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Simultaneous 2c-PLIF and µPIV measurements of droplets impingement on heated substrates and heat transfer mechanisms

Abstract:

Droplet impact on solid is a critical process in many technologies or industries including spray cooling, spray coating, inkjet printing, etc. Meanwhile, it inherently demonstrates the beauty and complexity of nature by including the interplay among liquid-solid interaction, interfacial phenomenon and heat transfer in a microscale transient process. For decades, researchers have been investigating phenomena, mechanisms and applications of fluid dynamics, heat transfer and phase change of droplet impingement in various droplet, substrate and environment conditions. Most of them utilized high-speed photography or interferometry to study droplets' morphological outcomes. In recent years, experimental methods i.e. such as IR imaging, LIF thermometry, and PIV are introduced to study the temperature and velocity distribution inside a droplet, providing us with new insights into microscale droplet heat transfer and fluid flow mechanisms.

However, simultaneous acquiring of internal velocity and temperature fields during droplet impingement, which can help us understand the interactions among droplet morphology, microscale heat transfer and microscale fluid dynamics, is rarely investigated. Two main challenges are simultaneous no-contact measurement of two fields in small time and length scales as well as reducing the influence of unneglectable reflection and refraction at varying droplet-gas interface.

In present research, we simultaneously applied µPIV and 2c-PLIF methods to study single and successive droplet impingement on heated smooth and engineered substrates. Our investigations revealed detailed droplet-wall heat transfer and fluid flow phenomena and microscale origins of different droplet impact outcomes at different substrate conditions. We found that droplet temperature distribution was strongly substrate-related: droplet was more likely to be heated from several near-wall points on hydrophilic substrates while more likely to be heated uniformly on hydrophobic substrates. The difference of droplet temperature caused differences in surface energy and surface wave motions which affected droplet morphologies. Vapor bubbles beneath the droplet affected the internal flow vorticity and droplet heating by bringing extra momentum and heat transfer resistance, resulting in a non- monotonic droplet heating trend with increasing wall temperature. The simultaneous droplet internal velocity and temperature field measurement method proposed in present study can help us understand the classic droplet impact process in a more detailed, real physical perspective in further investigation.

Bio:

Ruina Xu is a professor (tenured) of the Department of Energy and Power Engineering at Tsinghua University and Deputy Director of the Key Laboratory for CO_2 Utilization and Reduction Technology of Beijing. She obtained a B.S. in 2002 and PhD in 2007 from Tsinghua University. She has been researching convection heat/mass transfer, multiphase flow physics, prediction, control, and modeling to develop low carbon and carbon neutral solutions and spacecraft thermal protection applications, such CCUS, CO_2 enhanced unconventional gas/oil exploitation, and next generation of solar-thermal and geothermal systems. Her research aims to answer fundamental questions about the dynamics of multiphase flow, heat and mass transfer in micro-/nano-scale and complex porous networks. In her lab, her team develop *in-situ* high pressure visualization experiments and numerical models from atom-, molecular-, pore-, core-scale to field scale, such as: *in-situ* high-pressure, high-temperature core flooding system using Magnetic Resonance Image (MRI), micro-model experiments using microscope and designing 1D nano-porous structure, Computational Fluid Dynamics (CFD), Lattice Boltzmann Method (LBM), Molecular Dynamics (MD), etc. She has been in charge of several grants from NSFC, MOST, and international cooperation as the Principal Investigator. She has over 80 journal articles, as well as 27 authorized international and national invention patents.