Positron Emission Particle Tracking –
A Comprehensive Tool for Characterization of Fluidized Beds with Secondary Gas Injection

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Fluidized beds with secondary gas injection

Conventional characterization methods

Determination of the characteristics of the system:
• 1−ε: solids concentration
• Δh: penetration depth of the jet into the suspension phase
• θ: half jet opening angle

Measurement techniques:
• invasive
  • capacitance probes
  • optical fiber probes
• non-invasive
  • X-ray CT

Material and setup

Plant characteristics:
• hollow steel cylinder:
  – inner diameter: \( d_{\text{cylinder}} = 190 \text{ mm} \)
  – length: \( L_{\text{cylinder}} = 1900 \text{ mm} \)
• gas distributor:
  – porous sintered metal base plate
  – cylindrical nozzle with conical top section:
    \( d_{\text{nozzle}} = 10 \text{ mm} \)
• bed inventory:
  – fixed bed height: \( h_b = 500 \text{ mm} \)

Material properties:
• process fluid: pressurized air
• solids:
  – glass beads:
    \( x_{\text{diam}} = 732 \mu \text{m} \)
    \( \rho_s = 2480 \text{ kg m}^{-3} \)

Basic principle:
• \( \beta \)-decay
• annihilation of \( e^+ \) and \( e^- \)
• emission of back-to-back \( \gamma \)-rays
• tracer activity: 20–40 MBq

Positron emission particle tracking (PEPT)

Detection of radiation:
• ADAC Forte \( \gamma \)-ray cameras
• sampling frequency: 100 kHz

Solids concentration profile and residence time behavior of a single particle

Solids holdup (1−ε)

Methodology:
• derivation of continuous fields from discrete particle positions [1]

\[
\rho_s(x, t) = \sum m_i \delta(x - x_i)
\]

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\]

\[
(1 - \varepsilon) / \varepsilon = \sum \rho_s(x, t)
\]

Results:
• suspension phase: solids holdup close to minimum fluidization condition
• jet region distinguished by reduced solids holdup
• dimensions of the jet region:
  – half opening angle: \( \theta_{\text{jet}} = 16.1^\circ \)
  – penetration depth: \( \Delta h_{\text{jet}} = 275 \text{ mm} \)

Determination of the residence time of a single particle in the jet region

The residence time density \( \varepsilon_i \)

Methodology:
• relative residence time density \( \varepsilon_i \)

\[
\varepsilon_i = \sum \Delta t_i \cdot V_i / \varepsilon_{\text{inj}}
\]

Results:
• suspension phase: \( \varepsilon_i \) = 1.0
  – characteristic for ideally mixed systems
• jet region: \( \varepsilon_i = 0.699 \)
  – The residence time of a single particle in the jet region is 69.9% of that in an equally sized volume element in the suspension phase.

Summary and outlook

Positron emission particle tracking:

Powerful tool for design and optimization of fluidized bed reactors with a well defined reaction zone

Conclusions

... is a non-invasive tool for analysis of the behavior of single particles
... provides results with high temporal & spatial resolution
... provides data that cannot be obtained by conventional measurement techniques
... delivers important parameters for design and operation of reactors in continuous or batch mode

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