Impacting drops on soft surfaces

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Why study drops?

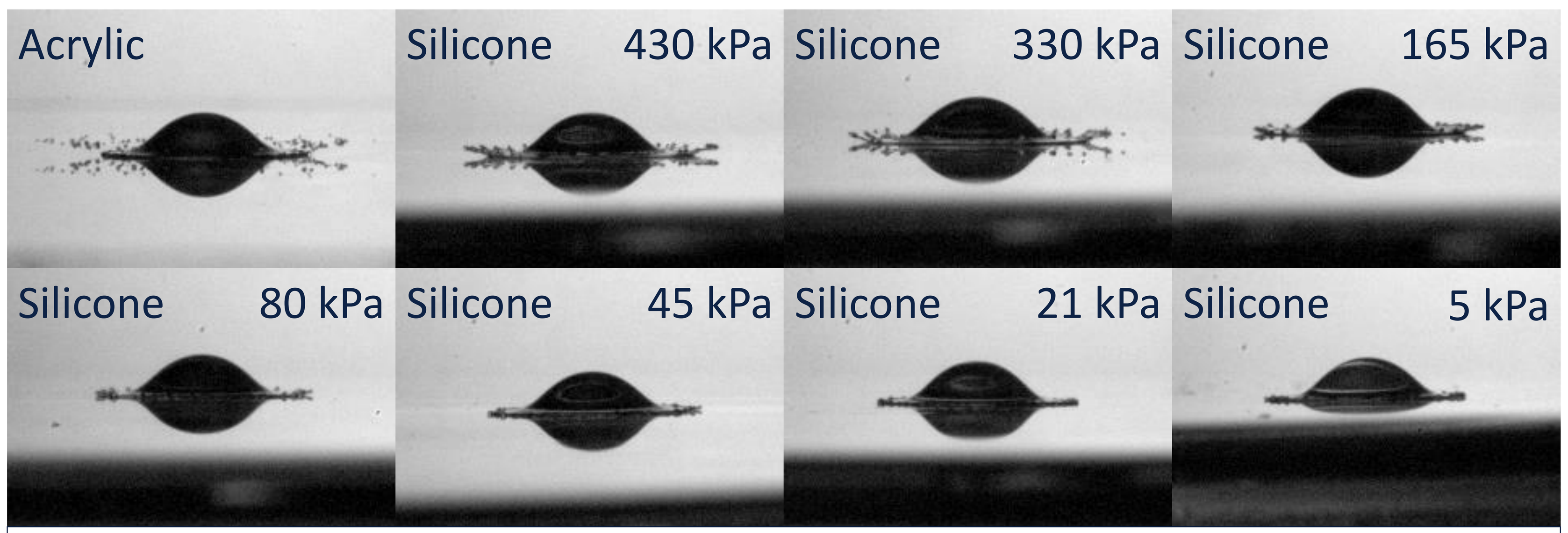
Drop impact is of interest to many fields thanks to its large range of applications. In engineering, these can include inkjet printing and spray cooling. The stain patterns of impacting blood drops also play a key role in crime scene analysis, so knowing the dynamics of drops hitting multiple surfaces can be incredibly important.

