CFD Simulation of Hydrodynamics in a Dual Fluidized Bed Gasifier

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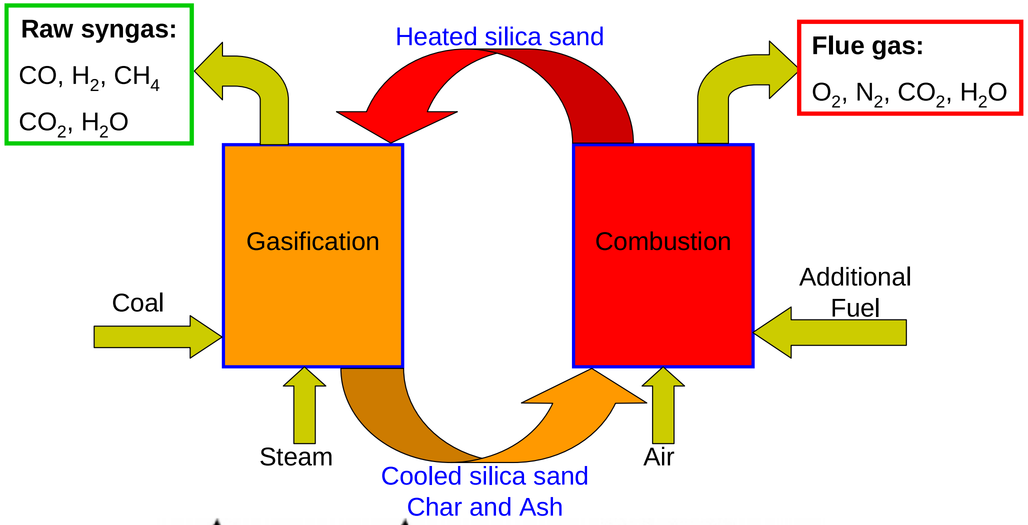
Objectives

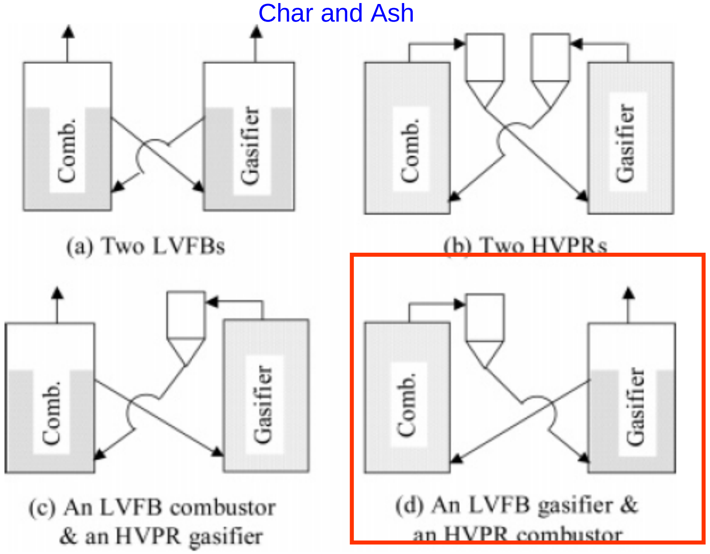
- Study on the hydrodynamics of gas and solid particle flows in a pilot-scale dual fluidized bed (DFB) gasifier using a computational fluid dynamics (CFD) code (Fluent, USA).
- Examine the effects of operating conditions on the solid holdup and solid circulation rate of the bed materials from the both experiment and simulation.
- Examine the performance of the loop-seal at various operating conditions
- Predict the solid holdup and solid circulation rate of the particle flow for the hot rigs in the DFB gasifier.

Outlines

- Gasification in a DFB gasifier
- Multiphase models
- Simulation setup
- Results and discussion
- Conclusions

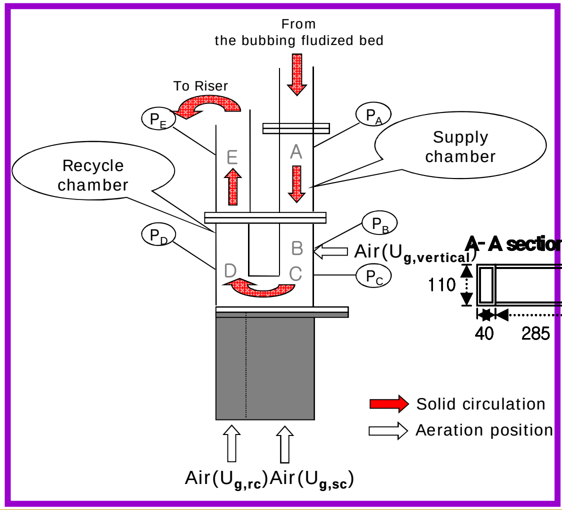
Gasification in a DFB gasifier





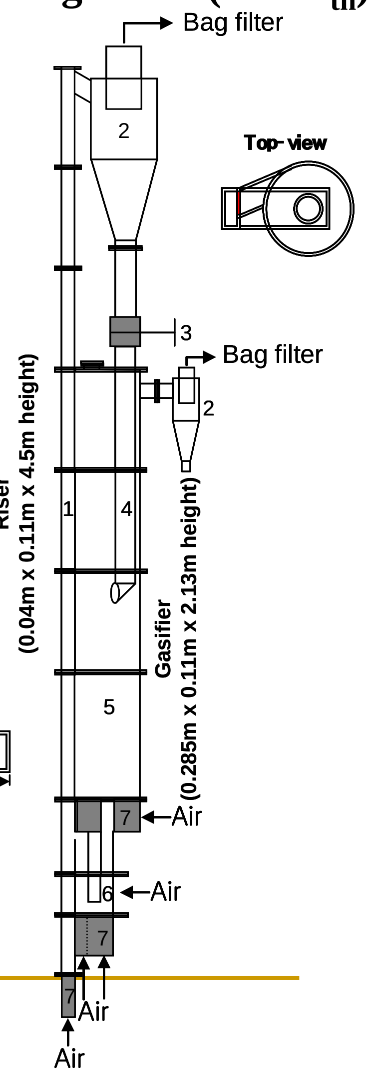
LVFB: Low-velocity Fluidized Bed
HVPR: High-velocity Pneumatic Riser

