Department of Multiphase Reactors

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Fields of research

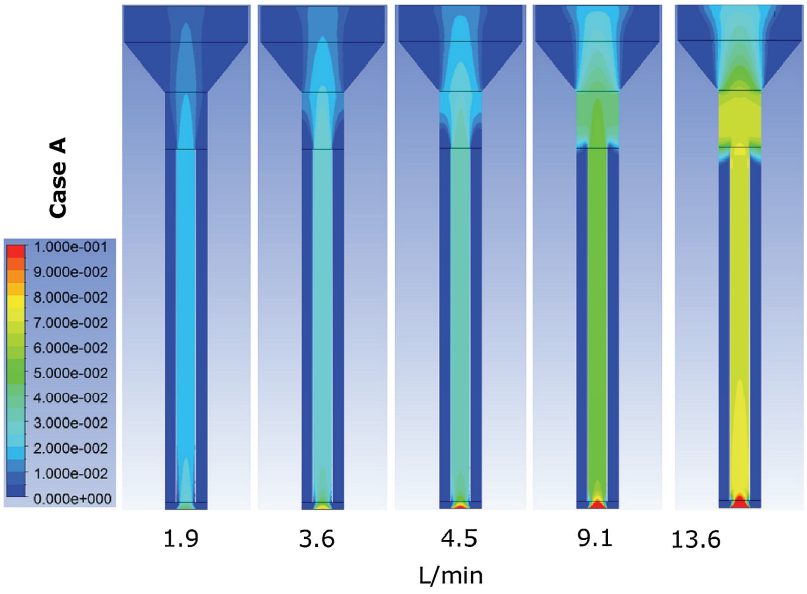
- Multiphase fluid dynamics and transport phenomena in different types of gas-liquid, liquid-solid or gas-liquid-solid systems
- Sedimentation of ensembles of polydisperse particles, deposit structure
- Flow of microdispersions and liquids with complex rheological behaviour
- Electrodiffusion diagnostics of the flow

Research projects

Hydrodynamics and transport phenomena in multiphase systems: from microscale to macroscale

(M. Růžička, joint project with TU of Ostrava, supported by GACR, grant No. GA104/07/1110)

Essence of the research project is the investigation into the basic physical mechanisms involved in hydrodynamics and transport phenomena in complex multiphase systems. Transport of mass and momentum in both two-phase systems (gas-liquid) and three-phase systems (gas-liquid-solid) were studied. The stress is put on the momentum transfer between the phases, i.e. on the hydrodynamics of multiphase flows. Hand in hand with the understanding the multiphase motion, the mass transfer phenomena were explored. The typical feature of the multiphase systems is the existence of a microstructure, given by the presence and configuration of the dispersed particles. The microstructure has a multi-scale nature and determines the system rheology. The project is aimed at resolving the relation between the microstructure and the macroscopic behaviour of the multiphase systems. [Refs. 4, 5, 7, 11, 14-16, 22, 24, 29, 32, 36-39, 54, 55, 58, 59]



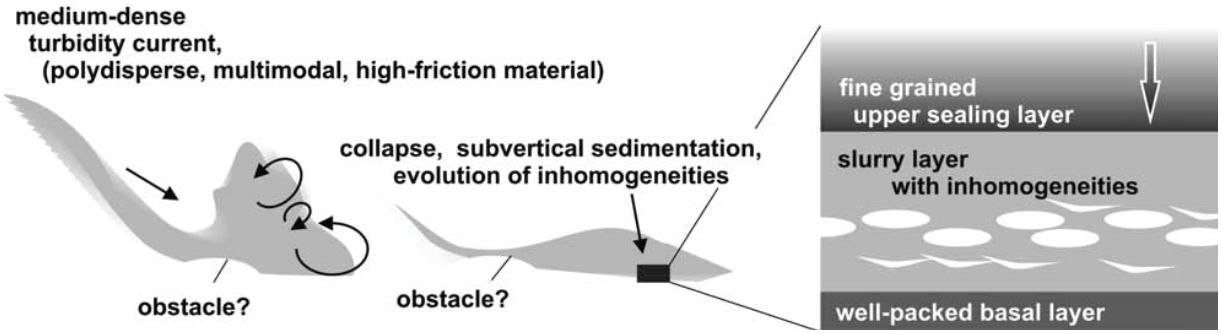
Case A simulations: Gas holdup fields for gas flow rates 1.9, 3.6, 4.5, 9.1, and 13.6 l min^{-1} (riser gas superficial velocity 1.0, 2.0, 2.5, 5.0, 7.5 cm s^{-1})

