Fractal dimensions of capillary force induced particle networks

Erin Koos*, Frank Bossler, Johannes Maurath, Katrin Dyhr, Norbert Willenbacher

Institute for Mechanical Process Engineering and Mechanics,
Karlsruhe Institute of Technology, Karlsruhe, Germany

*erin.koos@kit.edu

The rheological properties of a particle suspension can be substantially altered by adding a small amount of a secondary fluid that is immiscible with the bulk phase [1]. The substantial changes in the strength of these capillary suspensions arise due to the capillary forces induced by the added liquid leading to a percolating particle network. The capillary suspension networks are unique from other types of particulate networks due to the nature of the capillary attraction. Different three-phase contact angles of the secondary fluid towards the particle surface in bulk phase environment lead to very different microstructures. Contact angles smaller than 90° lead to pendular networks of particles connected with single capillary bridges or clusters comparable to the funicular state in wet granular matter, whereas a different clustered structure, the capillary state, can form for angles larger than 90°. Using a scaling theory by P. G. de Gennes, the fractal dimension can be deduced from the yield stress or the shear modulus as function of the solid volume fraction [2, 3]. Exponents obtained using aluminum oxide or calcium carbonate particles in the pendular state indicate an increase in the networks fractal dimension with increasing particle size. This transition may be explained by the corresponding reduction in the capillary force with increasing particle size. These fractal dimensions are compared with the values measured from confocal microscopy. Radial particle pair distribution functions are obtained by image analysis, which can capture some of these microstructural differences. The fractal dimension of the networks is computed from a power-law fit to the pair distribution functions. By using different sized silica microspheres, the fractal dimensionality is determined directly as a function of particle size and compared to microstructural changes in the network.

Figure 1 Confocal image of an oil-based model capillary suspension in the (left) pendular and (right) capillary states containing silica microspheres (red). The secondary fluid is shown in yellow.