18.JesseParticles3

Friday, April 08, 2011
1:38 PM

JesseCapslect_04062011
Inserted from: <file://C:\Users\hertzber\Documents\01CLASSES\FlowVis\Content\LectureNotes\JesseCapslect_04062011.pdf>

Flow Vis Lecture 4-6-11

Particle Tracer Methods

Particles can be added to a flow to trace fluid motion

Common Techniques

- Particle Tracking velocimetry
  - Technique to measure velocity of particles
  - Sparse seeding is used
  - Each particle trace can be analyzed individually
  - velocities inbetween particles are interpolated
  - only if $\boxed{\eta << \lambda}$ $\eta \equiv$ smallest scale of flow
    $\lambda \equiv$ mean free distance of particle
  - used mainly for laminar flow
- Particle Image Velocimetry
  - used to observe large ranges of eddies in turbulence
  - high particle density
  - image transparency is measured
  - Produces 2D vector fields

  SHOW IMAGE [Hertzberg PIV]
- other techniques
  - laser speckle velocimetry

Particle Generation

usually want non-invasive particles

Stokes Number: Ratio of particle relaxation time τ_p to characteristic flow time τ_f.

$$St = \frac{\tau_p}{\tau_f} \qquad \tau_p = \frac{\rho_p d^2}{18\mu} \quad \text{from stokes drag}$$

$$\tau_f = U_0 / L \qquad L \equiv \text{characteristic length}$$

if $St \ll 1$ particles will follow fluid stream lines closely (act as tracer).

if $St \gg 1$ particles will ~~follow 2 fluid~~ continue ~~sp~~ in a straight line, ~~as~~ fluid flow is affected.

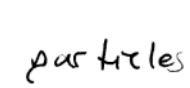
In general: $Re < 10{,}000$ particles must be less than 100 μm in water, less than 1 μm in air.

$\mu_w = 1.002E-3 \ N \cdot s/m^2$

$\mu_a = 1.82E-5 \ N \cdot s/m^2$

Example minute Paper

Flow past a sphere



Given: Water: $\rho = 1000 \ kg/m^3$, $\mu = 1.002e-3 \ N \cdot s/m^2$

$Re = 100$, $D_{cyl} = 0.2 \ m$

$\rho_p = 3300$ (sand)

what is particle diameter for $St = .01$?

$Re = \frac{U_0 \rho L}{\mu}$ $\therefore$ $U_0 = 5.01E-4 \ m/s$

$.01 = \tau_p / \tau_f \qquad \tau_f = U_0 / L = .002505 \ s$

$\Rightarrow 2.505e-5 = \frac{\rho_p d^2}{18\mu}$ $\boxed{d = 11.7 \ \mu m}$ Assuming stokes flow

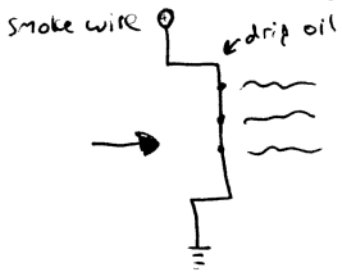
If [illegible] Re: $St = .05$

Generation and Injection Techniques

In air: smoke & fog

A) smoke = soot, carbon particles + heat

smoke wire:
- performs better in laminar flow
- can be used in turbulent flows
- electrical current is passed through a fine (~.1 mm diam) oil-coated metal wire.
- as wire is heated the oil is vaporized
- line of smoke is produced parallel to the wire and moved along with flow.



show image
flow over air-foil Re = 50,000
[University of Kentucky Flow lab]

or

Generate a volume of smoke (cigarettes / incense)

TiO_2 Titanium dioxide

start w/ titanium tetrachloride (liquid)

$+ H_2O$ vapor $\Rightarrow TiO_2$ smoke

- Dense cloud, 1 μm particles

- easily sticks to solid surfaces, reacts w/ moisture in the airflow to generate a bright, white fume of TiO_2.