Technical choice for DFB gasification



Pilot-scale DFB gasifier (30kW$_{th}$)

1. riser
2. cyclone
3. ball valve
4. downcomer
5. BFB gasifier
6. loop-seal
7. air box



Multiphase models (1/2)

<u>Disctrete Phase Model</u>

-Useful for dilute flows

-Particle volume fraction should be less than 10%

-Traces all particles and has detailed particle information

-Relatively fast (steady state flow) with reasonable particle number

-Easy to handle different particle diameters

Applied to:
Entrained bed or Free fall gasifiers

<u>Eulerian-Eulerian (E-E) model</u>

-More general and sophisticated multiphase model

-Can handle both dilute and dense flows

-Relatively slower (unsteady flow)

-Relatively difficult to handle different particle diameter

Applied to:
Fluidized bed gasifiers

Multiphase models (2/2)

Governing equations of Two-phase E-E model:

Mass conservations

$$\frac{\partial}{\partial t}(\alpha_g \rho_g) + \nabla.(\alpha_g \rho_g \vec{v}_g) = 0$$ (gas phase)

$$\frac{\partial}{\partial t}(\alpha_s \rho_s) + \nabla.(\alpha_s \rho_s \vec{v}_s) = 0$$ (solid phase)

gas/solid momentum exchange coefficient

Momentum conservations

$$\frac{\partial}{\partial t}(\alpha_g \rho_g \vec{v}_g) + \nabla.(\alpha_g \rho_g \vec{v}_g^{\,2}) = -\alpha_g \nabla p + \nabla.\overline{\overline{\tau}}_g + \alpha_g \rho_g \vec{v}_g + K_{gs}(\vec{v}_g - \vec{v}_s)$$ (gas phase)

$$\frac{\partial}{\partial t}(\alpha_s \rho_s \vec{v}_s) + \nabla.(\alpha_s \rho_s \vec{v}_s^{\,2}) = -\alpha_s \nabla p - \nabla p_s + \nabla.\overline{\overline{\tau}}_s + \alpha_s \rho_s \vec{v}_s + K_{gs}(\vec{v}_g - \vec{v}_s)$$ (solid phase)

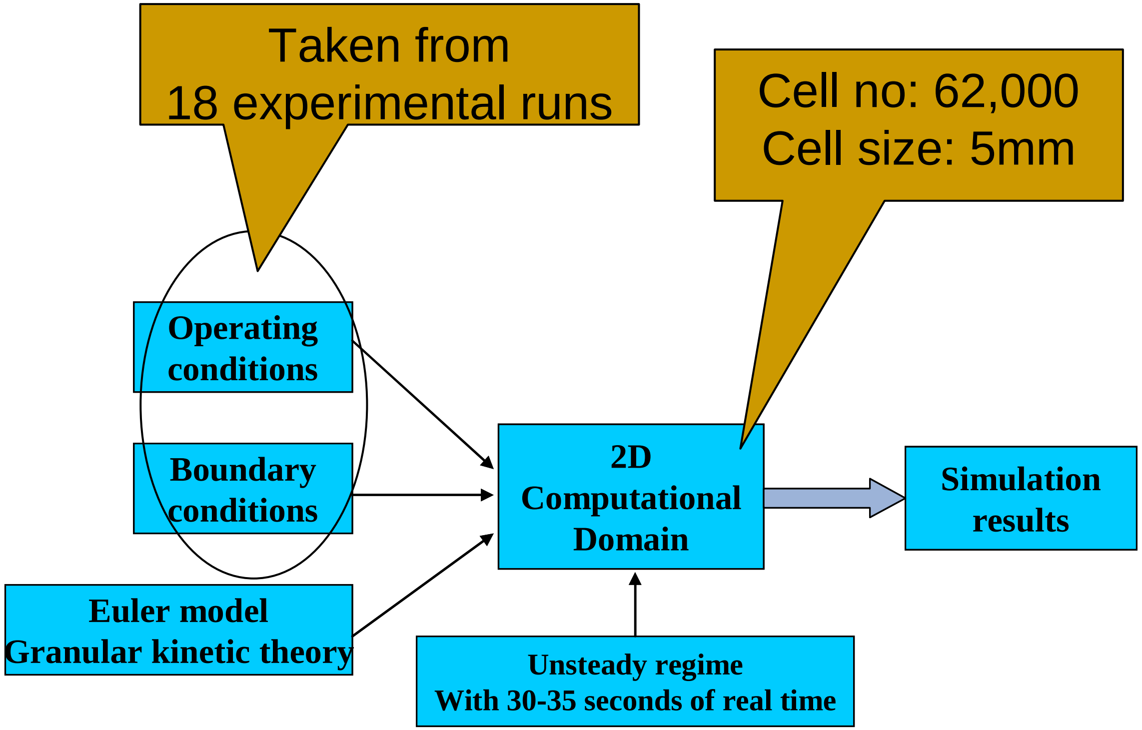
Fluctuation energy conservation of solid particles

$$\frac{3}{2}\left[\frac{\partial}{\partial t}(\rho_s \alpha_s \Theta_s) + \nabla.(\rho_s \alpha_s \vec{v}_s \Theta_s)\right] = (-p_s \overline{\overline{I}} + \overline{\overline{\tau}}_s) : \nabla.\vec{v}_s + \nabla.(k_{\Theta s} \nabla \Theta_s) - \gamma_{\Theta s} + \phi_{gs}$$

used as a drag function

Gidaspow drag function | **Syamlal-O'Brien drag function** | **Wen-Yu drag function**

