5-23-2016

Characterization of fuel segregation in a fluidized bed by magnetic particle tracking

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Experimental characterization of axial fuel mixing in fluidized beds by magnetic particle tracking

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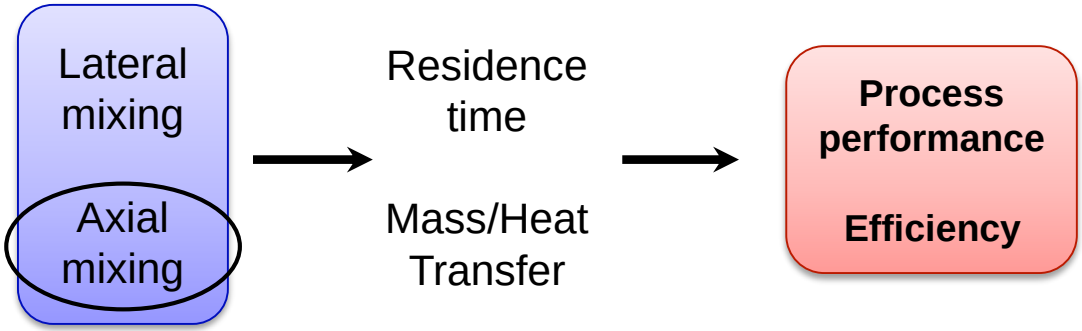
May 23rd, 2016
Fluidization XV – Fairmont Le Chateau Montebello
Quebec, Canada

Background

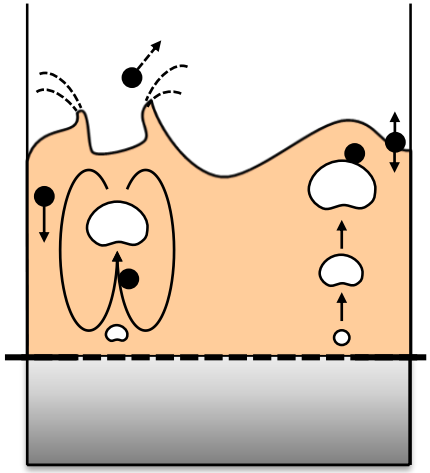
- Mixing of large particles in FB



  - Combustion (incl. CLC, OCAC), gasification
  - Industry (chemical, petrol, metal, pharma)

Background

- Mixing of large particles in FB
- Axial mixing
  - Bubbles in dense bed
  - Particle properties
  - Operational conditions



Aim

- Investigate axial mixing of single large tracer
  - Operational conditions (H_0, u_0-u_{mf}, $\Delta P_{Distributor}$)
  - 3 tracer densities

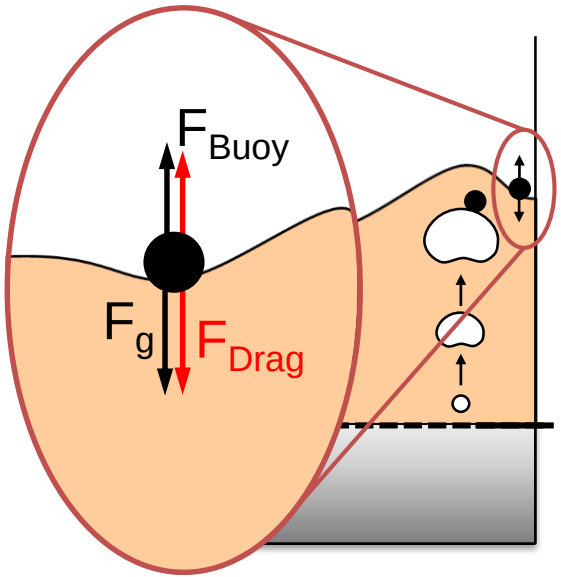
Method

- Magnetic particle tracking
  - 3-dimensional tracking
- Fluid-dynamical scaling
  - Relevant for industrial scale
  - Resembling hot conditions

Theory

- Axial mixing induced by bubbles
- Segregation

- Biomass fuel
  - Light particles
  - Large particles



Experimental setup

- Fluid-dynamic scaling

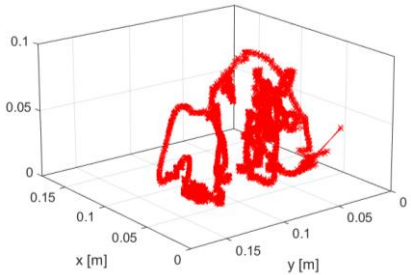
$$\frac{U_0^2}{gD} \quad \frac{\rho_p}{\rho_f} \quad \frac{\rho_p U_0 d_p}{\mu_f} \quad \frac{\rho_f U_0 D}{\mu_f} \quad \frac{L}{D}$$

