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Fields of research

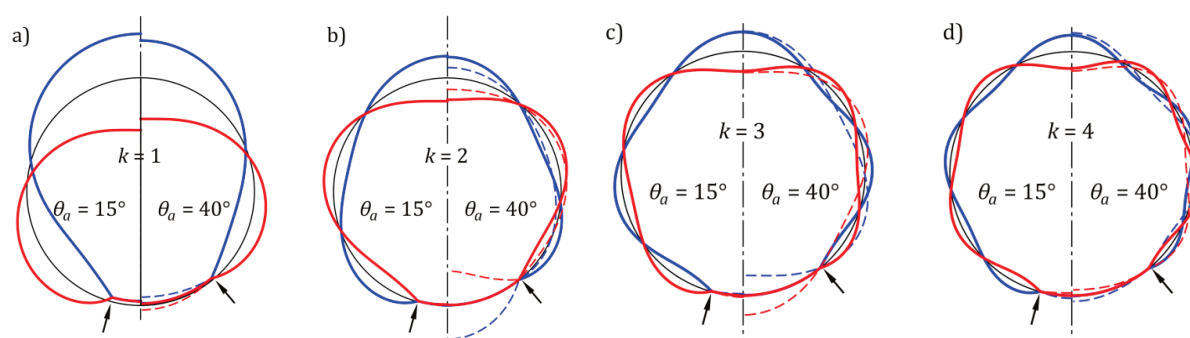
- Multiphase fluid dynamics and transport phenomena in different types of gas-liquid, liquid-solid or gas-liquid-solid systems
- Numerical simulations of transport phenomena in complex multiphase systems
- Influence of surface active agents on the multiphase flows
- Rheometry of microdispersions and non-Newtonian liquids
- Electrodiffusion diagnostics of the flow in microfluidic systems
- Flow characterization in fuel cells
- Hydroacoustic detection of bubbles using sonar in shallow reservoirs
- Sedimentation of polydisperse mixtures and complex ensembles
- Stability and behavior of complex beverage foams

Research projects

Effect of surfactants on the multiphase flow dynamics

(J. Vejražka, vejrazka@icpf.cas.cz; supported by GACR, project No. P101/11/0806)

The effect of surface-active agents on two-phase flows is studied. Flow types “air bubbles in the liquid” and “liquid drops in another immiscible liquid” are focused. Some specific situations, in which the surfactants modify the flow at the bubble/drop scale and in which this modification cannot be explained by a simple change of the equilibrium surface tension, are investigated experimentally. These situations are (i) the shape oscillations of a bubble/drop, both freely-rising or attached at a capillary tip; focus is put on the modification of oscillation frequency and decay time by surfactants; (ii) the coalescence of bubbles/drops, and also their attachment to a solid surface, with a focus on the drainage of liquid film between them; (iii) the bubble-solid surface collision, with a focus on suppression of the bubble rebound caused by surfactants and also on the modification of the attachment time; (iv) break-up of bubbles in a turbulent flow. The research should enlighten and document the effect of interfacial properties other than surface tension on two-phase flows. [Refs. 1, 11-13]

