketch of streamwise vortex structures in the IO nozzle jet.

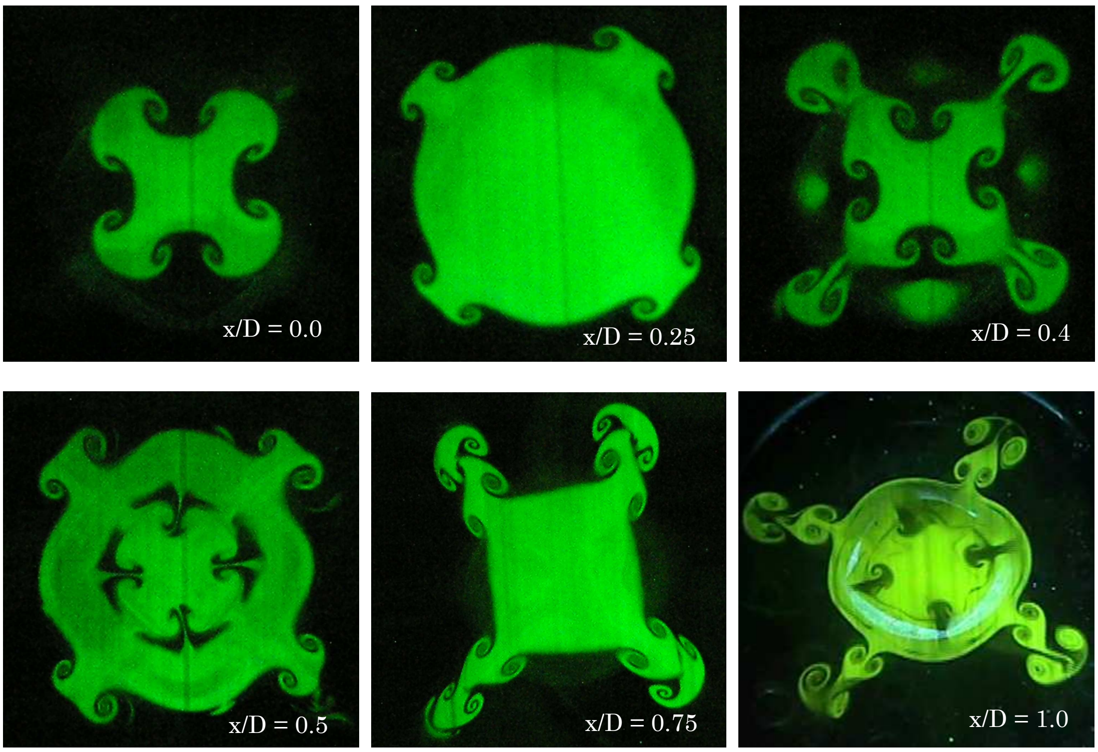


Fig. 3. Cross-sectional LIF flow visualizations at different downstream locations in the near-nozzle region.

"Incursion" streamwise vortex pairs are generated near the nozzle valley locations in braid regions of the jet. They entrain ambient fluid into jet core. These vortex pairs are confined in the jet core, and because of their close proximity, they reorganize to form the "excursion" vortex pairs, which expel the jet fluid into surroundings. The reorganization consists of streamwise vortices from adjacent pairs joining to form a different pair.

New sets of vortices are generated in each braid region. These vortices are initially incursion pairs and develop into excursion vortex pairs after reorganization. Up to three sets of vortex pairs in the radial direction were observed in the experiment before the jet transitioned to turbulence.

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Three-Dimensional Numerical Simulation of a Straight Channel Proton Exchange Membrane Fuel Cell

