Soft gel can repel liquid jet with low and high surface tension

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Summary

A liquid jet can stably bounce off a sufficiently soft gel. This phenomenon is relatively insensitive to the surface tension of the liquid, γ = 24-72 mN/m. In contrast, other jet rebound phenomena described are typically sensitive to γ: jet rebound off a hard solid (e.g. superhydrophobic surface) is possible only for high γ liquid whereas jet rebound of one liquid off the surface of another liquid is only possible for low γ liquid. This is because a stable air layer must exist between the two interfaces. We show that for a soft gel, no air layer is necessary and jet rebound remains stable even when there is direct liquid-gel contact.

Keywords: wetting, liquid-repellence, gel, jet

1. Introduction

The ability of surfaces to repel liquids, either in the form of droplets or jets, is of broad interest and has numerous applications. The rebound of an impinging water droplet off a solid substrate, e.g. a superhydrophic surface, is a well-known phenomenon; the equivalent rebound of liquid jet, on the other hand, is relatively less-studied. It was shown, only in recent years, that a water jet can stably bounce off a superhydrophobic surface with minimal energy loss [1]. In all the cases described above, the rebound of liquid droplet/jet is facilitated by a cushion of air layer between liquid and solid, typically with thickness in the range of 0.5 – 50 μm. When this air layer becomes unstable or disrupted, for example due to increased wettability of the solid, the rebound phenomenon is suppressed [2].

2. Results & Discussions

Here, we describe the mechanism and stability of jet rebound as it impacts a soft gel. This trampoline-like rebound phenomenon is observed for liquid jets over a wide range of surface tensions, γ = 24-72 mN/m, and intriguingly even when the gel contains the same liquid as the impinging jet, such as the case of a water jet (diameter $D \sim 1.0$ mm, velocity $V \sim 1$ m/s) bouncing off a gelatin gel that is 98.5 wt% water (Fig. 1a). The inset of Fig. 1a shows a 10 μl water droplet sitting on the gel with a contact angle of 16°, i.e. the gel is hydrophilic. The same rebound phenomenon was observed for other hydrogels, such as polyacrylamide, and also for hydrophobic polydimethylsiloxane gels (PDMS, contact angle of water = 90 ± 5°). Unlike superhydrophobic (SH) surface which loses its repellence for low γ liquid, the PDMS gel was able to repel liquid jet with γ as low as 24 mN/m. Fig. 1b illustrates this: soap-water jet (D = 0.3 mm, $V \sim 2$ m/s, γ = 30 mN/m) could bounce off the PDMS gel (E=1.2 kPa), but not the SH surface. The water jet, in comparison, was repelled by both surfaces. The insets show 10 μl droplets of either water or soap-water sitting on the corresponding surfaces. The SH surface was a hexagonal array of micropores of size ~ 1 μm, with static contact angle for water, θ = 150°, and contact angle hysteresis, Δθ = 10°. Most droplet and jet rebound phenomena are sensitive to effects of γ, because they require a stable air layer. This is not the case for jet rebound off a soft gel; experimentally, no air layer was detected.

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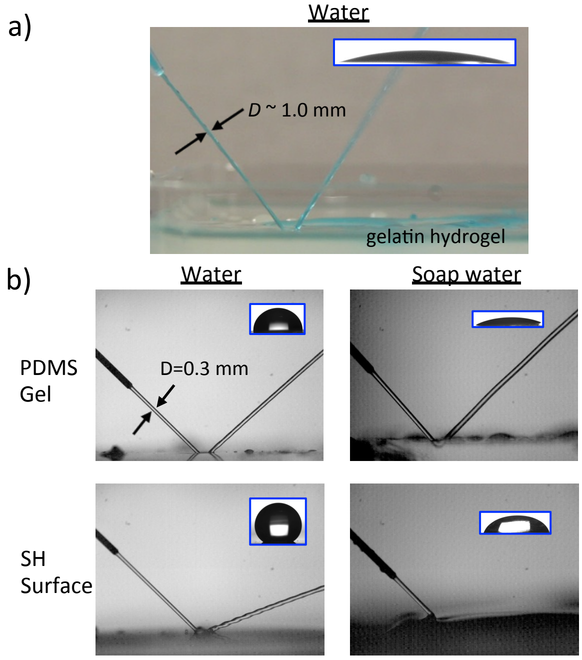

Figure 1. (a) A water jet can bounce off a hydrophilic gelatin gel that is 98.5 wt% water. The inset shows the resulting contact angle of 16^o for a 10 μl water droplet. (b) A soft PDMS gel (E=1.2 kPa) can repel both water and soap water, while a superhydrophobic (SH) surface loses its liquid repellence for soap water. The corresponding contact angles of 10 μl water/soap-water droplets shown in the insets are (left to right, top to bottom): 90^o, 60^o, 150^o, 30^o.

3. Conclusions

In conclusion, we have shown that a liquid jet with a wide range of $\gamma = 24 - 72$ mN/m can bounce off a soft gel. We further show that this jet rebound phenomenon is possible even when there is direct liquid-gel contact. This is unlike other jet rebound phenomena which require a stable air layer separating the jet and the substrate. This work also illustrates how the elastic nature of a material can have interesting implications for its wetting properties.

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