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5.20 Probability bubble distribution function vs chord length and sensor locations
(780 µm resin, $t = 0.005$m, $H_s = 0.25$m, ($U_0-U_{mf}$) = 0.08 m/s)

5.21 Probability bubble distribution function vs chord length and sensor locations
(250 µm sand, $t = 0.005$m, $H_s = 0.21$m, ($U_0-U_{mf}$) = 0.192 m/s)

5.22 Probability bubble distribution function vs chord length and static bed heights ($H_s$)
(256 µm glass-beads, $t = 0.005$m, sensor location = 0.18m, ($U_0-U_{mf}$) = 0.192 m/s)

5.23 Probability bubble distribution function vs chord length and static bed heights ($H_s$)
(256 µm glass-beads, $t = 0.01$m, sensor location = 0.21$m, ($U_0-U_{mf}$) = 0.096 m/s)

5.24 Probability bubble distribution function vs chord length and static bed heights ($H_s$)
(1002 µm mustard, $t = 0.005$m, sensor location = 0.21$m, ($U_0-U_{mf}$) = 0.224 m/s)

5.25 Probability bubble distribution function vs chord length and bed thickness ($t$)
(350 µm sand, sensor location = 0.15m, $H_s = 0.29$m ($U_0-U_{mf}$) = 0.064 m/s)

5.26 Probability bubble distribution function vs chord length and bed thickness ($t$)
(350 µm sand, sensor location = 0.18m, $H_s = 0.29$m ($U_0-U_{mf}$) = 0.064 m/s)

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5.27 Probability bubble distribution function vs chord length and bed thickness
(250 μm sand, sensor location = 0.15m, \(H_s = 0.29\) m \((U_o - U_{mf}) = 0.048\) m/s)

5.28 Probability bubble distribution function vs chord length and bed thickness
(250 μm sand, sensor location = 0.18m, \(H_s = 0.29\) m \((U_o - U_{mf}) = 0.048\) m/s)

5.29 Standard 180° bubble shapes with PDF

5.30 Comparison of experimental and generated PDF and bubble shape
(256 μm glass-beads, \(t = 0.015m\), \(H_s = 0.21\) m, sensor location = 0.15m,
\((U_o - U_{mf}) = 0.044\) m/s, error = 18.8%)

5.31 Comparison of experimental and generated PDF and bubble shape
(256 μm glass-beads, \(t = 0.015m\), \(H_s = 0.21\) m, sensor location = 0.15m,
\((U_o - U_{mf}) = 0.044\) m/s, error = 19.8%)

5.32 Comparison of experimental and generated PDF and bubble shape
(256 μm glass-beads, \(t = 0.015m\), \(H_s = 0.21\) m, sensor location = 0.15m,
\((U_o - U_{mf}) = 0.044\) m/s, error = 21.67%)

5.33 Comparison of experimental and generated PDF and bubble shape
(256 μm glass-beads, \(t = 0.015m\), \(H_s = 0.21\) m, sensor location = 0.15m,
\((U_o - U_{mf}) = 0.066\) m/s, error = 32%)

5.34 Comparison of experimental and generated PDF and bubble shape
(256 μm glass-beads, \(t = 0.015m\), \(H_s = 0.21\) m, sensor location = 0.15m,
\((U_o - U_{mf}) = 0.066\) m/s, error = 32.43%)

5.35 Comparison of experimental and generated PDF and bubble shape
(256 μm glass-beads, \(t = 0.015m\), \(H_s = 0.21\) m, sensor location = 0.15m,
\((U_o - U_{mf}) = 0.066\) m/s, error = 33.10%)

5.36 Comparison of experimental and generated PDF and bubble shape
(256 μm glass-beads, \(t = 0.015m\), \(H_s = 0.21\) m, sensor location = 0.18m,
\((U_o - U_{mf}) = 0.066\) m/s, error = 32.23%)

