Particle-Scale Dynamics of Fluidized Beds

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For the basis on the modeling of fluidized beds, we have constructed a model where the hydrodynamic interaction between particles through the fluid, which is the most important mechanism in fluidized beds, are focused on[1]. In this work, systematic simulations have been carried out and we have observed the phenomena shown in Fig.1. The fluidization can be characterized by the kinetic energy $E(t)$ per particle. From Fig.2, we can observe the fluidization at $u^{\infty} = u_c$ and linear behavior of $\bar{E}$ with u^{∞}. As the change of St, we have found two types of fluidized phases, *channeling phase* and *bubbling phase.*

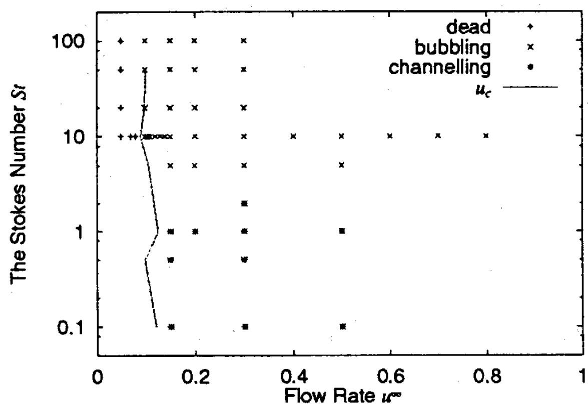

Figure 1: Simulations executed in the parameter space (u^{∞}, St). In this figure we show the behavior obtained, *fixed phase*, *channeling phase* and *bubbling phase* and the transition line between these phases discussed in the text.

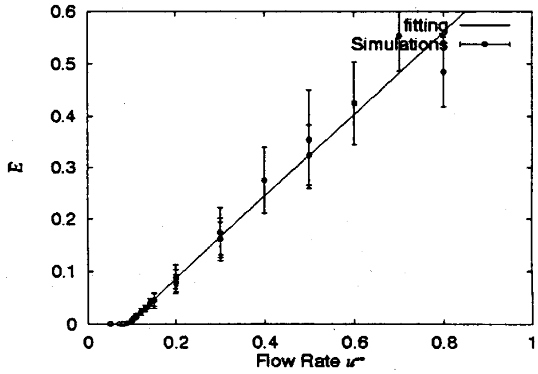

Figure 2: The flow rate dependence of the averaged energy $\bar{E}(u^{\infty})$ with $St = 10$.

We found that u^{∞} acts as the effective temperature (cf. Fig.2). In terms of the effective temperature u^{∞}, we have defined the effective viscosity μ_e from the Einstein relation as

$$\mu_e = \frac{u^{\infty}}{D_p}, \tag{1}$$

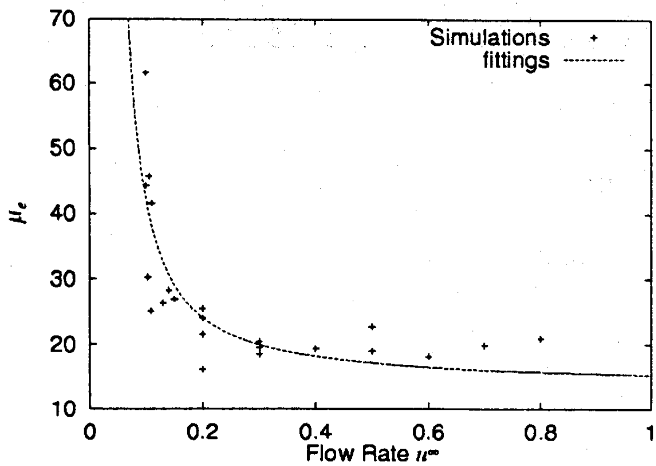

Figure 3: Effective viscosity $\mu_e(u^\infty)$. This result is calculated on the simulation with $St = 10.0$. The fitting by the Arrhenius type function.

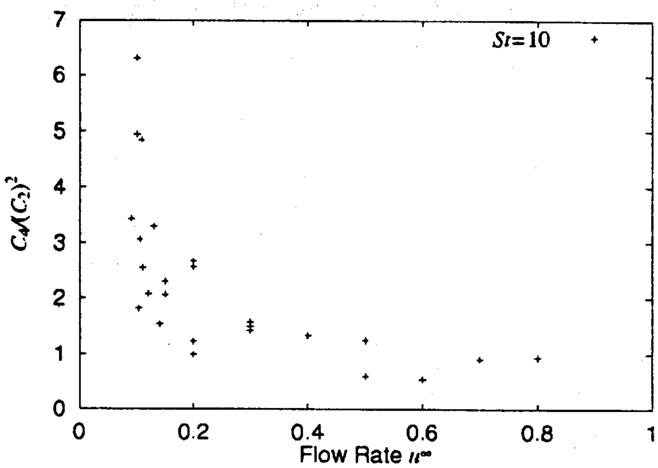

Figure 4: The non-Gaussian parameter $C_4/(C_2)^2$ with $St = 10$ for the change of u^∞.

where D_p is the diffusion constant(Fig. 3). The flow-rate dependence of the viscosity μ_e is the same as to the experiments for real fluidized beds[3] where $\mu_e(u^\infty)$ obeys the Arrhenius type function $\mu_e(u^\infty) = F\ e^{E_f/u^\infty}$ where F and E_f are the fitting parameter. It is also found that $\mu_e(u^\infty, St)$ corresponds to the non-Gaussian property of velocity distribution of particles $C_4/(C_2)^2$ where C_4 is the 4th cumulant defined by

$$C_4(U_x) = \langle {U_x}^4 \rangle - 3\langle {U_x}^2 \rangle^2 - 4\langle U_x \rangle \langle {U_x}^3 \rangle + 12 \langle U_x \rangle^2 \langle {U_x}^2 \rangle - 6 \langle U_x \rangle^4, \quad (2)$$

and C_2 is the square of the variance or the 2nd cumulant (Fig.4). The non-Gaussian parameter $C_4/(C_2)^2$ has the value zero for the Gaussian distribution and 3 for the exponential distribution. The behavior of steady state can be explained by means of the hole theory which is used for simple liquid.

References

[1] K.Ichiki and H.Hayakawa, *Phys. Rev. E*, **52**,658 (1995).

[2] K.Ichiki and H.Hayakawa, submitted to Phys. Rev. E. (preprint: cond-mat/9704208)

[3] J.Furukawa and T.Ohmae, *Ind. Eng. Chem.*, **50**,821 (1958).