Hydrodynamic concept of stromatactis formation in geology

(M. Růžička, joint project with Institute of Geology of the ASCR, v. v. i., supported by ASCR, grant No. IAAX 00130702)

Stromatactis cavities are present in fine-grained carbonate sediments in nature, forming the specific shapes and reticulate arrays. However, the mechanisms behind the origin of these cavities are subjects of heated discussions in geology for 125 years. Numerous biotic and abiotic factors were considered, but with unclear results. Most recently, our team produced a critical analysis of these sedimentary structures and formulated a new hypothesis that these cavities would likely originate during the rapid deposition of extremely polydisperse and multimodal granular mixtures. Although the first experiments simulated the production of these cavities with a considerably high level of similarity, there is a lot of work to be done if we wish really explain these unique phenomena in terms of hydrodynamics. The inter-

disciplinary study is novel, and the results are fundamental for sedimentology and hydrodynamics, with possible implications in related technologies. [Refs. 14, 24]

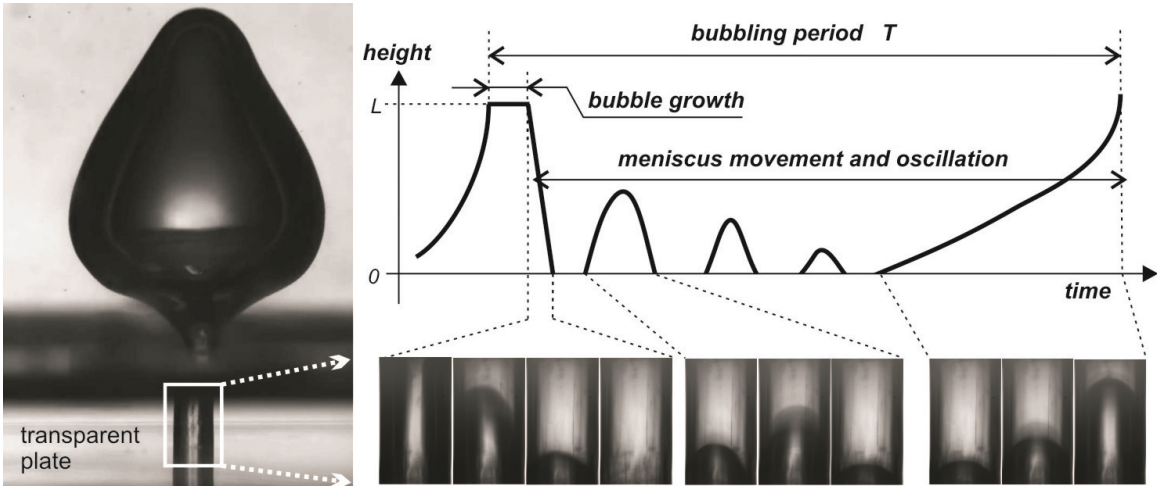


Event-sediment scenario for stromatactis-bearing beds

Dynamics of bubble formation at submerged orifices: Simultaneous formation and synchronous regimes

(P. Stanovský, supported by ASCR, grant No. KJB200720901)

