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TECHNION - ISRAEL INSTITUTE OF TECHNOLOGY

הפקולטה להנדסה כימית
ע״ש וולפסון
The Wolfson Department of Chemical Engineering

Wolfson Department of Chemical Engineering Seminar
Class 4 (2nd floor), Wolfson Department of Chemical Engineering,
Tuesday January 14, 2020 at 12:30

High-Speed Imaging of Rayleigh Breakup of a Charged Droplet Levitated in an Electrodynamic Balance

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Charged liquid droplets are often encountered in nature, for example, in electrified cloud droplets as well as in many engineering processes such as ink-jet printing and ion-mass spectroscopy. The investigation of breakup characteristics of a charged droplet has been an intense area of research ever since Lord Rayleigh (Rayleigh, 1882) gave a criterion for the threshold charge on the droplet. However the mechanism of droplet breakup is still not unequivocally demonstrated through experiments. One of the main reasons is the very fast dynamics (few tens of microseconds) of the breakup process. To observe the breakup of these droplets in actual electrospray experiments, we captured a chance encounter of breakup of an electrosprayed charged droplet at 200 thousand frames per second and observed that the droplets undergo asymmetric breakup, ejecting a jet and smaller progeny droplets. However, it was not clear from the experiments if the breakup is field induced or due to Rayleigh instability. Hence for systematic high resolution investigation of the fast temporal process as well as to understand the different degrees of freedom associated with the spatial characteristics of the breakup, we levitated a charged droplet in space using modified quadrupole trap. To capture the breakup event the entire quadrupole trap setup was constructed step-by-step from scratch. The modified ED balance was then calibrated by comparing the high-speed imaging of centre of mass (COM) motion of a levitated droplet with the numerical solution of the modified Mathieu equation.

After a successful levitation and characterization of the COM stability of a single charged droplet, the surface dynamics was analyzed using high-speed imaging. It was observed that, when the charge on the droplet is in the sub-Rayleigh limit the droplet undergoes a series of prolate and oblate shape oscillations. Simultaneously, the surface charge density increases due to continuous evaporation of the droplet which leads to increase in the amplitude of the surface oscillations. As the charge on the droplet exceeds the threshold value, the oscillation amplitude diverges with time and the droplet undergoes breakup. This is known as Rayleigh breakup.

The high amplitude of surface oscillations acts as an indicator of onset of breakup and was used to trigger the high-speed camera. This was necessary since while the droplet evaporation and oscillation occurs over few 10s of seconds, the breakup itself occurs over few microseconds. Our experimental observations confirms that the presence of finite amplitude shape oscillations of the charged droplet are responsible for the sub-critical Rayleigh breakup and the center of mass stability of the levitated charged droplet greatly affects the breakup characteristics of the droplet.

Refreshments will be served at 12:15