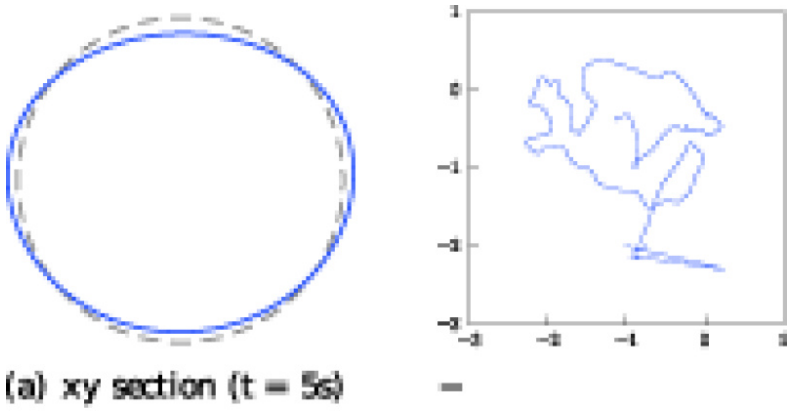
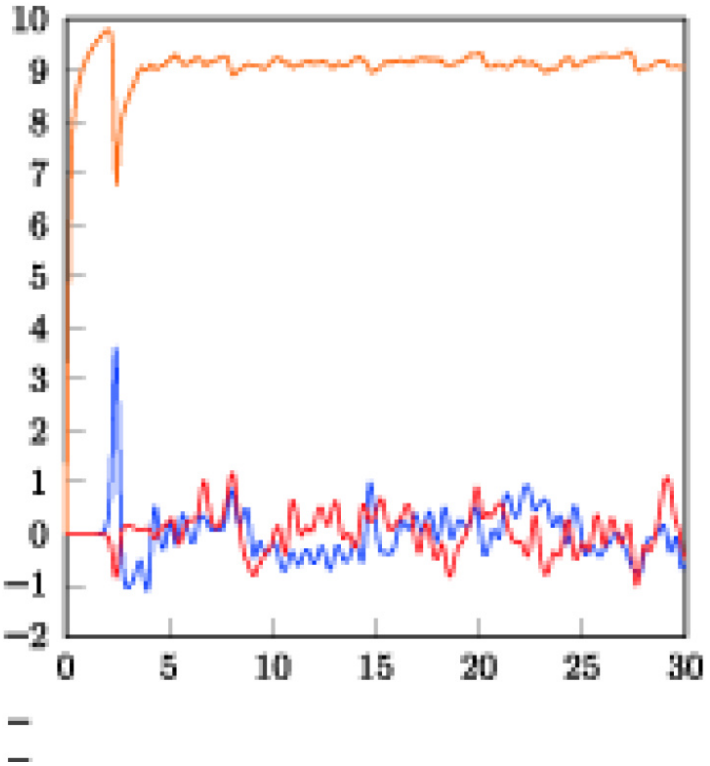
Dynamics of Buoyant High Viscosity Droplets Rising Freely in an Ambient Liquid





Figure_shape_5.7.eps : "xy section ($t=5$s)" Figure_vel_5.7mm_003.eps "center of mass velocity in cm/s over time (blue: u_x, red: u_y, orange: u_z)" Figure_xy_5.7mm_003.eps "xy trajectory in cm" Figure_entire.eps: "Shape, trajectory and velocity over time for droplet with $d=5.7$mm (initial)"

Researchers
Dr. Christoph Albert, Dr. Anne-Marie Robertson and Johannes Kromer

Principal Investigator
Prof. Dr. Dieter Bothe

Project Term
2009 - 2009

Project Areas
Mathematics

Clusters
Lichtenberg Cluster Darmstadt

Institute
Mathematical Modeling and Analysis

University
Technische Universität Darmstadt

Introduction

Fluid particles with deformable shape which move through an ambient liquid medium can be found in a wide range of industrial and environmental processes. Examples include falling rain drops, bubble column reactors, or heat exchangers. The dynamic behaviour of the involved particles is of crucial importance and thus needs to be investigated in detail. There is a wide scope of mechanisms taking place at the fluid interface, especially transfer of mass - i.e. solute species - and heat due to temperature differences. Thus, the shape of the fluid interface and its dynamics are of key interest.

Methods

The deformability of high viscosity droplets can be regarded as an intermediate case between free rigid particles and gas bubbles. Here, corn oil droplets rising in ambient water are considered as a prototype system. Droplets of different sizes exhibit a wide range of phenomena, especially concerning (in-)stability and bifurcations. Albert et al. [1] have conducted a systematic computational analysis, which is perpetuated by the authors. To get insight to the fundamental underlying flow dynamics, theoretical, experimental and numerical approaches can be taken. Theoretical results can usually only be obtained for a very limited number of flows, which restricts their application to problems of academic interest. Experimentally identifying the fundamental mechanisms is also difficult, due to the presence of severe influences, e.g. contamination with surfactants, which have effects on fluid properties like surface tension. The above disadvantages can be circumvented by direct numerical simulation (DNS) of the governing Navier-Stokes equations. In order to capture the flow physics with reliable accuracy, the computational domain must be resolved with sufficient resolution. Further, the domain dimension has to be chosen carefully to reduce boundary influences, implying large computational costs. The inhouse code FS3D, originally developed by Rieber[2] , is applied to numerically solve the two-phase formulation of the Navier-Stokes equations. The fluid phases (e.g., air/water or oil/water) are distinguished by means of a phase indicator function, which allows to reconstruct the fluid interface and the trajectory of the droplet center of mass.

Results

Figure (1) depicts the shape, trajectory and velocity of an initially resting cornoil droplet freely rising in water, with an initial diameter d=5.7mm. Although the trajectory is subject to oscillations, the shape of the droplet quickly stabilizes, while only its orientation changes over time. For larger droplets however, the shape oscillations are amplified, without reaching a steady state.

Outlook

As for the future, the shape oscillation characteristics with

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN TECHNISCHE UNIVERSITÄT DARMSTADT UNIKASSEL VERSITÄT Philipps Universität Marburg

respect to the droplet sizes will be studied in more detail. The work of J. Kromer is supported by the of the German Federal and State Governments and the Graduate School of Computational Engineering at TU Darmstadt.

Reference

[1] C. Albert, A.M. Robertson, and D. Bothe (submitted), Dynamic behaviour of buoyant high viscosity droplets rising freely in a quiescent liquid. https://doi.org/10.1017/jfm.2015.393

[2] M. Rieber (2004), PhD thesis: Numerische Simulation der Dynamik freier Grenzflächen in Zweiphasenströmungen, Universität Stuttgart.

Last Update: 2022-09-18 16:02