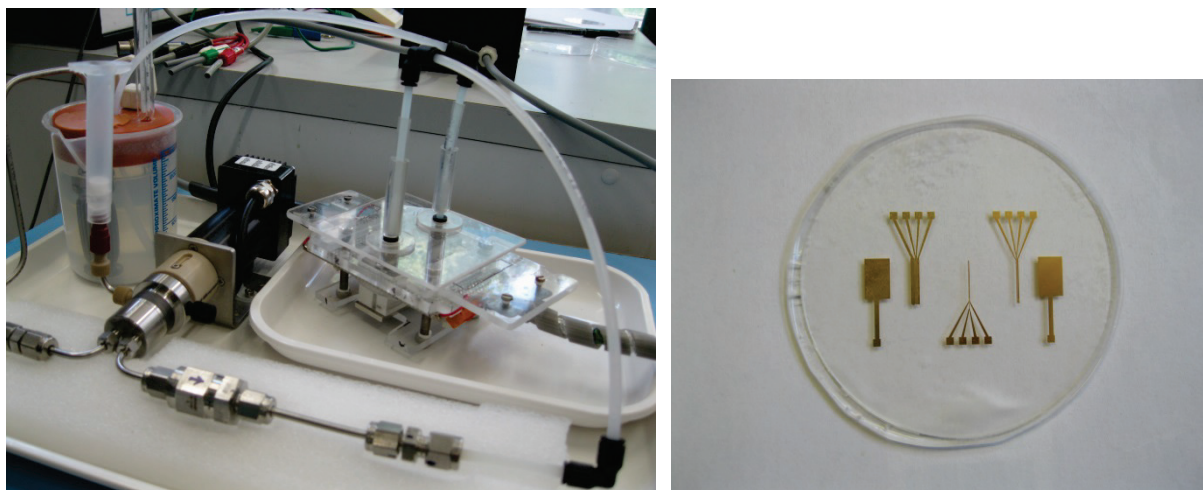


Shape of the first four eigenmodes of a pinned bubble. Left halves of figures represent attachment angle $\theta=15^\circ$, right halves of figures are for $\theta=40^\circ$. The attachment positions are indicated by arrows. Solid lines are for the Strani & Sabbeta constraint, dashed lines are for the Bostwick & Steen constraint. Blue and red lines correspond to positive and negative displacement of the interface at the apex, respectively

Application of the electrodiffusion sensors to the flow diagnostics in microfluidic systems

(J. Tihon, tihon@icpf.cas.cz; supported by GACR, project No. P101/12/0585)

The project is focused on characterization of two-phase flows in microfluidic systems. The high-tech fabrication techniques will be used to produce microdevices with precisely located microelectrodes. These electrodiffusion sensors for the near-wall flow diagnostics will be, for the first time, implemented at a microfluidic scale. The proposed measurements will provide information on the wall shear stress, the local flow structures, and the effect of bubbles/particles on the near-wall flow region (e.g. the liquid film under bubbles, the apparent wall slip in microdispersions). The application of the particle image velocimetry together with the microscopic visualization techniques will complete the hydrodynamic picture of the studied microfluidic flow configurations (junction, crossing, sudden expansion). It is expected that the electrodiffusion method will be proved as a suitable tool for microdevice diagnostics. The obtained experimental knowledge and the derived physical models will be useful for design, control, and optimization of microfluidic devices. [Ref. 9]

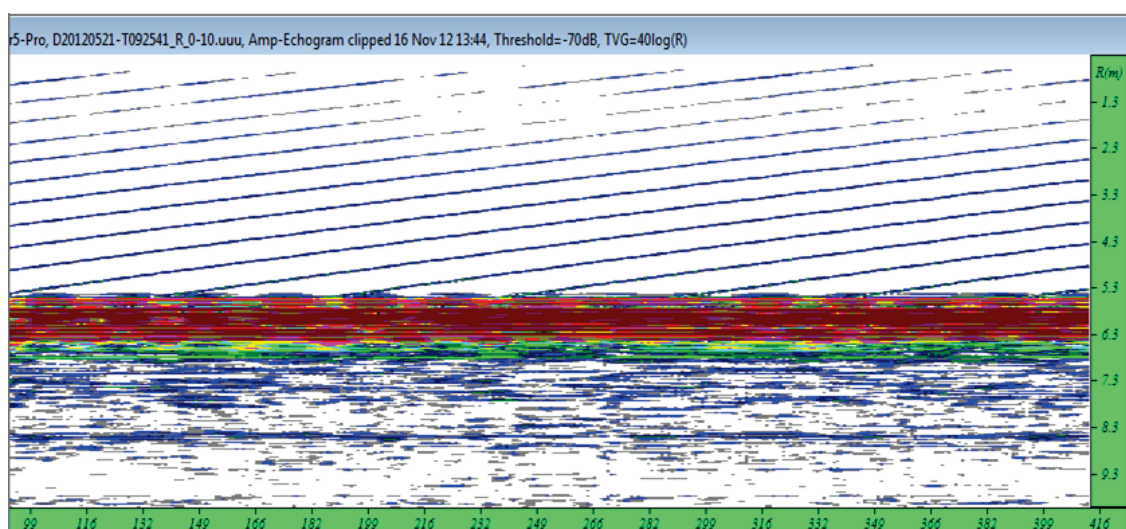


Experimental set-up used for electrodiffusion diagnostics of the flow in microchannels (left) and shown in detail the chip with microsensors (right)

