REGULAR ARTICLES

TRANSIENT NATURAL CONVECTION IN A HORIZONTAL FLUID LAYER, WITH A BLACKBODY BOTTOM; HEATED FROM ABOVE BY RADIATION

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***Abstract* - Transient natural convection in a horizontal fluid layer, with a blackbody bottom, heated from above by radiation was studied experimentally and numerically. The heat flux which reaches to the bottom is absorbed by the black surface and reheats the fluid layer from the bottom, creating an adverse temperature gradient at the bottom of the fluid layer similar to the one observed in the classical Rayleigh-Bénard problem.**
A mathematical model was developed and governing differential equations were numerically solved. The predictions of the model were found to be in an acceptable agreement with the experimental temperature distributions obtained in a laboratory scale pool by holographic interferometer techniques.
Experimentally and numerically calculated heat convection coefficients were correlated in terms of Nusselt and Rayleigh numbers and compared with a literature correlation. It is concluded that this problem is very similar to the classical Rayleigh-Bénard problem of a horizontal fluid layer heated from below.

***Keywords* - Transient natural convection, Rayleigh-Bénard problem, thermal instability, holographic interferometer.**

I. INTRODUCTION

Natural convection heat transfer in horizontal fluid layers has been widely investigated by number of researchers. In most of the cases the layer is heated from the bottom and cooled from the top. The first experimental studies were carried out in the beginning of the twentieth century (Bénard, 1901) and the theoretical ones were realized few years later (Rayleigh, 1916). Extended summaries of various studies, under different boundary conditions, by various researchers are presented by Gershuni and Zhukhovitskil (1972) as well as Chandrasekkar (1961).

In general, a horizontal fluid layer heated from the bottom is inherently unstable. Heat is transferred through conduction up to some certain temperature difference and in this regime the fluid is stable. After a critical value of temperature difference the fluid particles show a tendency to move vertically. At this point onset of convection is established. In convection regime some hexagonal cells, called Bénard cells, are formed (Bénard, 1901). After this point the movements of particles depend on two forces competing each other; buoyancy forces and viscous forces. Practical applications of this problem are seen in cooling of electronic equipments and thermal storage tanks.

Enhancement in Rayleigh-Bénard convection was studied by Domaradzki (1989), showing that with proper forcing, it is possible to control the size of convection cells. Hernández (1995), studied numerically the influence of heat transfer rate over the flow transition. Cerisier *et al.* (1998) analyzed the onset of convection in a horizontal fluid layer between two plates, with different thicknesses and thermal conductivities, and found a good agreement between his model and experiments. Thermal instability of fluids with high Prandtl numbers was experimentally studied by Wakitani (1994). Prakash and Koster (1996) studied the Rayleigh-Bénard problem in a system of two immiscible fluids. They observed that the convection in the two-layer system is characterized by two distinct coupling modes between the layers. They are thermal coupling and mechanical coupling.

On the other hand, in case of heating from above, if the bottom of the fluid layer is a blackbody, the heat flux which reaches to the bottom is absorbed by the blackbody bottom and reheats the fluid layer from the bottom, creating an adverse temperature gradient as the one encountered in the classical Rayleigh-Bénard problem of thermal instability. This is the phenomenon seen in solar ponds. Kozanoglu (1993) observed that, in case of heating from above, the instability phenomenon occurring at the bottom of the fluid layer with a blackbody bottom is very similar to the one in classical Rayleigh-Bénard problem and the experimental critical Rayleigh number is found to be very close to the theoretical critical Rayleigh number given in the literature.

II. EXPERIMENTS

Transient natural convection in a horizontal fluid layer with a blackbody bottom, heated from above was first studied experimentally. The holographic interferometry set-up shown in Fig. 1 was used to find time dependent temperature profiles through the fluid layer.

The experiments were carried out in a laboratory scale pool, with dimensions of 200mm x 70mm x 180mm. The bottom of the pool was made of 10 mm. thick aluminum, which is painted black, while