Hydrodynamics Study of a Bubbling Fluidized Bed

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Abstract

Hydrodynamic behavior of a bubbling fluidized bed was computationally analyzed in a 2D model. Different drag models were used to understand the variations of particle velocity and volume fraction at a certain bed height.

Keywords: Bubbling fluidized bed, Volume fraction, Drag models

Nomenclature

2D 2-Dimensional
K Momentum exchange coefficient
d Diameter
C_D Drag Coefficient
V Velocity
g Gas
s Solid
p Particle
$V_{r,s}$ Terminal velocity for solid phase

Greek Symbols
α Volume fraction
ρ Density
μ Dynamic viscosity
τ Particulate relaxation time

Non-dimensional Numbers
Re Reynolds number

1. Introduction

Fluidization is a process in which solid particles behaves as fluid due to suspension of a gas or liquid. This operation is generally used in industrial processes like catalytic reactions, particle coating, heating, cooling and drying etc. The physics behind the fluidization shows the significance of particle velocity, particle volume fraction, minimum fluidization velocity etc.

The velocity profile and volume fraction profile of particles have been analyzed and reported in this study.

2. Numerical Description

Table 1. Geometry and Computational Details

Parameter	***Detail***
Model	2D
Dimensions	0.4 m × 0.155 m (× 0.02 m)
Geometry and Mesh utility	blockMesh
Post-processing tool	Paraview, Sigma Plot
Solver	twoPhaseEulerFoam
Pressure-velocity coupling	PIMPLE algorithm [5]
Convective term solving scheme	V scheme [5]
Turbulent term solving scheme	Gauss limitedLinear [5]
Drag models	GidaspowErgunWenYu, Schiller–Naumann, Syamlal-O'Brien

Table 2. Solid properties and initial conditions

Parameter	***Value/Condition***
ρ	2500 kg/m^3
d_p	350 microns
Φ	0.6
e	0.99
V_{air}	0.587 m/sec
V_{wall}	Johnson-Jackson slip
Initial bed height	0.2 m
Initial solid α	40 %

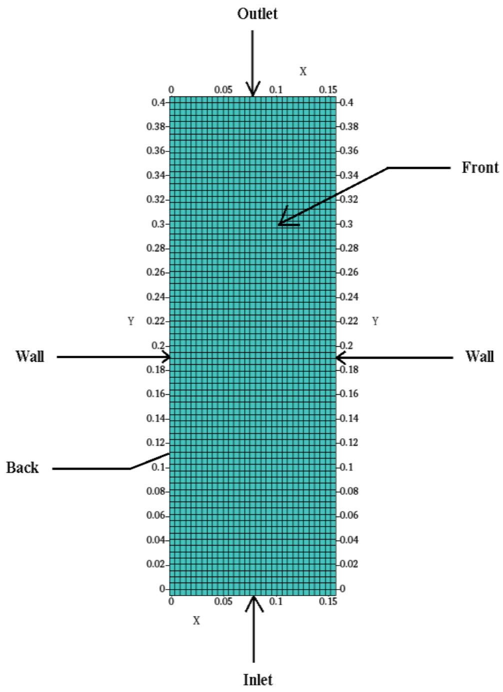

Fig. 1. 2D domain for numerical analysis

3. Drag Model Equations

3.1. GidaspowWenYu model: [4]

Wen-Yu model (1966)

$$K_{gs} = \frac{3}{4} C_D \frac{\alpha_g \alpha_s \rho_g}{d_p \alpha_g^{2.65}} \left| \vec{v_g} - \vec{v_s} \right|$$

Gidaspow model (1994)

$$K_{gs} = 150 C_D \frac{\alpha_s \mu_g}{\alpha_g d_p^2} (1 - \alpha_g)$$

$$+1.75 \frac{\alpha_g \rho_g}{d_p} \left| \vec{v_g} - \vec{v_s} \right| \quad ; \text{ for } \quad \alpha_g \leq 0.8$$

