

Electrolytic Techniques

Tin-Oxide Precipitation

The electrolytic precipitation method allows the introduction of a tracer into the flow with less disruption to the flow than occurs with dye injection. The tracer is an electrolytically precipitated oxide. In this case we describe the precipitation of tin-oxide, which is a highly reflective white powder.



Tin-oxide precipitated in the wake of a cylinder reveals the wake structure.
Contributed by Yukie Tanino

The anode is a thin (pure) tin wire that is sufficiently small that it does not interfere with the flow. The cathode can be any inert conductor. Copper works well as a cathode, and can be placed anywhere in the fluid where it will not obstruct the flow. Increasing the cathode surface area increases tin production and produces better photographic contrast. A copper mesh can be used for this purpose. The rate of oxide production also increases as the distance between the electrodes is decreased. The two electrodes are connected to a DC power supply that can be operated in short pulses using a simple switch. When the potential difference is applied across the electrodes, an electric current flows and induces tin dissolution from the wire. The dissolution of tin forms a precipitate of tin-oxide that appears as a highly reflective white smoke. The contrast can be enhanced by illuminating the oxide cloud by a light sheet. While the exact chemistry has not been studied, the compound is most likely a hydrated tin-oxide. Voltages in the range of 10V with currents around 10 mA are typically used. Higher voltages will increase the rate of tracer production, but if the voltage is too high, hydrogen bubbles will begin to form. Tap water can be used as the working fluid. While some papers suggest the addition of salt as a means of increasing the fluid's electrolytic conductivity, such additions may result in the production of tin chloride, which is toxic. This method also works with other metals. Solder is commonly suggested, but most solder contain lead, which is toxic. Finally, note that because tin is a heavy metal it must be filtered from the working fluid before releasing it to a drain. We used a 0.5 micron filter in a recirculating system. In addition to sequestering the heavy metal for easy disposal, the filter prohibits the build up of tracer which degrade the optical contrast. Because of the rate of tracer production, this method is limited to flow velocities less than 5cm/s.

See also. Taneda, S, Honji, H., and Tatsuno, M. (1977). The Electrolytic Precipitation Method of Flow Visualization. In, Proc. of the Intern. Symp. on Flow Visualization, ed. T. Asanuma, 133-138, Tokyo, Japan.

Hydrogen Bubble

Bubbles are produced at the surface of a thin (25-50 μm) platinum wire. The wire is used as the negative electrode and a positive electrode made of metal or carbon is placed nearby in the fluid. The positive electrode should be flat. DC voltage is applied to the wire, generating a current that passes through the water. Electrolysis at the wire surface generates bubble of hydrogen with diameters comparable to the wire diameter. The bubbles, which are very small, effectively follow the local velocity vector, allowing one to visualize the local flow structure.

<http://www.lehigh.edu/~fluids/images/apsposter.jpg>

The following movies show a series of bubble lines generated by pulsing the voltage source. The movies take about ten seconds to load.

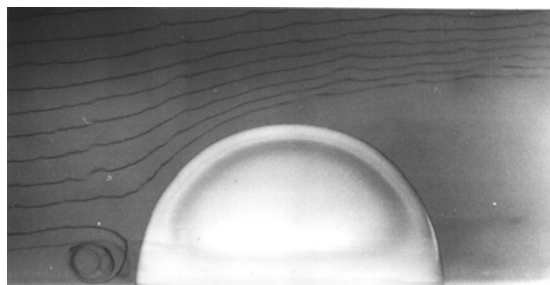
<http://cvu.strath.ac.uk/courseware/calf/CALF/images/eq6a.mov>

http://cvu.strath.ac.uk/courseware/calf/CALF/images/eq6b_01.mov

The diameter of the hydrogen bubbles will be of the order of the wire diameter. The typical voltage range to generate bubbles is 50-70 V with currents in the range of one amp. An electrolyte must be added to the water to enhance bubble production. Typically 100 mgL^{-1} of table salt or sodium sulfate is used. With a steady power source, a continuous sheet of bubbles is released into the flow. Pulsing the power supply creates a series of bubble lines that allow quantitative analysis of the local velocity. Greater voltage may be needed for long wires or multiple wire arrangements. The right amount of electrolyte is important. If concentration is too low, bubbles are too diffuse; if too high larger bubbles are created, causing buoyancy problems. The technique is most effective only at relatively low flow speed - $O(10 \text{ cms}^{-1})$. Finally, due to the high voltages used, great caution should be exercised when working with this technique. Contact with the wire, the positive electrode, or the water flow may result in an unpleasant electric shock.

Thymol Blue

Thymol blue is pH indicator that turns from yellow to blue between pH 8 and 9. The working fluid's pH is adjusted to just below this transition value, and the color change is triggered electrolytically. As in the hydrogen bubble technique, described above, a thin platinum wire placed in the flow acts as the cathode. The anode is placed at some distance away from the region of interest. When voltage is applied across this circuit, hydrogen ions are created by electrolysis. The hydrogen ions move toward the cathode, where they lose their charge and combine to form hydrogen. This produces an excess of OH ions near the cathode, which triggers a change in fluid color around the platinum wire. This technique effectively produces a line source of blue dye.

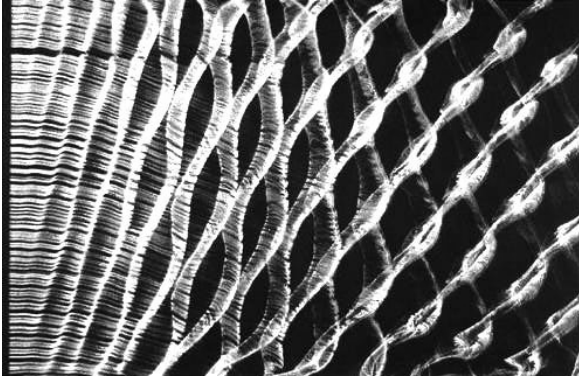


Side view, showing main horseshoe vortex (Thymol blue visualisation, $Re = 1.4 \times 10^3$)

<http://www.engga.uwo.ca/people/esavory/hemispheres.htm>

Smoke Wire

This technique is for visualization in air flow. Smoke is produced from a thin (0.1 mm) steel wire coated with oil. The wire is connected as a resistor to an electric circuit. When the circuit is on, the wire heats causing the oil to form smoke. By pulsing the circuit, a sequence of smoke lines can be produced, much like the hydrogen bubble technique above.



Visualization of the near-wake of a circular cylinder by smoke-wire technique, with the smoke-wire placed 50 diameters downstream of the cylinder. Prof. Williamson, Cornell University. http://www.efluids.com/efluids/gallery/wave_resonance.htm

Flow Visualization Provided by Clouds

Because clouds are opaque, they provide a natural tracer material.



Vortex street forming off the Guadalupe Island (August 20, 1999). NASA's Jet Propulsion Laboratory. http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/OCDST/vonKarman_vortices.html