Subprojet 6 "Physics of the Fluids and Materials in Space"

1. Context

The Laboratory Modeling and Numerical Simulation in Mechanics and Engineering (L3M), UMR 6181 CNRS-Aix-Marseille University, in partnership with the Hydrodynamic School of Perm, animates several research projects in the space field, in particular within the framework of the "Theoretical Support Group: Vibrational Dynamics and Control" of the European Space Agency, since June 2001, in the context of the use of the International Space Station, automatic satellites of FOTON type and sounding rockets. They also contribute jointly to the numerical study of complex convective flows occuring on ground-based facilities in which magnetic compensation simulate the conditions of microgravity, such as those developed by the CEA Grenoble (DRFMC) and by INPL-Nancy (LEM, UMR 7569 CNRS-INPL). Several French, Russian and European Laboratories are partners of these studies.

2. Research

(a) Material processing from melt; complex hydrodynamics and control

The main studies concern an hydrodynamic control of heat & mass transfers during material processing (mainly monocrystals) by the technique of directional solidification from melt (form of solidification facets, morphological instability, macrosegregation, microsegregation, etc.). Various types of hydrodynamic control are considered: by vibration mono-frequency (translational or torsional), and/or by magnetic field. The studies involve modeling and development of the suitable equations describing the fluid motion and the heat and mass transfers, generally three-dimensional and non stationary.

- Control of morphological instability by torsional vibrations (alternate rotations of the bulk of growth compared to its axis), in the case of a device of the Bridgman type; Coop. L2MP-Marseilles
- Vibrational Convection in a device of floating-zone type; experiment Maxus 6 (sounding rocket); high frequency vibrations are shown to reduce the thermocapillary flow in microgravity, molten metals and semi-conductors (at low Prandtl number: Pr=0.01-0.1); experiment prepared by the colleagues of the Institute of Crystallography of Freiburg (Germany) ; support ESA.
- Influence of vibrations to the measure of the coefficients of thermodiffusion (Soret) and diffusion in alloys (partnership, J.CL. Legros; Research Center for Microgravity, Univ. Libre de Bruxelles).
- Influence of vibrations on systems close to the critical point; partnership with Daniel Beysens (ESEME-CEA) and Yves Garabos (Univ. Bordeaux).
- Reaction of a dissipative granular gas and formation of clusters under vibration; partnership with Pierre Evesque (Ecole Centrale Paris).

(b) Modeling and numerical simulation of problems of flows and coupled transfers occuring in the environment of life, and/or the Life sciences during long-term missions (future planetary explorations).

- Modeling and numerical simulation of problems of 3D flows and transfers of heat, moisture and species (in particular, CO2) in a space module and/or a space greenhouse; i.e., with forced ventilation, heat transfer by radiation, evaporation/condensation, etc….

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- Application: Environmental control by an optimized forced ventilation, distributions of oxygen, temperature and moisture in such an environment.

(c) High performance computing

The complexity of the problems to solve (non stationary three-dimensional flows, coupled transfers: thermal and solutal), as well as the very great number of parameters impose the recourse to the techniques of high performance computing for the resolution of the equations describing the physicochemical phenomena in the liquid phases. Two ways of studies are considered: (a) numerical analyzis, and in particular, parallel algorithmic; (b) choice of architectures of the platforms of parallel computing: calculation on cluster, grid of calculation allowing to use simultaneously several distant platforms (cluster of clusters).

(d) Use of magnetic compensation systems to simulate the microgravity

The magnetic compensation of gravity is a technique developed in France in a partnership between the CEA - DRFMC in Grenoble and the LEM at INPL-Nancy. The magnetic compensation units are used to carry out studies on the behavior of space propergols. Within the framework of project ARCUS, the activity in this field is devoted, jointly with the Russian laboratories, to the study of granular media.

3. Research-training network

Several Russian students are associated with these joint studies as a research-training network, not only with the support of ARCUS programme, but also in the framework of french-russian research-training network of the MESR-DREIC, and additional support of the French Embassy.

It concerns co-supervision of doctoral and master Russian students from Perm State University, Institute of Continuous Media Mechanics in Perm, Novosibirsk State Technical University, Taganrog Institute of Technology (Federal Southern University).

Perspectives :

- dialog for the installation of an International Master of Fluid Mechanics, between Marseilles University and Perm State University (Leading School in Hydrodynamics of Russian Foundation of Basic Research); coord. Prof Christian Kharif (ECM).
- dialog for the installation of a Franco-Russian Research-Education Center in Continuous Media Mechanics (proposal made by Valeri Matveenko, director of the REC (Research-Education Center)" on nonequilibrium processes in continuous media" in Perm.

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