



FIG. 1. Visualization of fluid vorticity (red) and solid particles (white) of an initially spherical suspension falling due to gravity. Case A: (a)–(c); Case B: (d)–(f).

Simulation of Particle Laden Flows Using Particle Methods

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We present simulations of an initially spherical suspension of solid particles falling due to gravity in a viscous incompressible fluid. The numerical simulations are performed using three-dimensional viscous, vortex methods¹ with a *two-way* coupling between the fluid and the particles.²

We consider two cases: (A) the suspension is falling in a nonzero initial vorticity field, generated by allowing, for a short time, only one-way viscous coupling and (B) the suspension is inserted in a fluid with no initial vorticity field.

In case A [Figs. 1(a)–(c)], the particle suspension is entrapped by the initial vorticity field which dominates the dy-

namics of the flow. The solid particles are wrapped around the core of the vortex ring and are shed in its wake. This results in the formation of “Tintenpilze.”³ In case B [Figs. 1(d)–(f)], the falling of the solid particles imparts vorticity on the fluid elements, forming a vortex ring. The vortex ring becomes unstable and induces a bifurcation of the suspension of particles which in turn creates new vortex rings in a cascade-like fashion. The phenomena are qualitatively similar to experimental observations of liquid drops injected in lighter fluids.⁴

¹G.-H. Cottet and P. Koumoutsakos, *Vortex Methods: Theory and Practice* (Cambridge University Press, New York, 2000).

²J. H. Walther and P. Koumoutsakos, submitted to *J. Comp. Phys.*

³D. W. Thompson, *On Growth and Form* (Dover, New York, 1992).

⁴J. J. Thomson and H. F. Newall, *Proc. R. Soc.* **39**, 417 (1885).