A goal of this project is an experimental study of the dynamics of interfacial meniscus inside an orifice during bubble formation from a submerged orifice. Incorporation of the meniscus dynamics into a mathematical model of the bubble formation allows explaining aperiodicity in the bubble formation at one orifice. The project objectives are the experimental verification of the model in a wide range of parameters coupled with the study of interactions between external acoustic source and the meniscus motion. Finally, an extension of the model from one orifice to more orifices are done in order to explain a mechanism leading to an asynchronous regimes appearance during bubble formation at more orifices as well as an acquirement of new experimental data about simultaneous formation at multi-orifice spargers. [Refs. 4, 36-38]

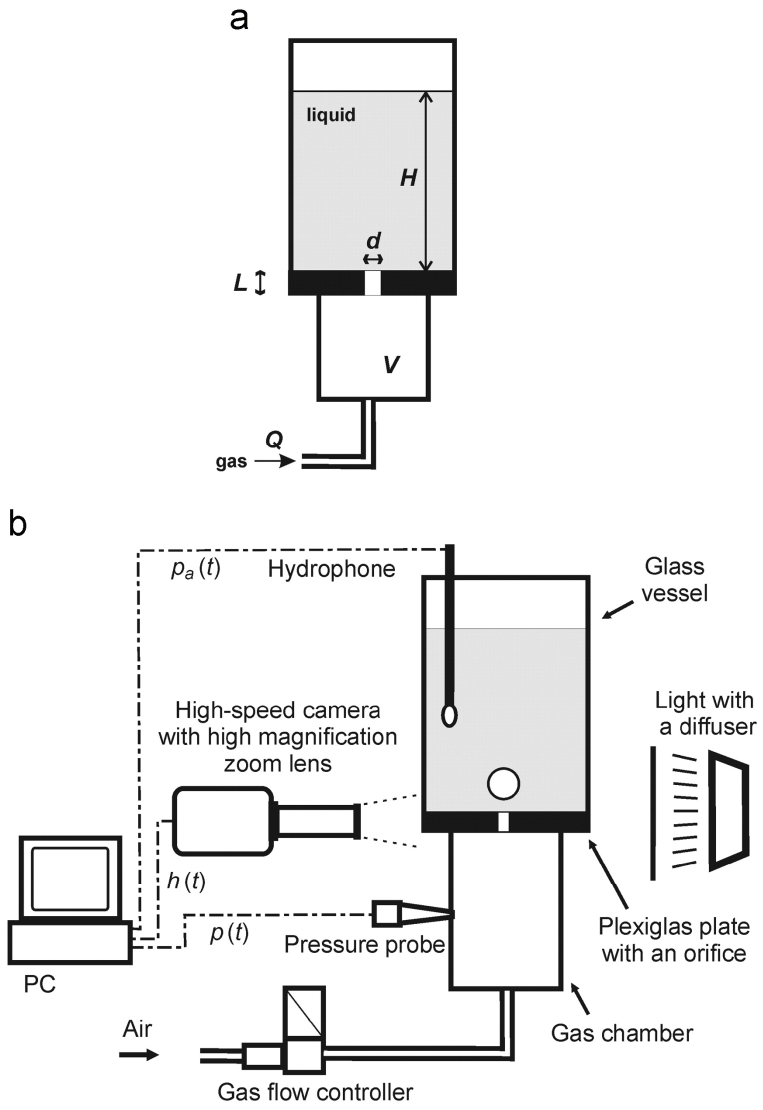


The studied key phenomena - *meniscus oscillation* - influencing the bubble size variability and bubble formation synchronicity at multiple orifices

Transport and reaction processes in complex multiphase systems

(J. Drahoš, joint project with ICT and UPCE, supported by GACR, grant No. GD104/08/H055)

Project is focused on training of doctoral students in the field of chemical engineering via targeted research in modern branches of chemical, pharmaceutical, biological and process industries with emphasis on research in new areas such as micro- and nanotechnologies and material engineering. It includes theoretical and experimental work of 20 students of Chemical Engineering Departments at ICT and UPCE, and at ICPF. Particular research programmes involve 16 areas from microsystems to industry-scale processes. Project is led by 18 supervisors. The training includes both general courses on mathematical modelling, statistical analysis and methodology of scientific work, and courses specialized on specific research fields. Students take part in national and international projects of cooperation with major research laboratories. The project output are publications in impacted international journals, presentations at conferences and special workshops with lectures by students, supervisors and invited specialists, published in proceedings. [Refs. 11, 14, 18-20, 22-24, 26-28, 50, 51]



