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PORTFOLIO

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Wake transition of a rolling sphere

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We present dye visualizations of the flow generated by a sphere rolling along a solid surface in a quiescent fluid at low Reynolds numbers. Recent experimental and numerical studies of this configuration (Stewart et al. 2008, 2010) have shown a transition from steady to periodic flow at a Reynolds number *Re* (based on the sphere diameter and rolling speed) near 100. The unsteady flow involves the shedding of hairpin vortices, and the flow remained symmetric in the Reynolds number range considered, up to $Re = 200$. The present visualizations show that for higher *Re* the spatial symmetry of the unsteady wake is lost.

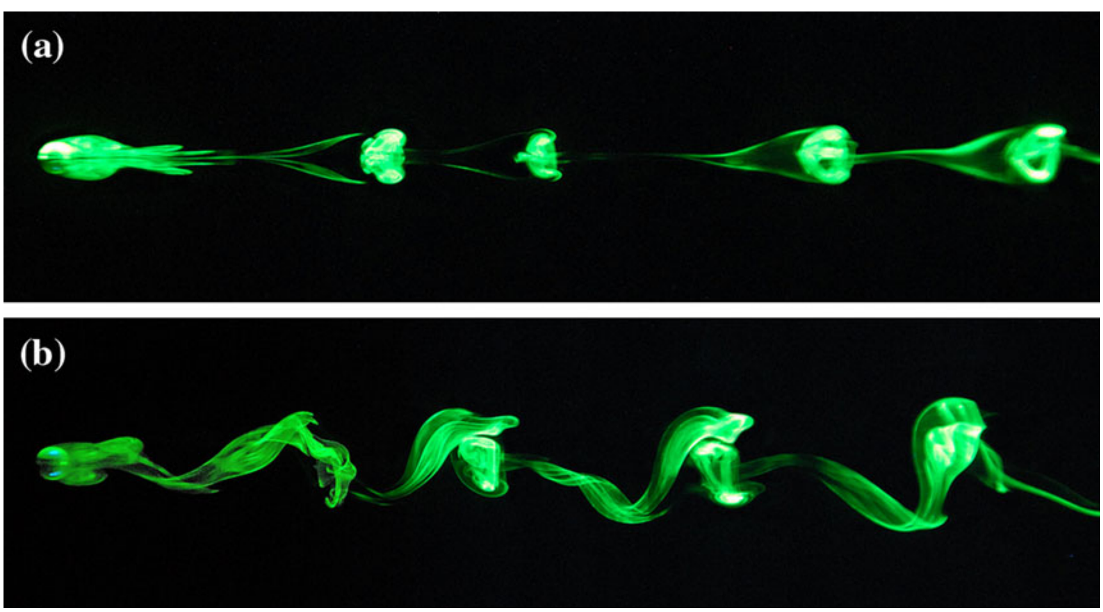

Fig. 1 Dye visualization of the rolling sphere wake, seen from above. **a** $Re = 190$, **b** $Re = 230$

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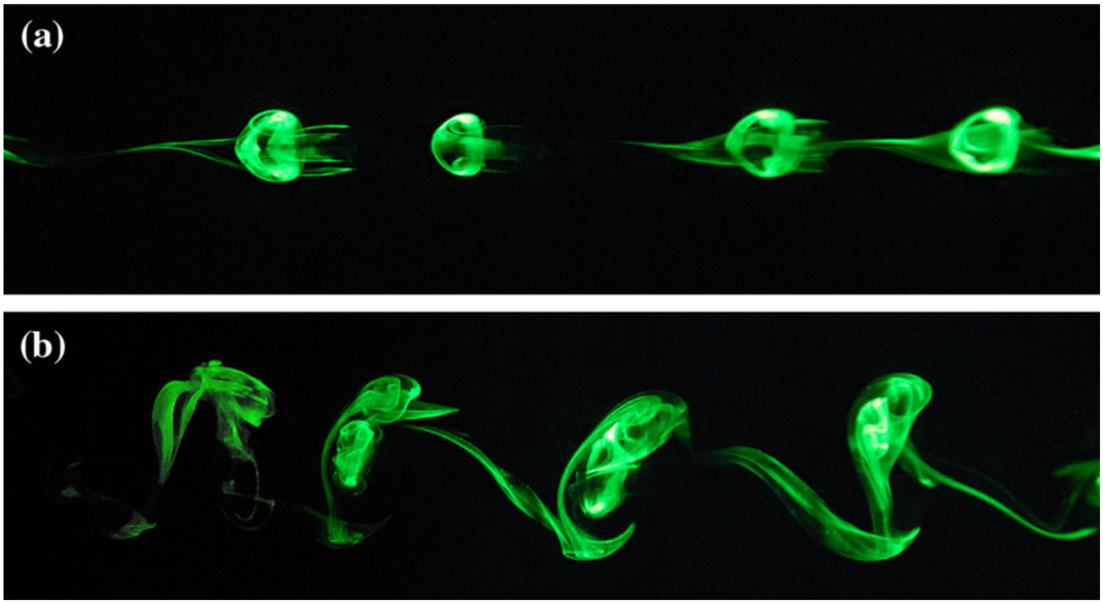

Fig. 2 Same as Fig. 1, a time interval of 30 (D/U) later

The flow was observed in a water tank, using steel spheres of diameters (D) 4.7 and 6.5 mm, rolling freely down a Plexiglas plate. A 1-mm groove in the plate surface ensured a rectilinear path of the sphere. The angle between the plate and the horizontal was of the order of 0.5° and could be fine-tuned for the sphere to reach the desired terminal velocity (U). Visualization was achieved by coating the sphere with a solution of fluorescein prior to its release in the tank, and illuminating the fluid in volume with the light from an argon ion laser.

Figure 1 shows the flow behind the rolling sphere as seen from above, for two Reynolds numbers. At $Re = 190$ (Fig. 1a), the wake is clearly symmetric, consisting of a succession of vortex loops (hairpins) lifting up away from the wall. The wake structure and mean streamwise wavelength are in good agreement with previous observations (Stewart et al. 2010). When Re is increased, the flow loses its symmetry. At $Re = 230$ (Fig. 1b), one observes a superposition of hairpins and a sinuous wake deformation. This sinuous motion is further amplified for even higher Re. Figure 2 shows the same structures a time 30 (D/U) later, when most of the motion has died out.

Preliminary numerical simulations confirm the existence of the new asymmetric mode in the wake of a rolling sphere for $Re > 200$, and a more detailed analysis of the transition is in progress.

References

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