Simulation setup

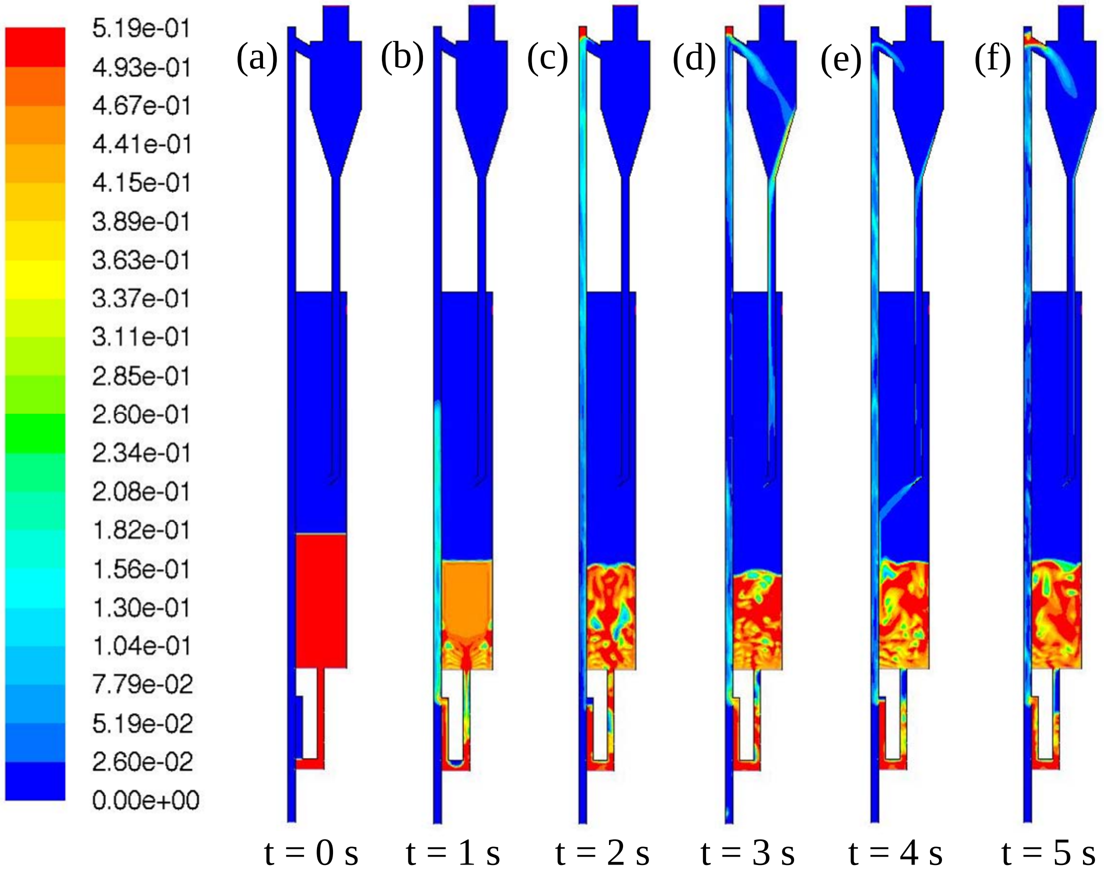


Simulation parameters

Parameters	Value
Initial solid packing, ε	0.519
Restitution coefficient	0.9
Inlet boundary condition type	Inlet-velocity
Outlet boundary condition type	Pressure-outlet
Time step	0.001 s
Maximum number of iterations	100
Convergence criteria	10^{-3}

Results and discussion (1/9)

Solid/gas flow pattern: start up flow



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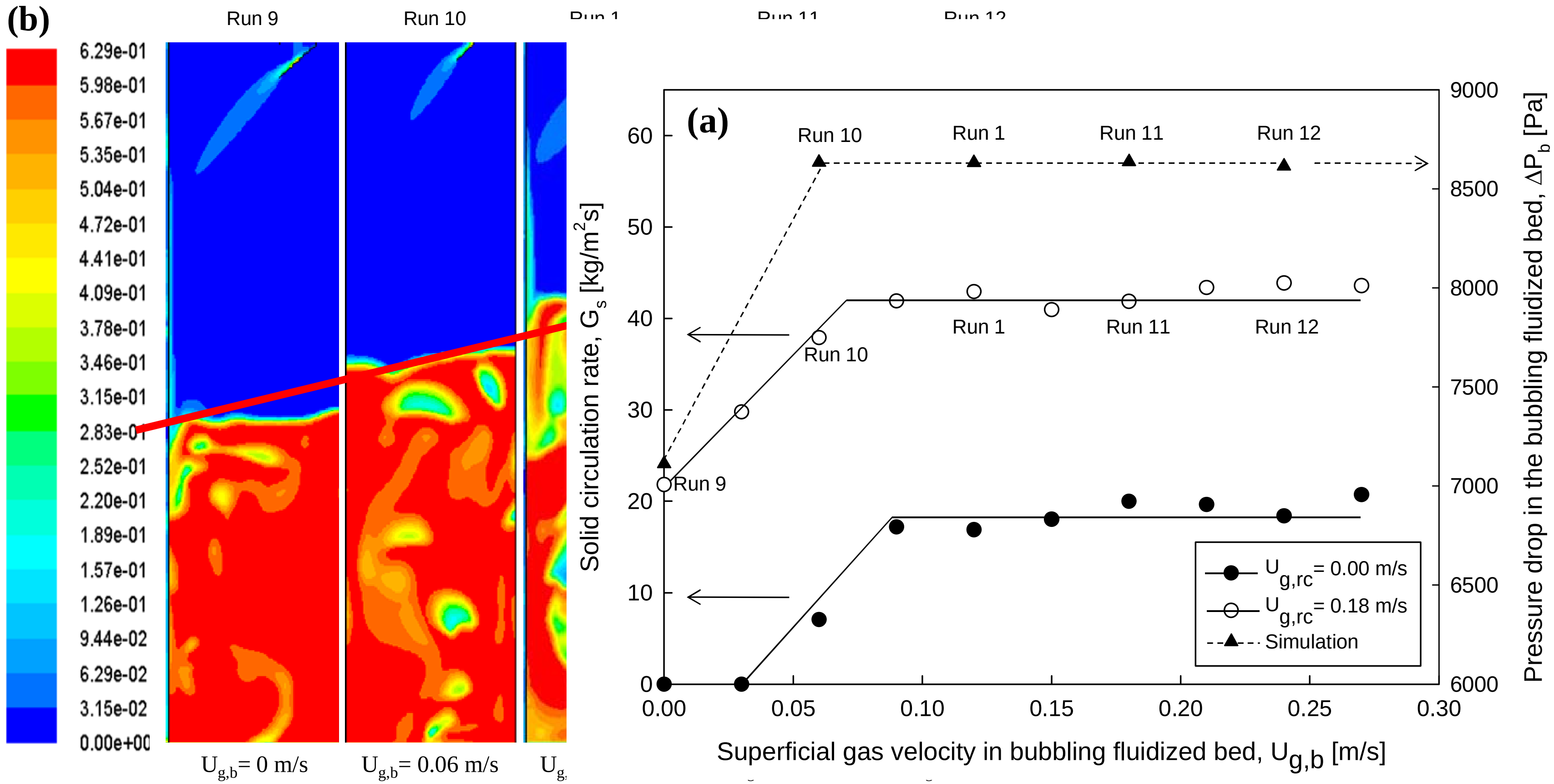
Results and discussion (2/9)