show image [Freymuth 1987]

B) Fog = aerosols of liquids

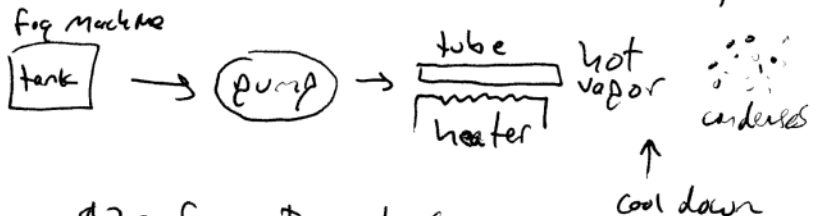
water fog: - ultrasonic humidifiers
- medical nebulizers
- dry ice (solid CO_2)

+ evaporates too fast at elevation *
but it is non-toxic, no residues

Bernoulli Atomizer (show image)
[Matt Blessinger, Get wet 2009)
- creates large droplets

<u>Stage Fog</u>: water + [glycerin or propylene glycerol] } slows evaporation

- flow is hot & rises
- use dry ice or ice bath to cool fog



- $20 from Target (1 mo. before Halloween)
otherwise ~ $100

- Health effects minimal except to asthmatics and singers

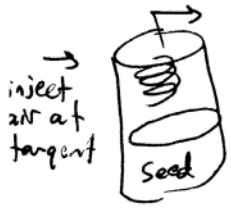
show image of vortex Gun

c) oil aerosols

AlO_2 = Alumina. Polishing powder. cheap.
will not burn so already fully oxidized
for filming individual particles through flames

Cyclone Seeder

- large particles centrifuge to walls
- only small particles allowed to exit



Fluidized Bed

- Air injected to dense bed of particles
- used for many applications
  - energy generation
  - metallurgy
  - pharmaceutical applications
  - waste-treatment etc.

[show simulation]

- Eulerian/Lagrangian technique
- Discrete Particle model
- 2-way coupling (particles affect flow)
- Re = 6000
- Bubbles form...