5.37 Comparison of experimental and generated PDF and bubble shape
(256 μm glass-beads, \(t = 0.015m\), \(H_s = 0.21\) m, sensor location = 0.18m,
\((U_o - U_{mf}) = 0.066\) m/s, error = 32.37%)

XIII
5.38 Comparison of experimental and generated PDF and bubble shape
(256 μm glass-beads, t = 0.015m, Hs = 0.21m, sensor location = 0.18m,
(Uo-Umf) = 0.066 m/s, error = 32.77%)

5.39 Comparison of experimental and generated PDF and bubble shape
(256 μm glass-beads, t = 0.015m, Hs = 0.21m, sensor location = 0.15m,
(Uo-Umf) = 0.11 m/s, error = 23.22%)

5.40 Comparison of experimental and generated PDF and bubble shape
(256 μm glass-beads, t = 0.015m, Hs = 0.21m, sensor location = 0.15m,
(Uo-Umf) = 0.11 m/s, error = 23.82%)

5.41 Comparison of experimental and generated PDF and bubble shape
(220 μm resin, t = 0.01m, Hs = 0.29m, sensor location = 0.21m,
(Uo-Umf) = 0.064 m/s, error = 33.6%)

5.42 Comparison of experimental and generated PDF and bubble shape
(220 μm resin, t = 0.01m, Hs = 0.29m, sensor location = 0.21m,
(Uo-Umf) = 0.064 m/s, error = 33.97%)

5.43 Comparison of experimental and generated PDF and bubble shape
(220 μm resin, t = 0.01m, Hs = 0.29m, sensor location = 0.21m,
(Uo-Umf) = 0.112 m/s, error = 13.38%)

5.44 Comparison of experimental and generated PDF and bubble shape
(220 μm resin, t = 0.01m, Hs = 0.29m, sensor location = 0.21m,
(Uo-Umf) = 0.112 m/s, error = 13.38%)

5.45 Comparison of experimental and generated PDF and bubble shape
(220 μm resin, t = 0.01m, Hs = 0.29m, sensor location = 0.21m,
(Uo-Umf) = 0.112 m/s, error = 14.10%)

5.46 Comparison of experimental and generated PDF and bubble shape
(220 μm resin, t = 0.01m, Hs = 0.29m, sensor location = 0.21m,
(Uo-Umf) = 0.16 m/s, error = 17.58%)

5.47 Comparison of experimental and generated PDF and bubble shape
(220 μm resin, t = 0.01m, Hs = 0.29m, sensor location = 0.21m,
(Uo-Umf) = 0.16 m/s, error = 17.58%)

5.48 Comparison of experimental and generated PDF and bubble shape
(220 μm resin, t = 0.01m, Hs = 0.29m, sensor location = 0.21m,
(Uo-Umf) = 0.16 m/s, error = 18.82%)

XIV
5.49 Comparison of experimental and generated PDF and bubble shape
(220 μm resin, t = 0.01 m, Hs = 0.29 m, sensor location = 0.18 m,
(Uo - Umf) = 0.16 m/s, error = 17.14%)

5.50 Comparison of experimental and generated PDF and bubble shape
(220 μm resin, t = 0.01 m, Hs = 0.29 m, sensor location = 0.18 m,
(Uo - Umf) = 0.16 m/s, error = 18.27%)

5.51 Comparison of experimental and generated PDF and bubble shape
(220 μm resin, t = 0.01 m, Hs = 0.29 m, sensor location = 0.18 m,
(Uo - Umf) = 0.16 m/s, error = 19.97%)

6.1 Schematic view of the experimental set-up used for pressure fluctuation
analysis

6.2 Power spectrum of pressure time series at varying excess gas velocities
(Uo - Umf) (220 μm resin, t = 0.01 m, Hs = 0.25 m, sensor location = 0.09 m)
(a) (Uo - Umf) = 0.00083 m/s
(b) (Uo - Umf) = 0.00249 m/s
(c) (Uo - Umf) = 0.00417 m/s
(d) (Uo - Umf) = 0.0075 m/s

