Packing dynamics of spherical and nonconvex equiaxed dendritic grains sedimenting at low Stokes number

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ABSTRACT

The random packing of sedimenting crystal grains during metal alloy solidification has a strong influence on the structure and the defects of the solidified material. The dynamics of sedimentation and packing in conditions encountered in metal casting processes is poorly known. The free-floating solid equiaxed dendritic grains sediment and pack in the viscous melt driven by a very low solid-liquid density difference. In this paper we investigate the transition from the purely sedimentation regime to the mechanical equilibrium (packing) for a condition of a low ratio of grain inertia to vicous dissipation, given by a low Stokes number, St, of $o(10^{-3})$, which is typical in solidification. The packing dynamics at a low Stokes of two monodisperse noncohesive grain collections (spheres and nonconvex equiaxed dendritic grains) is numerically simulated via an arbitrary-geometry Discrete Element Method (DEM) approach that accounts for the viscous melt presence through models of the interparticle lubrication forces, of the drag force, and of the buoyancy force.

An experimental setup that consists on the sedimentation and packing of two grain collections (spherical and nonconvex equiaxed grains) in a vertical column filled with glycerol is employed to calibrate our numerical model. A significant number of grains are experimentally tracked in order to obtain the mean grain trajectory during the packing dynamics that is used for the numerical calibration.

The numerical simulations enable us to access to information that is difficult to measure experimentally. The time-evolution of the local solid fraction, of the local contacting neighbor grains and of the grain orientation in the transition region between sedimentation and packing are determined. Finally, the transition time, Δt_{tr}, i.e. the time needed by the grains to cross the transition region and the size of the transition region, L_{tr}, are provided for both grain collections. This information can be used in process scale models of solidification during casting.

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