Schematic diagram of the experimental apparatus: (a) measuring cell and (b) complete set-up

Presidency of the European Federation of Chemical Engineering (EFCE)

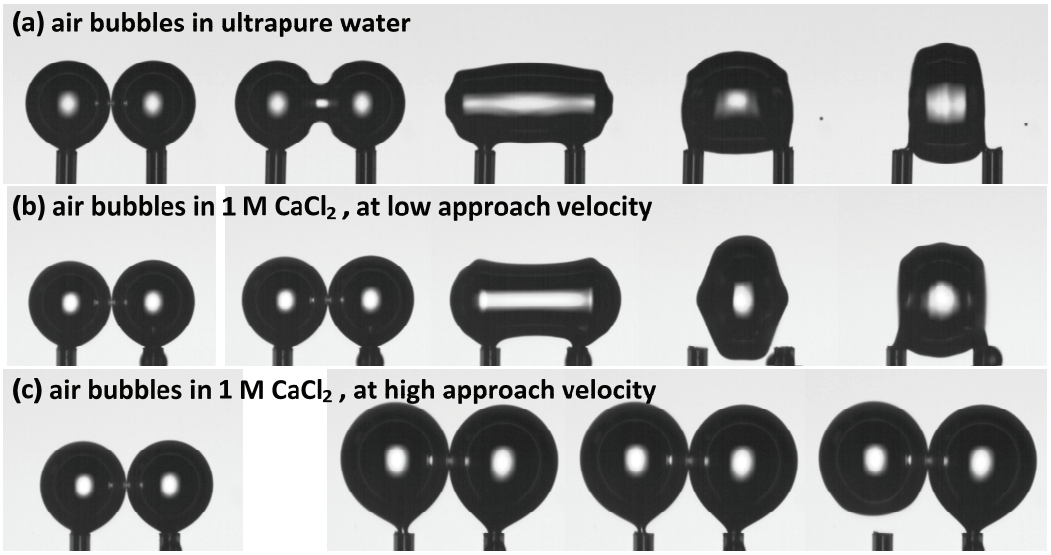
(J. Drahoš, supported by MEYS, INGO project No. LA 319)

The EFCE is one of the most important institutions in the field of chemistry. Prof. Jiří Drahoš successfully served for four years as its President for the period 2006-2009. Together with Prof. Růžička, he also participated at the activities of the EFCE Working Party Multiphase Fluid Flow. [Ref. 21]

Determination of the coalescence efficiency of bubbles in liquids

(S. Kordač Orvalho, supported by GACR, grant No. GP104/09/P255)

The coalescence phenomenon is of capital importance in the design and performance of multiphase contactors. Although studied for several decades, it is still not completely understood. The present project aims to improve our knowledge on the subject in the following way: to determine experimentally a relation between coalescence efficiency and the crucial control parameters (bubble properties, liquid properties, liquid flow conditions). Bubble coalescence was studied experimentally in a laboratory cell (pairwise first, multiple then) under well-defined conditions. Then, these small scale data have been related to the coalescence in real gas-liquid dispersions in bubble column reactors. [Refs. 29, 30]

