Droplet motion in a microfluidic channel under the effect of contact angle hysteresis

Guang Yang‡, Alexandros Terzis‡, Sihao Deng◊, Xu Chu‡, Bernhard Weigand‡, Rainer Helmig‡*

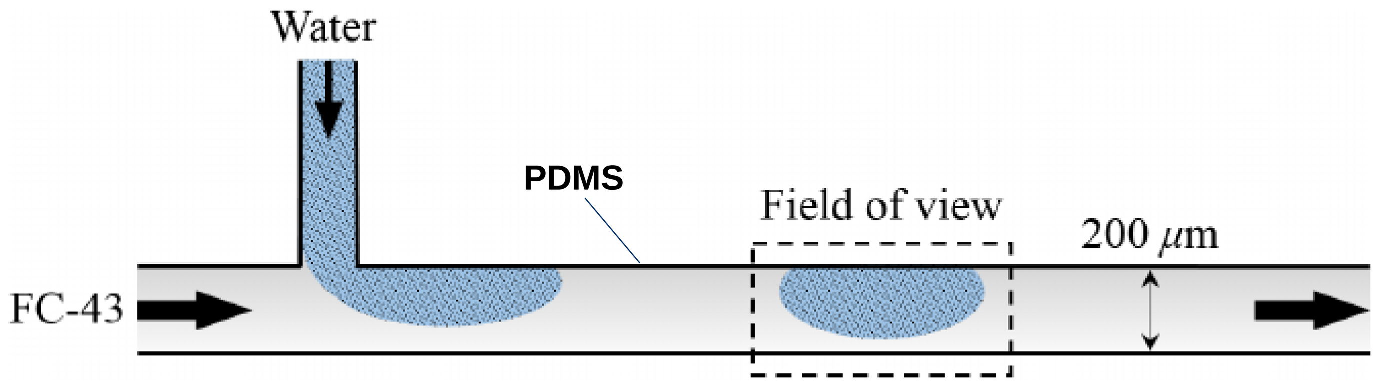
‡ University of Stuttgart ◊Karlsruhe Institute of Technology

Introduction

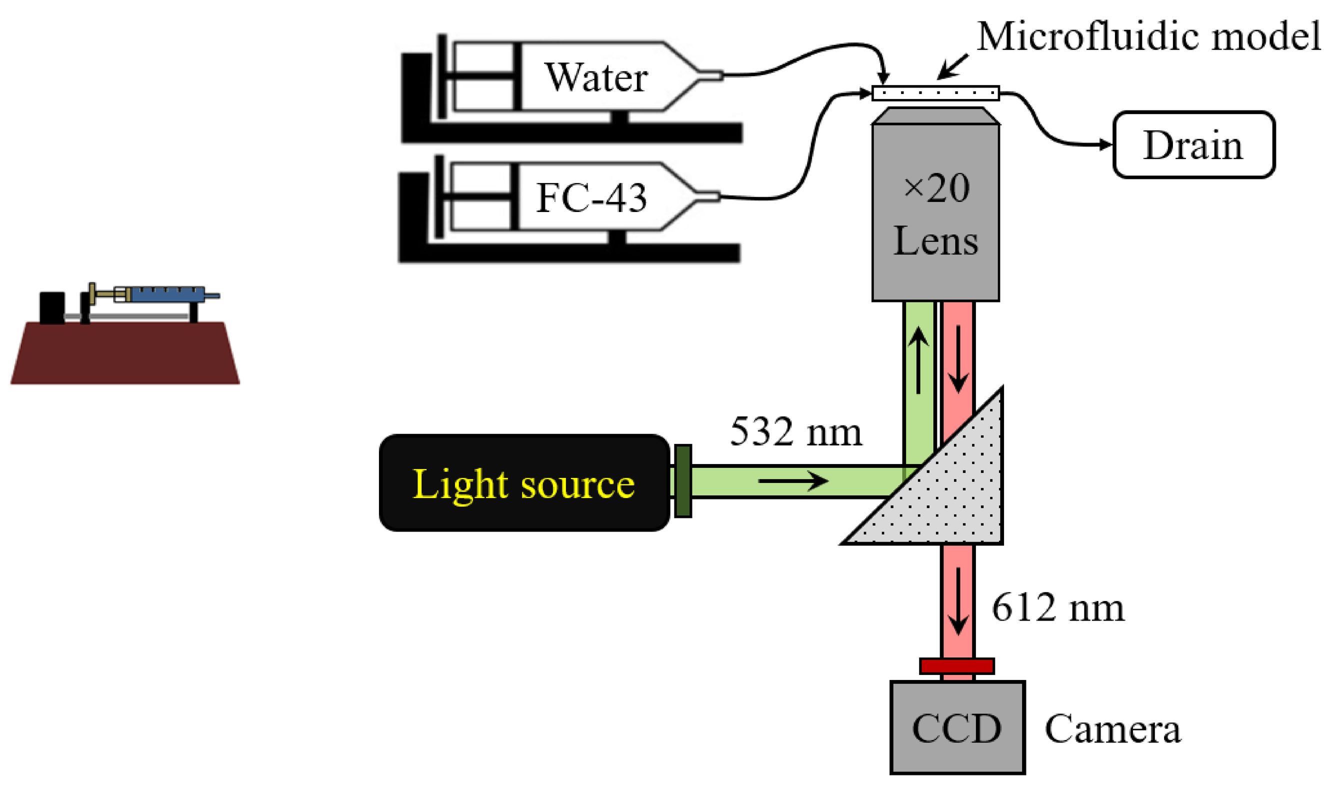
Droplet dynamics in viscous flow of an immiscible fluid is a characteristic feature of numerous applications including self-cleaning surfaces, cell movement in blood flow, membrane emulsification, water removal in fuel cells, spray coating, petroleum engineering, etc. The available literature sources focus on the overall movement or the shape deformation of the droplet. The internal fluidity of the droplet has not been adequately investigated so far.