The Project

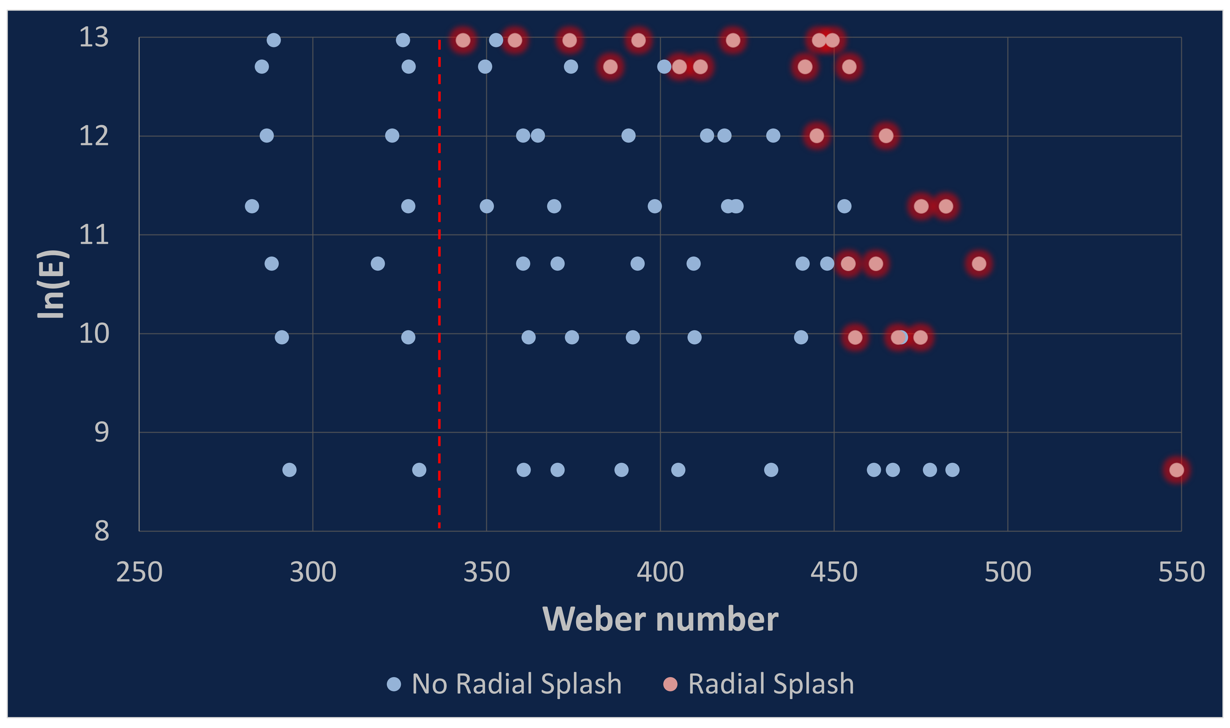
When a liquid drop hits a solid substrate, it can either rebound, splash, or be deposited on the surface. This depends on many properties of the liquid and the surrounding gas. We have investigated the differences that a soft substrate has on the dynamics by impacting drops on silicone samples of varying stiffness.

Key

E	Young's modulus
ρ	Density
σ	Surface tension
D	Drop diameter
U	Impact velocity
$We = \dfrac{\rho U^2 D}{\sigma}$	Weber number



Ethanol drops of equal size and speed strike a range of surfaces. The softest material resembles jelly, and the hardest silicone is similar to road tyre rubber. The Young's modulus of each silicone is shown in the top right of each image.



