CFD-DEM Simulations of Mixing of bi-Dispersed Solids in Biomass Fluidized Bed

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Highlights

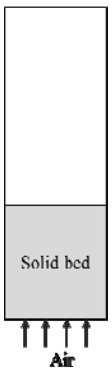
- Particle-scale DEM simulations of bi-dispersed biomass and glass beads are conducted.
- Simulations are conducted by using different initial conditions of positions of solids.
- Effect of bed configuration on mixing and hydrodynamics is investigated.

1. Introduction

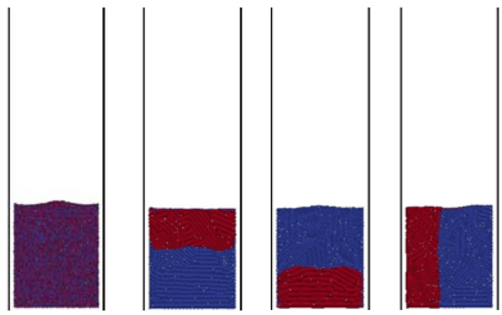
Mixing of sand and biomass in fluidized bed reactor is very critical for industrial-scale fast pyrolysis process. Several studies on bi-dispersed fluidized bed have reported the effect of particle properties, and operating conditions on mixing and segregation of the solids. However, a comprehensive study correlating the governing forces of drag and contact to mixing of bi-dispersed solids is still incomplete. This study conducts particle-scale DEM simulations of bubbling fluidization of biomass and glass beads to investigate the (i) effect of bed configuration on hydrodynamics and mixing of the two solids, and (ii) forces governing mixing/segregation during the transient state.

2. Methods

Computational model based on the Eulerian-Lagrangian approach is used with both biomass and glass beads treated as discrete phases, and gas resolved as a continuous phase. Interaction between particulate phases is modelled by using the discrete element model (DEM) with the soft sphere contact force model. The interaction between gas and solids is modelled using interphase exchange drag closure. Transient simulations are conducted by using different initial bed configurations, i.e. (i) case-1 - uniformly mixed solids, (ii) case-2 - segregated solids with biomass at top and glass beads at bottom, (iii) case-3 - segregated solids with biomass at bottom and glass beads at top, and (iv) case-4 - segregated solids with biomass at right hand side and glass bead at the left side. The simulations are performed for total 15 s flow time. The average particle height, mixing index and gas-solid drag force are analyzed for all the simulated cases.



Bed dim. (d × h) (cm^2)	10.2 × 81.6	
Material	Biomass	Glass bead
Particle dia. (cm)	0.09	0.055
Sphericity	1	1
Solid density (g/cm^3)	1.3	2.6
Min. fluidization vel. (cm/sec)	-	21.3
Initial ratio of volume fraction	0.5:0.5	
Superficial Velocity (cm/sec)	2 and 3$\mathbf{U}_{mf}$ of glass bead	



(b) case-1 (c) case-2 (d) case-3 (e) case-4

Figure 1. (a) Schematic diagram of simulated fluidized bed; (b) and (c) initial bed condition

3. Results and discussion

Simulation results of case-1 (Figure-1a) and case-2 (Figure-1b) 3$\mathbf{U}_{mf}$ of glass beads are compared. The average particle heights of both biomass and glass beads for case-1 (Figure-2a) are almost same at time t = 0, and they remain same for the whole simulated time. As the difference between the average bed heights indicates segregation of the two solids, it can be said that fluidization does not affect the uniform mixing in case-1. For case-2 at time t = 0, the average particle heights are wide apart with that of biomass being ~12

cm and glass bead being ~5 cm. With time t > 0, the average bed heights of both solids approach each other, and a mixed bed is formed just before 3 s. Transition from completely segregated to mixed condition can be attributed to higher gas velocity (3$\mathbf{U}_{mf}$ of glass beads, 21.3 cm/s – [1]). At this fluidization velocity, rapid bubble formation and bubble eruption cause mixing. When the average particle height behavior in case-1 and case-2 are compared, it is evident that the difference in bed behavior is during the first 3 seconds or transition time taken from the segregated bed of case-2 to become uniformly mixed bed. During this transition time, average interphase drag forces experienced by each of solids phases are plotted in Figure-2(c) and (d). The average drag force of glass beads in both the cases is around 600 gm cm/s^2, whereas that of the biomass is around 300 gm cm/s^2 in both the cases. The difference in the average drag can be directly linked to difference in particle sizes (biomass = 900 µm and glass bead = 550 µm). As the drag is inversely proportional to the diameter of particle, the average drag experienced by the glass beads is higher (~50%) than the biomass particles. The plot in Figure-2(c) and (d) suggests that instantaneous values are quite different. Instantaneous particle tracks at 0, 0.5 and 1 s are shown in Figure-2(e) and (f), which clearly suggests that local structures are quite different.

