EXPERIMENTS WITH HEAVY PARTICLES IN A VISCOUS FLUID: AMAZING OSCILLATIONS

Jakub Nowakowski and Maria L. Ekiel-Jeżewska
Institute of Fundamental Technological Research, Polish Academy of Sciences, Pawińskiego 5B, 02-106 Warsaw, Poland

SUMMARY

HANDS-ON

Do you want to entertain your kids during breakfast on Sunday? Take a very high jar of liquid honey and a number of small identical spherical beads, e.g. millimeter steel balls from a ball bearing. Prepare the beads before starting: mix them with a small amount of honey. Next, take into your fingers a triplet of the beads `glued' by the sticky liquid. Try to keep them as close to each other as possible and in a vertical plane, put above the open jar and then release and let them fall into honey. Guess what will you see?

SCIENCE

We present dancing beads, which try to perform periodic relative motions while settling down under gravity in a very viscous fluid . The snapshots shown below start at time t=0 and finish at t=T/6 (T is the period of the oscillations). The configurations at t=T/6 are almost the mirror images of the ones at t=0 (the mirror is vertical), except a permutation of particles. Therefore, periodic motions with the period T exist. In experiments, they are unstable and usually break up after a bit longer than 1/6 of the period.

OBSERVATION

Snapshots from observation of steel beads (with diameter 2.5 mm) falling in honey. Photographs were taken using the Canon EOS 50D camera at 0 s, 3 s, 7 s and 18 s.

EXPERIMENT

Snapshots are shown from experiment with glass beads (of density ρ_p = 2.49 g/cm^3 and diameter d = 1.3 mm) settling in silicon oil (of dynamic viscosity η = 2 Pa s and density ρ_f = 0.998 g/cm^3), in the central part of the glass container (with the height 70 cm and the square cross-section 25 cm x 25 cm). We used the Allied Vision Manta G-201 2Mpix camera. The time between consecutive frames is 3 s, starting from 0 s and finishing at 33 s, i.e. at 1/6 of the period T. Here, T/τ = 105, with $\tau = 3 \pi \eta d^2 / F$, where F is the external force acting on each bead. At the first and last frames, the angle φ=20-21º is observed between the line of centers of the beads and the horizontal plane.

THEORY

Snapshots from numerical simulations, separated by T/66. The results were obtained by solving the Stokes equations with the stick boundary conditions at the surfaces of three spherical particles (multipole method corrected for lubrication). Here, T/τ = 170, and φ=51º. This panel is reproduced with permission from M. L. Ekiel-Jeżewska, T. Gubiec, P. Szymczak, Stokesian dynamics of close particles, Phys. Fluids, **20**, 063102 (2008). Copyright 2008. AIP Publishing LLC.

CONCLUSION

In honey and silicon oil, three close non-touching beads stay together for a long time, and perform oscillations while settling down. Parts of their trajectories in the center-of-mass system resemble periodic solutions predicted theoretically for extremely close spheres.

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OBSERVATION | EXPERIMENT | THEORY