Solid/gas flow pattern: bed expansion



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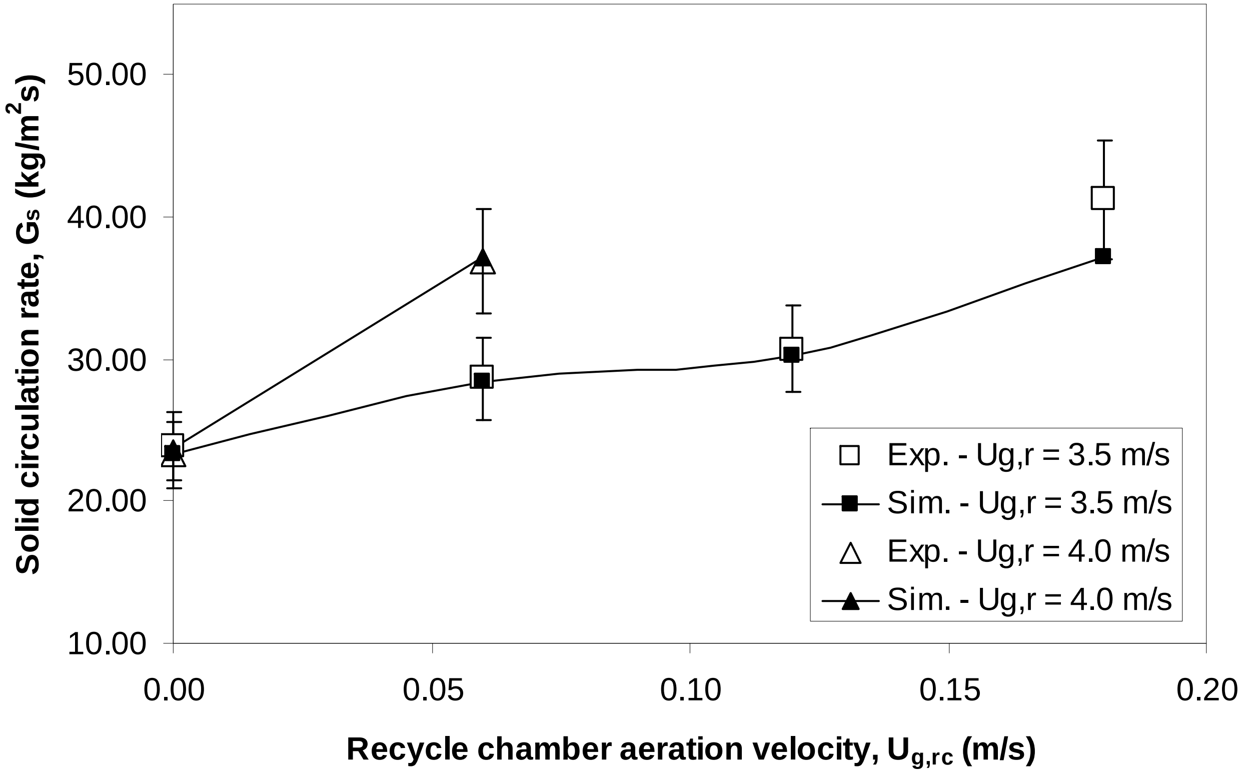
Results and discussion (3/9)