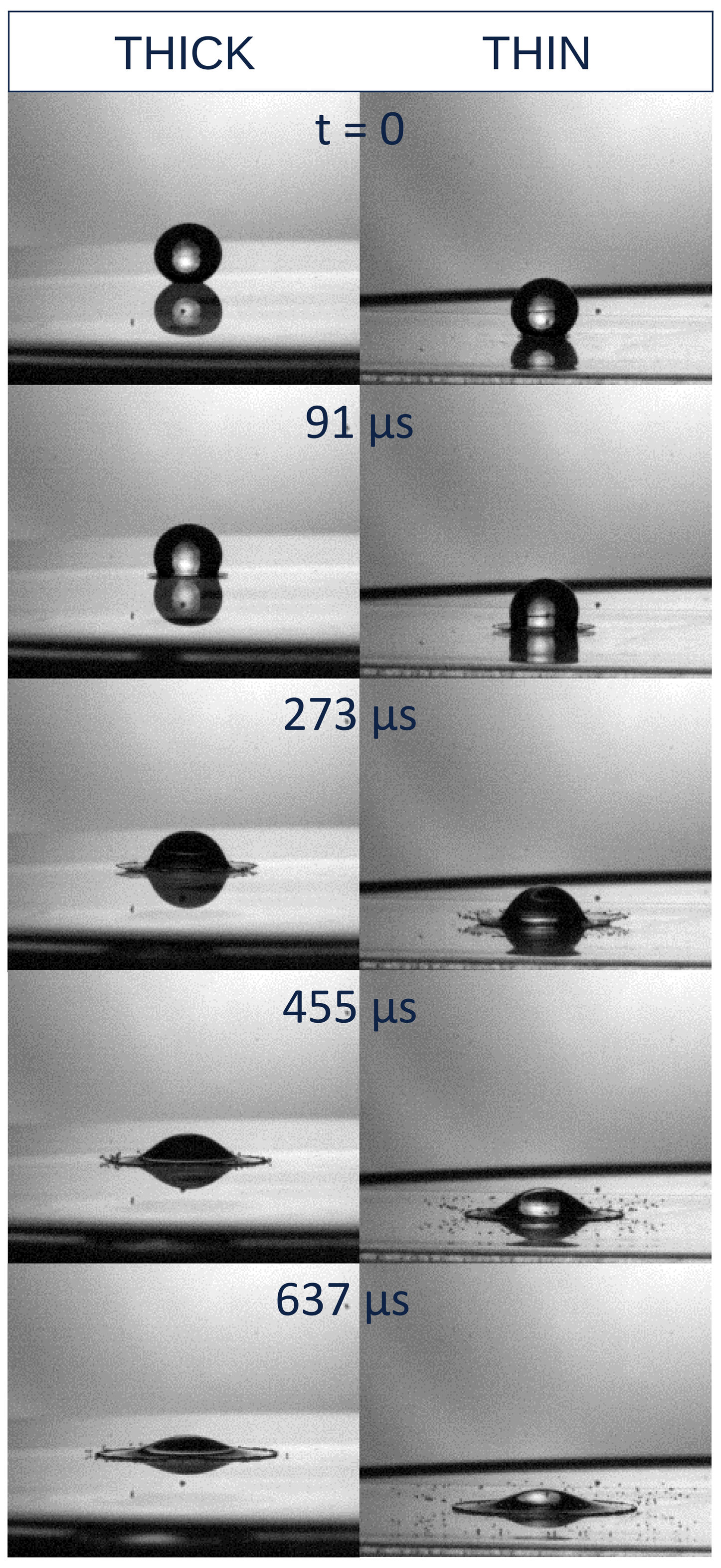
Splashing is reduced on softer materials, as shown by this graph plotting stiffness against Weber number. The red dashed line on the graph shows the splashing threshold for stiff materials for the same liquid drop size.

The above pictures clearly show that splashing is gradually suppressed as the substrate stiffness is reduced.

We confirmed that the splash reduction is due to the substrate deformation by impacting droplets on thick (~1cm deep) and thin (~30μm deep) layers of soft silicone coating rigid surfaces.

