FIG. 1. (a) Onset (at $t=7T$) and (b) growth (at $t=9T$) of centrifugal instability. (c) Example of fully developed Görtler vortices at $t=14T$. (d) Flow patterns resulting from vortex breakdown. (e)-(f) Closeup of vortex breakdown at (e) $t=5T$, (f) $t=6T$, and (g) $t=8T$.

Topology and breakdown of Görtler vortices on an oscillating cylinder
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Boundary layers with curvature are prone to a centrifugal instability. In the case of the boundary layer on a cylinder of diameter $D$ undergoing sinusoidal oscillations ($U = U_0 \sin(\omega t)$, $\omega = 2\pi/T$), instability can lead to formation of Görtler vortices with well defined wavelengths. Here we illustrate the onset and nonlinear development of these vortices. Important parameters are $Re=(U_0 D/\nu)$, $KC=(U_0 /\nu D)$ and $\beta=Re/KC$.

A cylinder was oscillated transversely using a PC-controlled stepper motor in an acrylic glass tank. To mark vorticity, Rhodamine B and Fluorescein dye were used on alternate sides by saturating cotton thread with the respective substances, and embedding the thread into thin slits carved on the cylinder surface. Flow visualizations were obtained via UV-induced fluorescence and captured with a digital SLR camera.

Figs. 1(a)-(b) depict the onset and growth of the centrifugal instability for $KC=0.75$, $Re=480$ and $\beta=640$. Fully developed Görtler vortices are shown in Fig. 1(c). After reaching finite amplitude, the vortices modify the mean flow leading to bursting and vortex breakdown as shown in Fig 1(d) for $KC=1.5, Re=700$ and $\beta=460$. Note the appearance of nodal critical points marked by dye streaks on the cylinder surface. Figs. 1(e)-(g) show a close-up of the cylinder surface during the transition from vortex breakdown to flow separation (parameter values are same as in Fig. 1(d)). At $t=7T$, the Görtler vortices have burst and their vorticity has been ejected into the outer flow. Vorticity continues to be generated at the cylinder surface, the axial wavelength of the instability is maintained, and the flow separates at the same location as the initial instability. Vortex merging is also observed in Figs. 1(e)-(f).

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