

# CONVECTION IN A RECTANGULAR CHANNEL WITH A FLOW OF WATER IN LAMINAR-TURBULENT TRANSITION WITH HIGH HEAT FLUXES

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**Abstract**— In this work we examine the phenomenon of laminar-turbulent transition in a heated rectangular channel under high heat fluxes and water as a working fluid. We use an experimental device that allows the electric heating of the walls and the measurement of its temperature through thermocouples housed beneath the surface. The results of this initial exploration clearly show the dependence of the convection coefficient on the heat flux through different mechanisms. In first place we can see an increase in the convection coefficient with the heat flux that is correctly predicted for laminar and turbulent flows by the Sieder-Tate correction. In second place, there was a clear change of behaviour that corresponds to the start of the transition to turbulence. The Reynolds number that corresponds to the departure from laminar behavior was independent of the heat flux in the walls within the conditions covered in this study.

**Keywords**— Convection, hydrodynamic transition, heat flux, rectangular channel.

## I. INTRODUCTION

The main objective of this work is to investigate experimentally the thermo-hydraulic behaviour of a coolant channel similar to those found in the core of a nuclear research reactor. In this particular work we focus on the laminar to turbulent transition hydrodynamic regime with high wall heat fluxes. In our laboratory we began working on this issue starting with the RA6 research reactor power increase project. The RA6 is a pool type research reactor with a downward refrigerating flow forced by a pump. In the original design the flow between the fuel plates is in the laminar regime. A possible operation scenario involves a refrigerating flow between the fuel plates in a transition regime. This situation prompted us to make an experimental study in order to verify if the convection correlations developed for round tubes would apply to rectangular channels with high heat fluxes and regimes close to the transition to turbulence (Silin *et al.*, 2007)

The pure hydrodynamic behaviour of rectangular channels has been studied under different conditions (Schlichting, 1979; White, 1991) resulting in a general

consensus that even in micro-channels (Hartnett *et al.*, 1965) the transition occurs for Reynolds numbers between 1800 and 2500. Above these Reynolds numbers the application of correlations for the turbulent regime is often accepted.

In contrast, the transition regime with heat transfer from the walls has not been studied experimentally in depth (Kandlikar *et al.*, 2006; Boye *et al.*, 2007). In an experimental study, Celata *et al.* (2002) have obtained the values of the transition Reynolds for capillary tubes of 0.13mm diameter, but even here the study is not detailed. It is a known fact that the transition regime is extremely sensitive to experimental conditions as the roughness of the walls and entry conditions (Schlichting, 1979; Wibel and Ehrhard, 2006). Similarly it is expected that in a heated section the varying properties of the fluid near the wall due to temperature gradient may also affect the transition to turbulence (Ozgen, 2004; Sameen and Govindarajan, 2007). In particular Ozgen, shows that in the boundary layer of external water flows the heat flux causes a delay the transition to turbulence. In contrast, the variation in the fluid density, that brings the natural convection phenomenon, appears to have a negligible effect in the transition regime in mini-channels (Delmastro *et al.*, 2007).

Another important aspect is the occurrence of gas phase, even at temperatures below the temperature of saturation. This phenomenon is originated in the increase of the water temperature, causing a significant reduction of the air solubility in the water. The presence of dissolved gas may lead to the nucleation of gas bubbles in small pores of the walls. In general this phenomenon improves convection, however it has been shown experimentally that in some cases it may also affect the convection adversely, such as in micro-channels (Steinke and Kandlikar, 2004). To prevent the occurrence of this phenomenon, in this work we make sure that there is no presence of dissolved air in the water by boil degassing it.

Thus we can see that the heat transfer in rectangular channels under high heat fluxes can present various phenomena that are beyond the more traditional approaches and require special attention. Moreover, the combination of these factors has to be subject to a thor-