EXPERIMENTAL STUDY OF HEAT TRANSFER RATE DURING EVAPORATION OF OZONE SAFE FREON R134a ON PLANE AND FINNED TUBES

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Abstract

Experimental definition of heat transfer rate during developed nucleate boiling of freon – 134a on plane and longitudinally finned tubes in the conditions of pool boiling in the range of heat fluxes of 8–63 kW/m^2 at saturation pressures of p_s = 0.5–0.8 MPa has been provided. The criterion equations are obtained enabling to calculate the heat transfer rate on horizontal plane technically rough tubes for the conditions of experiments.

KEYWORDS

Boiling, heat transfer, freon-134a, ribbing tube, criterion equation.

INTRODUCTION

In connection with the availability of auxiliary heat sources at the enterprises such as warm water discharges and exhaust air with the temperature of 5 to 25 °C it is becoming urgent to introduce vapor-compression and absorption thermo compressors for utilizing low potential heat and consequently to solve the heat and cold supply problem. In thermo compressor and refrigerating units 70 – 80 % of the total weight of the unit falls on heat exchange equipment including for the most part the weight of shell-and-tube vaporizers. The best way to considerably reduce the weight and the dimensions of thermo compressors, refrigerating units, boilers, evaporators is the intensification of liquid evaporation on finned tubes of the evaporator.

In consequence of signing by all industrial states the international protocol on gradual reduction and eventual complete rejection of producing ozone unsafe refrigerants, the problem of choosing the substances alternative to chlorofluorocarbons is very urgent. The designers have at their disposal a large number of alternative refrigerants including in the first place freon – 134a.

Since there are no recommendations in the literature on the calculation of a heat transfer coefficient during freon R 134a evaporation, the corresponding experiments on the study of heat exchange regularities in the process of the developed nucleate boiling of pure freon – 134a on horizontal plane rough tubes and three longitudinally finned pipes with various fin geometry were conducted.

EXPERIMENTS

Experimental Samples

Geometrical parameters of experimental tubes (1 – plane rough, 2 – longitudinal rectangular finning, 3 – longitudinal triangular finning, 4 – longitudinal trapezoid finning) are presented in Table 1.

Table 1. Geometrical parameters of the samples studied

No. of sample	d_0, mm	D_0, mm	d_{IN}, mm	φ_f, deg	δ_{BOT}, mm	δ_V, mm	L_S, мм	N_P	h_P, mm	F_M, m^2	F_O, m^2	D, mm
1	25	–	16	–	–	–	302	–	–	0,02372	0.02372	107
2		448		36	4	4	310	10	12	0,01310	0.05650	
3						0					0.04578	
4						2					0.05102	

where d_0 – sample diameter on the main surface, D_0 – fin outer diameter; d_{IN} – sample inside diameter, φ_f – inter fin angle; δ_{BOT} – fin thickness at the fin bottom, δ_V – fin thickness at the fin vertex, L_S – sample length, N_f – fin number, h_f – fin height, F_M – sample area on the main surface, F_O – sample total outside area, D – outside diameter of annular duct.

Experimental Results

The results of experimental study of pure freon boiling on all experimental tubes at saturation pressure of $p_s = 0.6$ MPa are presented in Fig. 1

