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FIG. 1. (Color)

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The Japanese geishas are famous for using decorated flapping fans to create a cooling breeze on warm summers days. In Fig. 1, we show the complex flow caused by a two-dimensional "fan": A rapidly pitching foil in an otherwise stationary and horizontal soap film. The colorful patterns stemming from thickness variations visualize the streaming clearly seen in the stripes on both sides of the foil (top center). Two vortical structures are formed at the tip in each oscillation period. These structures are advected downstream, while being stretched in the lateral direction and compressed in the streamwise direction. The pattern is a hitherto unknown example of a flow structure due to unsteady formation of separation vortices.[1] In contrast to the periodic vortex wake shed behind a similar pitching foil in a streaming soap film,[2] the fan flow forms a broadening layered pattern, which merges into two beautiful spiral rolls, giving the whole flow a butterfly shape. Take a look at the foil and follow the vortex pattern on one side—the row of vortices can be discerned all the way into the spiral, as footprints of the fan motion of the past.

The rigid foil is 12 mm long, 2 mm wide, and it is driven with simple harmonic pitching oscillations around the center of the semicircular leading edge at a frequency of 100 Hz and a lateral tip excursion of 1.5 mm. The fluid is a commercial soap bubble mixture, consisting of demineralized water, 5% Fairy Ultra detergent, 5% glycerin, 0.16% hydroxyethyl cellulose, 1.0% lauramidopropyl betaine, 0.80% propylene glucol, and 0.20% peg-80 sorbitan laurate. We speculate that non-Newtonian effects play a role in the pattern formation.

[1] A. Andersen, T. Bohr, and T. Schnipper, "Separation vortices and pattern formation," Theor. Comput. Fluid Dyn. **24**, 329 (2010).
[2] T. Schnipper, A. Andersen, and T. Bohr, "Vortex wakes of a flapping foil," J. Fluid Mech. **633**, 411 (2009).

