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BOILING OF BINARY ZEOTROPIC BLENDS IN THE PLATE HEAT EXCHANGER OF THE HEAT PUMP

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Abstract. In this paper, we consider the process of boiling in the evaporator of the heat pump. Zeotropic binary refrigerants R32/R152a (30/70%) and R32/R134a (30/70%) are used as working medium. Calculations are made for brazed plate heat exchanger during boiling of zeotropic blend refrigerants with account of peculiarities of this process. Results of calculation of the heat transfer coefficient for zeotropic blends are given.

1 Introduction

The evaporator is an integral part of the heat pump. The evaporator is a heat exchanger that takes heat from the low-potential source by evaporation of the working medium (refrigerant). To perform technical and economic analysis and select the heat exchanger, knowledge about the heat transfer coefficients at a change in the aggregate state during boiling is required.

The most common heat exchangers, used as evaporators of the heat pumps are the shell-and-tube ones. The processes of intra tube boiling of R32/R134a and R32/R152a refrigerants in the shell-and-tube heat exchanger were considered in [1, 2].

The shell-and-tube heat exchangers consist of tube bundles, mounted in tube plates, housings, covers, chambers, pipes and supports. The tube and inter tube spaces in these devices are separated, and each of them can be divided by partitions into several passages. The shell-and-tube heat exchangers have reliable construction, their sizes vary from small to large ones, they have broad limits of the pressure drops on both sides, i.e., their version are suitable for different operating conditions. However, such a variety of application conditions for the shell-and-tube heat exchangers and their constructions should not exclude the search for other, alternative solutions such as the use of the plate, helical, or compact heat exchanger in the cases, when their characteristics are acceptable, and their use can lead to solutions that are more economical.

The current study is aimed at determination of the heat transfer coefficient at refrigerant boiling in the evaporator of vapor-compression heat pump at a change in the qualitative index of blend composition.

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2 Results and discussion

The plate heat exchanger is chosen as the evaporator. Currently, the plate and plate-finned heat exchangers are the most advanced. The plate heat exchangers present a type of the surface recuperative heat exchangers with heat transfer surface, made of a thin sheet. The defining feature of the plate heat exchangers is design and shape of the heat exchange surface and channels for the working medium. The heat exchange surface is formed by individual plates and the channels for the working medium have the slot-like shape.

Zeotropic mixed refrigerants R32/R152a (30/70) и R32/R134a (30/70) are considered as the working body. The features of heat pump operation on zeotropic blends are presented in [3, 4]. The thermodynamic cycle of the heat pump is shown in fig. 1. Boiling process (5-1) occurs there at variable temperature. Then, dry saturated vapor enters the super heater (1-1’). Further, superheated vapor is supplied to the compressor (1’-2’). Enthalpy at point 2’ is obtained with consideration of the influence of indicated efficiency of compressor. Condensation of refrigerant vapors in process (2-3) takes place at variable temperature. In this case, we consider the heat pump cycle for the heating system. In this cycle, the heat of super cooling (3-4) is spent for overheating refrigerant vapors before entering the compressor (1-1’). A change in the position of point 5 at throttling characterizes the relative quality index of the blend (kg_{vapor} / kg_{total}). In the case, when throttling occurs along line 4’-5’ or 4”- 5”, the effect of vapor component of the blend on the boiling process reduces and the heat transfer coefficient increases.

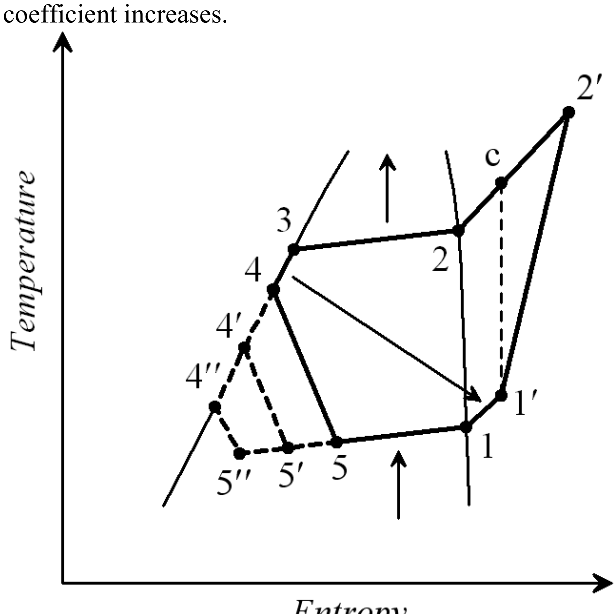

Fig. 1. Thermodynamic cycle of vapor-compression heat pump on zeotropic blends of refrigerants.