Now, GidaspowWenYu model; when $\alpha_g \geq 0.8$

$$C_D = \frac{24}{\alpha_g Re_s} \left(1 + (0.15 \alpha_g Re_s)^{0.687}\right)$$

$$Re_s = \rho_g \frac{d_p}{\mu_g} \left| \vec{v_g} - \vec{v_s} \right|$$

3.2. Schiller-Naumann model: [3]

$$K_{gs} = \frac{\alpha_g \alpha_s \rho_g f}{\tau_s}$$

$$\tau_s = \frac{\rho_s {d_p}^2}{18 \mu_g}$$

Where, $f = \frac{C_D Re_s}{24}$ and,

$$C_D = \frac{24}{Re_s} \left(1 + (0.15 \alpha_g Re)^{0.687}\right) \quad ; \text{for } Re \leq 1000$$

$$C_D = 0.44 \quad ; \text{for } Re \geq 1000$$

$$Re_{gs} = \rho_g \frac{d_p}{\mu_g} \left| \vec{v_g} - \vec{v_s} \right|$$

3.3. Syamlal-O'Brien model: [2]

$$K_{gs} = \frac{3}{4} C_D \frac{\alpha_g \alpha_s \rho_g}{d_p} \left(\frac{Re_s}{v_{r,s}^2} \right) \left| \vec{v_g} - \vec{v_s} \right|$$

$$v_{r,s} = 0.5(A - 0.06 Re_s$$
$$+ \sqrt{((0.06 Re_s)^2 + 0.12 Re_s (2B - A) + A^2)}$$

Where, $A = \alpha_g^{4.14}$ and

$B = 0.8 \alpha_g^{1.28}$ for $\alpha_g \leq 0.85$

$B = 0.8 \alpha_g^{2.65}$ for $\alpha_g > 0.85$

4. Results

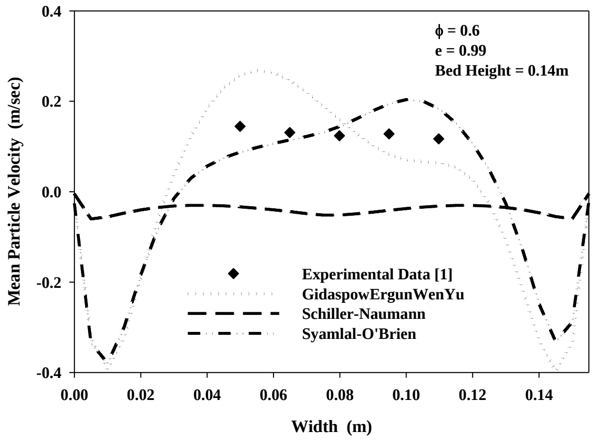

Fig. 2. Time-averaged particle velocity profiles at bed height = 0.14m

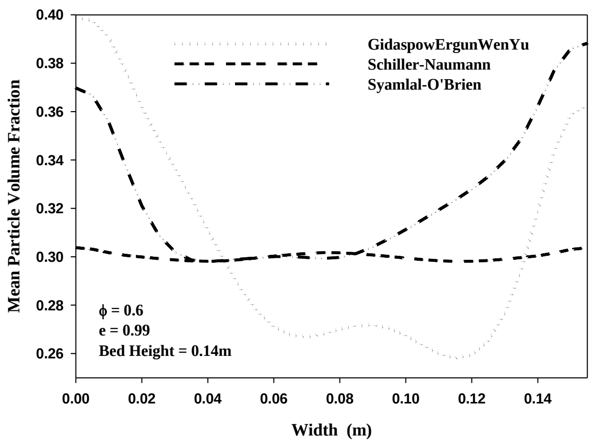

Fig. 3. Distributions of time-averaged particle volume fraction at bed height = 0.14m

Fig. 2. explains that GidaspowErgunWenYu and Syamlal O'Brien provide almost closed particle velocity to the experimental velocity. But Schiller-Naumann results underpredicted particle velocity.