→ **L**ength **M**ass **T**ime

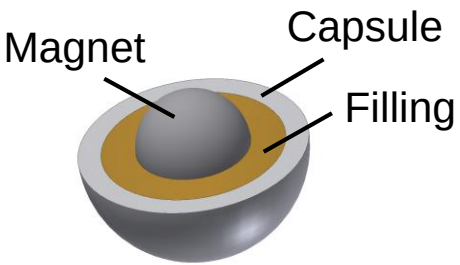
Parameter	Unit	Hot model	Cold model
Temperature	°C	800	20
Bed dimensions	m × m	0.74 × 0.74	0.17 × 0.17
Bed height	m	0.18 / 0.305	0.04 / 0.07
Superficial velocity	m/s	0.01 – 0.5	0.006 – 0.236
Bed material density	kg/m^3	2 600	8 900
Bed material size	µm	250	60
Tracer size	mm	44	10
Biochar density	kg/m^3	350	1 470
Biomass density	kg/m^3	800	2 980
Emulsion density	kg/m^3	1 230	4 320

Experimental setup

- 3D magnetic particle tracking
  - Spatial resolution: ~ 1 mm
  - Temporal accuracy: ~ 30 Hz

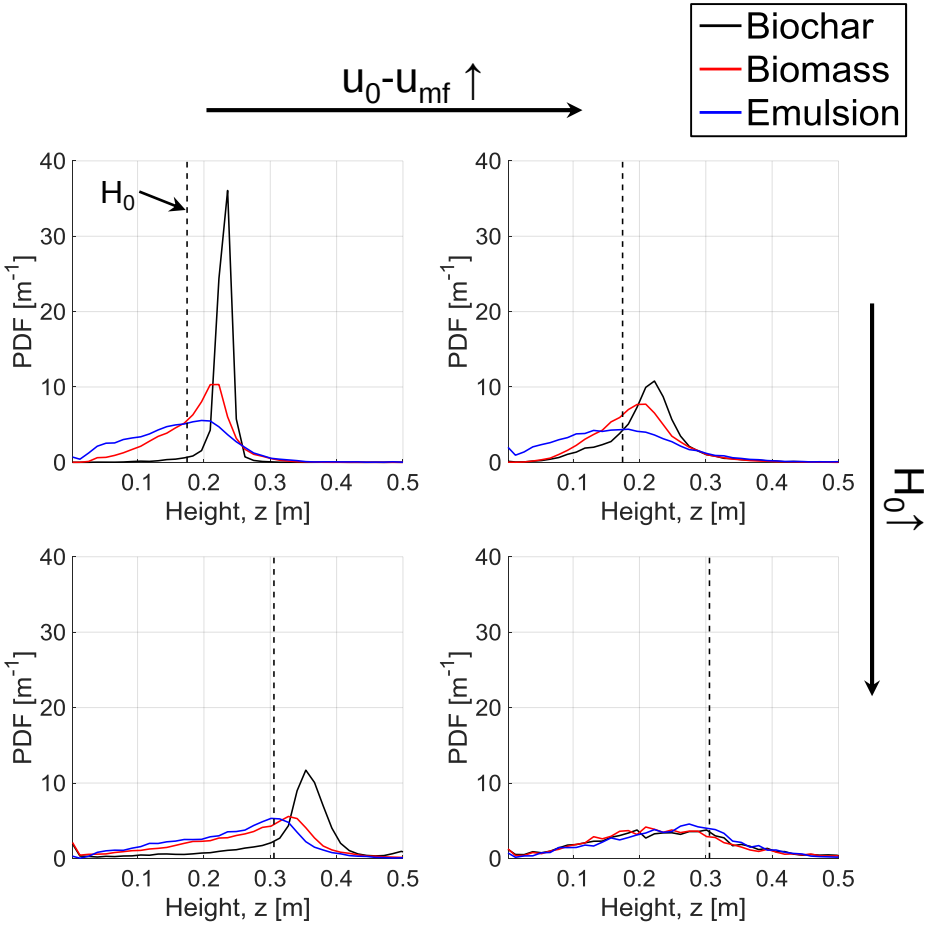


- Tracer
  - Permanent magnet
  - Spherical, const. diameter

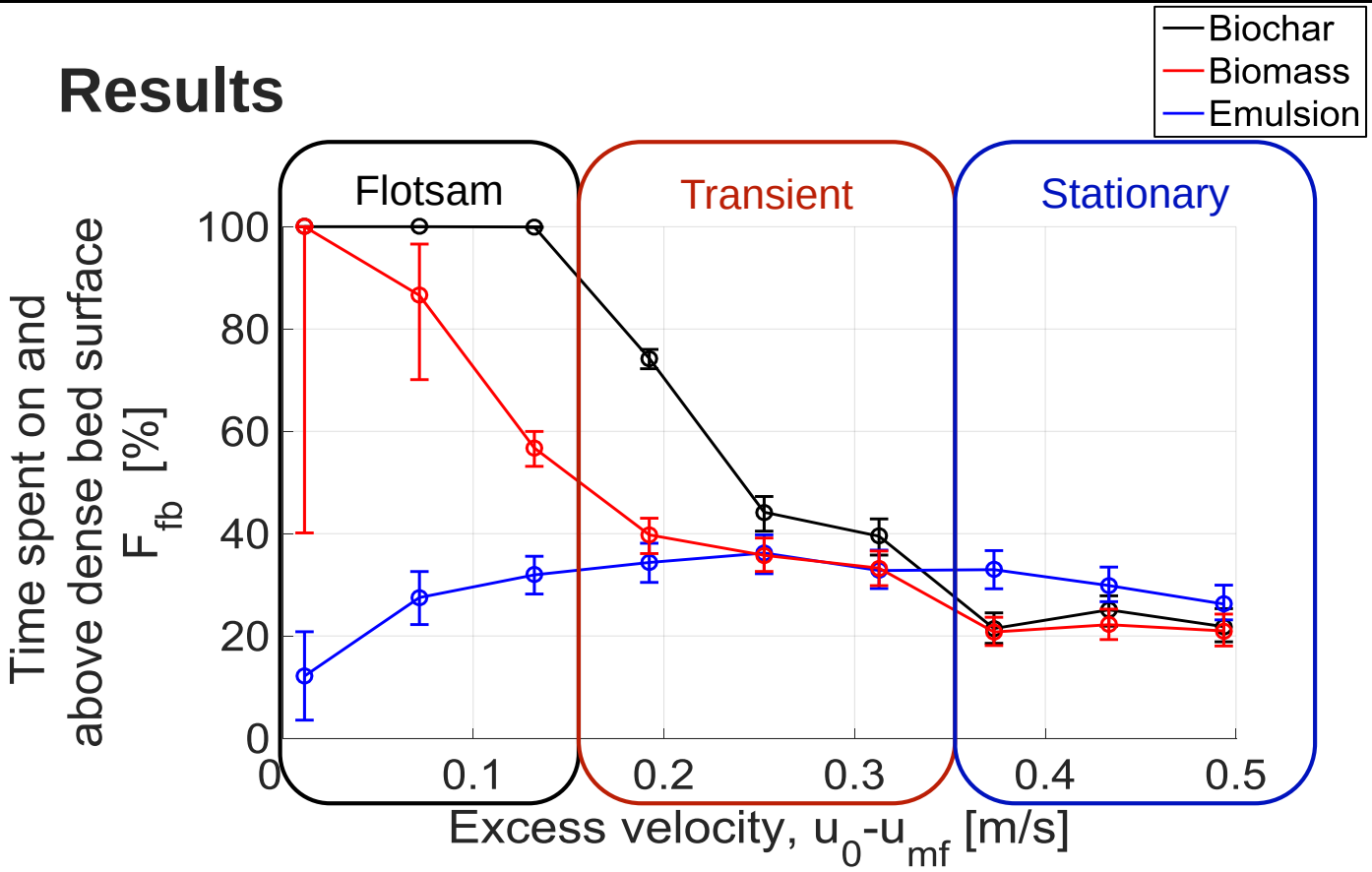


Results

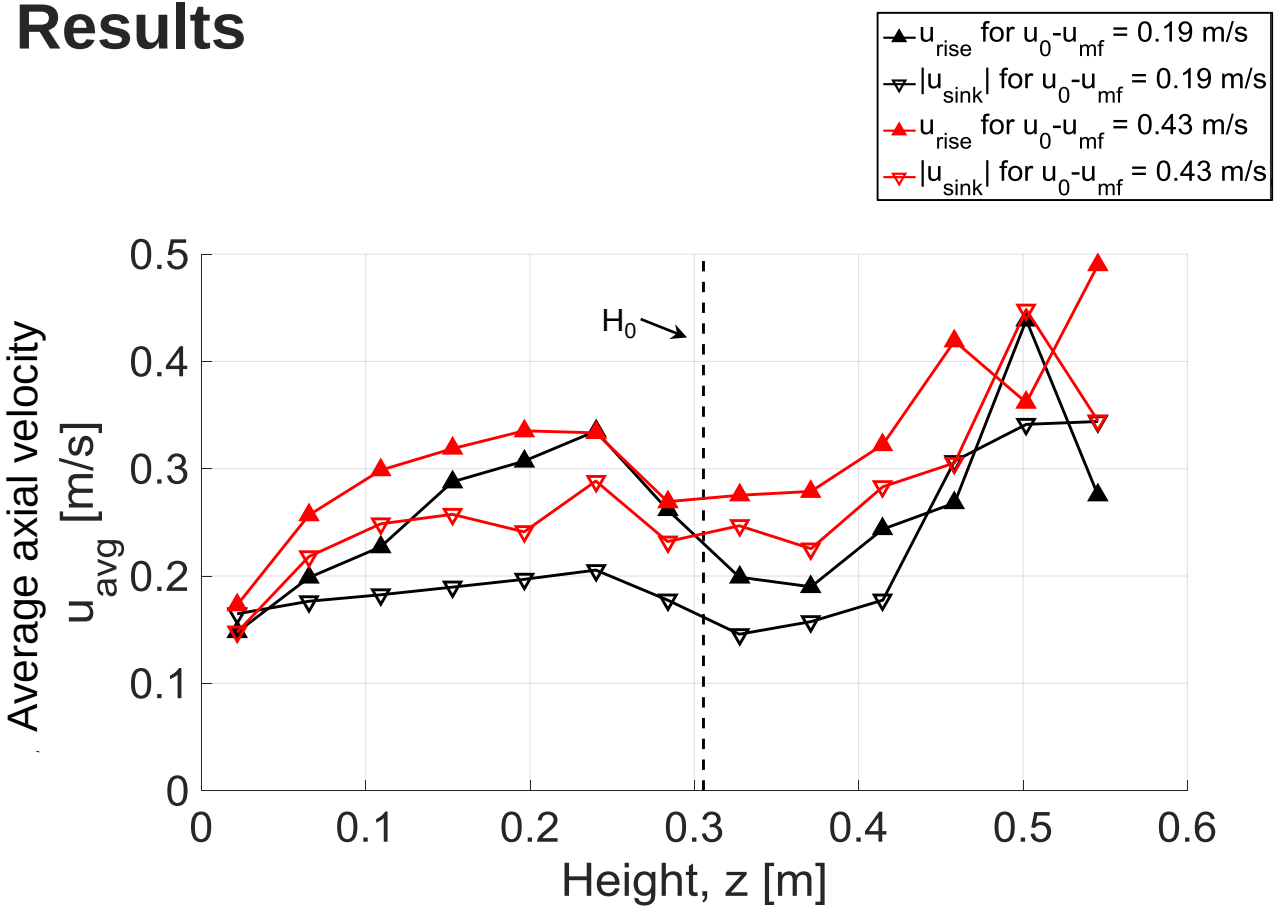
- Axial tracer location



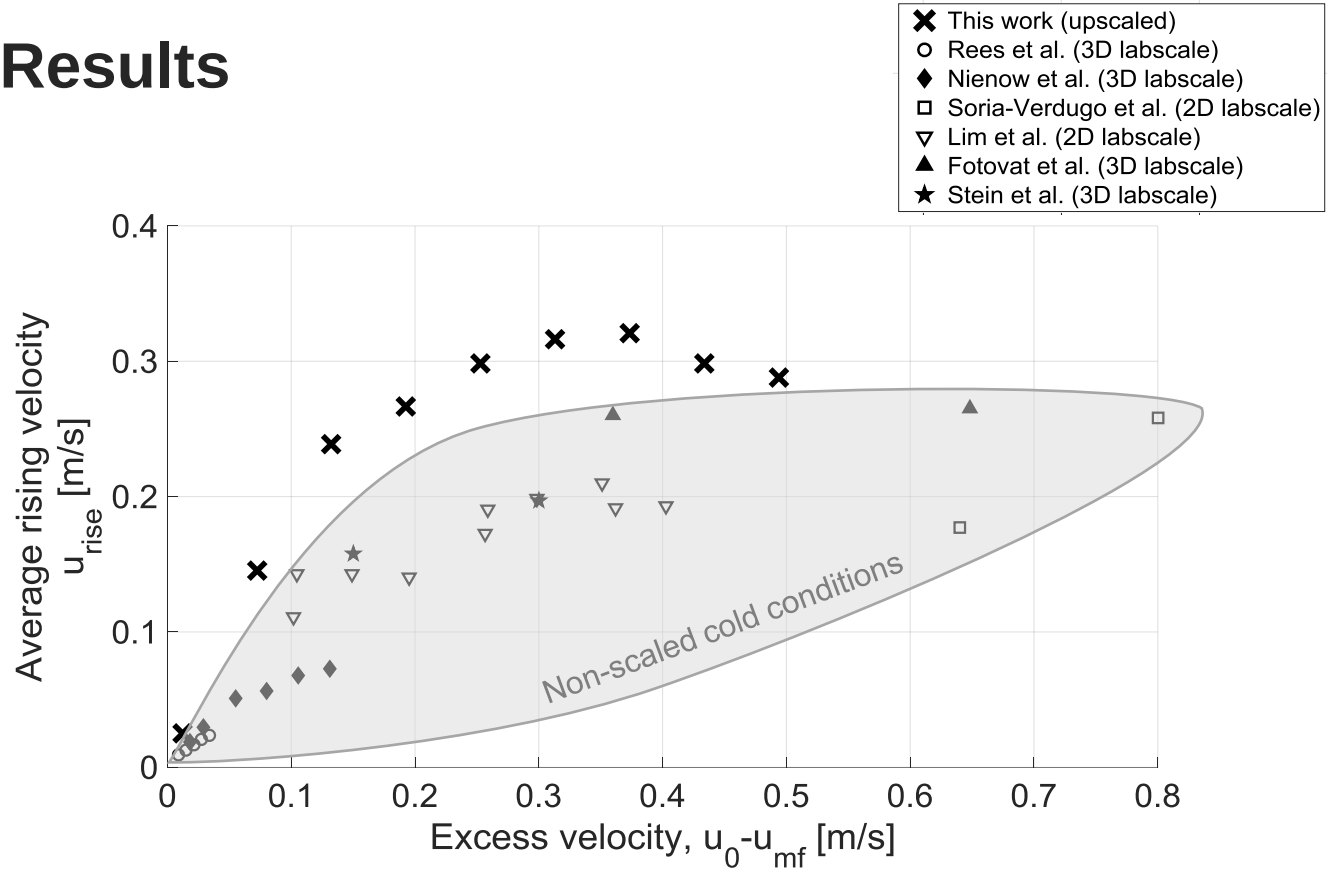
Results


Biochar
Biomass
Emulsion
Flotsam
Transient
Stationary
Time spent on and above dense bed surface
F_{fb} [%]
100
80
60
40
20
0
0
0.1