Solid circulation rate: Efect of recycle aeration



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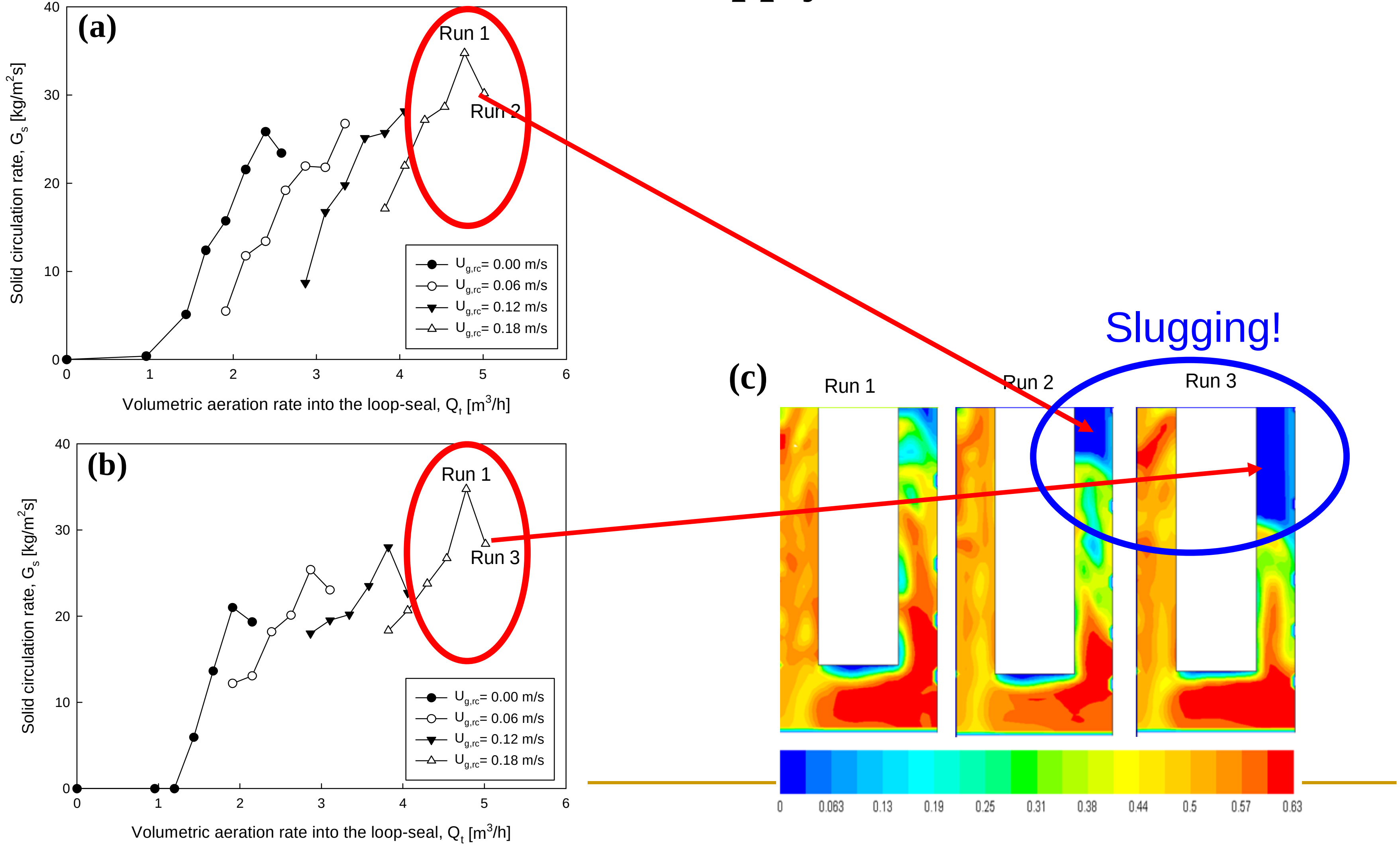
Results and discussion (4/9)

Solid circulation rate: Effect of supply chamber aeration



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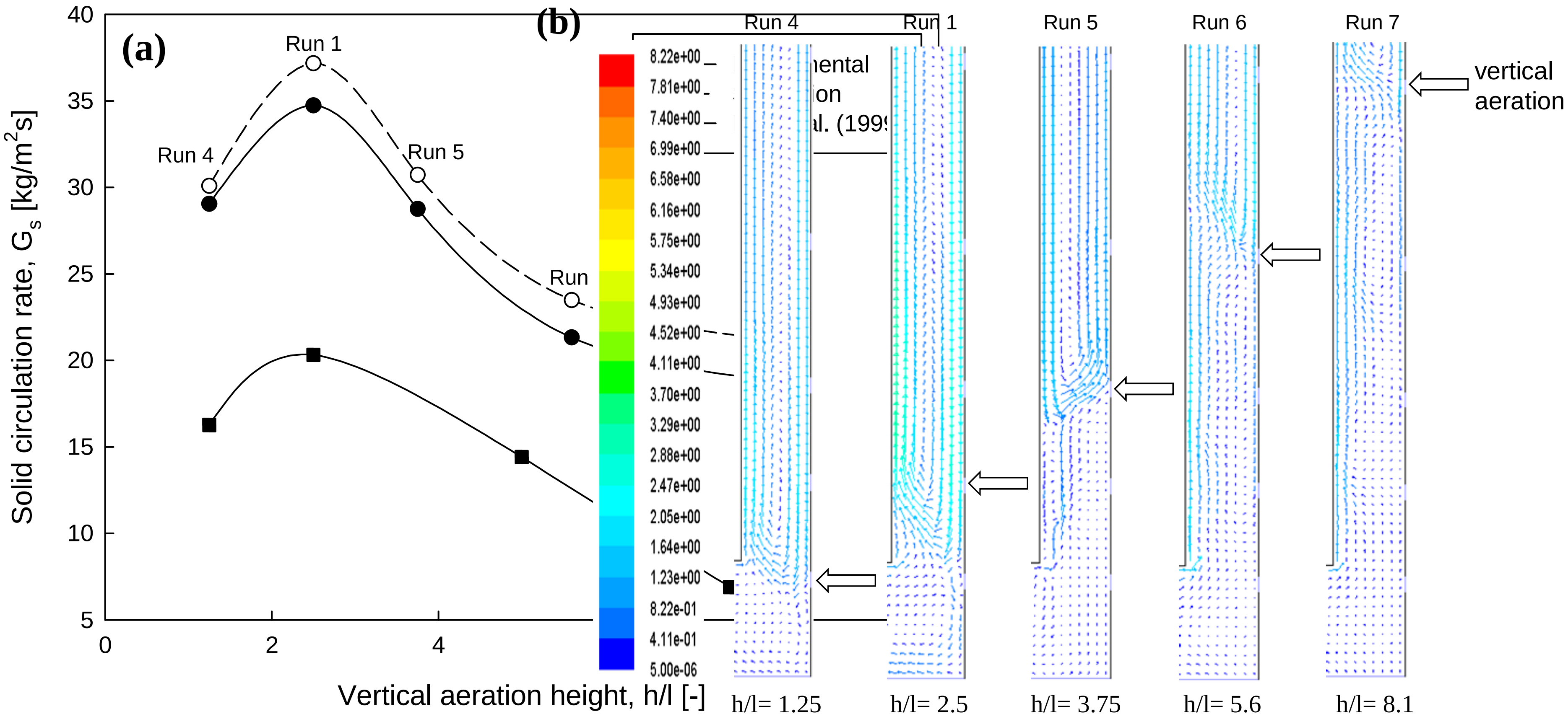
Results and discussion (5/9)

