62d Computational Validation of the Glicksman Scaling Laws Using Gas/Solids Fluidized Bed Simulations

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Scaling laws (*e.g.* Glicksman, 1984 and 1988; Glicksman *et al*, 1993) have been derived based on the governing equations describing multiphase flows in a quest for scaling laboratory-scale multiphase reactors to pilot-scale and later to industrial-scale. These scaling laws will also have applicability to processes under reduced gravity that are of importance to the ‘Mission to Mars' program initiated by NASA. A dimensional analysis of the multiphase flow equations reveals five dimensionless parameters (*full-set*) that can be used for scaling (e.g., Glicksman 1988). Since it is often impractical to match this full-set in lab-scale experiments, Glicksman *et al*, (1993) showed that a *reduced-set* of four parameters is sufficient when the system is operating under the viscous or inertial flow regimes. They assumed that the set would be sufficient for the intermediate flow regime as well. Bricout and Louge (2004) validated this assumption using a set of circulating fluidized bed experiments.

It is possible to validate the scaling laws using detailed numerical simulations because one has the flexibility to change gravity, fluid density, particle density, size, etc. in any desired combination. van Ommen et al. (2004) conducted such a computational validation of the scaling laws. Surprisingly they found that matching the reduced-set of parameters yielded better results than matching the full-set of parameters. In this paper we present a systematic computational study using the gas-solids flow code MFIX (www.mfix.org), progressing from simple to more complex flows, in order to investigate the validity of the full and reduced sets of scaling laws under different gas-solids fluidization conditions.

Fully developed riser flow: Glicksman scaling laws are completely valid in a fully developed riser flow simulations carried out so far. Scaled solids flux, velocity and solids volume fraction matched perfectly using 3 different riser diameters: 5 cm, 10 cm and 20 cm. Gas viscosity, particle diameter, riser diameter and the acceleration of the gravity were modified to satisfy the full-set of scaling parameters proposed by Glicksman.

Bubbling fluidized bed with jet: In a bubbling fluidized bed with a central jet, again by matching the full-set of scaling parameters, we were able to obtain good scaling of the bubble diameter as well as the power spectrum density (PSD) of the gas pressure fluctuations. We demonstrate that mismatching the gas viscosity, which results in mismatching the Archimedes (Ar) number, causes the bubble diameters not to scale.

Uniformly bubbling fluidized bed: In these cases, similar to those studied by van Ommen *et al.* (2004), the PSD of pressure fluctuations do not scale. We will apply additional tests reported in that paper (Kolmogorov Smirnov test for cycle time distributions and S statistic test for comparing attractors) and report the results in the final paper. We will conduct the following parametric studies to investigate how dynamic and time-averaged quantities scale while using the full and the reduced set of scaling parameters:

- Mesh resolution and the order of the spatial discretization schemes
- Boundary conditions
- Role of Kinetic Theory of Granular Flows (KTGF) and quasi-static stress theories (Frictional and Plastic)

Initial findings: Similar to the work of Detamore *et al.* (2001), we found that the ratio d_p/D (particle diameter to bed diameter) is very important in scaling and must be maintained constant during scale-up and scale-down in order to obtain a similar solution. Similar to the work of Bricout and Louge (2004), we found that mismatching the Ar number did not show significant differences in scaling-up a gas/solids flow in a riser. However, in a bubbling bed, the bubble diameter was not scaled properly when the Ar number was mismatched. Our numerical results show that in addition to the use of the full-set of scaling parameters, the same number of computational grids must be used when scaling a simulation of a fluidized bed; in contrast to experiments, scaling-down would not reduce the number of computational grids and, hence, the computational cost.

References:

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