0.2
0.3
0.4
0.5
Excess velocity, u_0-u_{mf} [m/s]

Results


u_rise for u_0-u_mf = 0.19 m/s
|u_sink| for u_0-u_mf = 0.19 m/s
u_rise for u_0-u_mf = 0.43 m/s
|u_sink| for u_0-u_mf = 0.43 m/s
H_0
Average axial velocity u_avg [m/s]
Height, z [m]
0
0.1
0.2
0.3
0.4
0.5
0.6

Results


This work (upscaled)
Rees et al. (3D labscale)
Nienow et al. (3D labscale)
Soria-Verdugo et al. (2D labscale)
Lim et al. (2D labscale)
Fotovat et al. (3D labscale)
Stein et al. (3D labscale)
Average rising velocity
u_rise [m/s]
Excess velocity, u_0-u_mf [m/s]
Non-scaled cold conditions
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8

Conclusions

- Enhanced axial mixing
  - Bed height ↑
  - Fluidization velocity ↑
  - Tracer density ↑
  - $\Delta P_{Distributor}$ –
- 3 mixing regimes with u_0-u_{mf} ↑

  1) Flotsam. 2)Transient. 3) Stationary.
- Tracers up-/downward velocities
  - Cold lab-scale ↔ fluid-dynamically down-scaled

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