Again, Fig. 3. shows that volume fraction profiles are not so symmetric for the three drag models mentioned above.

5. Contours

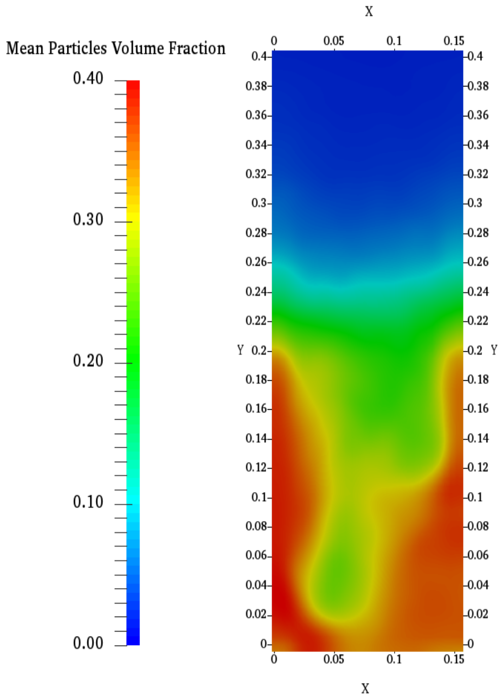

Fig. 4. Time-averaged particle volume fraction for GidaspowErgunWenYu

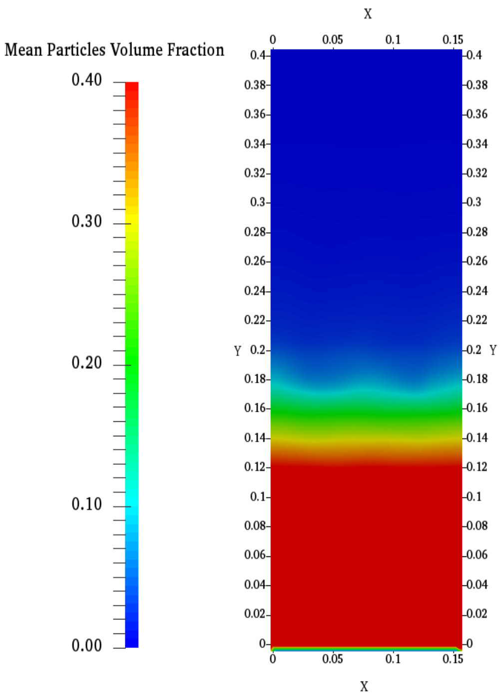

Fig. 5. Time-averaged particle volume fraction for Schiller-Naumann

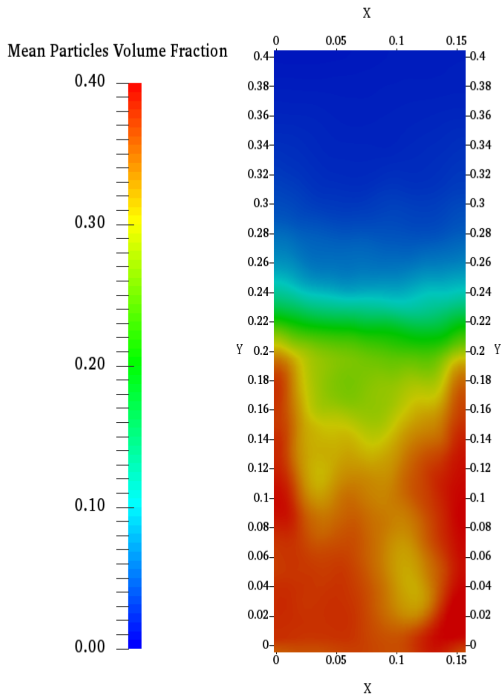

Fig. 6. Time-averaged particle volume fraction for Syamlal-O'Brien

References

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