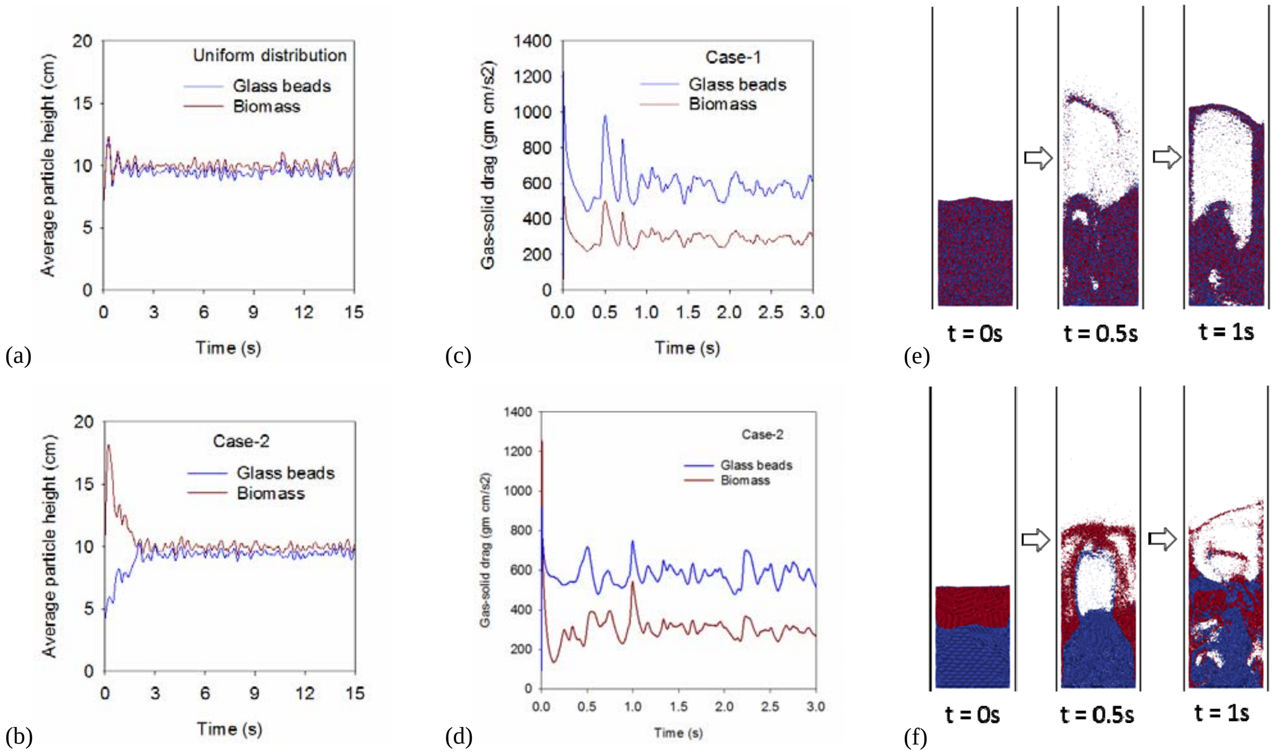


Figure 2. For case-1 and case-2, (a) and (b) average particle height vs time; (c) and (d) average gas-solid drag on particles vs time; (e) and (f) particle tracks.

4. Conclusion

Initial bed configuration do not affect steady state mixing or segregation, however instantaneous and local flow structures are significantly affected by the initial bed configurations. The bubble formation starts mostly in lighter and less dense biomass phase. A further detailed study during the transient phase will be carried out to investigate the influence of drag, contact and gravitational force on mixing in bi-dispersed BFB. The insight of dominant forces in mixing will give us a better understanding of mixing phenomena of bi-dispersed solids in BFBs.

References

[1] W. Bai, N.K.G. Keller, T.J. Heindel, R.O. Fox, Powder Technology 237 (2013) 355–366

Keywords
Bi-dispersed fluidized bed, mixing, drag