Experiments

Schematic representation of the experimental methodology:
A T-junction microfluidic model and a microscope measurement system.

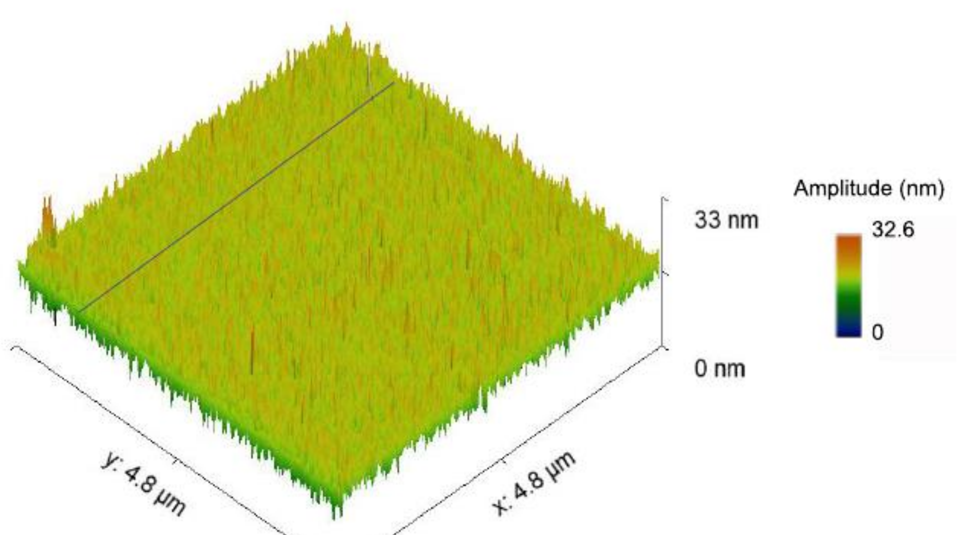


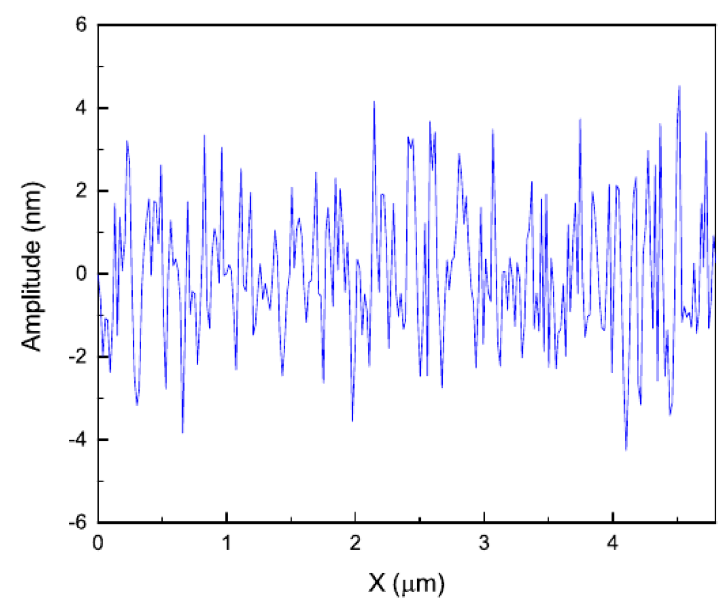
(a) T-junction microfluidic model



(b) Microscope setup and instrumentation

The PDMS surface has a RMS roughness of 1.8 nm, so the roughness has no influence on the contact angle hysteresis:



