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ANALYSIS OF IMPACT OF A DROPLET ON TO MOVING LIQUIDS

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Abstract:
A droplet obliquely impacting a bath surface of the same fluid can traverse along the interface while slowing at an exponential rate. The droplet rests on a thin film of air and deforms the bath surface creating a dimple and travels along the surface similar to a wave pulse. Viscous coupling of the droplet and bath surfaces through the air film leads to viscous drag on the bath and perturbs the wave motion of the otherwise free surface. By using the new experimental setup, we successfully levitate silicone oil droplets of 1 cSt kinematic viscosity, similar viscosity of water. We calculate the relative wall velocity ΔU which is the difference between the wall velocity U and surface velocity of the droplet u. We suggest a mechanism of viscous effect on droplet levitation. In addition, we measure the surface velocity u to investigate the validity of the theoretical surface velocity u required to calculate the relative wall velocity ΔU. There is a discrepancy between theoretical value and measurements of surface velocity u.

1. INTRODUCTION

For several industrial processes from spray painting and crop pulverized printing to inkjet printing, the effect of droplets on moving fluid surfaces and lms occur. The latter probably attracted the latest concern, as they are able to supply precise quantities of material under digital control in the form of liquid droplets. Not only are inkjet methods used more and more for graphic printing, they are also central to many styles of 3D printers aimed at manufacturing goods that can not be created with a different approach. A better understanding of gout formation, droplet-substrate interaction, pinning, drop coalescence, and material compatibility is needed for the continuously production of inkjets, and in order to overcome current limitations.It is typically predicted that drops on solid or liquid surfaces, such as a raindrop, on a wall or a puddle can make contact with the surface affected. However, the persistence of the air layer that separates the drop from the surface prevents contact under some circumstances. It's an curiosity and its significance in various applications, such as gout combustion, emulsion separation and spray paint, which has been studied as a counterintuitive phenomena. Configurations that endorse the non-contact were investigated, e.g. by encapsulating drop with the powder of hydrophobic powder

(Aussillous & Qu'er'e 2001), by oscillated the liquid surface to refresh the aerial film on a periodic basis (Couder et al. 2005), or in heating the surface to preserve the vapor film (Qu'er'e 2013).

We present an experimental system which allows the drop to move freely and distort in order to clarify the mechanism of levitation and to research the details of the air film. The movement in a rotating flow of a bubble or a solid sphere is centered on the same principle and consists of a drop gently placed on the inner wall of a hollow solid cylinder revolving about its horizontal axis. The motor is spinning around it (Bluemink et al. 2005, 2008, 2009; Tagawa et al. 2013). The drop lifts and achieves a stable angular position for a reasonable rotation rate at which the weight of the drop drag and lift balance. This stable levitation means a steady flow around and below the drop. The air drag on a drop and the 3D shape of a film where the lifting force is generated helps us to quantify the dragging of air**.**

2. LITERATURE REVIEW

The numerical model for the static combustion of goutlets was proposed by Puri and Libbi and the transportation of the gas phase is defined appropriately. The vaporization rate and flame position model predictions showed strong agreement with experimental results. The empirical, stable state, droplet burning model with regard to temperature dependence for transport coefficients was proposed by Fachini, and a Lewis Number was not unitary. Their findings did not align with the experimental findings, however.

To ease quasi stable gas phase assumptions, King used a numerical analysis technique while retaining other assumptions of the QS model for microgravity, which is a spherically symmetric combustion of dropples. Results indicated that gas behavior at the droplet surface was almost stable but significantly deviated from near-stationary flame-situating behavior which leads to projections that are qualitative with experimental observations (non-constant F / D ratio). In the study of the combustion of liquid heptane fuel injected by a porous sphere at a levels equalto the rate at which it evaporates (no surface accumulation of oil), this modeling method was also applied. Such calculations also show that a quasi-stable behavior adjacent to the pore sphere is approached quickly (which leads to almost a consistent fuel vaporisation), but that quasistadic behavior in the flamma is approached much slower.

Ulzama and Spechthave established, with regard to both a relatively stable and transient nature of gout combustion, an analytic spherical-symmetrical model of an isolated n-heptane droplet microgravity. The model used an alternate approach when describing the combustion of droplets as a process in which the diffusion of fuel vapour within the region between the droplet surface and the flame interface is quasi-steady, while the diffusion between the flame interface and the ambient atmosphere is unstable within the field. The modeling approach focused especially on the estimation of the variations of gout and flame diameters with burning time, the effect of vapors enthalpy on burning behaviour, the average rate of burning and the effect on the flame structure of changes in atmospheric oxidizing concentrations. Comparing the modeling findings with experimental results, the simplified quasistatic transition to droplet combustion led to behavior close to the conventional droplet theory.

