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Tomasz Hałon, Msc.

„OPTIMISATION OF BOILING IN LOW PRESSURE ADSORPTION TRIGENERATION SYSTEM"

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PhD summary:

High values of Heat Transfer Coefficient during boiling are a consequence of nucleation, growth and departure of vapor bubbles The growing bubble receives the heat through evaporation of the liquid phase into the vapor feeding the bubble. The growth of the bubble causes the movement of the liquid close to the heating surface, and its departure causes the mixing of the liquid boundary layer. This is the reason why the shape, the diameter and the bubble departure frequency are important during boiling.

Among the known fluids, the water is characterised by the highest latent heat of evaporation. This means that in terms of mass unit, the water is able to receive the biggest amount of heat. It is one of the most widespread substances on Earth and non-toxic, non-flammable and environmentally neutral. These properties make water a potentially efficient refrigerant. The negative aspect of using water as a refrigerant is its high saturation pressures corresponding to the temperatures suitable for air-conditioning (5-12°C). These are 0.87 and 1.4 kPa respectively.

Analysis of the data available in the literature shows that during sub-atmospheric boiling, the nacessary wall superheat for the onset of boiling is higher than 10 K. Under such conditions, the bubbles have diameter bigger by the order of magnitiude compared to those under atmospheric pressure, and their departure frequence is lower. Moreover, heat transfer coefficient is about the order of magnitude lower than at the atmospheric pressure. This causes the necesary heat transfer area of the evaporator to increase, and thus the pressure drop to rise, and the evaporator efficency to fall.

Despite the high numver od experimental and theoretical studies, the mechanism of boiling has not been entirely described. The most common formulas for heat transfer coefficient are empirical or semi-empirical. They do not cover the pressure range used in sorption refrigeration.

The aim of this thesis is maximisation of boiling heat transfer coefficient, with the lowest wall temperature superheat. This leads to miniaturisation of adsorption refrigeration systems used in trigeneration. It also causes the increase of such systems efficiency.

Disertation covers boiling of natural refrigerants. It is targeted at designing an evaporator for trigeneration adsorption system. The subject of the thesis is low pressure boiling from the plain surface and finned-tunnel structures.

The conducted research refers to distilled water and methanol boiling under the pressures in the range of 0.3-18 kPa. The experimental campaign covers heat flux ranging from 0.43-5.93 W/cm^2 and liquid level from 5 to 32.3 mm.

Two different types of complex surfaces were analyzed: Narrow Tunnel Structures (NTS) and Tunnel Structures (TS). The structures have been developed by dr hab. inż. R. Pastuszko from Kielce University of Technology. They are finned surfaces in which some channels are covered with the perforated copper coil creating tunnels.

All the structures have similar geometry with certain differences regarding the shape and depth of the tunnels. Each sample consists of three rows of fins situated on a 32 mm square base. The fins in a row are separated (in NTS) or bridged (in TS). The side length of the sample is 27 mm (measured from the edge of the leftmost fin to the edge of the rightmost fin).

The research has been conducted on two experimental stands. The influence of pressure and the liquid level on the boiling heat transfer from a plain surface at sub-atmospheric pressure was carried out in the laboratory of Refrigeration and Cryogenics, Faculty of Mechanical and Power Engineering at Wroclaw University of Science and Technology. The experimental campain covered measurements of heating surface temperature and vapor pressure. On the basis of measured wall superheat the heat transfer coefficient was calculated. The bubble nucleation and growth time was determined through the measurement of wall temperature change over time.

Boiling from finned-tunnel structures has been conducted in the Centre of Power and Thermal Engineering (Centre d'Energetique et de Thermique de Lyon – CETHIL) which is a part of the National Institute of Applied Sciences (Institut national des sciences appliquees de Lyon – INSA). The experimental campain covered measurements of instantaneous heat flux, wall temperature at the structure base in three spots and vapor pressure. On the basis of the instantaneous heat flux and wall superheat, the heat transfer coefficient was determined. Moreover, the nucleation process was recorded by means of high speed video camera (1000 fps).

Thesis covers development of new empirical constants used in heat transfer coefficient formulas for boiling of water and methanol from the plain surface. Visualisations of bubble incipience and growth, as well as data from thermal measurements from the finned-tunnel structures are presented. The obtained results showed that the structure with a square shaped tunnel and the biggest tunnel pitch increases the heat transfer coefficient ten times compared to the plain surface. The remaining structures increase the heat transfer coefficient two to five times compared to the plain surface. The bubbles in the structure with the highest heat transfer coefficient are of an order of magnitude smaller than the bubbles from the remaining surfaces.

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