Introduction to Modern Measurement Technology

and

Applications in Coastal and Ocean Engineering

Kuang-An Chang
Ocean Engineering Program
Department of Civil Engineering
Texas A&M University
What Do We Need to Measure in Coastal and Ocean Engineering?

- Water elevation
- Force
- Pressure
- Velocity
- Concentration
Available Tools for Non-Intrusive Quantitative Measurement Techniques:

• Laser Doppler Velocimetry (LDV)
  Point velocity measurement, high sampling rate, small sampling volume

• Particle Image Velocimetry (PIV)
  Full field velocity measurement, usually low sampling rate

• Laser Induced Fluorescence (LIF)
  Flow visualization, scalar field (concentration, heat) measurement, usually qualitative
Drawing of Leonardo Da Vinci

Structures within a water flow
Laser Induced Fluorescence

Turbulent round jet under waves
How Does LDV Work?
Measurement of flow field around a 1:5 scale car model in a wind tunnel

Photo courtesy of Mercedes-Benz, Germany
Measurement of air flow field around a ship model in a wind tunnel

Photo courtesy of University of Bristol, UK
LDV System at TAMU
LDV Measurement
How Does PIV Work?

- Mirror
- Pulsed laser with light sheet optics
- Thin sheet of light
- Digital camera head
- Water seeded with small particles
- Camera field of view
- Light sheet optics
PIV Setup

- Pulsed laser (Nd:YAG)
- Mirror
- Light sheet optics
- Thin sheet of light
- Free surface
- Jet seeded with small particles
- Video
- Computer
Laser trigger signal

Camera Trigger signal

Image pair

Image pair

$\Delta t$

512 × 512 pixels
Naive PIV Technique

Frame 1
\[ t = t_0 \]

Frame 2
\[ t = t_0 + \Delta t \]
PIV Technique (2-frame/single-pulsed)

Frame 1

\[ t = t_0 \]

Frames 2

\[ t = t_0 + \Delta t \]
Cross-correlation: \[ R(\bar{s}) = \iiint_{\text{sub-window}} f(\bar{x}) g(\bar{x} + \bar{s}) d\bar{x} \]
Instantaneous Velocity Measurements

• Turbulent Round Jet 1
• Turbulent Round Jet 2
How Does LIF Work?

- CW laser with light sheet optics
- Thin sheet of light
- Jet mixed with fluorescent dye
- CW laser with light sheet optics

Light sheet optics
Fluorescein Characteristics
LIF Setup

- Jet mixed with fluorescent dye
- Connected to constant head reservoir
- Scanning beam
- Galvanometer
- FOV
- CW laser (Argon-Ion)
- Power meter
- Thin glass
- Mirror
- Free surface
- Video
- Computer
- Power meter
- Thin glass
PIV/LIF Setup

- Pulsed laser (Nd:YAG)
- Light sheet optics
- Jet mixed with fluorescent dye and seeding particles
- Connected to constant head reservoir
- Thin sheet of light
- Scanning beam
- FOV
- Video camera
- Computer
- CW laser (Argon-Ion)
- Power meter
- Thin glass
- Mirror
- Galvanometer
- Shutter
- Freesurface
Simultaneous velocity and concentration ($Re = 4210$)
Simultaneous velocity and concentration (Re = 4210)
Animation - Turbulent Round Jet

$Re = 360$. Simultaneous PTV-LIF Measurements
Applications

- Pollutant transport in coastal water
- Current structure interaction
- Wave-structure interaction
Jet under Waves
The plume is intruding into a narrow layer. At the time the picture was taken, the mean current field was moving the plume off-shore.
tracer-study plume conducted at the mouth of a river entering into an estuary

One can clearly see the fine-scale structure of the plume interacting with ambient turbulence and the slow nature of lateral spreading.
joining of three different rivers

The one on the left, with very high particulate concentration, joins with the two rivers on the right. The larger of the two rivers carries a higher particulate load, thus the darkest (cleanest) smallest river is also visible. Notice how sharp the boundaries are separating the various river flows.
Tung-Hsiao, Taiwan
Tung-Hsiao, Taiwan
Sketch of Horseshoe Vortex System
Experimental Setup

(a) honey comb

constriction section

meshes

valve

pump

test section

stainless flow regulator

stainless flow regulator

(b)

122 cm

100 cm

200 cm

305 cm

122 cm

36 cm

885 cm

50 cm
Experimental Setup

- **U_0**: Velocity
- **h**: Height
- **H**: Height of the model
- **W**: Width of the model
- **Z**: Height of the support
- **X**: Width of the support
- **Y**: Width of the bottom glass
- **Z**: Height of the support
- **model**: The experimental model
- **side wall glass**: The side walls of the experimental setup
- **base plate**: The supporting plate
- **support**: The support structure
- **bottom glass**: The bottom glass of the experimental setup
PIV Velocity
Animation

Cylinder-Plate Juncture Flow
Bridge Scour
Bridge Scour
Bridge Scour
Bridge Scour
Bridge Scour
Navy barge ship model test

Side View:
- Wave maker
- Capsizing Position: ≈ 8 m
- SWL
- Wave Absorber
- Barge
- 33 m
- 0.9 m
- h = 0.8 m

Top View:
- Wave maker
- Capsizing Position: ≈ 8 m
- SWL
- Wave Absorber
- Barge
- 33 m
- 0.9 m
- h = 0.8 m
Barge Model
Wave Interaction with Barge

- Wave Elevation Gauges
- FOV
- Mirror
- Light sheet
- Barge
- Absorber
- Wavemaker
- Unit: mm
- Slope: 1/5

Side View
### Sketch of rolling barge and PIV fields of view

<table>
<thead>
<tr>
<th>Condition</th>
<th>FOV size (mm²)</th>
<th>Spatial resolution (mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Barge (large FOV)</td>
<td>142×113</td>
<td>1.8×1.8</td>
</tr>
<tr>
<td>Fixed Barge (small FOV)</td>
<td>57×47</td>
<td>0.74×0.74</td>
</tr>
<tr>
<td>Free Rolling Barge</td>
<td>121×96</td>
<td>1.5×1.5</td>
</tr>
</tbody>
</table>
Vorticity (Fixed Barge, $T=1.0$ s)
Turbulent kinetic energy
(Fixed Barge, $T=1.0 \text{ s}$)
Vorticity (Rolling Barge, $T=2.0$ s)
Waves runup
Instantaneous velocity field
Laboratory equipment
Wave Tank & High Speed PIV System
High Speed PIV System
Nd:YAG PIV System
LDV System
Why be a coastal engineer?

Can always claim that we are working when going to beach!
Our problem of interest
Our measurements
Our Working Place
Our field equipment