The effects of heat conduction on a droplet evaporating in a heavy convective flow were investigated by Yang and Wong. A droplet with an initial diameter of 700 or 1000μm was suspended at the tip of a quartz fiber horizontal or vertical (diameter 50, 150 or 300μm) to be disappeared into a hot flow of upwards air, at either 490 or 750K. In combination with droplet evaporation, a simple one-dimensional model of transient conduction was devised.

3. METHODS

A new experimental setup

In this study, a new experimental setup is fabricated to expand ranges of experimental condition. Fig. 1(a) and Fig. 1(b) show the new setup used in this study and a conventional setup, respectively. Because a circular cylinder was used in the conventional setup (see Fig. 1(b)), it is possible for a levitating droplet to move in a direction of the cylinder axis. With higher wall velocity (U > 2.0 m/s), the levitating droplet significantly moves in the direction, presumably due to an air flow inside the cylinder, and goes out of the cylinder. For this reason, the difficulty lies in observation of droplet levitation with higher wall velocity. To solve this problem, a cylinder with flask-like shape is applied in the new setup (see Fig. 1(a)).

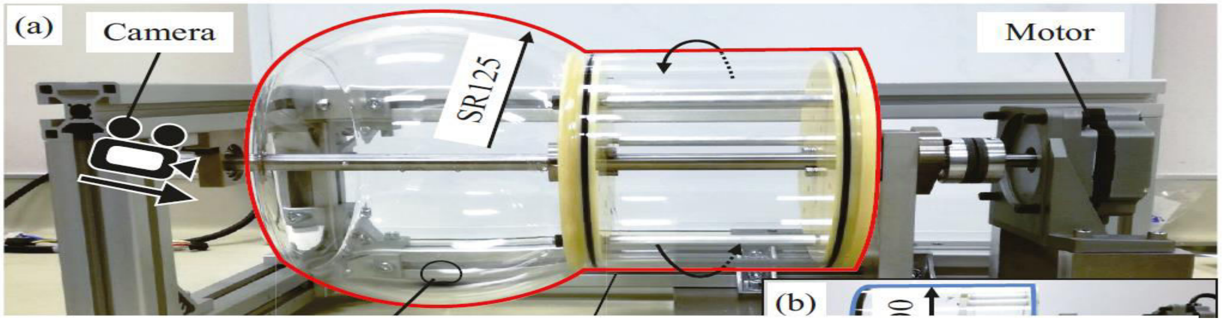

Fig 1: experimental condition.

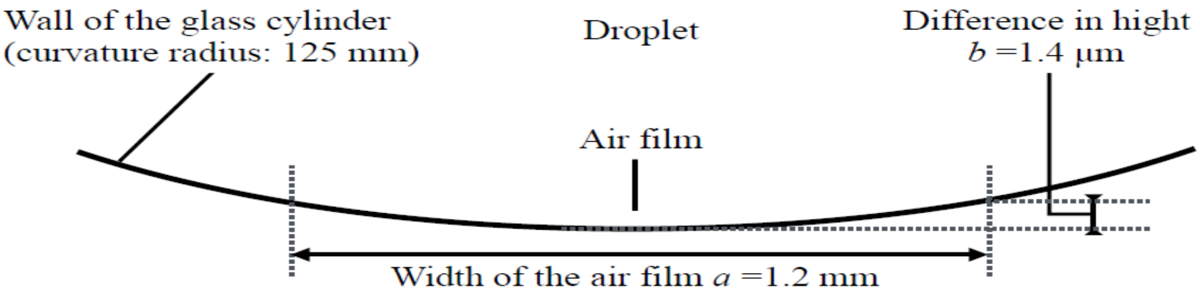

Fig. 2. A schematic of a levitating droplet with a curved wall of a glass cylinder.

By using the new setup, the droplet can levitate with higher wall velocity without escaping from the cylinder. The radius of curvature is 125 mm, which is larger than the radius of the conventional cylinder (100 mm). In addition, we examine effect of the curvature on the air film. The air film curves along the inner wall of the cylinder. Given that the radius of curvature and a width of the air film *a* is 250 mm and 1.2 mm, the height difference of cylinder in the range of the air film *b* is 1.4 □m (see Fig. 2). *b* (=1.4 □ m) in comparison with *a* (=1.2 mm) is sufficiently small. Therefore, we assume that the curvature of the new cylinder has negligible effect on the air film.

