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Numerical study of droplet behaviour in complex flow conditions using an optimised feedback deceleration technique (FDT)

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The understanding of droplet dynamics on solid surfaces is essential in order to ensure the correct functionality of certain technical applications, e.g. to avoid droplet movement in electronic components. The corresponding processes strongly depend on several system conditions: the capillarity and wetting phenomena, the flow properties, the surrounding geometry, and potential external perturbations, like mechanical vibrations. By means of the numerical simulation a wide range of system parameters and their impacts on the droplet behaviour can be analysed while gaining a detailed insight into the flow characteristics. The main challenge regarding the simulation of droplet dynamics is the correct modelling of the contact line dynamics including the contact angle hysteresis. In the present investigation, an optimisation of an existing numerical implementation of the adhesion effect, e.g. the contact line pinning, is introduced. Based on the explicit and non-iterative feedback deceleration technique, the adapted method contains a new definition of its main control parameter and is applicable for various fluid-solid constellations. The validation of the method is performed by investigating droplet dynamics and comparing the numerical results with the experimental data. Therefore, the droplet movement on flat surfaces as well as the droplet deformation and breakup on obstacle geometries are investigated. In all cases the numerical results are in good agreement with the measured data. In accordance with the experimental findings, a dependency of the critical velocity, i.e. the velocity of the air flow which is necessary to move the droplet, on droplet sizes and on the contact angle hysteresis is shown for droplets in shear flow. Further, it is demonstrated that the superposition of gas flow and surface vibration additionally reduces the critical velocity value either for certain vibrational frequencies or by increasing the vibrational acceleration. The results regarding the droplet deformation and breakup on obstacles with a rectangular cross-section are presented as a function of nondimensional parameters.

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