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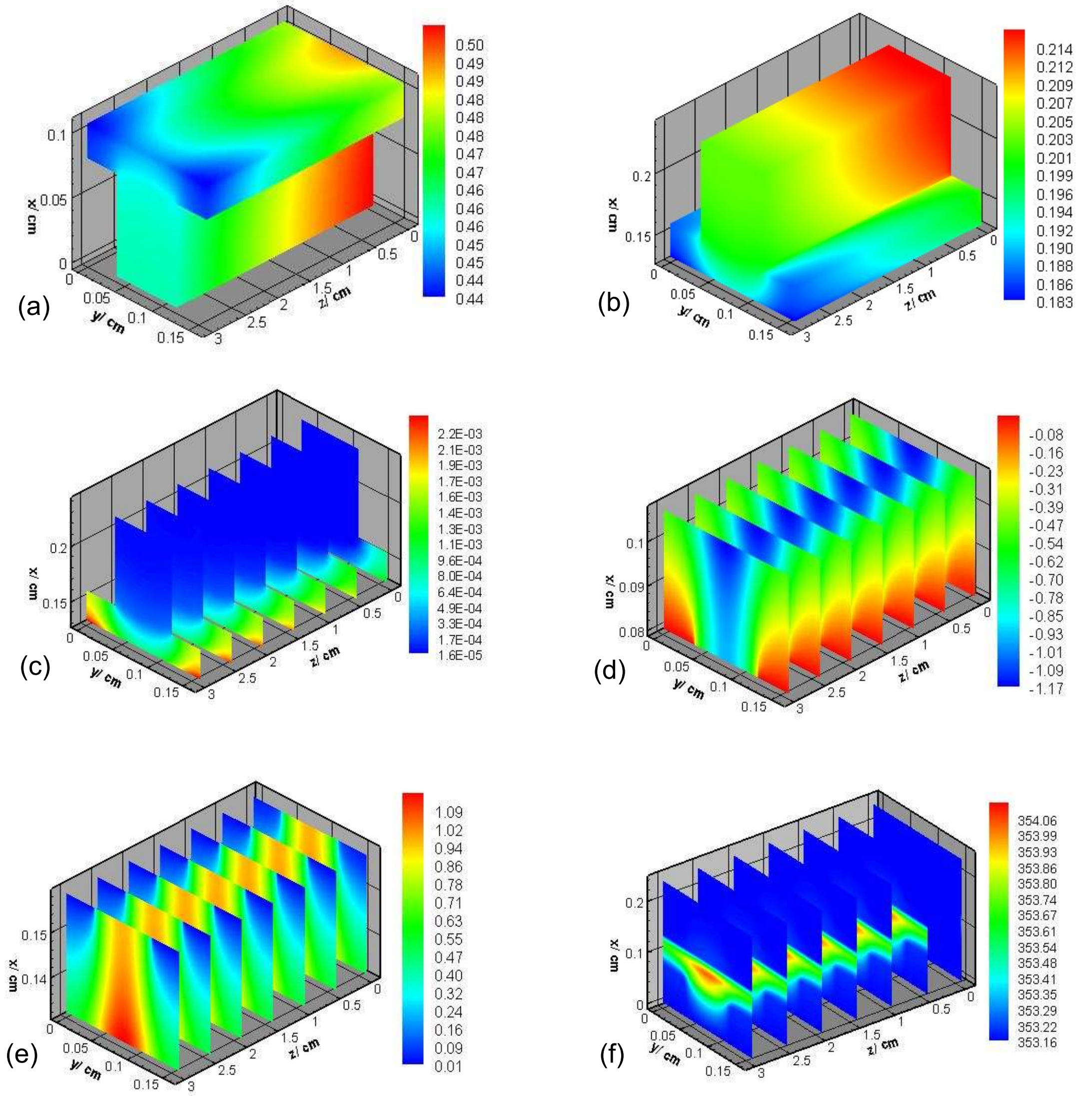

Fig. 1. Computed results of characteristic parameters. (a) Hydrogen mass fraction; (b) Oxygen mass fraction in the cathode; (c) Liquid saturation of water in the cathode; (d) Carbon phase potential in the anode(mV); (e) Carbon phase potential in the cathode(mV); (f) Temperature.

