EFFECT OF THERMAL BOUNDARY MODULATION IN A RESTRICTED FLUID DOMAIN OF A 3D VERTICAL BRIDGMAN APPARATUS

E. Semma[1], M. El Ganaoui[1], R. Bennacer[2], V. Timchenko[3], and E. Leonardi[3]

1) SPCTS-UMR CNRS 6638, Université de Limoges/Faculté des Sciences, Limoges

2) LEEVAM, Univ. Cergy-Pontoise, 5 mail Gay Lussac, Neuville sur Oise 95031, France

3) The University of New South Wales, Sydney, Australia 2052

Fluids heated from below provide non linear behaviour very rich and interesting in many scientific fields. The classic Rayleigh-Benard problem offers a first approach to this complexity of flow evolving from a conductive to convective regime and a first predictive way of coupling with solid/liquid transition.

Phase change is of great importance in the materials and crystal growth processes. The control of this phenomena permits growth of high quality pure crystals. Stable dynamic solutions are of interest in practice because of their impact on the constitution control. For example, in electronic applications, growth involves convection dominating dopant segregation and influencing interface shape.

Two-dimensional (2D) models are used for predictive investigation of directional solidification configurations based on thermal or solutal control, under full or low gravity conditions. Recently three-dimensional (3D) computations have been limited to high Prandtl number. This study focuses on the three-dimensional character of low Prandtl number flows and on symmetry breaking phenomena which can produce some unsteadiness in the flow and consequently perturb the solid/liquid interface shape and dopant distribution. Only the hydrodynamics in the melt is analyzed in this paper.

In past papers the critical stability limit for the onset of the natural convection in two-dimensional flows was undertaken and the threshold value for breaking symmetry and unsteadiness were identified. In the present work, this problem is studied using three-dimensional simulations thus overcoming the limitation of the 2D assumption. The geometry studied is shown in Figure 1. It has been found that the initially steady symmetric flow in the 3D case becomes asymmetric for lower *Ra* number than for the 2D case. The breaking in symmetry occurs firstly in the transverse plane. For the relatively low *Ra* number we still have no intensification in the global heat transfer but it appears that the heat transfer increases locally on the bottom and decreases on the vertical active walls. The classical spiral flows typical for the 3D effect (in the third direction) is also identified.

Heating conditions varying with time interacts with flow characteristics and the unsteadiness thresholds, such situations are encountered for example for electronic component energized inducing unsteady generation of heat.

The heat and mass transfer regarding the amplitude and the frequency of a given oscillation imposed to the hot wall $T_H = 1 + \varepsilon \sin(2\pi f t)$ exhibits a particular behaviour when compared to the configuration without modulation. Starting with the steady regime for a given low Rayleigh number, modulation can activate a resonant state for which it is possible to predict the next oscillatory state that the system can reach without modulation but only with increasing the intensity of the convection (higher Ra).

2D observation with modulation will be investigated for the 3D case, the steady state regime will be studied on terms of stream function variation an averaged Nusselt number.

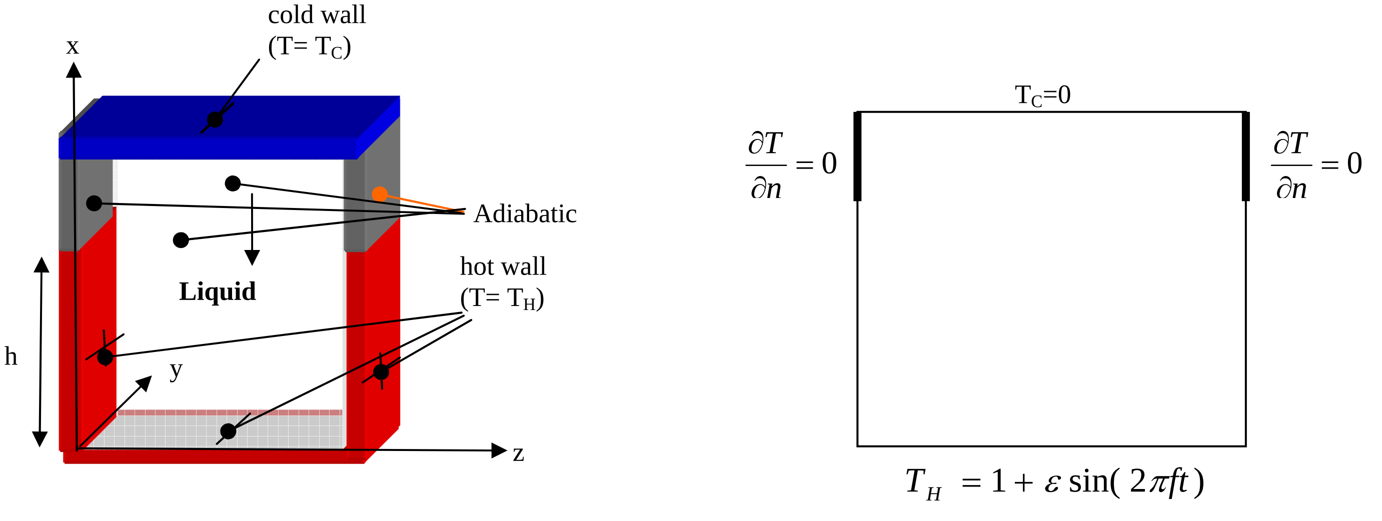

Figure. 1 : Geometrical configuration - 3D full domain and 2D domain.