6.3 Effect of sensor location on transition point
(640 μm glass-beads, t = 0.01 m, Hs = 0.29 m sensor location = 0 m)
(a) K and D2 vs Uo/Umf
(b) K and λmax vs Uo/Umf
(c) λmax and D2 vs Uo/Umf

6.4 Effect of sensor location on transition point
(640 μm glass-beads, t = 0.01 m, Hs = 0.29 m, sensor location = 0.09 m)
(a) K and D2 vs Uo/Umf
(b) K and λmax vs Uo/Umf
(c) λmax and D2 vs Uo/Umf

6.5 Effect of sensor location on transition point
(640 μm glass-beads, t = 0.01 m, Hs = 0.29 m, sensor location = 0.18 m)
(a) K and D2 vs Uo/Umf
(b) K and λmax vs Uo/Umf
(c) λmax and D2 vs Uo/Umf

6.6 Effect of sensor location on transition point
(640 μm glass-beads, t = 0.01m, H_s=0.29m, sensor location= 0.27 m)
(a) K and D_2 vs U_{o}/U_{mf}
(b) K and \lambda_{max} vs U_{o}/U_{mf}
(c) \lambda_{max} and D_2 vs U_{o}/U_{mf}

6.7 Effect of particle size on transition point

(460 μm glass-beads, t = 0.01m, H_s=0.29m, sensor location= 0.18 m)
(a) K and D_2 vs U_{o}/U_{mf}
(b) K and \lambda_{max} vs U_{o}/U_{mf}
(c) \lambda_{max} and D_2 vs U_{o}/U_{mf}

6.8 Effect of particle size on transition point

(350 μm sand, t = 0.01m, H_s=0.29m, sensor location= 0.09 m)
(a) K and D_2 vs U_{o}/U_{mf}
(b) K and \lambda_{max} vs U_{o}/U_{mf}
(c) \lambda_{max} and D_2 vs U_{o}/U_{mf}

6.9 Effect of particle size on transition point

(250 μm sand, t = 0.01m, H_s=0.29m, sensor location= 0.09 m)
(a) K and D_2 vs U_{o}/U_{mf}
(b) K and \lambda_{max} vs U_{o}/U_{mf}
(c) \lambda_{max} and D_2 vs U_{o}/U_{mf}

6.10 Effect of particle density on transition point

(220 μm resin, t = 0.01m, H_s=0.29m, sensor location= 0.09 m)
(a) K and D_2 vs U_{o}/U_{mf}
(b) K and \lambda_{max} vs U_{o}/U_{mf}
(c) \lambda_{max} and D_2 vs U_{o}/U_{mf}

6.11 Absolute pressure time series plot for varying U_{o}/U_{mf}

6.12 Reconstruction of attractor from pressure time series data

(250 μm sand, t = 0.01m, H_s=0.25m, sensor location= 0.18 m)

6.13 Reconstruction of attractor from pressure time series data

(220 μm resin, t = 0.01m, H_s=0.25m, sensor location= 0.18 m)

6.14 Effect of 3-D rectangular fluidized bed for FCC catalyst on transition point (150 μm catalyst, t = 0.03m, H_s= 0.25m, sensor location = 0.18 m)
(a) K and D_2 vs U_{o}/U_{mf}
(b) K and \lambda_{max} vs U_{o}/U_{mf}
6.15 Pressure fluctuation time series at varying $U_o/U_{inf}$
(780 $\mu$m resin, $t = 0.01$m, $H_s=0.29$m)
(a) sensor location = 0.09m
(b) sensor location = 0.18m
(c) sensor location = 0.27m

6.16 Power spectral density (PSD) at varying sensor locations
(350 $\mu$m sand, $t = 0.01$m, $H_s=0.25$m, $U_o-U_{inf} = 0.048$ m/s)