A comprehensive gas-liquid two-phase mathematical model is developed to better study transport phenomena in the whole proton exchange membrane fuel cell (PEMFC). Almost all important transport phenomena such as fluid flows, heat transfer, mass transfer, electrochemical kinetics, and charge transfer, as well as the effect of phase change on mass transfer and temperature field are accounted for in this model. As a result of electrochemical reaction, hydrogen and oxygen are consumed, which cause the mass fraction decreasing along the flow direction, illustrated as (a) and (b). As a product of the electrochemical reaction, water is generated in the cathode, which makes liquid saturation of water increases along the flow direction, as shown in (c). Carbon phase potential loss is very small with the order of 1 mV because the electron conductivity is very high, as shown in (d) and (e). In (f), the peak value of temperature lies in the middle of membrane for the ohm heating of proton current.

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Vented Circular Cylinder as a Vortex Generator

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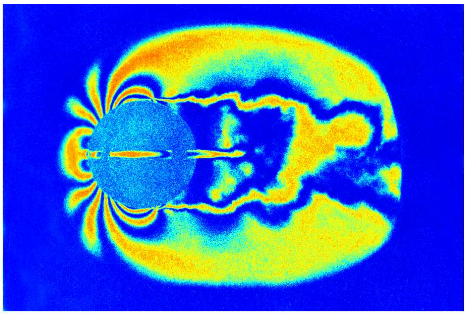
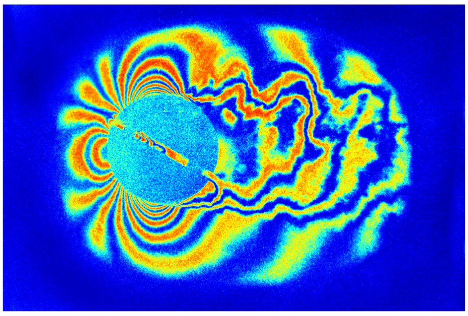
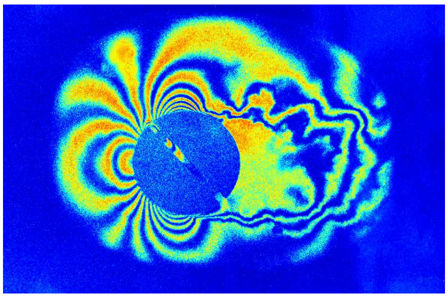


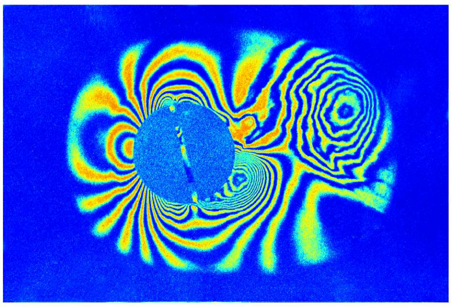
$\alpha = 0°$



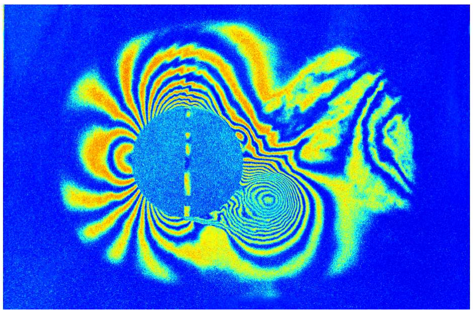
$\alpha = 15°$



$\alpha = 45°$



$\alpha = 75°$



$\alpha = 90°$

These Mach-Zender interferograms show the effect of slot incidence on the near-wake features of a circular cylinder with natural ventilation. When the slot incidence angle is varied in the range 60° to 90° with respect to the mean flow, dramatic change in the flow features can be observed, as compared to the basic cylinder. Alternate blowing and suction take place across the slot, resulting in the formation of huge vortices accompanied by generation of sound. Due to the very low pressures in the core of the vortex leaving the near wake flow-field, the instantaneous flow remains attached up to 180° from the stagnation point. At $\alpha = 60^{\circ}$, significant difference in the locations of mean separation lines on top and bottom sides was seen, suggesting production of lift. The interferograms were obtained at free-stream conditions of $M = 0.31$ and $Re = 0.47$ million at the 0.3 m vacuum wind tunnel at the Max-Planck Institute of Fluid Mechanics, Goettingen, Germany. The cylinder diameter was 50 mm, and the vent slot had dimensions of 4 mm at the entrance and 4 mm at the exit.

