Shape Deformation and Atomization of Functional Droplets in Contact with a Vibrating Surface

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Abstract

In this work we experimentally study the shape deformation, bulk oscillation, spread rate and dynamic contact angle variation of functional droplets with varying surface tension, viscosity and density. Seven major types of droplets were studied, namely, (a) water; (b) colloidal suspension of SiO2 nanoparticle in water at three different volume fractions, namely, 0.27, 0.1 and 0.05; (c) glycerol and (d) aqueous solution of glycerol at volume concentrations of 0.2 and 0.9.

The experimental setup consists of a piezoelectric transducer vibrating at 100 kHz and a high speed camera. Due to the presence of the reflector opposite this vibrating surface a standing wave was created in the vertical direction. The droplet is first generated on the transducer surface such that it is located asymmetrically in the standing wave. Subsequently, the transducer is made to oscillate at same amplitude for each droplet resulting in a shape oscillation in the droplets. A high speed camera with a resolution of (896 x 392) was used to image the deformation at 20000 fps.

Once the transducer starts oscillating the droplets undergo different stages of deformation. Droplets of low viscosity are found to eventually atomize, whereas high viscous fluids resist atomization thanks to viscous damping. Different regimes of the process are identified as follows: (1) Small-scale Oscillation Regime; (2) Droplet Spreading Regime; (3) Two-lobe Regime and (4) Film-spreading/Atomization Regime. The physics of each of these regimes is explained. The droplet spreading regime is further analyzed in depth. A theoretical model is formalized to simulate the droplet deformation in this regime, elucidating the major parameters controlling the process. The spread-rate of droplets is found to be a characteristic of the fluid viscosity. The non-Newtonian behavior due to presence of nanoparticles in the case of nanofluid can affect the droplet spreading characteristics substantially. Based on the model and experimental data, correlations are proposed to relate the fundamental non-dimensional numbers that are involved.