Probe Effects on the Local Gas Holdup Conditions in a Fluidized Bed

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What is a Fluidized Bed?
Fluidized Beds

- Used commonly in industry because they provide:
  - High levels of intermixing of the particles
  - High heat transfer rates
  - High relative velocities between fluid and particles
- Hydrodynamic behavior is very complex
- Characteristic Parameters:
  - Minimum Fluidization Velocity ($U_{mf}$)
  - Gas Holdup ($\varepsilon_g$)

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**Fluidized Bed Diagram**

**Probe Geometries**
**Characteristic Parameters: \( U_{mf} + \varepsilon_g \)**

- **\( U_{mf} \)**
  - Defined as the minimum superficial gas velocity to fluidize the bed.
  - Sets the lower boundary for fluidization.
  - Determined by measuring pressure drop across the bed.
  - Two superficial velocities used in this study:
    - \( 1.5U_{mf} \)
    - \( 3U_{mf} \)

- **\( \varepsilon_g \)**
  - Defined as volumetric fraction of gas present within the fluidized bed.
  - Fluidization quality and mixing quality can be characterized.
  - Used X-ray computed tomography to determine local gas holdup.
X-ray computed tomography (CT)

- X-ray source (cone beam)
- Object to image
- Single CT slice location
- X-ray detector (imaging device coupled to a CCD camera)

- Rotate source/detector pair or object
- Multiple radiographs from different projections are reconstructed to show internal details of object cross-section
- CT slice (2D; time averaged)

Multiple CT slices “stacked” together to generate a 3-D image
Three different types of images were taken to calculate the time-average gas holdup of the bed:

- A bulk file ($I_b$)
- An air file ($I_g$)
- A flow file ($I_f$)

where $\rho_b$ is the bulk density and $\rho_p$ is the particle density.

\[ \varepsilon_g = \frac{I_f - I_b + (I_g - I_f)(\varepsilon_{g,b})}{I_g - I_b} \]

\[ \varepsilon_{g,b} = 1 - \frac{\rho_b}{\rho_p} \]
Gas Holdup Maps

$U_g = 3U_{mf}$

No Probe

$h/D = 0.5$

Flat Horizontal Probe

$h/D = 0.5$

Needle Horizontal Probe

$h/D = 0.5$

Round Horizontal Probe

$h/D = 0.5$

Flat Vertical Probe

$h/D = 0.25$

Needle Vertical Probe

$h/D = 0.25$

Round Vertical Probe

- The effect of the vertical probes is limited at the probe tip.
- Gas holdup values are higher along the length of the probe, which infers that a spout of air traversing up the length of the probe.
- Trends between flow rate are inconsistent.
- The horizontal probes have a distributed effect on the local gas holdup.
- The vertical probe orientation has a more localized increase right at the probe tip.
Effect of Probe Axial Location

- The lower the probes are inserted, the larger the local variations around the probes.
- 3 different tip geometries showed no differences
Conclusions

• Measurement probes have minimal impact on the overall gas holdup, but there are significant local variations.
• Effects were more prevalent the closer the probe was placed to the aeration plate.
• Flow rate impacted the scale of the probe effects, although the trends were inconsistent.
• Probe orientation (horizontal, vertical) differed in altering the gas holdup values; neither orientation exhibiting an obvious improvement.
• Probe tip type was not a factor in the observed localized effect in the gas holdup values.
• Dr. Ted Heindel

• Dr. David Escudero

• Everyone at the Experimental Multiphase Flow Lab
Questions?