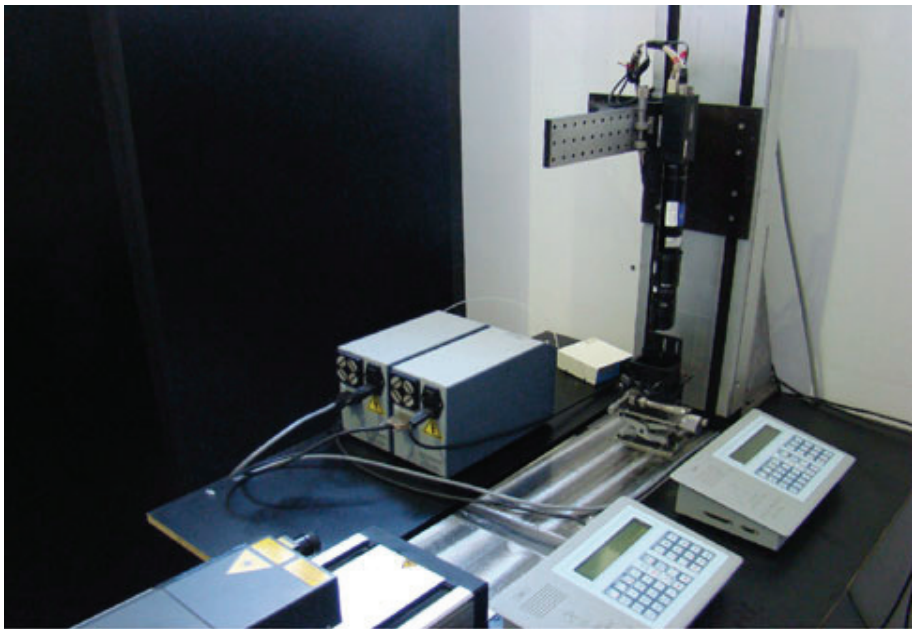


Example of the effect of approach velocity on the coalescence of air bubbles in liquids coalescent ultrapure water and in non-coalescent calcium chloride, c($CaCl_2$) = 0.056 M

Application of the electrodiffusion sensors for the flow diagnostics in microchannels

(J. Tihon, supported by ICPF)

The electrodiffusion technique has been improved to become applicable for the flow measurements in microchannel devices. The technique of photolithography has used to prepare very small but precisely shaped flow sensors. To gain experience with practical measurements on microfluidic scale, the electrodiffusion sensors has been tested under steady flow conditions in straight microchannels. [Ref. 1]

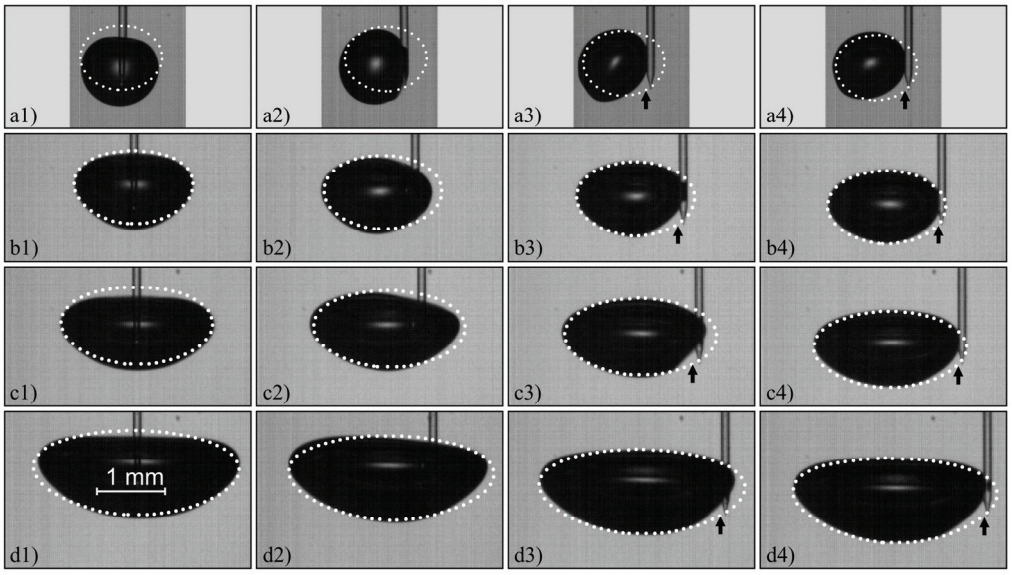


Particle image velocimetry (PIV) set-up

Analysis of hydrodynamic forces acting on bubbles by PIV measurements

(J. Vejražka, supported by ASCR, grant No. IAA200720801)

