Damped Spring-Mass Analogy of Droplet Oscillations

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Abstract

After a droplet strikes a solid surface, there is a period of time where the drop oscillates between a nearly hemispherical shape and a toroid until it comes to rest. In the study of drop solidification and drop heat transfer, understanding the motion of the fluid after impact is essential. Connecting the impact characteristics, droplet properties, and surface features to the oscillating motion of the drop after impact will benefit applications of spray cooling and spray materials deposition.

Using a high speed video camera (Phantom V7.1), drop fluids spanning two orders of magnitude range of viscosity (1.0E-6 to 1.1E-4 m^2/s), and three surfaces with differing wetting characteristics, we have measured the characteristics of drop oscillation for low Weber number ($We \approx$ 20-30) impacts. Measuring the thickness at the center of the drop splat, the magnitude and frequency of oscillation are found over time.

We examine this oscillation through the lens of a harmonic vibration analogy. The ultimate goal of this study is to develop this analogy such that, based on fluid properties and wetting and impact characteristics, the magnitude and duration of oscillations can be predicted from the equations of harmonic motion. This vibration analogy has been made in the past- notably, "Water Spring: A model for bouncing drops" by Okumura, et al [1], who used the idea of the analogy to predict deformation and bouncing of drops impacting highly hydrophobic surface. We have carried the idea one step further in attempting to directly apply the equation of harmonic motion to the drop behavior. Based on the hypothesis that the drop behaves as a damped harmonic oscillator, the analogues of the damping coefficient and the spring constant are computed and compared to the drop fluid properties and surface wetting tendencies.

Drop viscosity and surface wetting are shown to interact non-trivially in their effects on droplet oscillations. Separately, each follows intuitive trends- more viscous liquids tend to have more strongly damped oscillations on a wetting-similar surface, and hydrophobic surfaces tend to reduce damping for most drops. Examining the spread across the range of both characteristics, however, leads to behavior akin to frequency forced damping, resonance, and fluctuating amplitude of oscillation counter to intuitive trends.

References

1. Okumura, K., Chevy, F., Richard, D., Quéré, D., and Clanet, C., *Water spring: A model for bouncing drops*, Europhysics Letters, 2003. **62**:2, 237-243.

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