Solid circulation rate: Effect of vertical aeration position



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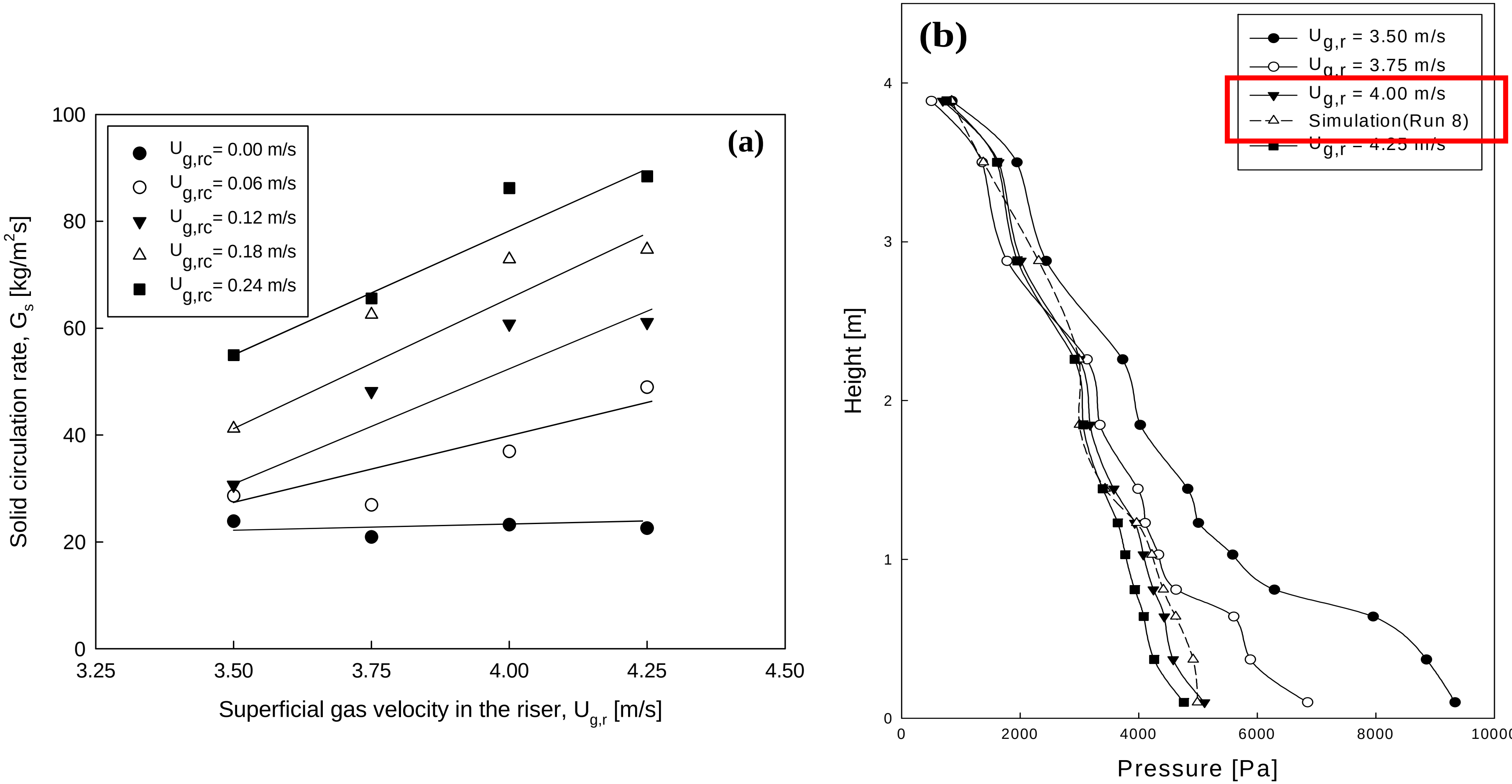
Results and discussion (6/9)

