Attractive particle interaction forces and packing density of fine glass powders

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Introduction – It is a challenging problem to ***predict*** the packing density of a certain powder specified by the particle size distribution and material properties. Indeed, the relevance of the different types of attractive particle interaction forces – such as adhesion and non-bonded van der Waals forces – for the packing behavior of powders is still largely uncertain.

Here we study the packing density of fine glass powders of different size distributions (Fig. 1) both experimentally and by DEM simulations (Fig. 2).

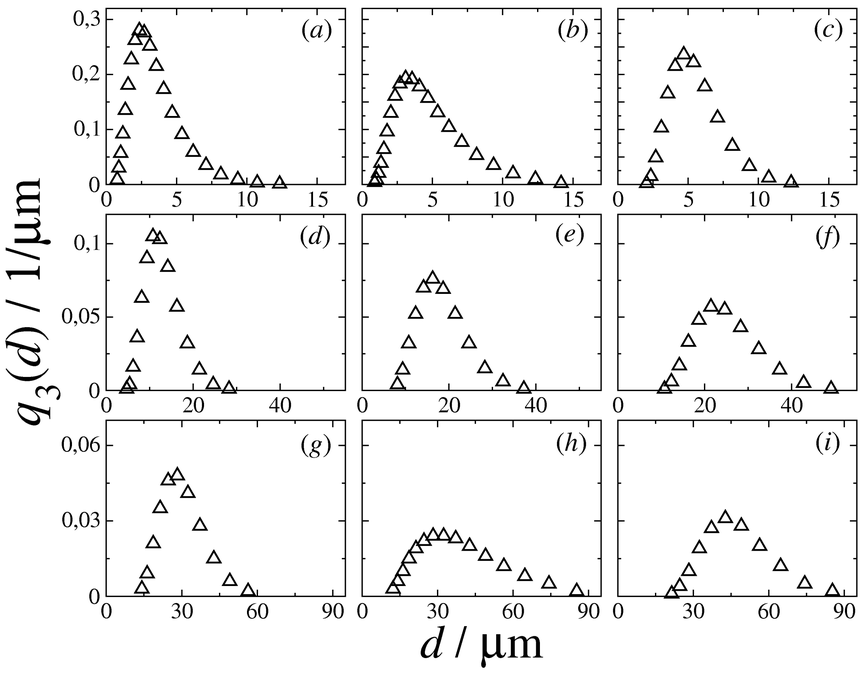

Fig. 1 – Experimental particle size distributions. In each plot, the volume density distribution is shown as a function of the particle size.

DEM model – In our simulations we consider following models for particle interaction forces:

Model 1: viscoelastic forces;
Model 2: viscoelastic forces and adhesion (modeled through JKR theory);
Model 3: viscoelastic, adhesion and non-bonded van der Waals forces.

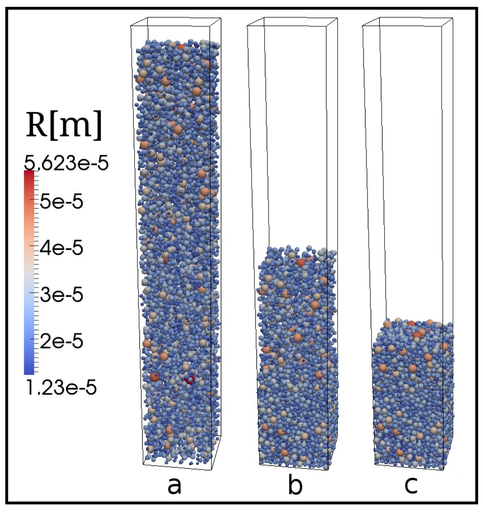

Fig. 2 – Snapshots of the DEM simulation using the particle size distribution is from Fig. 1j. R denotes the particle radius, and time increases from a – c. Simulations were performed using the Open Source DEM solver LIGGGHTS, which was extended here in order to account for the attractive particle interaction forces.

