LMPT

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e Propriedades Termofísicas

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Scientific Exchange Mission

Programme International de Cooperation Scientific (Pics) France-Brazil

28/11/2003-18/12/2003

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Present scientific exchange mission was undertaken for exploring possible cooperative research works among Porous Media and Thermophysical Properties Laboratory from Federal University of Santa Catarina (LMPT/UFSC), Groupement d'Études sur les Milieux Poreux from the Institut de Mécanique des Fluides de Toulouse (GEMP/IMFT) and the Fluides, Automatique et Sciences Thermiques Laboratory (FAST/Université Paris XI).

Agenda

29-30/11: Displacement Florianópolis-Toulouse

01-5/12: Contacts and discussions with researchers of GEMP/IMFT

07/12: Displacement Toulouse-Orsay

08-12/12: Contacts and discusion with researchers of FAST/Orsay

17-18/12: Return to Brazil

Contacts and discussions with researchers of GEMP/IMFT

Monday 01/12 morning: Discussion with the doctoral students Frederique (Percolation networks for modelling the fluid flow in the porous space formed by contacting two rough surfaces), Olivier Amyot (Visualizaton of two-phase flow in the porous space formed by contacting a rough and a plane transparent surface, Break-up of the invading phase in constrictions), and Olivier Chapuis (Fuel-cells).

Monday 01/12 lunch with Vincent Pavan and Paul Duru

Monday 01/12 afternoon: Discussion with the doctoral students Vincent Pavan (Optimisation of mould and core quality and materials usage in the metal castings industry), Laurent Oxarango (Filtration), Franck Noel (Boundary elements for modelling the monophasic flow through beds of particles with excentric exit sections) and Kader Benmachou (Filtration).

Tueday 02/12 morning: Discussion with Michael Quintard (volumetric averages, combustion)

Tuesday 02/12 lunch with Michael Quintard

Tuesday 02/12 afternoon: discussion with B. Camassel (Evaporation in capillaries and micromodels: influence of liquid films on the drying rate, infrared visualizations of temperature fields).

Wednesday 03/12 morning: discussion with Marc Prat

Wednesday 03/12 lunch with M. Prat

Wednesday 03/12 afternoon: Discussion with M. Clifton, M. Meireles and P. Joly from L'Instutut National Sciences Appliquées (INSA/Toulouse). Presentation of LMPT activities in lattice gas and lattice-Boltzmann studies. Phase transition in microcapillaries.

Thursday 04/12 morning: Meeting with Stephan, M. Clifton, M. Meireles and P. Joly at L'Instutut National Sciences Appliquées (INSA/Toulouse). Presentation of LMPT activities in lattice gas and lattice-Boltzmann studies. Phase transition in microcapilaries.

Thursday 04/12 lunch with F. Plouraboué.

Thursday 04/12 afternoon: Discussion with F. Plouraboué (Percolation networks for modelling the fluid flow in the porous space formed by contacting two rough surfaces, visualizaton of two-phase flow in the porous space formed by contacting a rough and a plane transparent surface, break-up of the invading phase in constrictions).

Friday 05/12 afternoon: Presentation of a lecuture about lattice-gas and lattice-Boltzmann models for fluid flow inside porous microestructures.

Contacts and discussions with researchers of FAST/Orsay

Main discussions were undertaken with D. Gobin (Splash), L. Talon (Lattice-Boltzmann based model for studying fluid flow through two-dimensional representations of non-homogeneous pore structures), H. Auradou (Dispersion and miscible displacement in fractures) and N. Rakotomalala (Viscous instabilities in heterogeneous porous media).

A discussion was undertaken with D. Humières and P. Lallemand from École Normale Supérieure de Physique about lattice-Boltzmann modelling and simulation.

Possible cooperation works that could be undertaken

Several research works that are being developed at GEMP and FAST are of great scientific interest and present very interesting perspectives in various technological fields: space industry, energy, petroleum exploitation, hydrology, rejects propagation in soils, metallurgy etc.

Considering the present fields of interest at the LMPT, I found very promising issues for a scientific exchange work in relation with the topics below.

a) Fluid flow visualization and modeling in the space between rough surfaces. Both at FAST and GEMP, rough surfaces are being produced by using a ~300 μm curvature radius miller in a computer -operated milling machine, giving a rough surface with some 10 μm of spatial resolution. This surface is pressed against flat transparent surfaces for flow visualization (Figure 1).