Solid circulation rate:Effect of gas velocity in the riser



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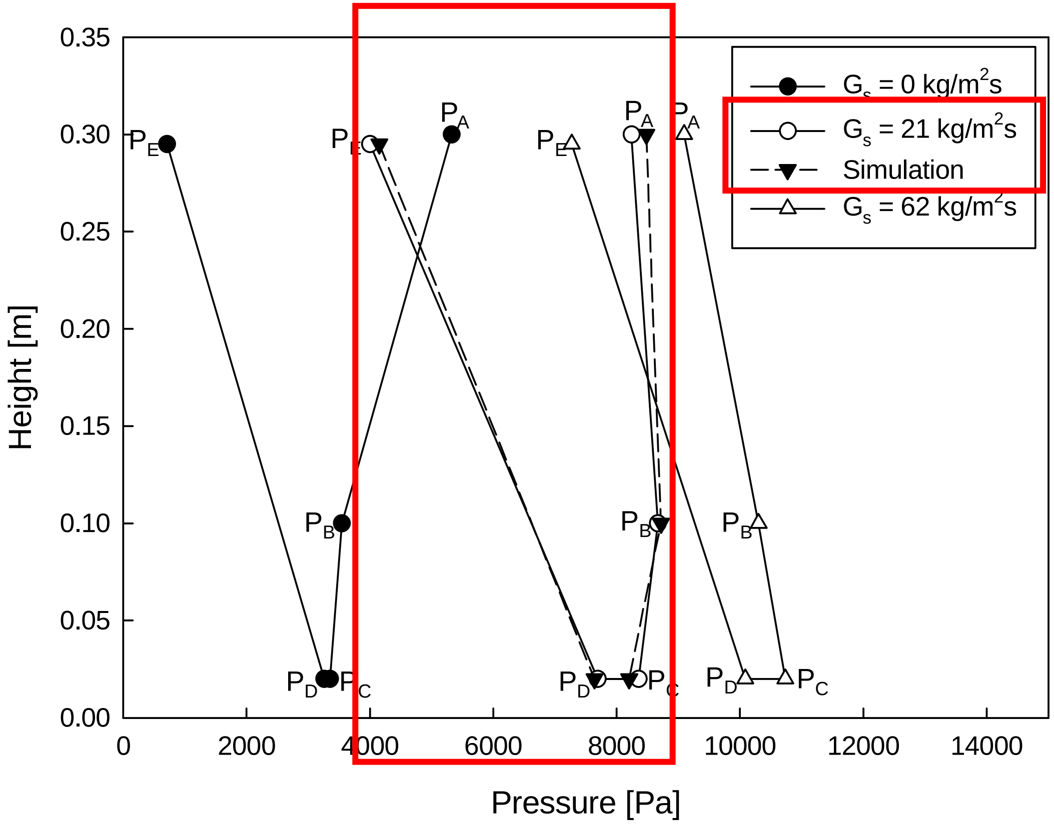
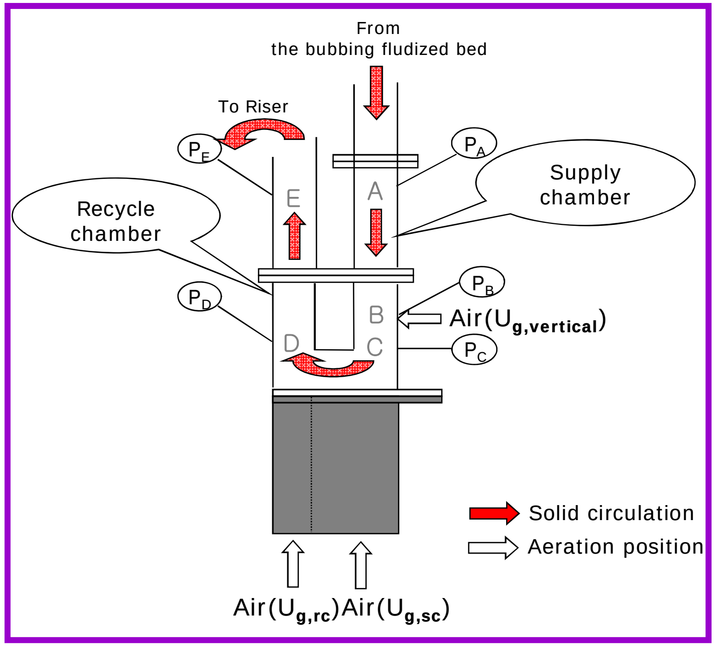
Results and discussion (7/9)