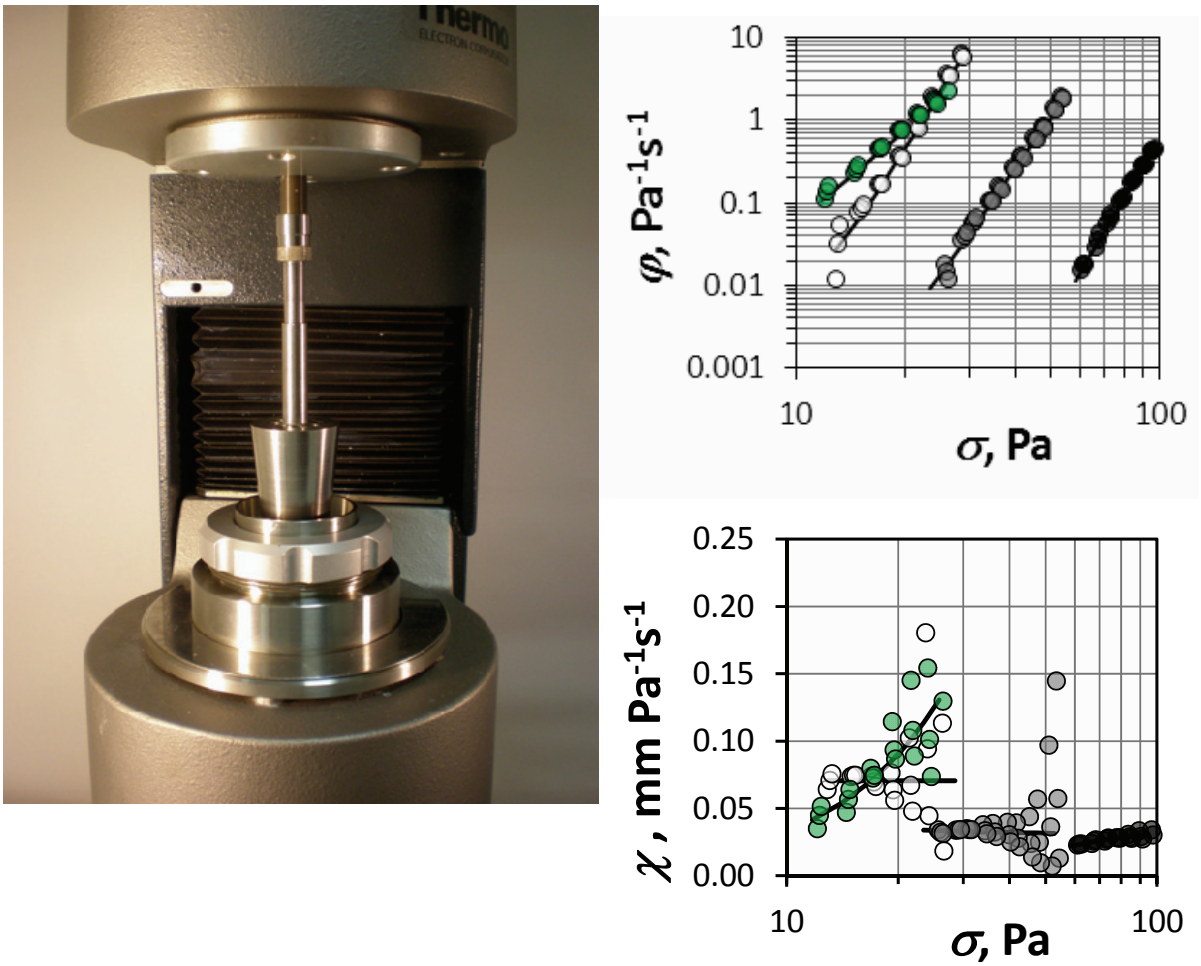
The liquid flow in proximity of bubbles is studied experimentally by using the time-resolved particle image velocimetry and high-speed flow visualizations. The measured velocity field was treated in order to get information on the forces acting on bubbles in different flow situations. The calculation and analysis of the viscous dissipation and inertia of liquid in motion were performed for various situations both in pure liquids and in surfactant solutions. The results were enlarge the knowledge of bubble flow dynamics, required to improve computational models used for the prediction of macroscopic two-phase flows. [Refs. 7, 11, 13, 34, 35, 46-51]