Results – We obtain quantitative agreement between experiments and simulation if model 3 is used, that is if *both* types of attractive forces of particle interaction, adhesion and non-bonded van der Waals forces are taken into account. Neglecting any of these forces may lead to incorrect numerical prediction of the behavior of fine powders (see Fig. 3).

Our results lead to a mathematical expression to estimate the packing fraction φ of fine polydisperse powders as a function of the average particle size $\langle d \rangle$, which is valid for $10^0 < \langle d \rangle / \mu\text{m} < 10^2$,

$$\varphi = \varphi_\infty - \frac{C}{\langle d \rangle^\alpha}$$

where $\varphi_\infty \approx 0.64$ (random close packing), while C and α are fit parameters (see Fig. 3).

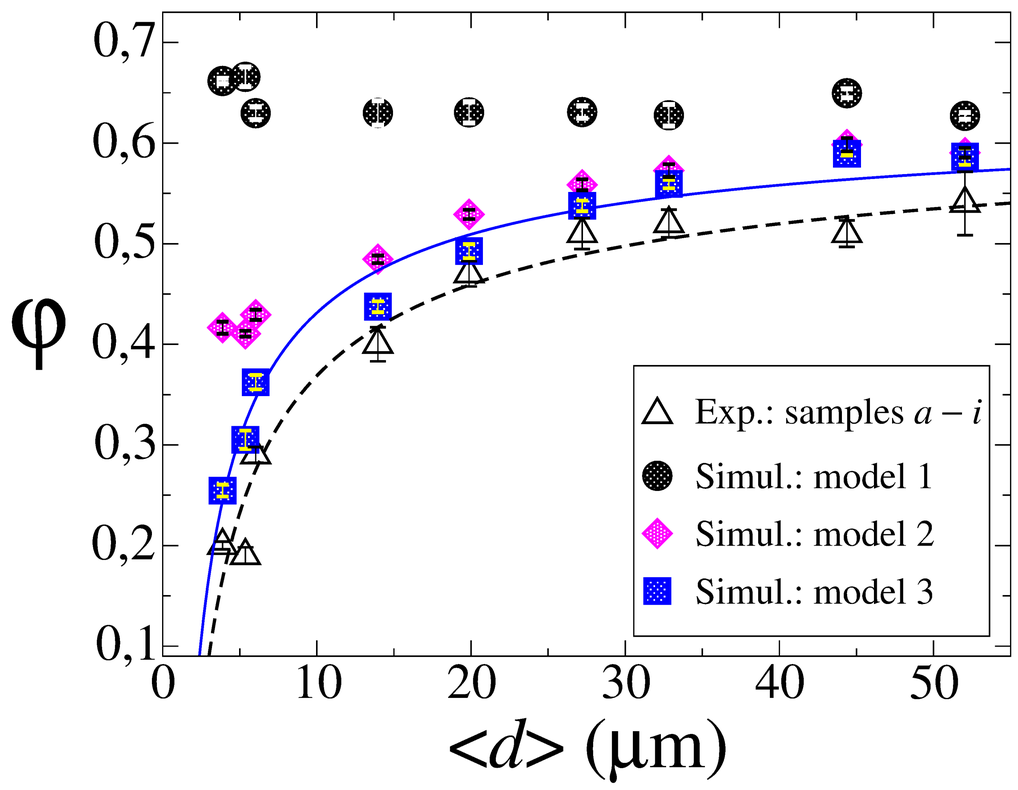

Fig. 3 – Packing fraction as a function of the average particle size. Empty and filled symbols denote results from experiments and simulations using models 1 – 3, respectively. The best fit to the experimental data obtained using Eq. (1) yields $C \approx 1.05$ and $\alpha \approx 0.59$ (dashed line). The continuous line denotes the best fit to the simulation data obtained with model 3, which gives $C \approx 0.99$ and $\alpha \approx 0.68$.

We believe that our results, obtained for fine glass powders, will be of relevance also for other powder systems containing a significant fraction of small particles or a wide distribution of particle sizes.

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