Minute Paper

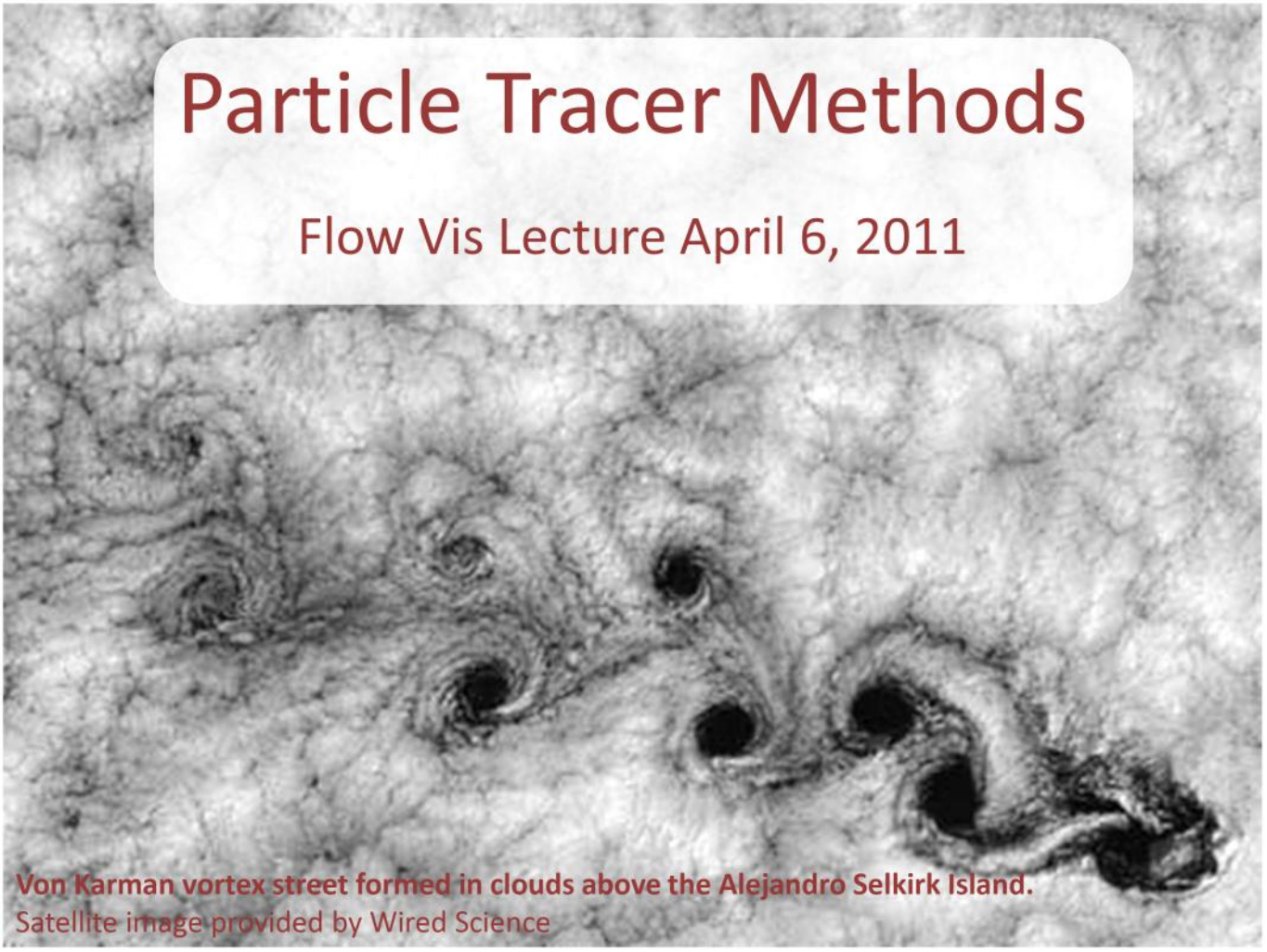
Additional techniques?
High temp / low temp techniques

JesseCapsflowvis_0406...

Inserted from: <file://C:\Users\hertzber\Documents\01CLASSES\FlowVis\Content\LectureNotes\JesseCapsflowvis_04062011.pptx>