Solid circulation rate:Pressure profile across the loop-seal





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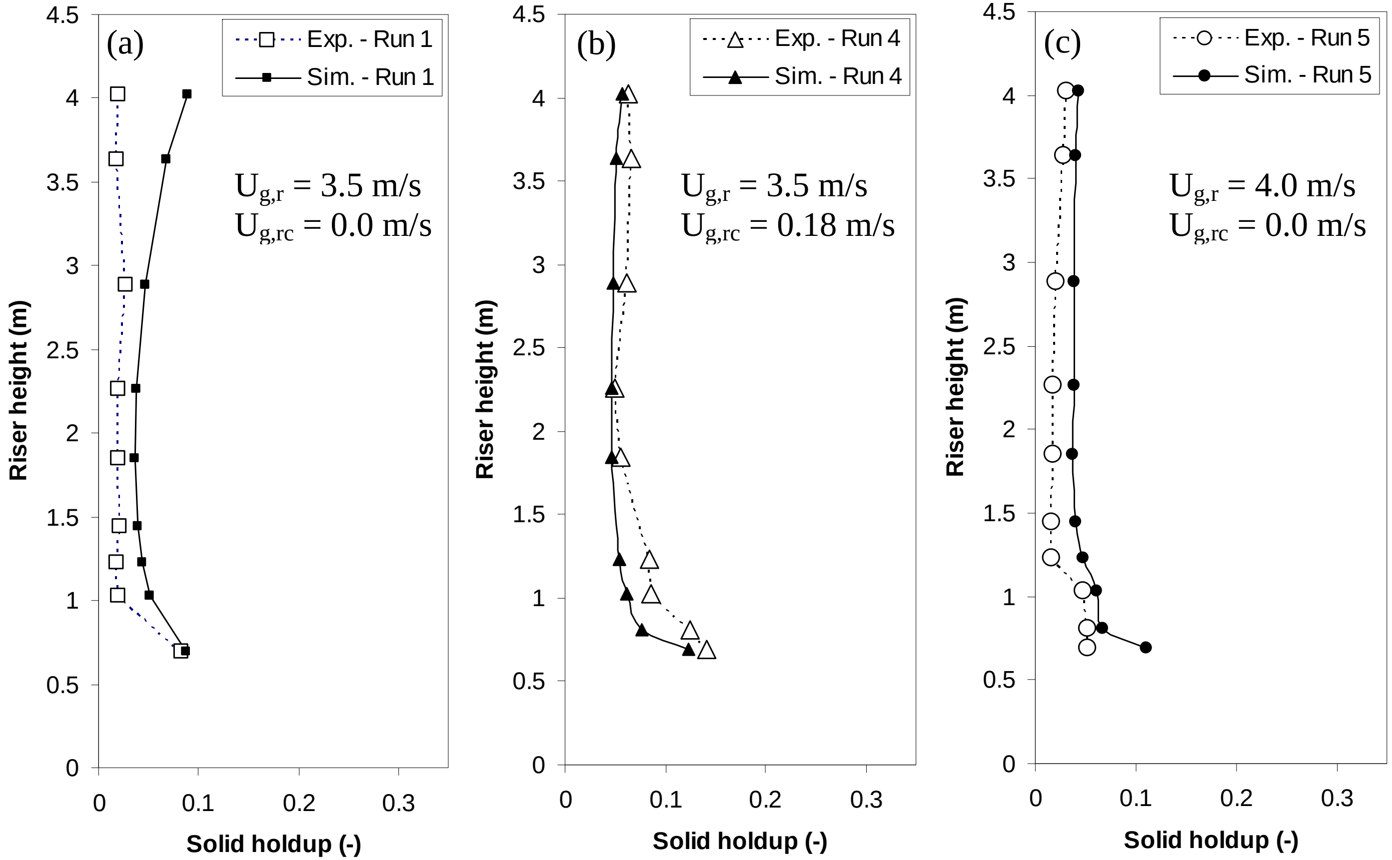
Results and discussion (8/9)

Solid holdup along the riser



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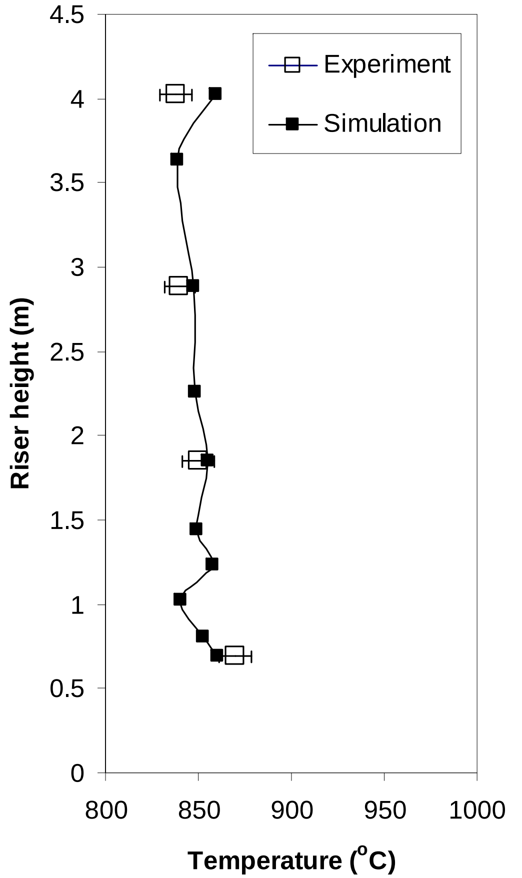
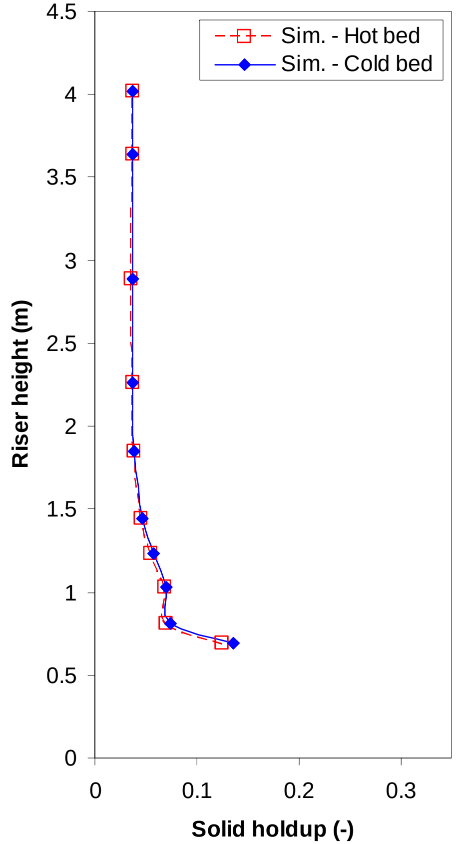
Results and discussion (9/9)

Prediction for the hot bed rig





Solid circulation rate:

Cold rig: 41.2 kg/m^2-s

Hot rig: 41.2 kg/m^2-s

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Conclusions

1. A two-dimensional CFD simulation with the multiphase Eulerian model incorporating the kinetic theory of solid particles is applied to investigate hydrodynamics of a pilot-scale DFB gasifier in the cold mode.
2. Hydrodynamic characteristics of the cold DFB gasifier are examined by both computational simulation and experiment.
3. The simulation results show a similar trend compared to the experiment data and other studies on the fluidized beds from the literature.
4. The CFD model used in this study predicts well the solid circulation rate in the cold DFB gasifier.
5. Optimum vertical aeration position on the loop-seal is obtained from both experiment and CFD simulation.
6. Hydrodynamic similarity is obtained from simulation for both cold and hot rigs.

Acknowledgement

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Thank you for your attention!