Experimental Study of Surface Dynamics of a Liquid Jet
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Introduction
An interface between a liquid and a gas can exhibit various intricate shapes such as:

- Spray/Atomization
  - Fuel injection
  - Water jet breakup
- Aeration/Gas entrainment
  - Oxygen for aquatic life
  - Atmospheric CO2 absorption by oceans
- Heat and mass transfer
  - Heat exchanger
  - Mixing process

This has very important consequences on:

- Spray/Atomization
  - Fuel injection
  - Water jet breakup
- Aeration/Gas entrainment
  - Oxygen for aquatic life
  - Atmospheric CO2 absorption by oceans
- Heat and mass transfer
  - Heat exchanger
  - Mixing process

An experimental approach is necessary to investigate such complex flows.

Experiment and Instrumentation
This research focusses on instabilities arising when the flow exits a wall. A 0.8” thick water jet flows from a contoured nozzle onto a transparent channel at velocities of 0 to 33 ft/s. A pulsed laser illuminates a cross section of the flow and two high speed cameras are simultaneously imaging the surface profile and the flow beneath it.

Machining of the nozzle out of aluminum.
Jet exiting the nozzle, laser sheet is visible.

2D spanwise disturbances are visible on the surface of the jet. These are very small: \( \text{scale 1:1} \), thus high magnification optics are required.

Particle Image Velocimetry (PIV) reveals the 2D velocity field below the surface.
Time series of streamline plots showing the deformation of the surface by the vortexes.
The shear layer rolls up and forms a series of vortexes which deforms the surface.
- The first part is characterized by a quick growth (waves B and C).
- The second part is defined by a constant growth rate (waves D and E). The waves and the vortexes are then coupled. This can sustain the waves for a long period.

Surface profile from PLIF has been used to mask the image above the interface.
Particle Image Velocimetry (PIV) reveals the 2D velocity field below the surface.

For higher velocities, the waves collide. A counter-rotating vortex pair is injected in the flow from the closing troughs:

The bubbles are convected by the vortex pairs:

Surface dynamics from initial disturbances to large amplitude deformations have been studied and characterized. Injection of vortex pairs has been observed for the first time. A new air entrainment mechanism in the trough of waves is also reported. The experiment offers the possibility to investigate primary breakup and other turbulent air entrainment mechanisms. Measurements of interphase gas transfer will be implemented in the near future. These results will help developing empirical correlations and validate high fidelity multiphase flow numerical simulations.