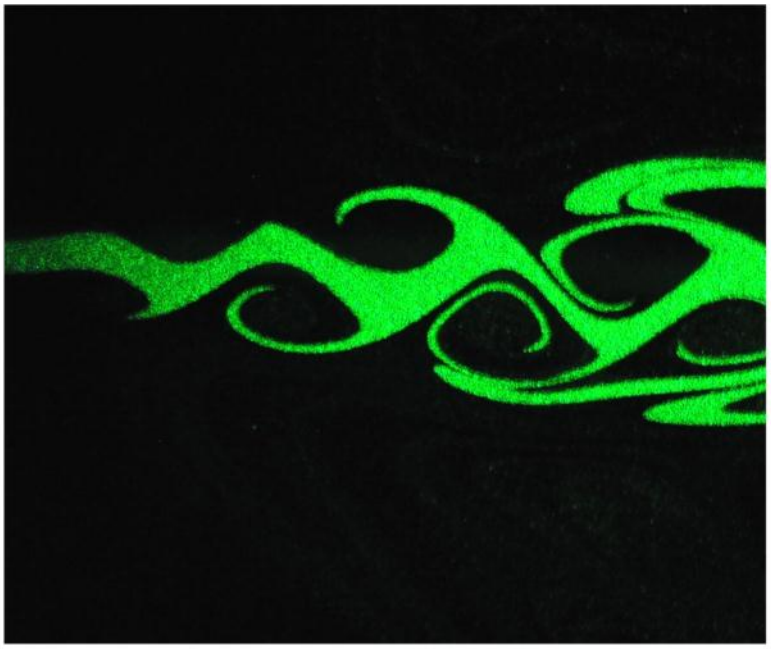
Particle Tracer Methods

Flow Vis Lecture April 6, 2011



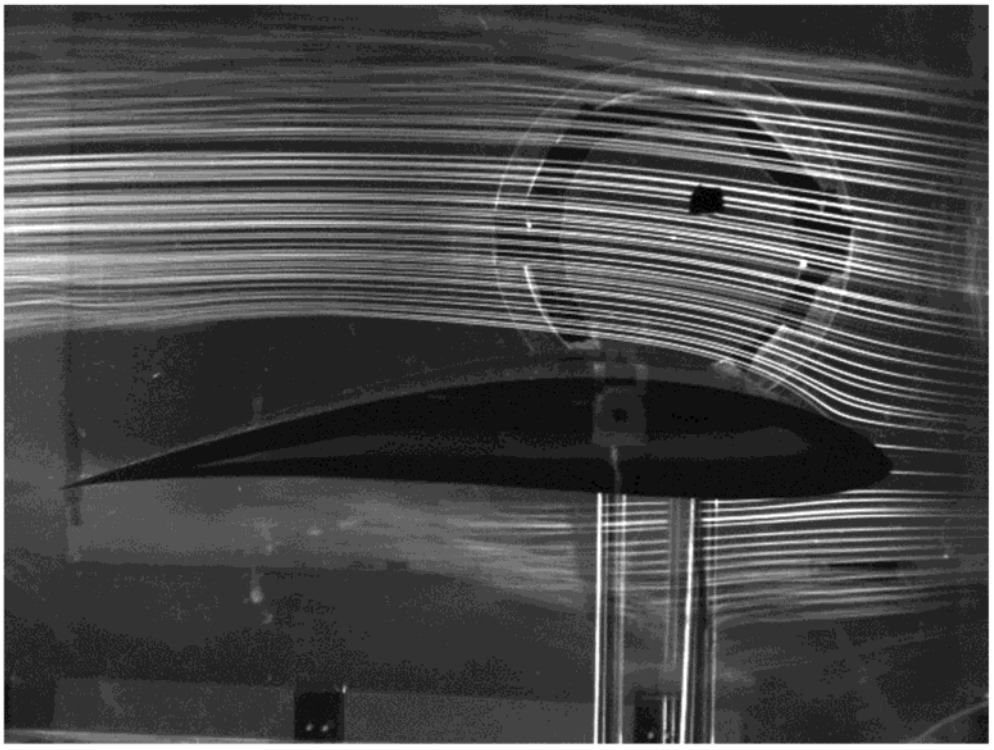
Von Karman vortex street formed in clouds above the Alejandro Selkirk Island.
Satellite image provided by Wired Science

PIV



Hertzberg, CU Boulder

Smoke Wire



Flow over an air foil. Re=50,000. University of Kentucky, Fluid Mechanics Lab.