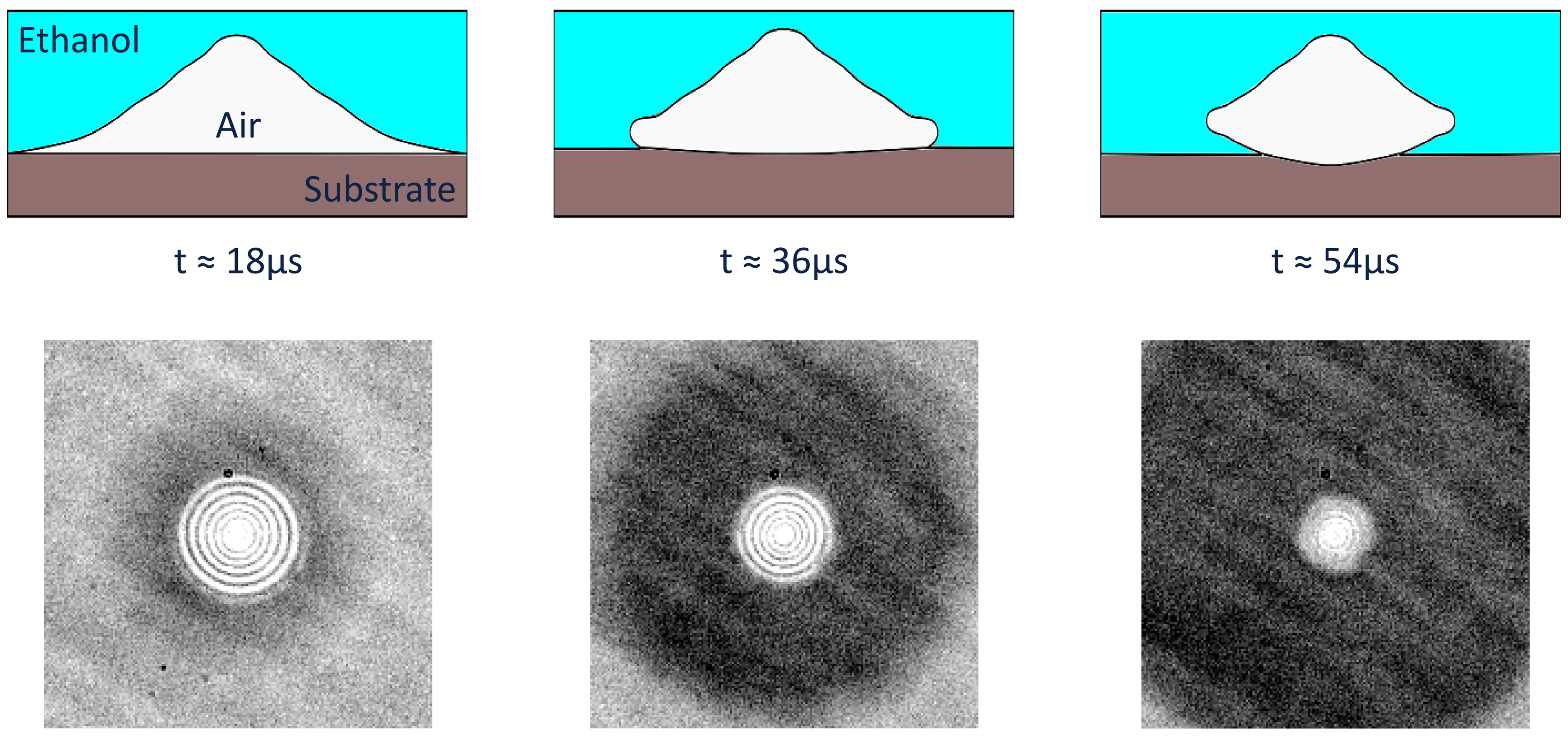
It can be seen clearly that the drop barely breaks up at all on the thicker sample, whereas it splashes quite violently on the thin coating.

This confirms that splashing is suppressed due to substrate deformations upon drop impact.