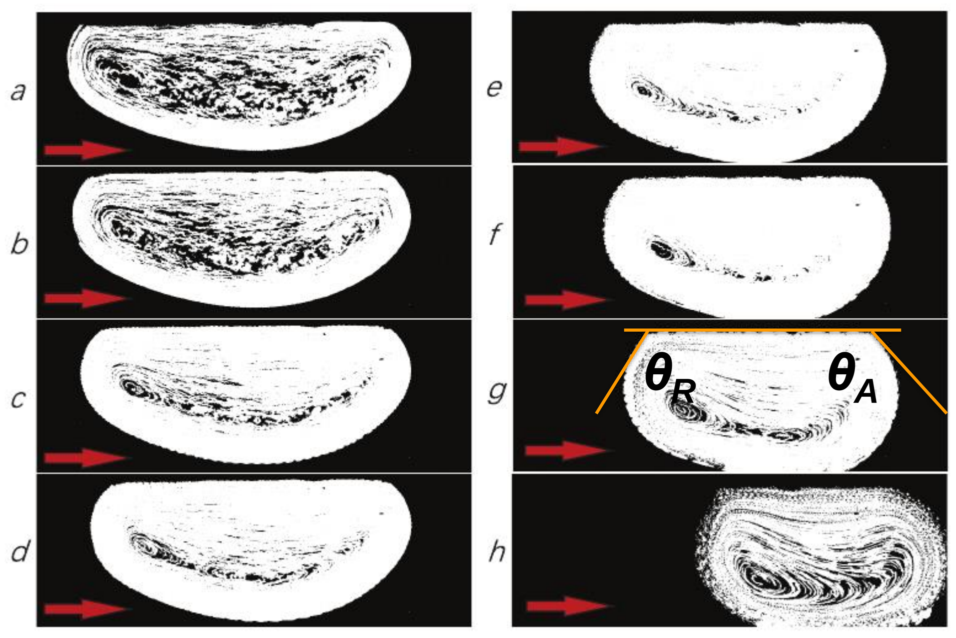


（a）A morphology AFM image

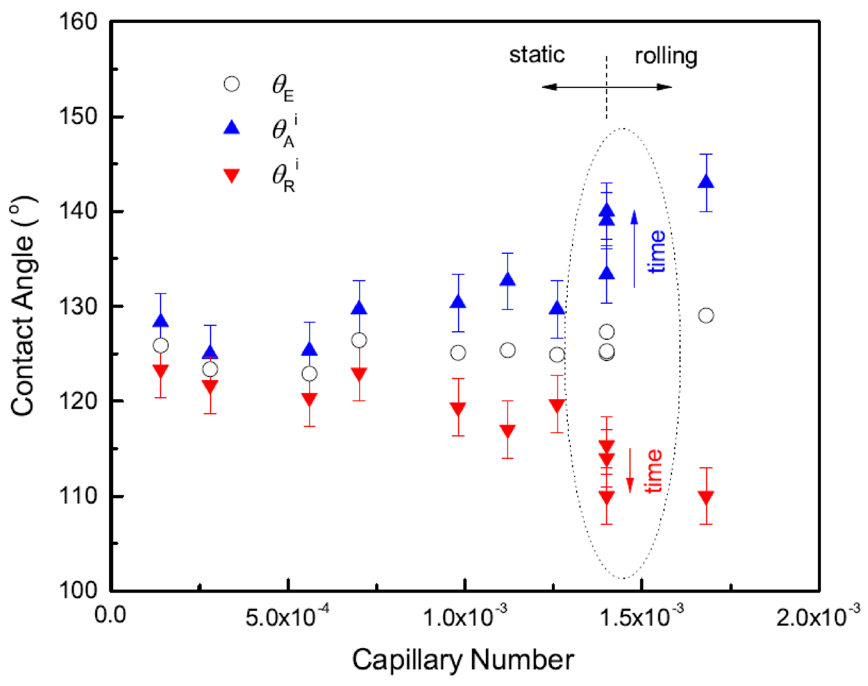
(b) Roughness on the surface

Droplet motion

Droplet shapes as Capillary number increases stepwise:
a-f: droplet pinned; *g* and *h:* droplet rolling.