Relationship for determination of the Nusselt number in application to the plate heat exchangers is suggested in [5]:

$$Nu_R = a \cdot Nu_L^b \cdot Bo^c \cdot Fr^d \cdot \omega^e \cdot Co^f \cdot X_{tt}^g \cdot M^h \quad (1)$$

where *a, b, c, d, e, f, g, h* are the constant for the boiling process.

The Nusselt number for the liquid phase is determined by formula:

$$Nu_L = 0.16 \cdot \mathrm{Re}_L^{0.89} \cdot \mathrm{Pr}_L^{0.3(0.4)} \quad (2)$$

The Reynolds number is determined by formula:

$$\mathrm{Re}_L = \frac{w_R \cdot d_E \cdot (1-\bar{x})}{\nu_L} \quad (3)$$

$\bar{x}$ – average qualitative index of composition;
Pr_L – Prandtl criterion (at average refrigerant temperature);
w_R – velocity of refrigerant flow in a tube, m/s;
ν_L – kinematic viscosity of refrigerant, m^2/s;
d_E – equivalent hydraulic diameter, m.
The Froude number is determined by formula:

$$Fr = \frac{\omega^2}{g \cdot d_E} \quad (4)$$

g – acceleration of gravity, m/s^2;
ω – acentricity factor:

$$\omega = -\log_{10}(P/P_C) \quad (5)$$

P – blend pressure, MPa;
P_C – critical pressure of blend, MPa.
The convective number is determined by formula:

$$Co = \left(\frac{\rho_V}{\rho_L}\right)^{0.5} \cdot \left\{\frac{(1-x)}{x}\right\}^{0.8} \quad (6)$$

ρ_V, ρ_L – refrigerant densities in vapor and liquid phases, respectively, kg/m^3;
x – relative qualitative index of composition, kg_{vapor}/kg_{total}.

Results of calculation of the heat transfer coefficient for zeotropic blends R32/R152a (30/70) and R32/R134a (30/70), carried out by formulas (1-6), are shown in fig. 2.

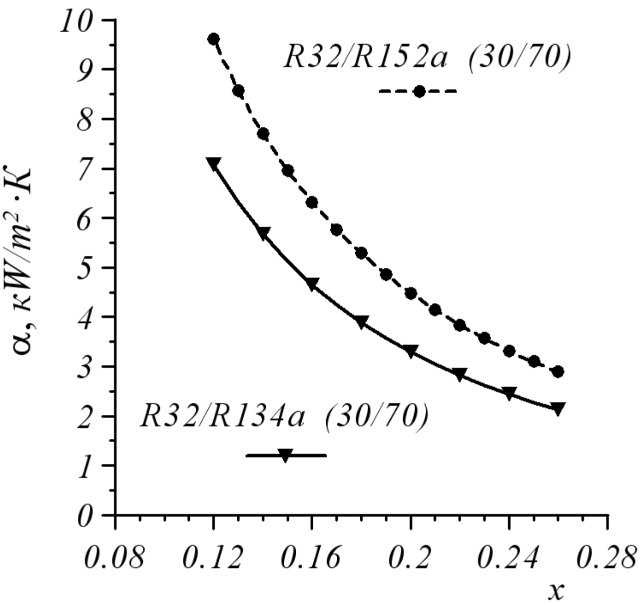

Fig. 2. A change in the heat transfer coefficient vs. relative qualitative index of zeotropic blend composition.

3 Conclusion

According to analysis of results, at a change in the relative qualitative index (vapor content) from 0.12 to 0.26 (an increase in the vapor component), the heat transfer coefficient increases by 3.3 times.

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