The bubble-probe interaction and comparison of the initial and the terminal bubble shape

Wall effect in flowing microdisperse liquids: apparent slip and electrokinetical potential
(O. Wein, joint project with TU of Ostrava, supported by GACR, grant No. 104/09/0972)

The project aims at a phenomenological characterization of liquid micro-dispersions (aqueous nanofluids and colloidal clay suspensions) by means of three experimental methods. Theory of the electrodiffusion friction probes, including their automated calibration, has been extended to non-linear velocity profiles. AWS viscometry and routine measuring of zeta-potential (ξ) have been applied for a class of nanofluids, prepared using several different dispersing methods. [Refs. 2, 31-33, 43-45]



The AWS (apparent slip at wall) viscometric technique using the novel KK-sensor for microdispersion liquids

Effect of the surface roughness, ohmic resistance, and electrode kinetics on autocalibration of electrodiffusion friction probes
(O. Wein, supported by GACR, grant No. GA104/08/0428)

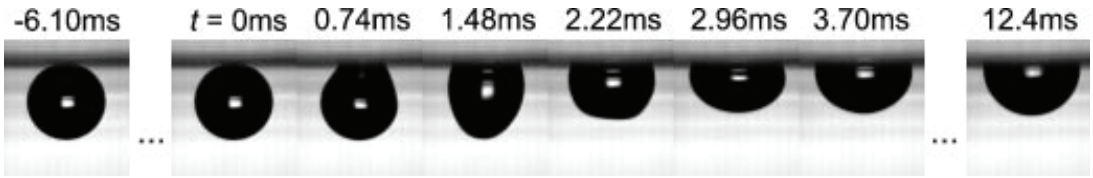
Experimental part of the project consists in studying fast transient processes driven by a step change of voltage in electrolytic microcells. In the first year of the project, an experimental set-up (electrolytic cells, working electrodes, measuring and controlling hardware) were prepared and tested. The programs for PC-driven process control and data acquisition, written under LabView, were prepared and tested. This preparatory activity is documented in a series of three research reports. The related results in electrodiffusion diagnostics of flow were published. [Refs. 6, 8-10, 12, 40-42, 52, 53]

Electrodiffusion friction probes

Hydrodynamics of bubble-particle interactions under liquid circulation

(M. Zedníková, supported by GA ASCR, grant No. KJB200720801)

The project deals with bubble-particle interactions under liquid circulation. Theoretical description exists only for small particle - large bubble interactions, used in mineral flotation. If the objects proportion is inverted, the mechanism of interaction is no longer fully understood. Thus, the objectives of the project are to study: i) small bubble-large particle interactions under liquid circulation and ii) interaction of more bubbles with a particle and formation of stable bubbles-particle aggregate. The bubble trajectory, velocity, momentum and deformation during impact are obtained by high speed camera visualization and the liquid velocity flow field is measured by the particle image velocimetry (PIV). The experimental data were create a base for theoretical description of bubble-particle interactions. [Refs. 11, 17, 25, 56-59]



Sequence of bubble attachment process to the solid surface.
PE surface, deionised water, D_b = 1.05 mm

International co-operations

Berlin Institute of Technology, Germany: Multiphase flow diagnostics
CRTT, Saint Nazaire, France: Microfluidics
Eindhoven University of Technology, the Netherland: Oscillations of fluid particles
Institute of Chemical Engineering, BAS, Sofia, Bulgaria: Gas-liquid reactors
Institute of Fluid Mechanics, Toulouse, France: Effect of surfactants on multiphase flows
Institute of Fluid Mechanics, Toulouse, France: Hydrodynamic interactions of bubbles
Martin Luther University, Halle, Germany: Hydrodynamics of bubbly flow
Norwegian Institute of Technology (NTH), SINTEF, Trondheim, Norway: Bubble columns