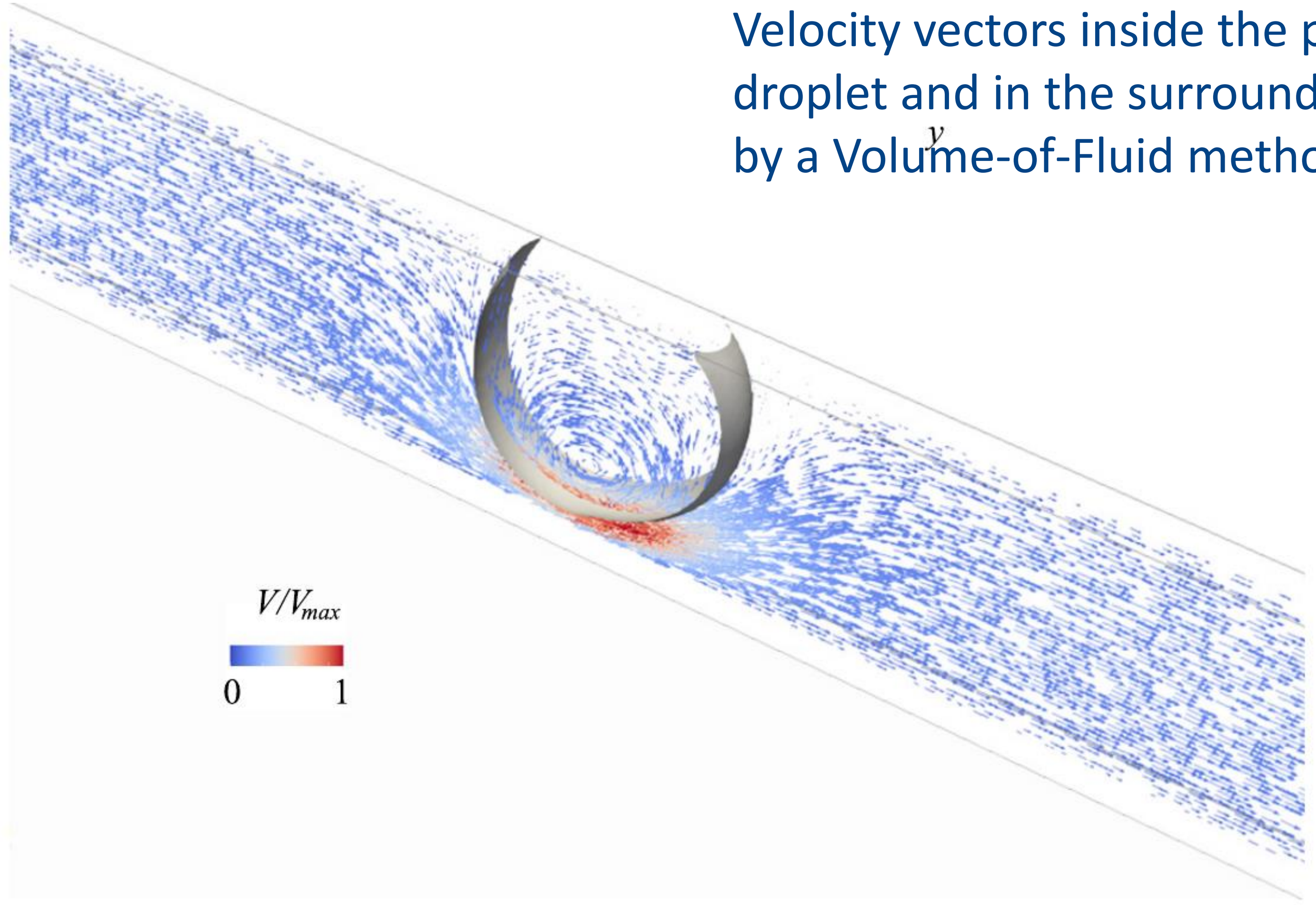


Contact angle hysteresis: θ_A-θ_R



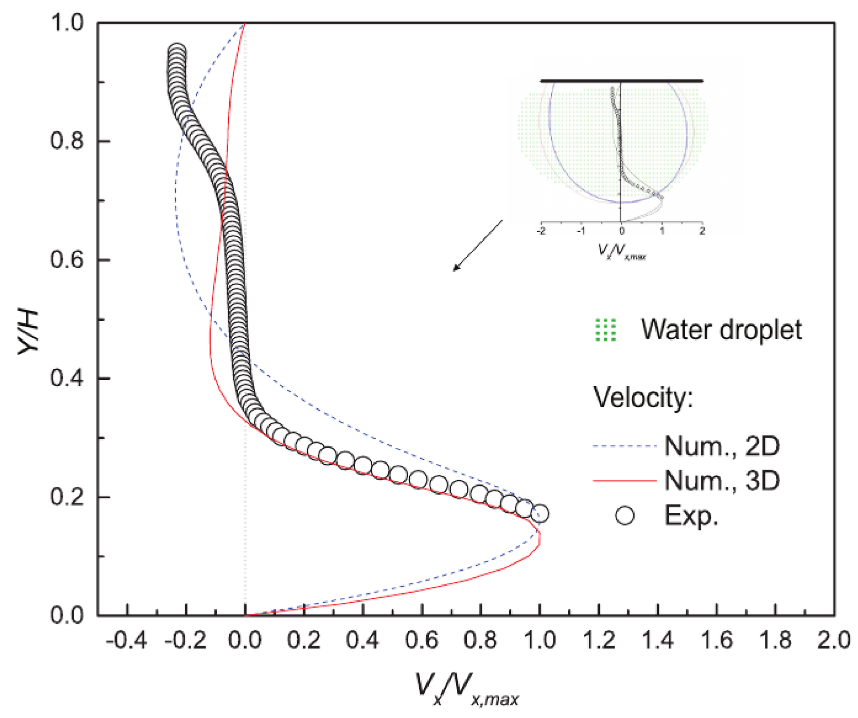
Contact angles at the contact line for various Capillary numbers.