Hydroacoustical distinguishing between fish and bubbles, and quantification of methane bubble ebullition in freshwater reservoirs of temperate zone

(P. Stanovský, stanovsky@icpf.cas.cz; joint project with Institute of Hydrobiology and Biology Centre of the ASCR; supported by GA CR, project No. P504/12/1186)

The acoustic parameters of rising methane bubbles will be measured by echosounders at different frequencies at man-made bubbles. The special algorithms using multi-frequency record will be developed to distinguish the bubble echoes from the fish echoes having the same acoustic size. The obtained method will be used to estimate of fish abundance and biomass more accurately. Further, the model describing the bubble rise and dissolution in will be modified for freshwater lakes. The relation between bubble volume and acoustic echoes from experiments with man-made bubbles will be used to gain more exact data about the amount of the methane bubbles ebullated from the chosen reservoirs in temperate zone. The spatio-temporal changes in their productions will be monitored also. At the end, the research should enlighten the correlation of the quantity and quality of ebullated methane bubbles with the environmental conditions.



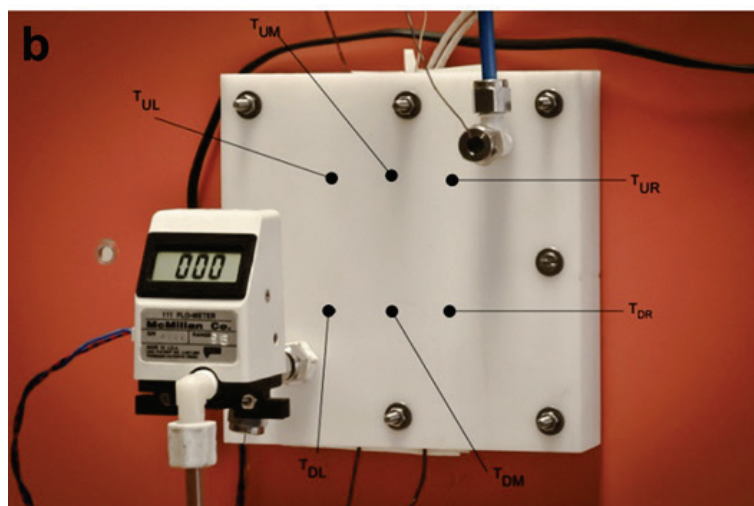
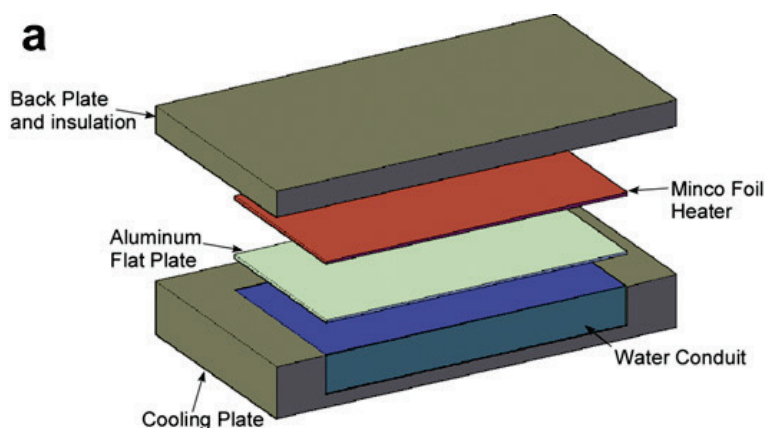
Acoustic echoes of 3 mm bubbles acquired by vertical 120 kHz sonar.
Blue lines represent rising bubbles and brown bar represents bottom of the lake
(ordinate – water depth, abscissa – time scale in signal pings)

