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Dynamics of Droplets under Shear Flow on Surfaces Containing Areas of Different Wettability

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Extended Abstract

Droplet dynamics on surfaces under shear flow affect the efficiency of the removal of water condensate in condensation. Surfaces containing areas of different wettability (referred to as heterogeneous surfaces) are popular in condensation as the utilization of these surfaces can facilitate droplet removal and thus enhance the heat transfer rate. As such, droplet dynamics on heterogeneous surfaces are investigated in this study. A centrifugal fan is used to generate channel flow, a two-duct method is employed to achieve designed air velocity instantly, and a high-speed camera is utilized to capture droplet behaviors. Experiments are performed for droplets with different volumes under different air velocities. Silicon wafers, which possess a hydrophilic (HI) property, are used as the substrates for surface fabrication. In order to turn hydrophilic areas to hydrophobic (HO), the surfaces are processed with O_2 plasma and then through chemical vapor deposition [1-4]. The HO areas acquired through the vapors of 1H,1H,2H,2H-Perfluorooctyltriethoxysilane and 1,3-Dichlorotetramethyldisiloxane are referred to as HO-POTS and HO-PDMS respectively. The HO-POTS areas have a large contact angle hysteresis (CAH), while the HO-PDMS areas have a small CAH. To acquire superhydrophobic (SHO) areas, textures are fabricated in advance through laser ablation before the O_2 plasma process [1-2,4]. There are six heterogeneous surfaces for investigation with different combinations of the areas of various wettability: HI+SHO, HO-POTS+SHO, HO-PDMS+SHO, HI+HO-POTS, HI+HO-PDMS, and HI+HO-PDMS+SHO.

Due to the discrepancies of surface free energy (SFE) between the surface areas, droplet needs sufficient air velocity to move from an area with high SFE to a low-SFE area. Critical velocities of airflow for droplets to pass the boundaries between various areas are measured. The HI+SHO and HI+HO-POTS surfaces require the largest air velocities for droplets to cross the boundaries, followed by the HI+HO-PDMS surface. The boundary between the HO-PDMS and SHO areas features the smallest critical air velocities, indicating the smallest differences in SFE. Droplet motion on the HI+SHO surface under 15.5 m/s airflow can be divided into 5 stages. During the process of passing through the boundary, ligament breakup and baby droplet generation are observed. Droplets display different phenomena on the HO+SHO surfaces when moving through the border, which include tail formation, tail detachment and tail retraction. On the two HI+HO surfaces, although droplet speed decreases when crossing the boundary, droplet does not detach from surface throughout the whole process unlike the surfaces containing SHO areas. It should be noted that on the HI+SHO and HI+HO-POTS surfaces small droplet(s) would be separated from the main droplet and remain at the boundary after the droplet crosses the border due to the largest differences in SFE. There are no small droplets remaining at the boundaries on the HO-POTS+SHO, HO-PDMS+SHO and HI+HO-PDMS surfaces, indicating a better performance of droplet removal. It can be concluded that adding a SHO area to a hydrophilic surface would assist in droplet removal. However, in order to avoid small droplet(s) remaining at the boundary and increase the performance of droplet removal, a hydrophobic area with a small CAH should be added between the HI and SHO areas. Therefore, experiments are also performed on the HI+HO-PDMS+SHO surface and the conclusion is verified. The results of this study can be used as a baseline for further investigation of droplet dynamics under shear flow as well as a reference for the design of surfaces that facilitate droplet removal.

References

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