A Cartesian grid-based sharp interface method is presented for viscous simulations of shocked particle-laden flows. The moving solid–fluid interfaces are represented using level sets. A moving least-squares reconstruction is developed to apply the no-slip boundary condition at solid–fluid interfaces and to supply viscous stresses to the fluid. The algorithms developed in this paper are benchmarked against similarity solutions for the boundary layer over a fixed flat plate and against numerical solutions for moving interface problems such as shock-induced lift-off of a cylinder in a channel. The framework is extended to 3D and applied to calculate low Reynolds number steady supersonic flow over a sphere. Viscous simulation of the interaction of a particle cloud with an incident planar shock is demonstrated; the average drag on the particles and the vorticity field in the cloud are compared to the inviscid case to elucidate the effects of viscosity on momentum transfer between the particle and fluid phases. The methods developed will be useful for obtaining accurate momentum and heat transfer closure models for macro-scale shocked particulate flow applications such as blast waves and dust explosions.