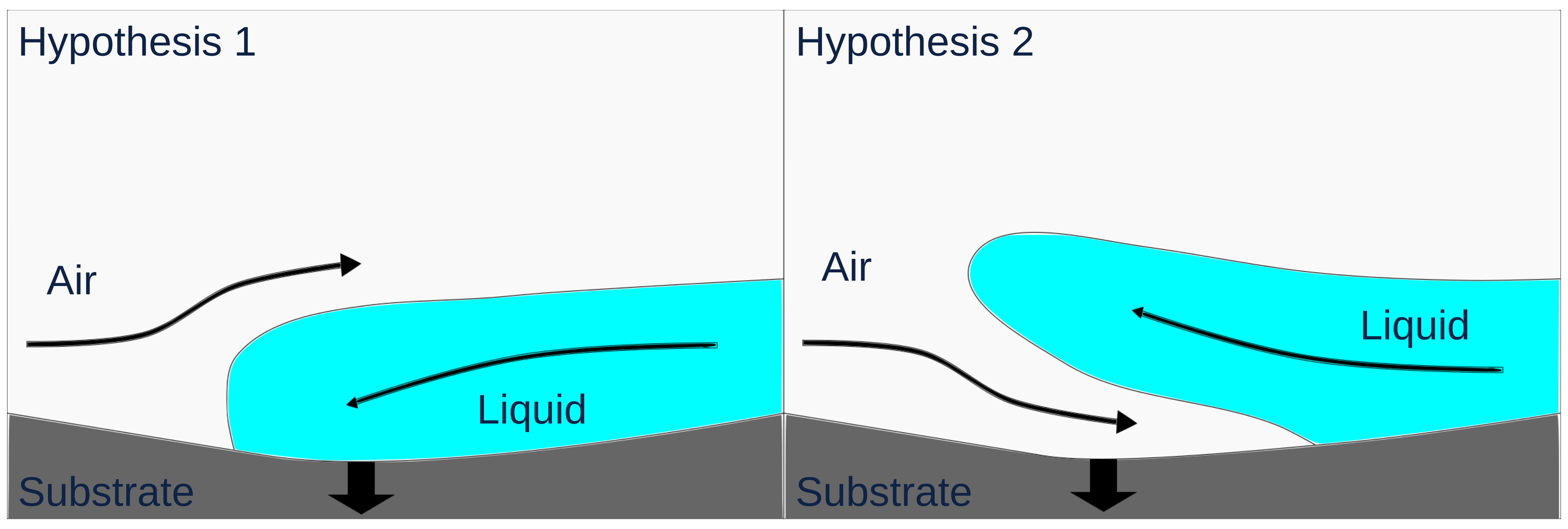
Interferometry

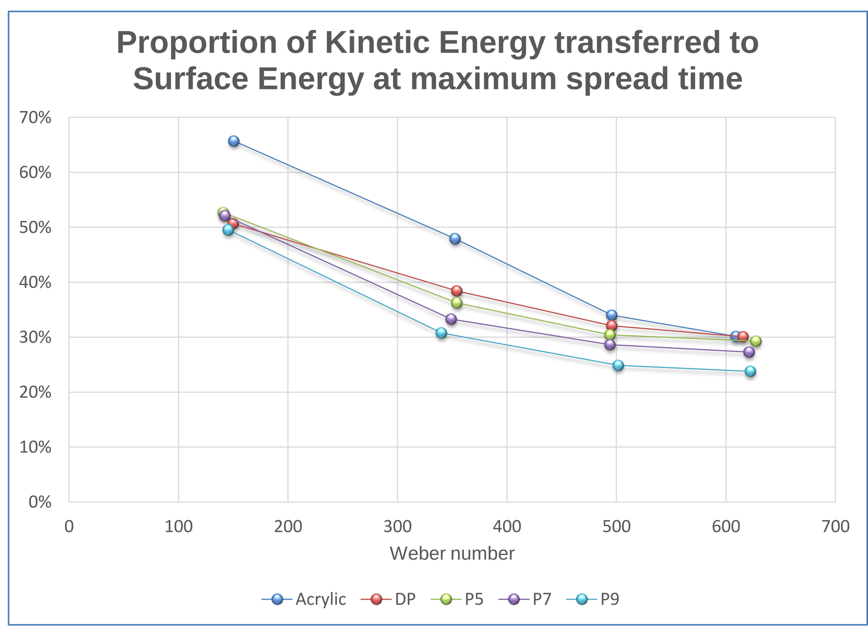
Recent research papers have highlighted the importance of the thin air film that forms between drop and substrate as the impact occurs. High speed thin film interferometry was used to investigate how the air film changes at the centre of the drop, where a tiny air bubble is trapped after impact. From our limited data, the central air bubble does not seem to depend on the softness of the substrate, but the mechanism for the entrapment of the air is shown below:



Hypotheses

The soft material deforms at the leading edge of the spreading drop. This may allow the expanding liquid film to be thicker, or it may mean that the air that gets under the film can escape downwards, preventing instabilities. Alternatively, the substrate may absorb some kinetic energy as the drop impacts, effectively reducing the Weber number of the impacting liquid, and hence reducing splashing.





Spreading Dynamics

The effect of the softness of the substrate can be seen by comparing the initial kinetic energy to the surface energy of the drop when it has spread to its widest point. The graph to the left implies that more energy is absorbed by the softer solids, since less energy is transferred to surface energy.

Conclusions

- Soft surfaces reduce splashing
- There seems to be a threshold stiffness below which splashing is reduced
- We think soft substrates deform significantly at the contact line of the spreading droplet and this suppresses the instabilities that lead to splashing
- A soft substrate will also absorb some of the drop's kinetic energy upon impact, which should also reduce the likelihood of splashing