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The Effect of Streamwise Vortex Structures on the Particle Distribution in the Roll-Up*

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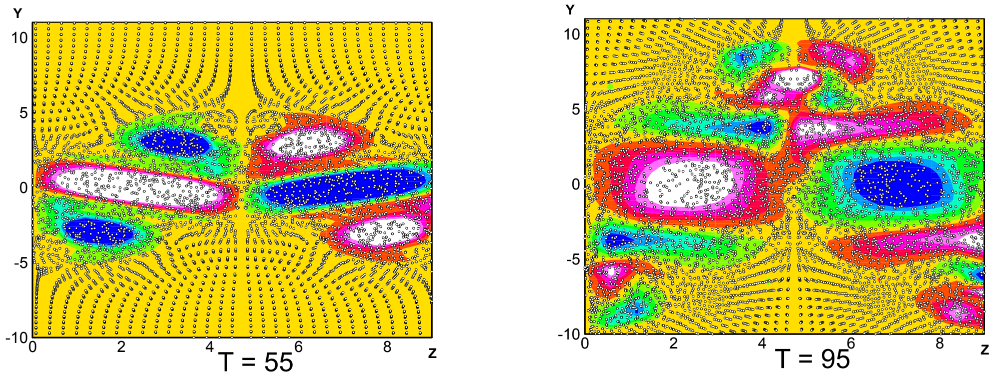

Fig. 1. Particle distribution along the spanwise for *St* = 0.01 at two instants.

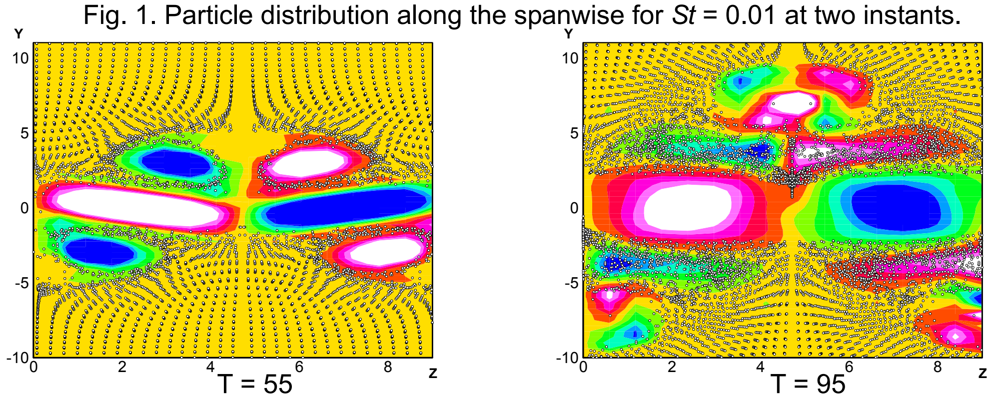

Fig. 2. Particle distribution along the spanwise for *St* = 1 at two instants.

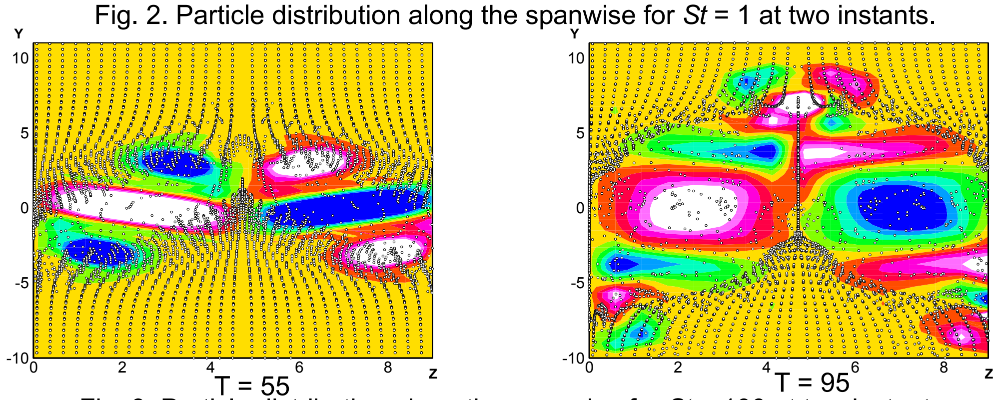

Fig. 3. Particle distribution along the spanwise for *St* = 100 at two instants.