Smoke Wire using TiO_2

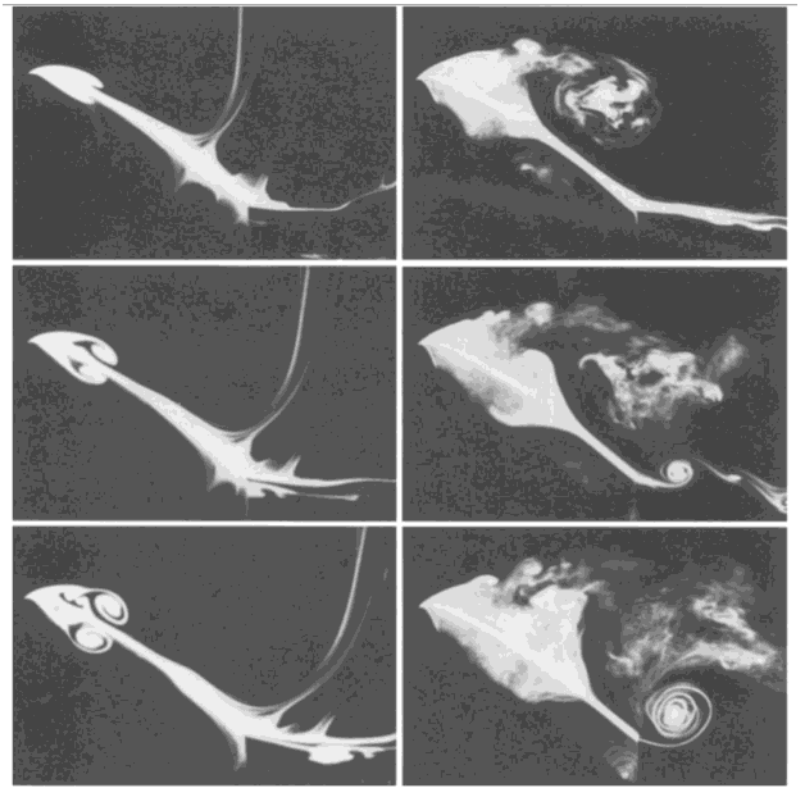
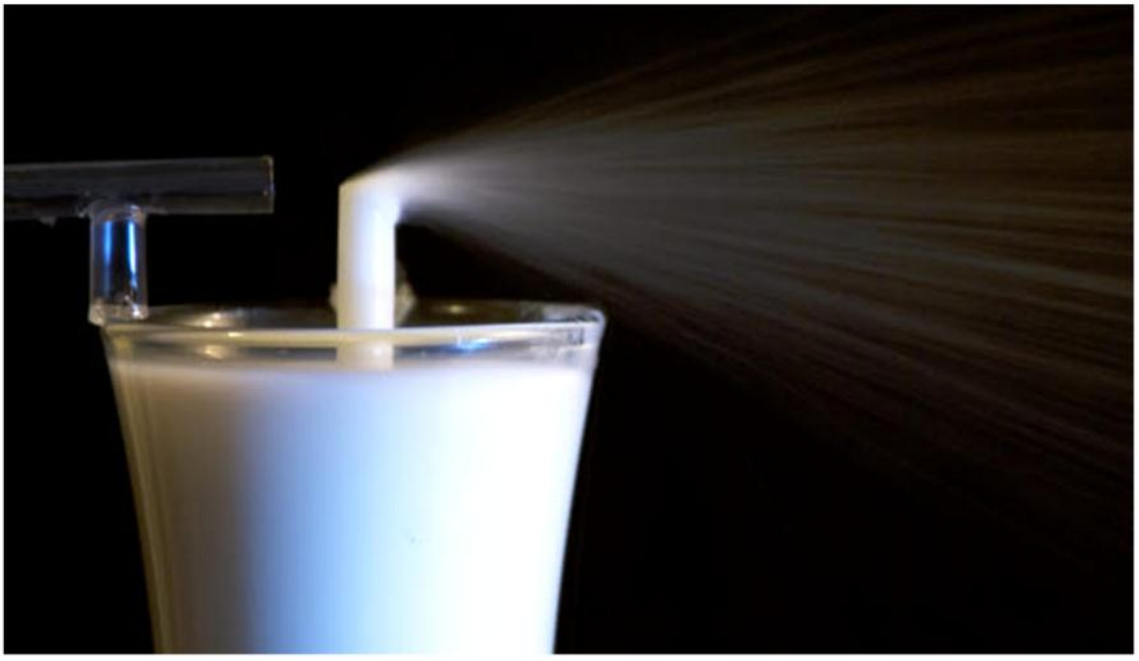


Fig. 1. Sequence characterizing vortical developments for an angle of attack $\alpha = 30°$ and a Reynolds number $R = 5{,}200$

