The sedimentation of flexible filaments: Movie captions

Harishankar Manikantan[1], Lei Li[2], David Saintillan[1], and Saverio E. Spagnolie[2]

[1]Department of Mechanical Science and Engineering, University of Illinois at Urbana-Champaign, 1206 W. Green Street, Urbana, IL 61801, USA
[2]Department of Mathematics, University of Wisconsin-Madison, 480 Lincoln Drive, Madison, WI 53706, USA

(a) Trajectories of weakly flexible filaments

Numerical simulations show that sedimentation causes weakly flexible filaments to reorient and eventually reach a terminal settling shape. In this video, two non-interacting filaments (with $\beta = 0.02$) are initially placed at the origin at angles $\pi/4$ and $\pi/64$ with respect to gravity, and are allowed to sediment freely. The instantaneous shape and orientation are tracked along with the position of the center of the filaments, and the time-dependent trajectories and filament shapes are illustrated. Analytical expressions for these quantities have been determined using a multiple-scale asymptotic expansion, as described in the paper.

(b) Particle clouds

The individual filament trajectories suggest an interesting possibility for the spreading dynamics of a cloud of flexible filaments, which we model as non-interacting in a dilute limit. This video shows the sedimentation of such a non-interacting collection of filaments, placed initially at the same location but with different orientations with respect to gravity, with $\beta = 0.1$. In stark contrast to the dynamics of rigid rods, flexible filaments are restricted to a cloud with a width that can be shown to be proportional to the elasto-gravitation number.

(c) Buckling of flexible filaments

The tension acting on a filament backbone when it sediments along its length is compressive in the filament's leading half. This compression leads to a buckling instability if the filament is sufficiently flexible. In this video, we show this buckling instability by numerical simulations for three different values of the elasto-gravitation number ($\beta = 5 \cdot 10^{-3}, 10^{-4}, 6.25 \cdot 10^{-5}$). As predicted by our analysis, smaller wavelength perturbations are more unstable for smaller β (increased filament flexibility).