Optimal heat integration of fuel cell systems

(J. Tihon, tihon@icpf.cas.cz; joint project with Aristotle University of Thessaloniki, Greece; supported by MEYS, project No. 7AMB12GR018)

Objectives of the project are as follows:

1. Develop electrodiffusion microsensors suitable for diagnosing flow in microfluidic devices using photolithography.
2. Use electrodiffusion and micro-PIV (particle image velocimetry) measurement technique to study the structure of the flow in microchannels with complex geometry.
3. Perform CFD (computational fluid dynamics) numerical simulations to study the effect of the geometry of heat exchangers for heat transfer and temperature homogeneity blocks PEM (polymer electrolyte membrane) fuel cells.
4. Propose a methodology for efficient management of heat transfer in mini heat exchangers used to cool the PEM fuel cells.



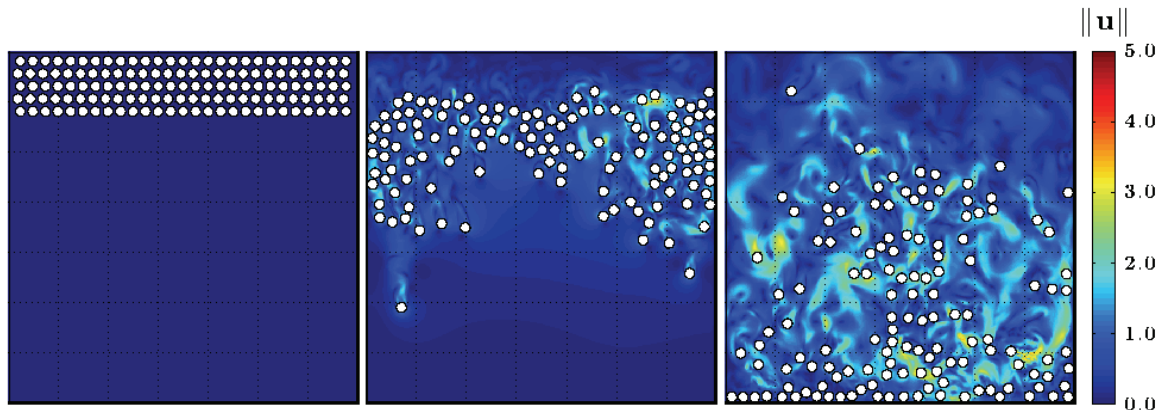
The experimental unit for the study of thermal behavior of the PEM fuel cells in Thessaloniki: (a) schematic representation, (b) photograph with the marked positions of thermocouples

Hydro-mechanical interactions of particles in solid-fluid systems

(J. Havlica, havlica@icpf.cas.cz; joint project with ICT; supported by GACR, project No. P105/12/0664)

The solid-fluid dispersions are very complicated multiphase systems with a wide range of interactions of different physical nature. The suggested project is focused on specific topic from this field: the hydromechanical interactions between the solid particles (discrete phase)

dispersed in a carrying fluid (continuous phase). The typical feature of these dispersions is the presence of two kinds of force interactions: the fluid forces on the dispersed particles and the mechanical forces between the particles at collisions. These interactions have crucial importance for prediction of flow behavior in process apparatuses or for correct design of industrial technologies. The main aim is to develop physical modeling concepts for solid-fluid dispersions. This concept is based on numerical simulations of these systems and benchmark experiments on static and dynamic behavior. We expect that the project brings important original results, which will help to understand flow behavior of multiphase systems. [Ref. 10]