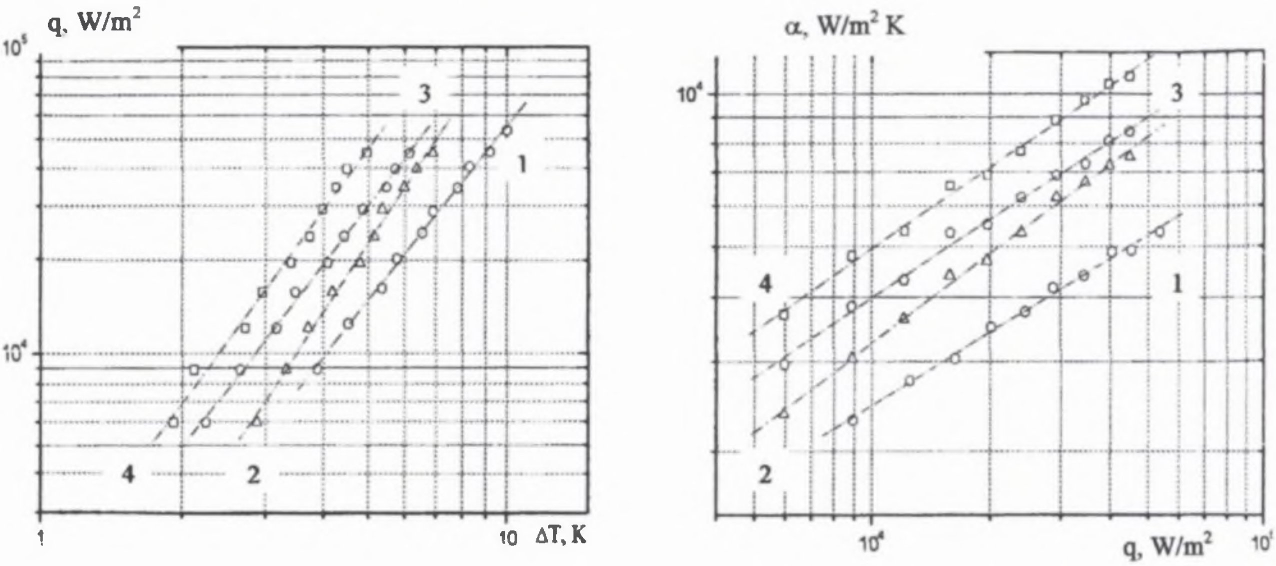

Fig. 1. Comparison of experimental data for plane and finned pipes at saturation pressure $p_s = 0.6$ MPa (1 – technically rough, 2 – longitudinal triangle finning, 3 – longitudinal trapezoid finning, 4 – longitudinal rectangular finning).

As the graphs show heat transfer coefficients during freon-134a boiling on finned surface are much higher than on plane-rough one, i. e. during nucleate boiling on finned surfaces heat transfer rate is 2-4 times higher than on an undeveloped surface.

Specific features of heat exchange on the finned surface under study are determined by the following circumstances. At the fin bottom the highest liquid superheat and local wetting deterioration are observed resulting from the change of surface configuration and local stresses. On these surface areas undissolved gases are adsorbed being the centers of vaporization in the beginning of the process and vapor nuclei are trapped when vapor phase is detached from the surface during stabilized boiling.

The confinement of small volumes of liquid by fins provides its greater average superheat and the improvement of bubble growth conditions. At the comparable relationship between fin spacing S_f and bubble detachment diameter D_{det} the most intensive supply of heat is provided not only from the microlayer of liquid at the bubble bottom as in the case of plane surface but also from super heated thin layer of liquid confined between the bubble and the fin. The presence of more intensive vaporization in small volumes of water confined in interfin spaces causes the increase of turbulence disturbances of boundary layer as compared with plane surfaces. The above circumstances cause the decrease of driving temperature difference at the same heat flux densities and saturation pressure for finned pipes in comparison with the plane ones.

The influence of finning on heat transfer coefficient is greater at he initial stage of developed boiling, i. e. at low densities of heat flux. At higher values of heat flux densities ($q > 50$ kW/m^2) an intensive coalescene of vapor bubbles occurs and the deterioration of conditions of removing vapor phase out of interfin areas is observed. This results in so-called "steaming" of heat exchange surface and heat exchange deterioration. Hence in boiling on finned surfaces with the comparable relationship between fin spacing S_f and bubble detachment diameter D_{det} the process of heat exchange does not depend on geometrical characteristics (fin spacing, height, thickness at al). They are significant for the process of heat exchange during boiling and must appear in the conditions of single valuedness.

Thus experimental dependencies $q = f(\Delta T)$ and $\alpha = f(q)$ presented in Fig. 1 confirmed high efficiency of finned surfaces. Intensification of the process of heat exchange was observed in the whole range of heat demand values.

Following the generalization of experimental data a dependence was obtained explaining experimental data on boiling on plane tubes with an error of ± 23%

$$\mathrm{Nu} = 9 \cdot \mathrm{Re}^{0.5} \cdot K_p^{0.11} \cdot \mathrm{Pr}^{-0.3},$$

where

$$\mathrm{Nu} = \frac{\alpha l_0}{\lambda_l},\quad \mathrm{Re} = \frac{q}{r\rho_v a}\sqrt{\frac{\sigma}{g(\rho_l - \rho_v)}},\quad K_p = \frac{p_s}{\sqrt{\sigma g(\rho_l - \rho_v)}}.$$

CONCLUSION

The efficiency of finning is confirmed by the experimental data. Intensification of heat exchange process was observed in the whole range of heat demand values. The values of heat transfer coefficients are 2-4 times higher than those for technically rough surfaces. The use of finning results in heat transfer intensification mainly due to the development of heat exchange surface and the improvement of vapor bubble origination and growth conditions.

The experimental data obtained can be used in designing heat exchange equipment of evaporative type operating with the ozone safe refrigerants.