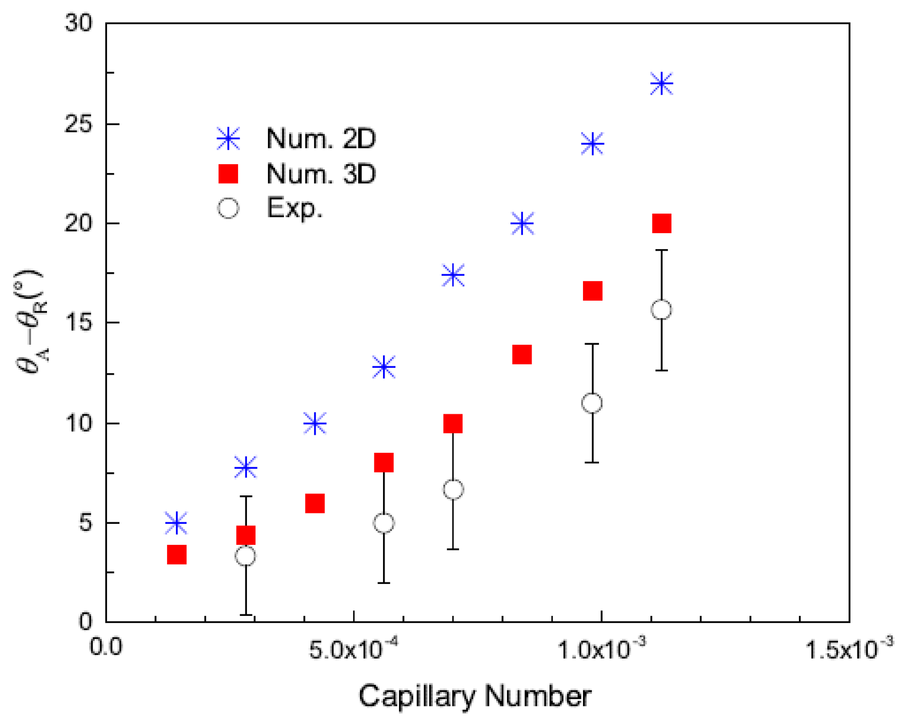
Numerical Results



Velocity vectors inside the pinning droplet and in the surrounding flow by a Volume-of-Fluid method.