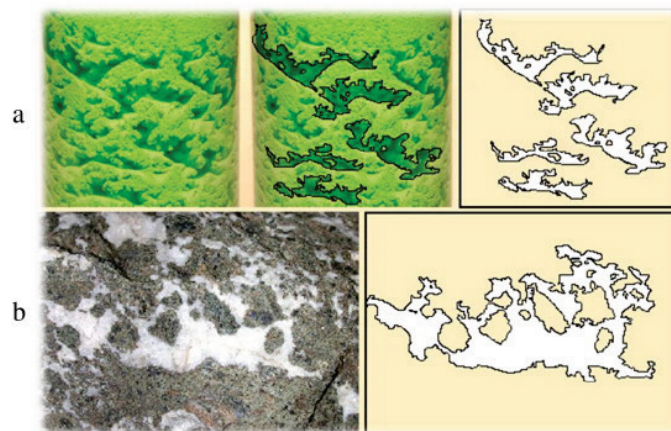


Sedimentation of 135 rigid particles simulated with immersed boundary method

Hydrodynamic concept of stromatactis formation in geology

(M. Růžička, ruzicka@icpf.cas.cz; joint project with Institute of Geology ASCR; supported by GA ASCR, project 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. [Ref. 3]

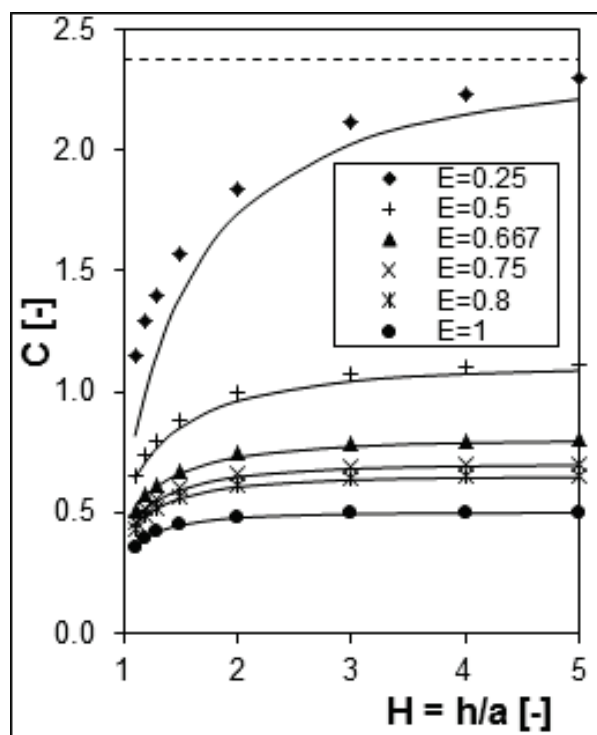


Stromatacta: arching caverns in sedimentary deposits.
a) Artificial man-made laboratory sample (picture width 6 cm)
b) Genuine petrified geological sample (picture width 10 cm)

Added mass closures for multiphase flow systems by means CFD

(M. Šimčík, simcik@icpf.cas.cz)

The added mass coefficient C is calculated for dispersed particles in different flow situations using the CFD simulations. Several geometrical configurations are considered, which are physically relevant and difficult to treat analytically. We study a single spherical and ellipsoidal particle near a gas/liquid interface, a pair of ellipsoidal particles in both the in-line and side-by-side arrangements, and an infinite array of spherical particles at different vertical and horizontal spacing. The effect of the key control parameters on the added mass is demonstrated. Where possible, easy-to-use closed formulas (correlations) are provided for the value of C . [Ref. 7, 8]



Added mass coefficient C for ellipsoidal particle near liquid / gas interface.
 C – particle added mass coefficient, H – dimensionless distance of the particle centroid from the interface, h – distance from the interface, a – particle semiaxis (perpendicular to the interface), E – particle semiaxis ratio (a/b)

International co-operations

Centre de Recherché et de Transfert de Technologies, Saint Nazaire, France: Microfluidics

Institute of Fluid Mechanics, Toulouse, France: Effect of surfactants on multiphase flows

Technical University Eindhoven, Eindhoven, The Netherlands: Bubble oscillations

Aristotle University of Thessaloniki, Thessaloniki, Greece: Microfluidics

Norwegian Institute of Technology (NTH), SINTEF, Trondheim, Norway: Bubble columns

Visitors

C. van der Geld, Technical University Eindhoven, The Netherlands
A. Passos, Aristotle Univ. of Thessaloniki, Greece
I. Stogiannis, Aristotle Univ. of Thessaloniki, Greece
T. Sanada, Dept. of Mechanical Engineering, Shizuoka University, Japan
M. I. A. Guerreiro, University of Braga, Braga, Portugal
M. Forest, INP ENSEEIHT Toulouse, France
A. Birem, INP ENSIACET Toulouse, France

