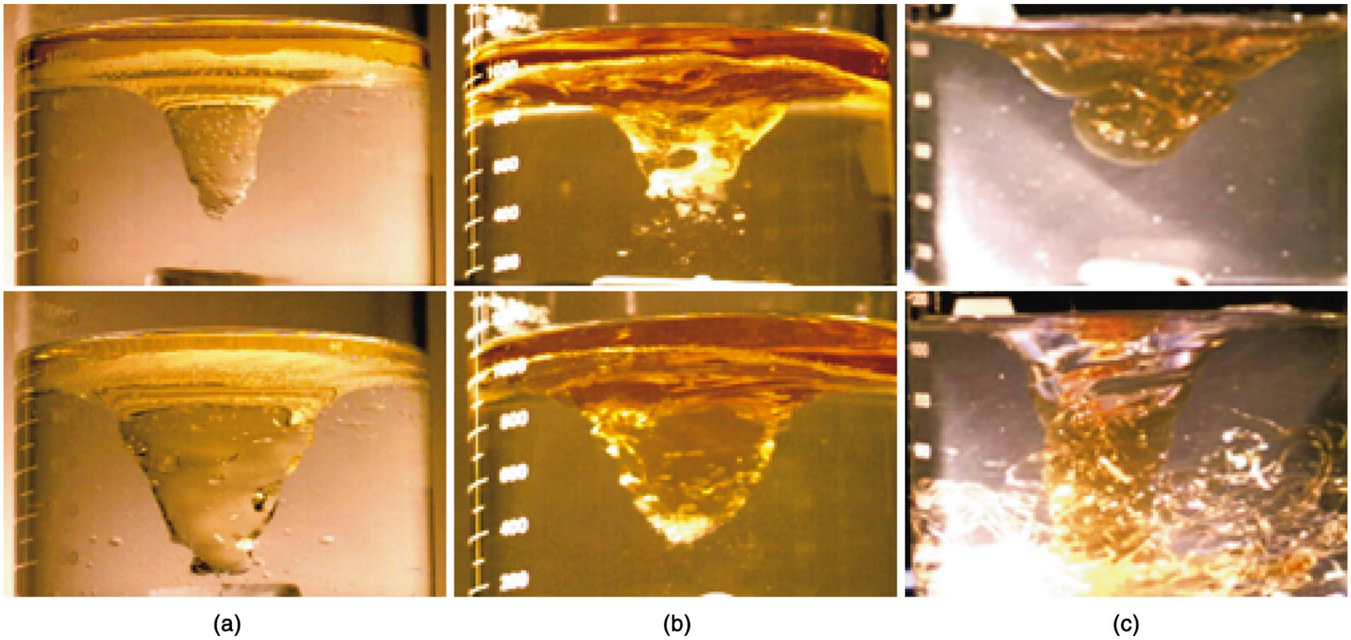

FIG. 1. (a) Canola oil and H_2O; the interface is smooth; stable satellite droplets are present. (b) Fuel treatment and H_2O; the interface exhibits turbulent motion; irregular fingering and ribbing; nonuniform satellite droplets are present. (c) Oil treatment and H_2O: the interface exhibits turbulent instability and wide fingering patterns; spaghetti-like filaments are present.

Vortical Interfaces Between Immiscible Fluids

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The formation of vortical interfaces between immiscible fluids was observed by using a high-speed digital camera. These interfaces were formed between two immiscible fluids (water at the bottom and oil on top) in a 2000 mL beaker. A stir bar was used to accelerate the water. The interfaces were tracked to determine how the rheological properties of oils influence the vortex formation and morphology.

The first observed vortical interface was between canola oil and H_2O [Fig. 1(a)]. *Canola oil* is a Newtonian fluid with a viscosity of 0.058 Pa·s and a density of 0.79 g/mL. In this case the structure of the vortical interface was uniformly smooth. The formation of stable satellite droplets was also noted to accompany the stabilization of the interface.

The second case we studied was between *STP™ fuel treatment* and water. STP™ fuel treatment is a non-Newtonian fluid with shear thinning but no elastic properties. Its zero shear viscosity is 0.0025 Pa·s and its density is 0.74 g/mL. For these fluids, the interface became turbulent during the motion and nonuniform fingers were observed on the interface. Moreover, many irregular satellite droplets formed during the process [Fig. 1(b)].

The third tornado-like interface was formed between *STP™ oil treatment* and water. The STP™ oil treatment is a viscoelastic fluid with a relaxation time of 0.02 s. It has a zero shear viscosity of 14.95 Pa·s and a density of 0.86 g/mL. In this case, the interfacial dynamics were dominated by the elastic instability between the STP™ oil and water. In particular, wide fingering patterns and tangled spaghetti-like filaments were observed [Fig. 1(c)]. Moreover, no satellite droplets were formed for this case.

In conclusion, the morphology and instability of vortical interfaces formed between immiscible fluids depends sensitively on the rheological properties of the fluids. Theoretical modeling and simulation based on these experiments is expected to reveal detailed mechanisms underlying our reported observations.

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