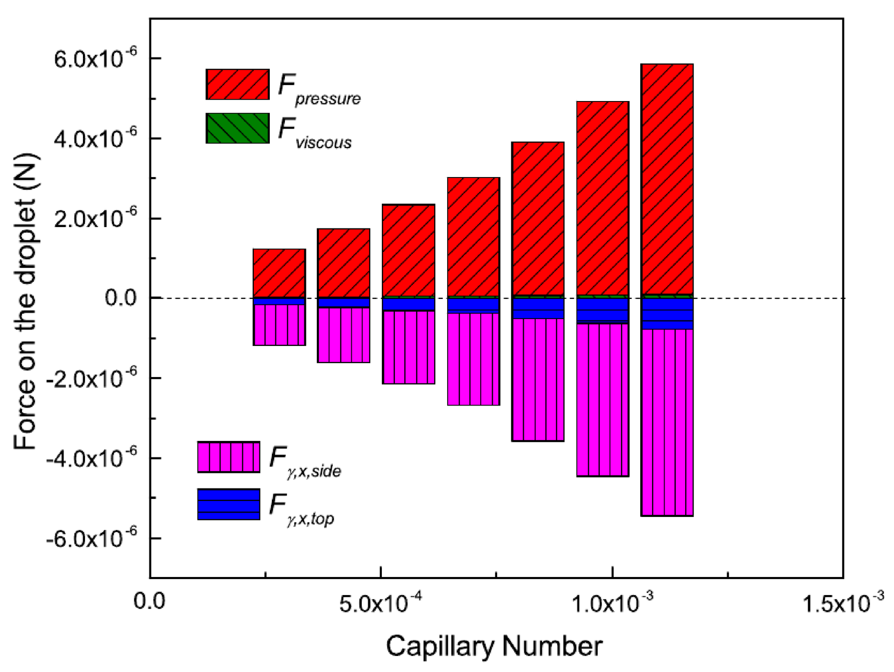
Comparison of the local velocity distributions and contact angle hysteresis obtained by experiment and numerical simulations:



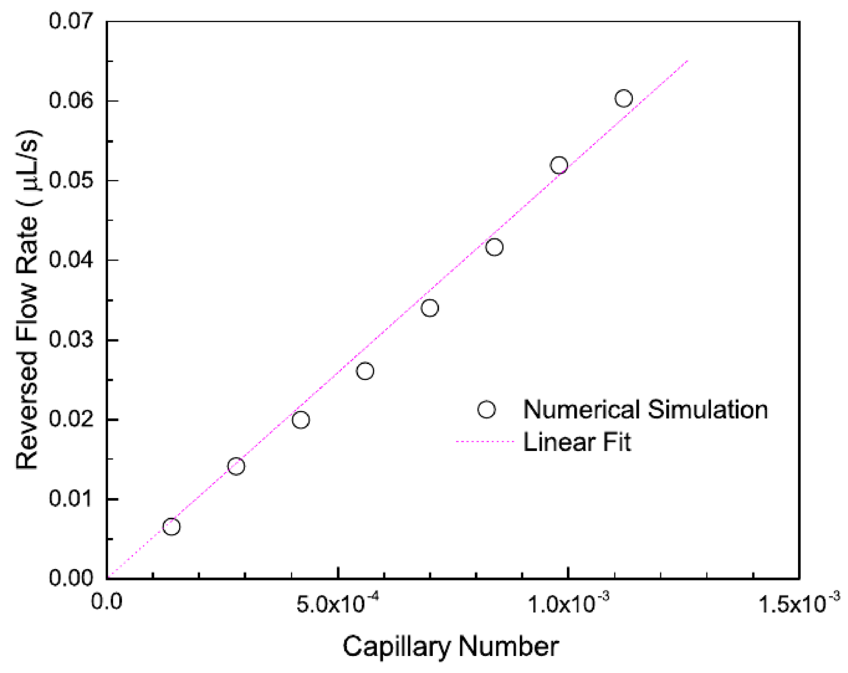


Force analysis and rotation intensity

Variation in the force components on the droplet with Capillary number:



Flow rates of the reversed flow vs Capillary numbers:



Concluding Remarks

- Droplets can be pinned on the solid surfaces because of the contact angle hysteresis when the Capillary number is low.
- The internal rotational of the pinned droplet has been observed and quantified through a micro-PIV for the first time.
- The internal fluidity has been simulated successfully with a VOF method, with a good agreement with experiments.
- The intensity of the internal rotation of the droplet can be predicted by a linear function of the capillary number.

Acknowledgments

SFB1313
CRC1313
Alexander von Humboldt Stiftung/Foundation

*Please follow our work on ResearchGate: https://www.researchgate.net/profile/Guang_Yang59

University of Stuttgart
Germany

Institut of Aerospace Thermodynamics
ITLR