University of Minho, Braga, Portugal: Multiphase bubble bed reactors
Worchester Polytechnic Institute, Worchester, MA, USA: CFD

Visits abroad

V. Sobolík: University of La Rochelle, France (12 months)
J. Vejražka: IMFT Toulouse, France (1 month)

Visitors

E. Barros, Univiversity of Minho, Portugal (Erasmus)
N. Deshayes, Institut National Polytechnique de Toulouse, France (Intership)
A. Martins, University of Minho, Portugal (Erasmus)
N. Postic, Institut National Polytechnique de Toulouse, France (Intership)
M. Shirota, Hirosaki University, Japan
A. Shirota, Ikadogen Apple Institute Co., Japan

Teaching

J. Drahoš, M. Růžička: ICT, Faculty of Chemical Engineering, postgraduate course "Multiphase Reactors"
J. Havlica: UJEP, Faculty of Science, course "Mathematics for chemists"
J. Tihon, J. Vejražka: ICT, Faculty of Chemical Engineering, postgraduate course "Drops, bubbles, and particles"

Publications

Original papers

[1] Ait Mouheb N., Montillet A., Solliec C., Havlica J., Legentilhomme P., Comiti J., Tihon J.: Flow Characterization in T-Shaped and Cross-Shaped Micromixers. (Eng) Microfluid. Nanofluid. 10(6), 1185-1197 (2011).
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[14] Kulaviak L., Hladil J., Růžička M.C., Drahoš J., Saint-Lary L.: Patterns formation in sedimentary deposit. (Eng) Chem. Eng. Sci., submitted.

Chapters in books

[15] Gogová Z., Hanika J., Markoš J.: Optimal Design of a Multifunctional Reactor for Catalytic Oxidation of Glucose with Fast Catalyst Deactivation. (Eng) (Brito A.V., Ed.), pp. 209-232, Intech, Vukovar 2010.
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International conferences

[17] Basařová P., Vejražka J., Zedníková M., Hubička M.: Theoretical Description of Motion of a Spherical Bubble in Neighbourhood of a Falling Particle. (Eng) 19th International Congress of Chemical and Process Engineering CHISA 2010 and 7th European Congress of Chemical Engineering ECCE-7, Summaries 3, p. 905 (10 pp. full text on CD-ROM), Prague, Czech Republic, 28 August - 01 September 2010.
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[22] Fialová M., Orvalho S.P., Zedníková M., Drahoš J., Růžička M.: Volumetric Mass Transfer Coefficient and Gas Hold up in Solution of Electrolyte in Different Flow Regimes in Bubble Column. (Eng) 19th International Congress of Chemical and Process Engineering CHISA 2010 and 7th European Congress of Chemical Engineering ECCE-7, Summaries 3, p. 1031, Prague, Czech Republic, 28 August - 01 September 2010.
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[27] Novák P., Baszczyński M., Brányik T., Růžička M., Drahoš J.; Foam stability: effect of physico-chemical properties of beer. EUFOAM 2010 Conference, Borovets, Bulgaria, 14-16 August 2010.
[28] Novák P., Baszczyński M., Brányik T., Růžička M., Drahoš J.,: Influence of Physical Properties of Beer on Foam Stability: Bubble at Interface. 2nd International Symposium for Young Scientists and Technologists in Malting, Brewing and Distilling, Weihenstephan, Germany, 19-21 May 2010.

[29] Orvalho S.P., Cachaza E.M., Abadie T., Drahoš J., Růžička M.: Effect of Velocity on the Coalescence of Bubbles. (Eng) 19th International Congress of Chemical and Process Engineering CHISA 2010 and 7th European Congress of Chemical Engineering ECCE-7, Summaries 3, p. 1086, Prague, Czech Republic, 28 August - 01 September 2010.
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