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Title of the thesis: *„Boiling of water at low pressure: the role of subcooling and thermophysical properties on the bubble dynamics and heat transfer"*

Abstract of the manuscript

Boiling is a common heat transfer mode used in many applications, e.g. evaporators of air-conditioning and refrigeration units. I is considered very efficient heat transfer mode, as generally it is characterized by higher values of heat transfer coefficient in comparison to natural or forced convection [1]. Recently, there is a sparkling interest in the development of efficient cooling technologies which utilize environmentally-friendly refrigerants. Some of those mediums, e.g. water, need to evaporate at low pressure to achieve cooling: for instance, a saturation temperature of 10°C corresponds to a saturation pressure of 1.2 kPa).

Close to the triple point, the physics of boiling is significantly different in comparison to atmospheric pressure. This statement concerns both, thermal features (larger wall superheat required to initiate boiling, smaller values of heat transfer coefficient) and bubble dynamics (larger bubble size, smaller frequency of bubble detachment) [2, 3]. Although the knowledge on subatmospheric boiling is slowly growing, many of its aspects remain unknown or vaguely theoretical. For that purpose, there is still a need to extend the knowledge concerning boiling phenomena from a fundamental point of view. To do so, extensive experimental studies should be performed.

The initial analysis provided in this thesis was focused on isolated bubbles. A novel heat flux sensor was used to measure the instantaneous heat flux independently in seven concentrically zones of a heated surface on which boiling was taking place. Its utilization was especially beneficial at low pressure as larger bubble size simplified the observation of the bubble foot. Such analysis allowed to discover three types of low pressure bubbles and confirm existence of associated thermal phenomena, such as microlayer evaporation and movement of the liquid pool during bubble growth.

In order to get an insight into boiling phenomena for more practical applications, another test campaign was conducted on a rough surface where multiple nucleation sites were activated simultaneously. The experiments were carried out for a wide range of operating parameters. A special attention was put towards the level of liquid, as it creates a pressure-induced subcooling resulting in the strong effect on the bubble diameter and bubble growth time. Because of the random character of the boiling process, a statistical analysis of the instantaneous heat flux was proposed. Based on this approach, four distinct boiling regimes were distinguished and characterized. To provide a more general description of boiling regimes over wide range of operating conditions, a dimensionless boiling regime map was proposed. Such interpretation is also useful in order to determine the thermo-hydrodynamic features of subatmospheric boiling and to verify what regime is expected under specific working conditions.

An alternative idea for some types of low-pressure evaporators (e.g. shell and tube) can be the evaporation of small droplets sprayed onto the heated wall. Such approach can be beneficial at low pressure, as large bubbles could form dry patches on the heated surface inhibiting the efficient heat transfer normally expected. In the literature, there is lack of knowledge concerning the evaporation process at subatmospheric conditions. For that reason, the last experiments were focused on the evaporation process of a small drop or thin layer of liquid from a hot horizontal surface. Based on the heat flux measurements and high-speed camera recordings, distinct thermal processes occurring during drop evaporation were distinguished. This demonstrated that the use of this heat flux sensor is a promising track for the study of drop evaporation and spray cooling at low pressure.

Literature:

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Signature of the PhD student