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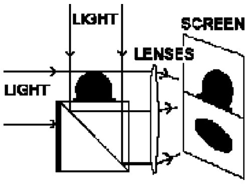

FIG. 1. Experimental setup.

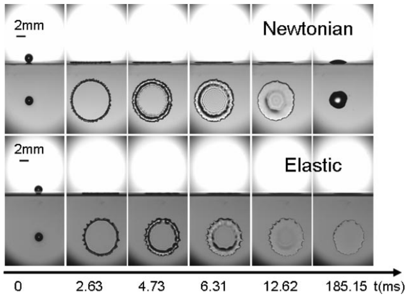

FIG. 2. Drop impact on a hydrophilic surface.

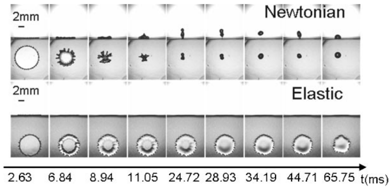

FIG. 3. Drop impact on a hydrophobic surface.

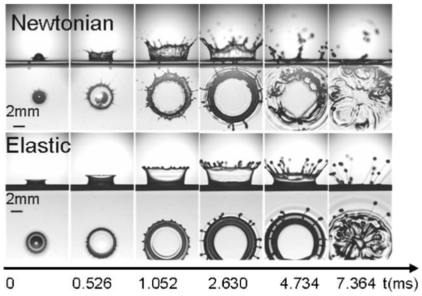

FIG. 4. Drop impact on a fluid film.

Drop Impact of Newtonian and Elastic Fluids

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We studied the dynamics of drops of a Newtonian fluid (water) and a constant viscosity elastic (Boger) fluid of matched shear viscosities ($\eta_N = 1.1$ mPa·s, $\eta_E = 1.3$ mPa·s) impacting on hydrophilic and hydrophobic surfaces and on a thin liquid film (~1 mm) of the same fluid. The elastic solution has a Zimm relaxation time $\lambda = 1.1 \times 10^{-4}$ s. During the drop spreading, both solutions have an equivalent surface tension of $\sigma_{\mathrm{Dmax}} = 72.1$ mN/m. At long time, the surface tension of the elastic solution decreases to $\sigma_{\mathrm{E}} = 62.0$ mN/m. In all experiments, the impact velocity and initial drop diameter are 2.48 m/s and 1.68 mm, respectively. The Reynolds and Weber numbers are Re=4166 and We=142 for the Newtonian solution and Re=3205, We=166 for the elastic solution. To observe the impact of liquid drops from both bottom and side views, we used a beam splitter cube setup (Fig. 1) with a high speed video camera.

On a hydrophilic surface (Fig. 2) the spreading of the two solutions occurs over the same time interval. At the maximum diameter, both solutions display a flat disc surface with peripheral fingers with different amplitude and frequency. During recoil, the Newtonian solution exhibits capillary waves from the outer ring to the center of the disc. These waves are dampened in the elastic solution. The rate of retraction and the final shape of the drops at long time differ significantly between the two solutions. Such differences cannot be explained by the difference in surface tension of the solutions and it is believed to be due to the adsorption of the polymer to the surface during spreading resulting in the improved wetting on the hydrophilic surface, even above that of the pure water.

On a hydrophobic surface (Fig. 3), the spreading is identical for the two solutions, but the behavior is completely different during recoil,[1] with no significant retraction occurring for the elastic solution. The recoil dynamics of the Newtonian solution are extraordinary, peripheral fingers grow through coalescence during retraction to form star-like arms. The high surface energy results in a strong flow inside the drop and eventually results in the whole drop leaving the surface. For the elastic drop there is less recoil and no rebound due to the energy dissipation[2] during the biaxial extensional flow and the adsorption of the high molecular weight polymer to the surface.

When both the Newtonian and elastic drops impact a thin liquid film of the same fluid (Fig. 4), both solutions form a crown of thin liquid film.[3,4] Almost immediately, peripheral jetting occurs from the upper rim of the Newtonian crown, producing many small individual drops. Once the maximum height is achieved, the crown collapses due to gravity and surface tension, causing waves at the film surface and a complete rapid disintegration of the crown. For the elastic solution the crown grows with evolution of small bulbs of fluid at the upper rim. When the crown breaks down, thin threads are formed between the upper rim and the bulbs, driven by the elongational properties of the fluid. The threads continue to lengthen and when surface tension energy exceeds the elastic energy secondary drops are formed along the thin threads. Finally, after the drops lose their kinetic energy, they collapse onto the surface fluid carrying the elongated threads with them.

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