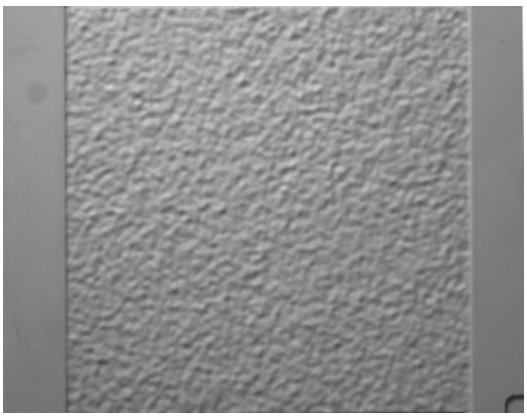


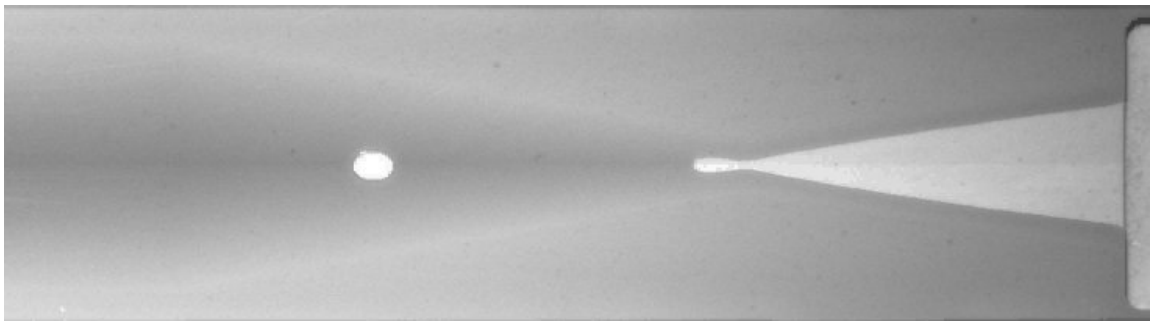
Figure 1 Rough surface produced by milling at GEMP (Courtesy of O. Amyot)

At FAST rough surfaces are, also, produced by melting plastic materials against fractured rock surfaces. By using asymptotic expansions Plouraboué, Geoffrey and Prat, from GEMP, found the hydraulic conductance of a small slope single constriction in terms of local curvature radii. This result is, presently, being used by the doctoral student Frederique for the estimation of the overall hydraulic conductance of joints. Imbibition and drainage visualizations were being undertaken by Olivier Amyot. At FAST, the permeability of fractures with shifted rough surfaces was studied and the dispersion trace particles in self-affine fractures was experimentally observed and simulated using a lattice-Boltzmann model in cooperation with Joel Koplik from the City University of New York.

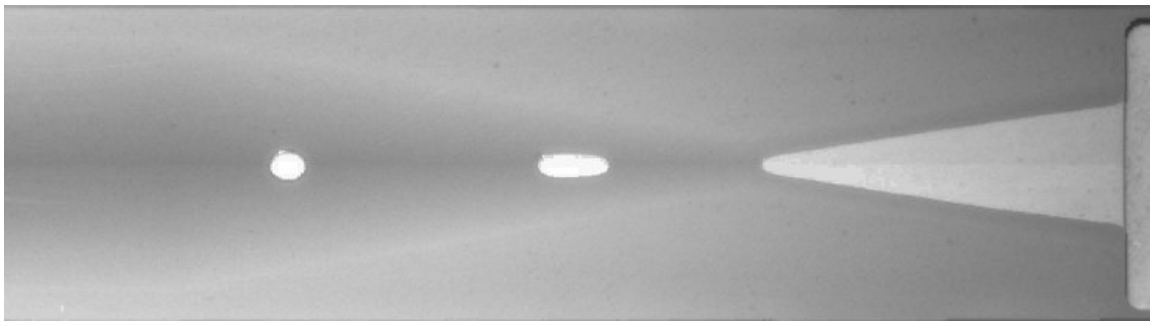
Comments. i) Lattice-Boltmann simulation in fractures with rough surfaces, for comparative purposes, requires simulating in lattices with around 50 X 10^6 sites; ii) The production of rough surfaces could, perhaps, interest Precision Mechanics Laboratory (milling) and Materials Laboratory (laser) of our Mechanical Engineering Department at UFSC.

b) Break-up of the invading phase in constrictions.

This is a very interesting dynamical effect, which is being investigated at GEMP and that could be, possible, numerically investigated with the IMLB model developed at LMPT. There is, apparently, the formation of a Landau-Levich-Bretherton thin film around the non-wetting phase at the entrance, before the constriction. In the macroscopic approach, this film was introduced by equating the surface and viscous forces as a necessary condition for avoiding a singularity in the contact angle at the triple line. In IMLB lattice-Boltzmann model the triple line is, in fact, an *entire transition region* which is the site of a strong field interference (Figure 3). A detailed LB investigation of this region could, perhaps, help to understand the overall dynamical behavior of the triple line and the formation of Landau-Levich-Bretherton films.



