Influence of particle collision properties on fluidization behavior at elevated temperatures

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Highlights

- Better prediction of minimum fluidization conditions.
- Improved insight on fluidization.
- Elucidation of effects of friction and restitution coefficient on fluidization behavior.

1. Introduction

Recent experiments have shown a pronounced influence of temperature on the minimum fluidization conditions and average particle velocities of a gas-solid fluidized bed, even when the gas phase density and viscosity have been kept constant (Campos Velarde et al., 2016). Correlations that are available in the open literature for the description of the minimum fluidization velocity (U_{mf}) and bed voidage at minimum fluidization conditions (ε_{mf}), fail to accurately describe the experimental data on minimum fluidization conditions at elevated temperatures. These correlations are typically obtained from measurements in fluidized beds operated at cold-flow conditions and only the change in gas properties as a function of temperature are taken into account. Campos Velarde et al. proposed a new empirical correlation to more accurately describe the minimum fluidization conditions as a function of temperature. However, in order to arrive at a better prediction of the minimum fluidization conditions we need to improve our fundamental understanding of how the temperature influences the fluidization conditions via the particles properties, in particular the particle collisional properties. In this work we investigate the effect of the normal restitution coefficient and particle friction coefficient on the fluidization behavior, with focus on the minimum fluidization conditions, average particle velocities and average bubble size using numerical simulations with a Discrete Particle Model (DPM).

2. Methods

DPM is an Euler-Lagrange type model with a discrete description of the solids phase and a continuous description of the gas phase. Particle-particle collisions are dealt with in a deterministic fashion using a soft-sphere collision model, which allows multiple simultaneous contacts between several pairs of particles. The motion of each individual particle is tracked and described with Newton's second law.

3. Results and discussion

Depending on the material of the particle, the normal restitution coefficient (e_n) and the particle friction coefficient (μ_f) can change significantly with temperature. For instance, for the glass beads that were used in the experiments of Campos Velarde et al. it is reported in the literature [2] that both collision parameters increase with temperature. We investigated to what extent and how the change in these collision parameters affect the minimum fluidization conditions, particularly via the minimum fluidization porosity.

It was found that the particle friction coefficient has a more pronounced influence on the minimum fluidization conditions than the normal restitution coefficient (see Figure 1), detailed investigation on this observation is still ongoing. The relative difference of the minimum bed porosity with changes of the friction coefficient and normal restitution coefficient is shown in Table 1. Simulated values are compared with the values calculated using Campos Velarde's correlation, showing a significant discrepancy.

For a better comparison it is important to experimentally determine the collisional parameters of the used particles as a function of temperature, and most probably the impact angle and velocity. Laverman et al. (2006) have investigated the influence of the particle collision parameters on average particle velocities. This research will be extended to investigate the influence of the temperature on the fluidization characteristics via the particle properties.

Table 1. Minimum fluidization bed porosity as a function of the normal restitution coefficient and particle friction coefficient

T = 573K, μ_f=0.1						T = 573K, e_n=0.97					
e_n	0.82	0.86	0.88	0.9	0.92	μ_f	0.12	0.14	0.16	0.18	0.2
ε_{mf} (sim)	0.4037	0.4018	0.4002	0.4027	0.396	ε_{mf} (sim)	0.400	0.403	0.409	0.413	0.411
ε_{mf} (calc)	0.447					ε_{mf} (calc)	0.447				
relative $\Delta\varepsilon_{mf}$	0.098	0.102	0.106	0.100	0.115	relative $\Delta\varepsilon_{mf}$	0.106	0.099	0.086	0.078	0.081

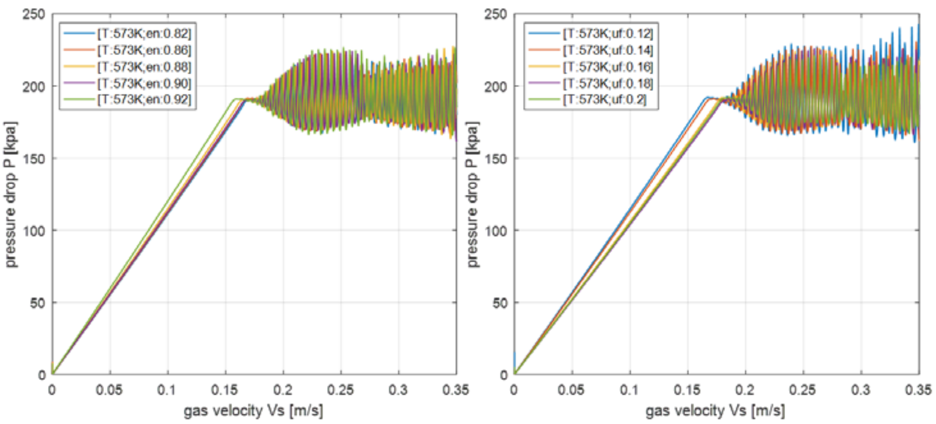

Figure 1. Influence of the normal restitution coefficient (en, left) and the particle friction coefficient (μf, right) at 573 K on the pressure drop over the bed as a function of the superficial gas velocity.

4. Conclusions

Both the particle friction coefficient and the normal restitution coefficient affect the minimum fluidization porosity and hence also the minimum fluidization velocity, which is not accounted for in any available semi-empirical correlations. With changes in particle collision properties towards less ideal conditions ε_{mf} increases due to increased particle friction and higher energy dissipation, however, a more detailed investigation is required. Since with higher temperature the friction coefficient also tends to increase, more aggregates could form under higher temperatures. Future work will extend this investigation into the effects of the collisional parameters on the macro-scale circulation patterns and bubble size distributions.

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References

[1] J.A. Laverman, M. van Sint Annaland, J.A.M. Kuipers, “Hydrodynamics of bubbling gas-solid fluidized beds using discrete bubble model”, Fifth International Conference on Computational Fluid Dynamics in the Process Industries, Melbourne, Australia 2006.

[2] J.M. Delimont, "Experimental Investigation of Temperature Effects on Microparticle Sand Rebound Characteristics at Gas Turbine Representative Conditions." (Doctoral dissertation) 2014.

[3] I.C. Velarde, R. Grim, F Gallucci, M. van Sint Annaland, “Influence of Temperature on Minimum Fluidization Properties of Gas-Solid Fluidized Beds”, Powder Technology, 2016.

Keywords
Multiphase modeling; Discrete Particle Model; fluidized beds; particle collision properties