# Effects of drop and film viscosity on drop impacts onto thin films

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**Abstract**

While drop-film impacts have been studied extensively in the past, little thought has been given to separating the effects of the drop fluid properties and those of the film. Notably in the field of pool fire suppression, sprays impact pools consisting of different fluids, and both the spray properties and the pool properties will govern the resulting behavior [1, 2]. Distinguishing between the film and droplet's effects will also provide insight into behaviors observed on more common same-liquid drop-film impacts.

In this study, the central parameter examined is the fluid viscosity. Using various mixtures of water and glycerol, as well as FC-72, a range of kinematic viscosity covering 3 orders of magnitude (3.8E-7 to 1.1E-4 $m^2/s$) is examined, while the surface tensions cover a smaller range, from 0.01 to 0.07 N·m. A microliter valve creates mm-scale drops that freefall into the target film at velocities of 0.5 to 3.5 m/s, where a high speed video camera records the impact. The final parameter considered in this study is the ratio of pool depth to droplet diameter, which is examined in three regimes: 0.5 (shallow film), 1.0, and 3.0 (deep pool). This configuration covers Weber numbers from 20 – 3000 and Reynolds from 20 – 14000.

The impact outcomes characterized are coalescence, crown formation, jetting, and splashing of the crown and the jet. These regimes have been defined by past work, and for the same film-droplet liquids they have been mapped to ranges of dimensionless numbers, primarily the Weber number. These dimensionless ranges are examined for differing liquid impacts. To correct for differing drop and film properties, alternative dimensionless criteria are suggested. These criteria are proposed in light of substrate effects in the shallow film regime as well as in the deep pool regime where bottom effects are lessened.

Crown formation and subsequent crown splashing are shown to be governed by the viscosity and surface tension of the film, with minimal dependence on drop fluid properties. With a dimensionless pool depth (H* = pool depth/drop diameter) of 1, for every fluid examined, the critical Weber number for crown formation is on the order of 100 when pool density and surface tension are used. Applying the drop density and surface tension gives no apparent correlation between common dimensionless groups and observed behavior. In contrast, when characterizing the appearance of a post-impact Worthington jet, the drop's properties play a much larger role, with a critical minimum Weber number utilizing drop surface tension and density between 50 and 200 resulting in the appearance of a jet. The impact outcomes in other pool depth regimes are explored, as well.

**References**

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