Freymuth, 1987

Bernoulli Atomizer



Matt Blessinger, Get Wet 2009

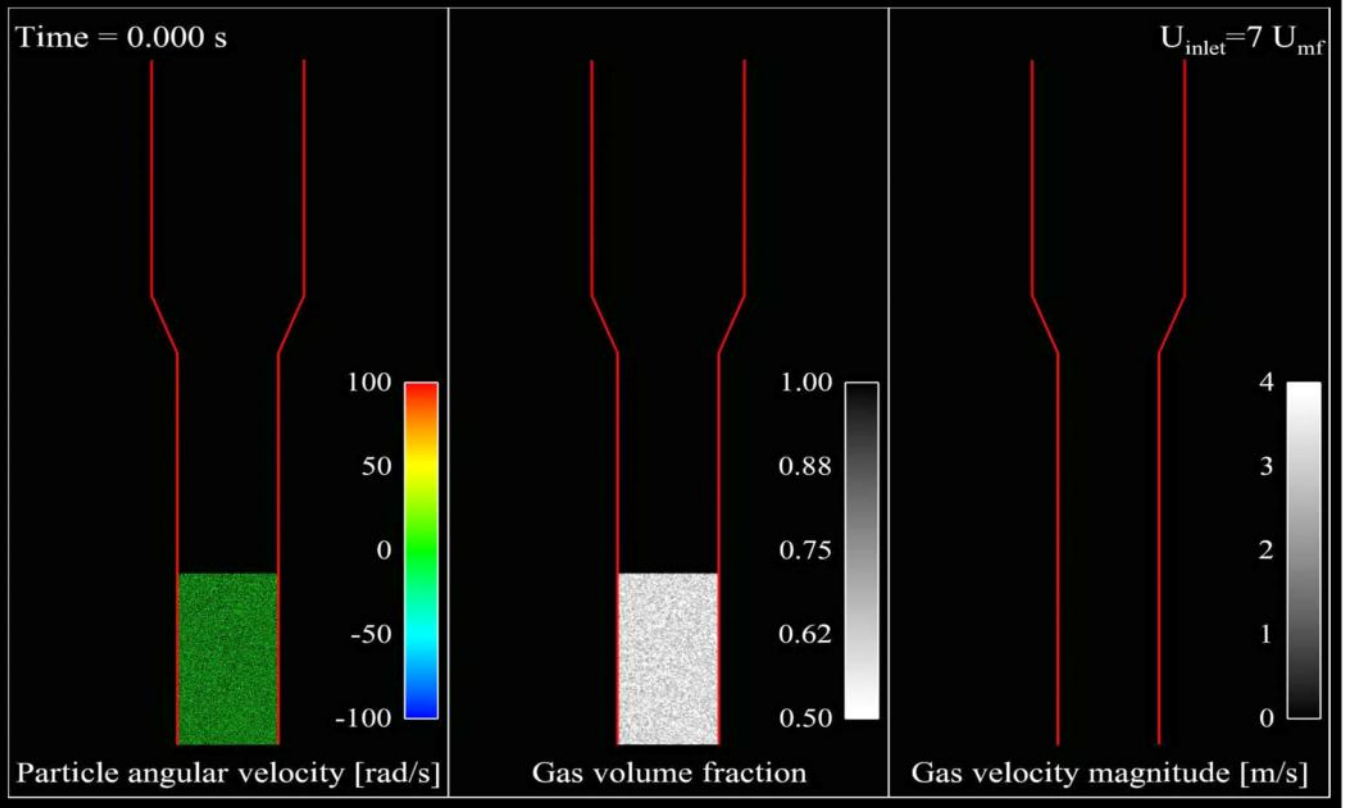
Vortex Guns

Wikipedia

Physics Learning, Colorado.edu

NREL's 4" Fluidized Bed

4” FBed Simulation



Scale: 1:1, Number of particles: 341,000