A direct numerical simulation is employed to demonstrate how the streamwise large-scale structures affect the particle distribution in a three-dimensional free shear flow. The black dots in the figures represent the particles distribution, and the color contours represent the pairs of counter-rotating streamwise vortices. It is obvious that the particles with $St = 1$ accumulate most on the circumference of the large-scale structures while other particles distribute more evenly along spanwise direction. The spanwise variation of the concentration is dependent on the streamwise vortex structures. With the development of the streamwise structures and three-dimensionality, the spanwise variation of particle distribution gets stronger, and finally leads to the 'mushroom' shaped pattern of the spanwise particle distribution, this is especially true for the intermediate Stokes number of 1.

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Shear Layer Instability at Low Reynolds Numbers

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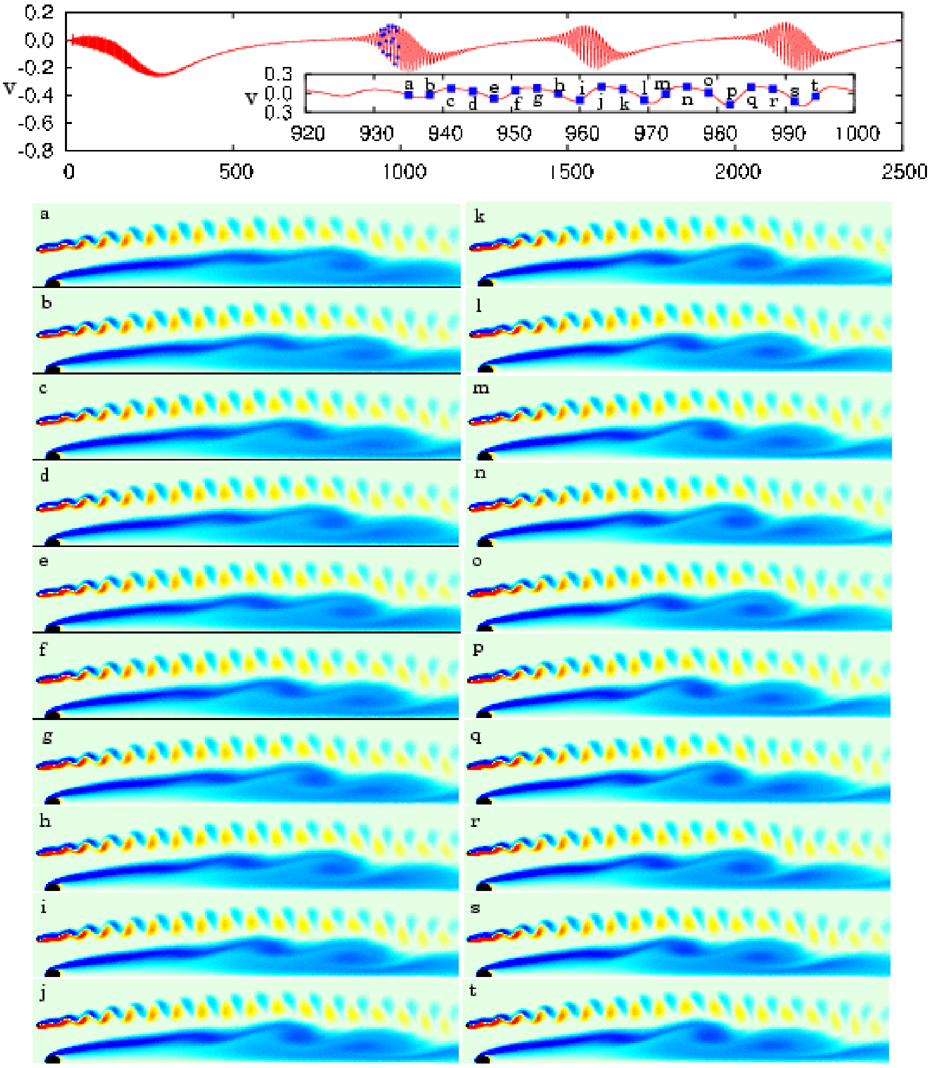

Fig. 1. *Re* = 300 flow past half a cylinder in the presence of a smaller secondary cylinder of one-fifth the diameter: time history of the vertical component of velocity at (15D, 2D) and vorticity field at various time instants. Red color indicates counter-clockwise while the blue color shows clockwise vorticity.