Teaching

J. Drahoš, M. Růžička: ICT, Faculty of Chemical Engineering, postgraduate course
“Multiphase Reactors”
J. Havlica: UJEP, Faculty of Science, courses “Mathematics”, “Chemical Engineering”,
“Programming in Chemistry”, “Numerical Modelling of Heat and Mass Transport”
J. Tihon, J. Vejražka: ICT, Faculty of Chemical Engineering, postgraduate course “Bubbles,
Drops, and Particles”
M. Poštulková: ICT, Faculty of Food and Biochemical Engineering, “Cultivation Techniques
and Modeling of Bioprocesses”

Visits abroad

V. Sobolík: University of La Rochelle, France (12 months)

Publications

Original papers

- [1] Hubička M., Basařová P., Vejražka J.: Collision of a Small Rising Bubble with a Large Falling Particle. *Int. J. Miner. Process.* 121, 21-30 (2013).
- [2] Kárászová M., Šimčík M., Friess K., Randová A., Jansen J.C., Růžička M., Sedláková Z., Izák P.: Comparison of Theoretical and Experimental Mass Transfer Coefficients of Gases in Supported Ionic Liquid Membranes. *Sep. Purif. Technol.* 118, 255–263 (2013).
- [3] Kulaviak L., Hladil J., Růžička M., Drahoš J., Saint-Lary L.: Arching Structures in Granular Sedimentary Deposits. *Powder Technol.* 246, 269-277 (2013).
- [4] Poštulková M., Vitoušová K., Novák Pavel, Fiala J., Růžička M., Brányik T.: Historie a nové trendy v oblasti výzkumu přepěňování piva. (Czech) History and New Trends of Research Into Over-foaming of Beer. *Kvasný průmysl* 59(10-11), 317-320 (2013).
- [5] Růžička M.: On Stability of a Bubble Column. *Chem. Eng. Res. Des.* 91(2), 191-203 (2013).
- [6] Růžička M., Drahoš J.: O vícefázové hydrodynamice. (Czech) On the Multiphase Fluid Mechanics. *Čs. časopis pro fyziku* 63(4), 211-219 (2013).
- [7] Šimčík M., Růžička M.: Erratum to Added Mass of Dispersed Particles by CFD: Further Results [Chem. Eng.Sci. 97(2013), 366–375]. *Chem. Eng. Sci.* 99, 139-140 (2013).
- [8] Šimčík M., Růžička M.: Added Mass of Dispersed Particles by CFD: Further Results. *Chem. Eng. Sci.* 97, 366-375 (2013).
- [9] Tihon J., Pěnkavová V., Vejražka J.: Wall Shear Stress Induced by Taylor Bubbles in Inclined Flow Channels. (Eng) *EPJ Web of Conferences* 45, 01089 (2013).

- [10] Trávníčková T., Havlica J., Ždímal V.: Description of Fluid Dynamics and Coupled Transports in Models of a Laminar Flow Diffusion Chamber. *J. Chem. Phys.* 139(6), 064701-14 (2013).
- [11] Vejražka J., Vobecká L., Tihon J.: Linear Oscillations of a Supported Bubble or Drop. *Phys. Fluids* 25(6), 062102 (2013).
- [12] Vejražka J., Vobecká L., Tihon J.: Oscillations of Bubbles Attached to a Capillary: Case of Pure Liquid. *EPJ Web of Conferences* 45, 01092 (2013).
- [13] Vobecká L., Vejražka J., Tihon J.: Modification of Shape Oscillations of an Attached Bubble by Surfactants. *EPJ Web of Conferences* 45, 01095 (2013).

Patents

- [14] Brányik T., Růžička M., Poštulková M.: Zařízení pro stanovení přepěňování sycených nápojů. (Czech) Device for determining excessive foam formation of saturated beverages. *Pat. No. 26362/PUV 2013-28285*. Applied: 13.08.05, Patented: 14.01.20.