6.17 Coherent output PSD ($\text{COP}_{xy}(f)$) at varying sensor locations
(350 $\mu$m sand, $t = 0.01$m, $H_s=0.25$m, $U_o-U_{inf} = 0.048$ m/s)

6.18 Maximum amplitude of pressure vs sensor location at varying $(U_o-U_{inf})$
(350 $\mu$m sand, $t = 0.01$m, $H_s=0.25$m)

6.19 Incoherent output PSD ($\text{IOP}_{xy}(f)$) at varying sensor locations
(350 $\mu$m sand, $t = 0.01$m, $H_s=0.25$m, $U_o-U_{inf} = 0.048$ m/s)

6.20 The incoherent standard deviation($\sigma_{xy}$) vs sensor locations at varying $(U_o-U_{inf})$
(350 $\mu$m sand, $t = 0.01$m, $H_s=0.25$m)

6.21 Parity plot of measured bubble size (pr analysis) vs measured bubble size
(image analysis) at varying $(U_o-U_{inf})$
(350 $\mu$m sand, $t = 0.01$m, $H_s=0.25$m)

6.22 Power spectral density (PSD) at varying sensor locations
(460 $\mu$m glass-beads, $t = 0.01$m, $H_s=0.25$m, $U_o-U_{inf} = 0.049$ m/s)

6.23 Coherent output PSD ($\text{COP}_{xy}(f)$) at varying sensor locations
(460 $\mu$m glass-beads, $t = 0.01$m, $H_s=0.25$m, $U_o-U_{inf} = 0.049$ m/s)

6.24 Incoherent output PSD ($\text{IOP}_{xy}(f)$) at varying sensor locations
(460 $\mu$m glass-beads, $t = 0.01$m, $H_s=0.25$m, $U_o-U_{inf} = 0.049$ m/s)

6.25 The incoherent standard deviation($\sigma_{xy}$) vs sensor locations at varying $(U_o-U_{inf})$
(460 $\mu$m glass-beads, $t = 0.01$m, $H_s=0.25$m)

6.26 Parity plot of measured bubble size (pr analysis) vs measured bubble size
(image analysis) at varying $(U_o-U_{inf})$
(460 $\mu$m glass-beads, $t = 0.01$m, $H_s=0.25$m)

6.27 Power spectral density (PSD) at varying sensor locations
(450 $\mu$m resin, $t = 0.01$m, $H_s=0.25$m, $U_o-U_{inf} = 0.048$ m/s)

6.28 Coherent output PSD ($\text{COP}_{xy}(f)$) at varying sensor locations

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(450 μm resin, $t = 0.01m$, $H_s = 0.25m$, $U_o-U_{mf} = 0.048$ m/s)

6.29 Incoherent output PSD ($IOP_{xy}(f)$) at varying sensor locations

(450 μm resin, $t = 0.01m$, $H_s = 0.25m$, $U_o-U_{mf} = 0.048$ m/s)

6.30 The incoherent standard deviation($\sigma_{xy}$) vs sensor locations at varying

(450 μm resin, $t = 0.01m$, $H_s = 0.25m$)

6.31 Parity plot of measured bubble size (pr analysis) vs measured bubble size (image analysis) at varying $(U_o-U_{mf})$(450 μm resin, $t = 0.01m$, $H_s = 0.25m$)

7.1 Parity plot of measured bubble size (pr analysis) vs measured bubble size (image analysis) at varying $(U_o-U_{mf})$

(450 μm resin, $t = 0.01m$, $H_s = 0.25m$, $U_o-U_{raf} = 0.048$ m/s)

7.1 Parity plot of measured bubble size (pr analysis) vs measured bubble size (image analysis) at varying $(U_o-U_{mf})$

(350 μm sand, 460 μm glass-beads, 450 μm resin)

F1 Original absolute pressure time series

F2 Modified absolute pressure time series