The critical Reynolds number (Re_c) for the onset of the shear layer stability in the wake of the cylinder has been a topic of debate in the past. While some researchers have found $Re_c \sim 1200$, others have observed shear layer vortices at *Re* as low as 350. Here, we investigate the instability of the separated shear layer for the *Re* = 300 flow. To suppress the primary wake instability, flow past half a cylinder with symmetry boundary conditions at the wake center line is considered. It is found to be stable. However, when the separated shear layer is excited by the vortex shedding from a secondary cylinder, it looses stability. The secondary cylinder, located at (-1.0D, 2.5D) with respect to the center of the half cylinder, is one-fifth its diameter (D). Figure 1 shows the time history of the vertical component of velocity at (15D, 2D) and the vorticity field at various time instants. The shear layer instability can be clearly observed. It is periodic, but intermittent in nature. The computations have been carried out using a stabilized finite element forulation. The mesh consists of 97,474 nodes and 194,056 triangular elements.

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Dispersion of Ink in a Bubble Column

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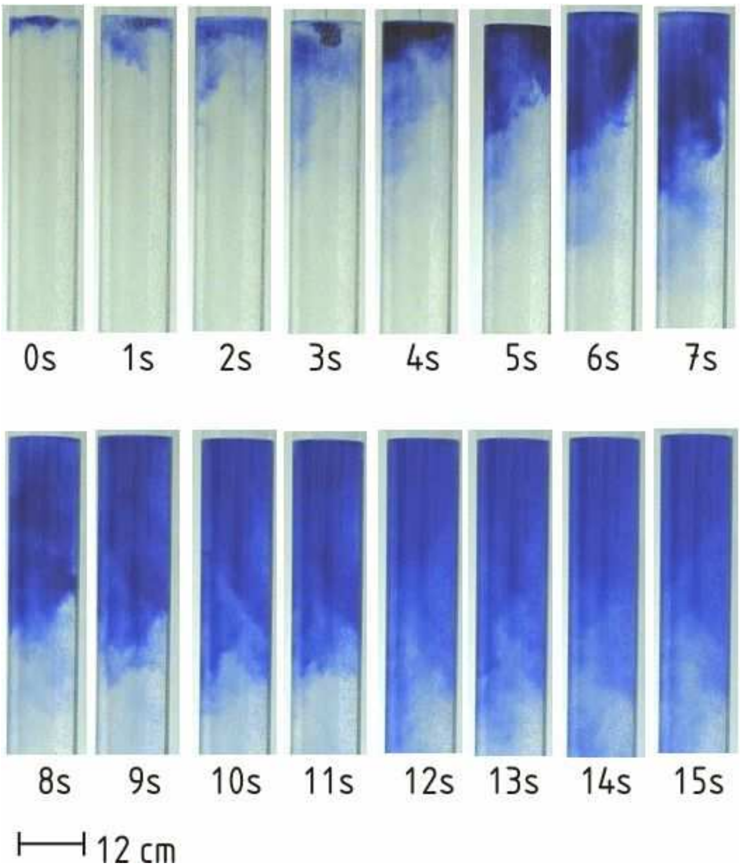

The photographs show the dispersion of ink in the upper part of a bubble column, which is of 1.3 m height and 0.12 m diameter. The liquid phase is tap water, the gas phase is air. Small bubbles rise up and induce the liquid flow field. Thus in particular in the center of the column the liquid is transported upwards. At the free surface the phases are separated and the liquid flows downwards near the column wall. The resulting flow field is characterized by several large scale vortices, which significantly affect the dispersion of the ink. For longer times dispersion phenomena in the axial and radial direction lead to a homogeneous distribution of the ink within the liquid.