Lubricant dynamics

To understand the lubricant dynamics entrained by moving droplets, we track the size of the wetting ridge and the thickness of the lubricant in key position with time [Fig. 3(a)]. The droplet is held in place by a capillary tube, while the SLIPS sample with initial film thickness hi is moved at controlled speeds U =75–700 µm=s using a linear motor. We find that pinning the droplet above a moving surface has a negligible effect on the droplet behavior compared to the more conventional case of a droplet moving on an inclined surface . In all of our experiments, the SLIPS samples consist of randomly oriented nanoplates of size 10 nm, spaced 200 nm apart on glass substrates.

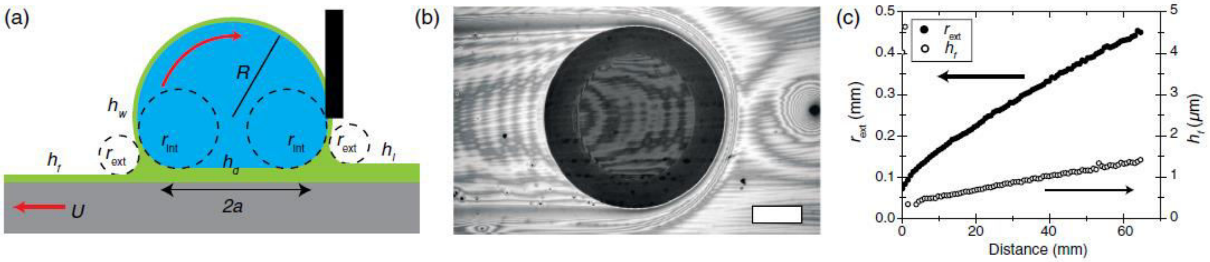

FIG. 3. (a) Schematic of the experimental setup used to study the lubricant dynamics. The substrate is moved while the droplet is held in place by a capillary tube, allowing for measurement of the wetting ridge and lubricant thicknesses in various positions. (b) RICM image demonstrating the lubricant profile around a moving droplet (scale bar ¼ 1 mm). See the Supplemental Material Video S1 for lubricant dynamics visualized using RICM. (c) Typical experimental measurement of hf and rext for a droplet moving on a lubricantinfused surface.

Lubricant depletion

Here, we explain how lubricant depletion arises from the interconnected lubricant dynamics and how it is intimately linked to the growth of the wetting ridge. In particular, we explicitly show that the volume of the wetting ridge Vridge is equal to the volume of lubricant being depleted Vlost due to the change in thicknesses Δh= hi − hf. With this physical insight, we are then able to describe the process of lubricant depletion in SLIPS fully.

First, we note that

$$V_{\text{ridge}} = \alpha 2\pi a r_{\text{ext}}^2$$

where α is a geometric factor to account for the exact shape. The exact value of α can change as the wetting ridge grows in size and can depend on Ca; nevertheless, α should remain at about 0.5, since the wetting ridge can be approximated in the first instance as a triangle.

RESULTS

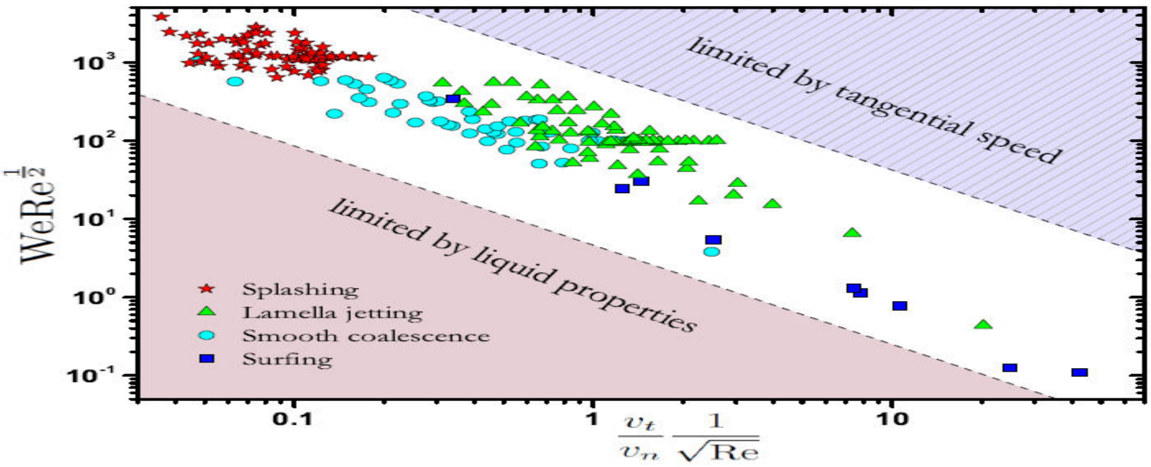

FIG. 4: Regime diagram showing the di_erent impact dynamics in terms of relevant dimensionless numbers for glycerol-water mixtures over a wide range of impact conditions.