(a)



(b)

Figure 2 Break-up of the invading phase in constrictions (Courtesy of O. Amyot)

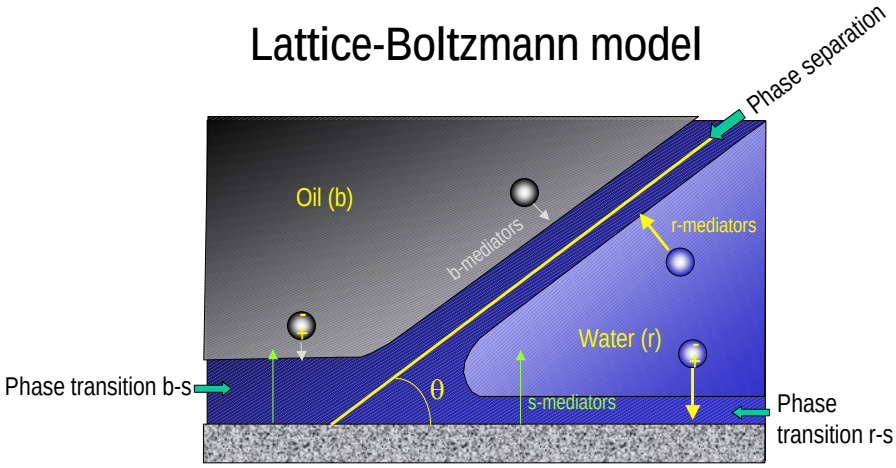


Figure 3 Triple line structure.

c) Phase transition inside capillaries and micromodels.

Although a main research line at GEMP in the last ~10 years, giving rise to the doctoral thesis of J. B. Laurindo from UFSC, this work is presently being developed at GEMP/IMFT in cooperation with Energetics Laboratory of INSA/Toulouse and concerns the analysis of the porous element of capillary heat pumps, during drying. B. Camassel doctoral thesis was developed in this context. Main scientific results were obtained concerning the analysis of the influence of liquid films on the evaporation rate, both in very thiny capillaries and in conventional micromodels made up by two-dimensional arrays of square sections cylinders. Experiments were conducted by using an infrared camera for temperature field visualization.

Comments: A lattice-Boltzmann model is presently being developed at LMPT/UFSC for phase transition in the context of Rodrigo Surmas doctoral thesis. Capillary heat pump analysis is among

LABCET/UFSC (Edson Bazzo and Amir Martins de Oliveira) and INPE (Vlassov) main research interests and a cooperation work could be accomplished by extending the present cooperation work to involve the brazilian laboratories LABCET, LMPT and INPE and the french laboratories GEMP and INSA.

d) Droplet impact on solid surfaces

The fundamental problem of a liquid droplet impacting on a solid surface is a chief problem in coating deposition, in metallurgy. This work has been developed at FAST in the context of the doctoral thesis of R. Rioboo (2001). Several experimental visualizations were performed using a high-speed camera for the impact of water droplets on polished glass, wax and PVC. The spreading, crown formation, tiny droplets projection and rebound during the impact was observed to be higly dependent on the wettability, Reynolds and capillary number and on the surface roughness.

Comments: i) *Lattice-Boltzmann simulation of droplet impact on solid surfaces using IMLB model could be developed in the context of Fabiano Gilberto Wolf doctoral thesis at LMPT; ii) This kind of work could perhaps interest Welding Laboratory at UFSC, which is developing studies in coating deposition on metallic surfaces.*

Proposed cooperation works

LMPT/UFSC-GEMP/IMFT

Lattice-Boltzmann simulation of fluid flow through constrictions for arbitrary curvature radius. Comparison with asymptotic results.

Drainage from a constriction leading to the break up of the invading non-wetting phase.

Drying inside capillaries and porous elements (involving INSA, LABCET and INPE)

LMPT/UFSC-FAST/Orsay

Splash: lattice-Boltzmann simulation of the droplet impact against solid surfaces.

Further contacts

Very fruitful discussions were undertaken with Energetics Laboratory researchers from INSA/Toulouse (Stephan, Joly, Clifton and Meirelles) and with D. d'Humières and P. Lallemand from ENSP/ Paris (École Normale Superieure de Physique).

A version of LMPT software (Imago) was left with M. Clifton for the prediction of macroscopic properties of porous media starting from micrographies of porous microstructures. Further contacts are expected concerning the use and the feasibility of the software Imago in predicting the permeability and other relevant macroscopic parameters of interest .

An important discussion was undertaken with D'Humières and Lallemand, who are among the world main responsibles for lattice-Boltzmann development. LMPT developments in lattice-Boltzmann theory (IMLB model for immiscible fluids and lattice-Boltzmann modelling of fluid-solid interaction) were discussed. Intensive scientific exchange between LMPT and ENSP is expected in 2004, particularly, in the following topics: a) moments method for immiscible fluids / stability analysis (L.A. Hegele doctoral thesis); b) boundary conditions; c) thermodynamic consistent lattice-Boltzmann models leading to phase transition (Rodrigo Surmas doctoral thesis) and d) fluid-solid interaction (Fabiano Wolf doctoral thesis).

Final Comments

In author's opinion, present exchange mission was very fruitful from a scientific point of view. Cooperation works with GEMP and FAST and involving not only the LMPT, but also some other laboratories in Brazil were envisaged. Author is indebted with C. Moyne, M. Prat and D. Gobin for making the present mission possible.

Florianopolis, January, 19, 2004

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