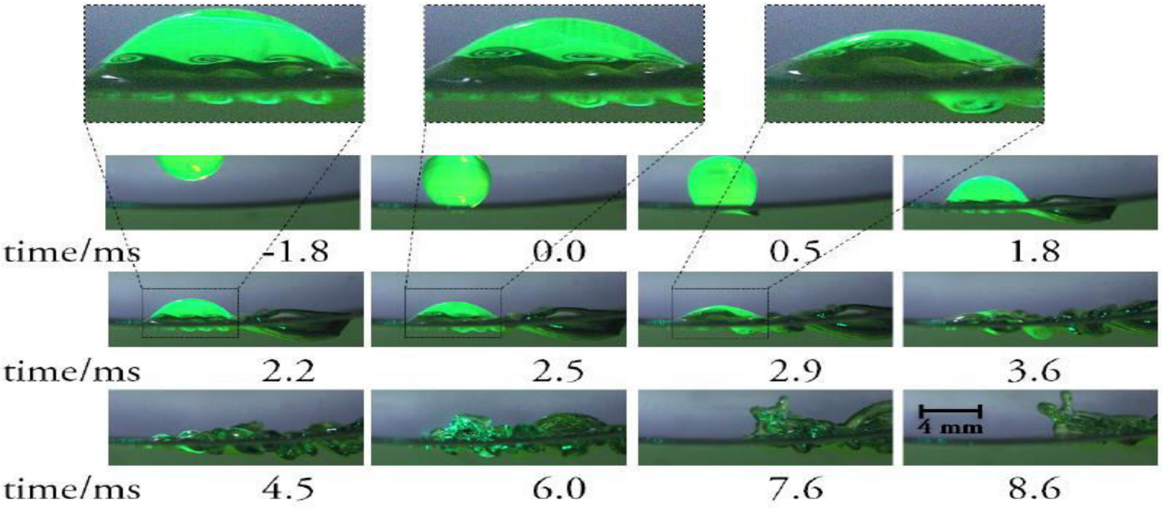

FIG. 5: Time evolution of the impact of a droplet with viscosity 5 mPa s at a normal speed of 1.3 m/s on to a pool of the same liquid moving from left to right at 3.3 m/s. Laser and colour high-speed imaging were combined to observe the mixing process; the impacting droplet contained 0.02% uorescein.

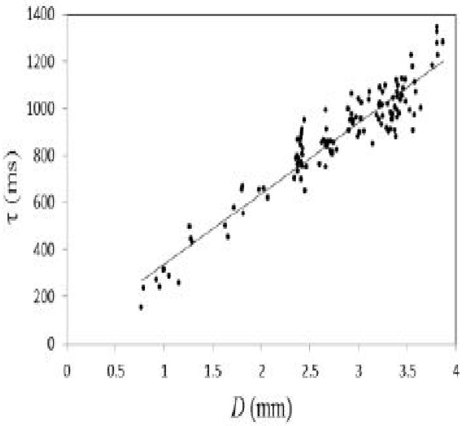

Figure 6. The rate of decay of velocity, , as a function of droplet diameter.

CONCLUSION

A rotating ring, a basic and original set-up, has been used to research the levitation of one drop over a moving surface and to achieve a steady movement of the other. For many drop-sizes above a critical surface speed that increased with drop-size we have observed levitation. The movie reveals a flat area that extends further with a drop size that goes up on the downstream and lateral sides, surrounded by a ridge with limited air film thickth. This shape is a result of the pressure distortion of the drop interface due to the gradient flow in air film, as seen in a simplified 2D modell. Finally, let us list some more levitative drop investigations that emerge from this study naturally. In order to test the validity of the asymptotic predictions we make, we will expand the measurements of film thickness and air drag. It is still not understood the exact effect of fluid viscosity, nor is the functional velocity threshold requirement for levity. Finally, it would also be worth researching the continuous wake of the drop and the relationship between levitation drops. In these inquiries, the experimental device we proposed is an appropriate setup.

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