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The effect of vapour super-heating on hydrocarbon refrigerant condensation inside a brazed plate heat exchanger

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ABSTRACT

This paper investigates the effect of vapour super-heating on hydrocarbon refrigerant 600a (Isobutane), 290 (Propane) and 1270 (Propylene) condensation inside a brazed plate heat exchanger.

Vapour super-heating increases heat transfer coefficient with respect to saturated vapour, whereas no effect was observed on pressure drop.

The super-heated vapour condensation data shows the same trend vs. refrigerant mass flux as the saturated vapour condensation data, but with higher absolute values. A transition point between gravity controlled and forced convection condensation has been found for a refrigerant mass flux around 15–18 kg m^{-2} s^{-1} depending on refrigerant type. The super-heated vapour heat transfer coefficients are from 5% to 10% higher than those of saturated vapour under the same refrigerant mass flux.

The experimental heat transfer coefficients have been compared against Webb (1998) model for forced convection condensation of super-heated vapour: the mean absolute percentage deviation between the experimental and calculated data is ±18.3%.

HC-1270 shows super-heated vapour heat transfer coefficient 5% higher than HC-600a and 10–15% higher than HC-290 together with total pressure drops 20–25% lower than HC-290 and 50–66% lower than HC-600a under the same mass flux.

1. Introduction

In the inverse cycle machines the refrigerant vapour coming from the compressor at the inlet of the condenser exhibits some degrees of super-heating, normally from 10 °C to 50 °C, depending on the isoentropic characteristics of the refrigerant and the pressure ratio. Therefore it is interesting, under a technical point of view, to evaluate the performance of the condenser not only in saturated vapour condensation as it is usual, but also in the real operating conditions in chiller and heat pump considering the effect of vapour super-heating.

Minkowycz and Sparrow [1,2] analytically investigated the effect of vapour super-heating both in laminar film and forced convection condensation by integrating the energy and momentum equation in the boundary layer. For steam condensation they computed a maximum heat transfer coefficient increase of 3%.

Mitrovic [3] for laminar film condensation and Webb [4] for forced convection condensation shown that the condensate film is thinner and therefore the heat transfer coefficient is larger for super-heated vapour than for saturated vapour condensation. They provided also analytical solutions accounting for super-heating effect on condensate film thickness and heat transfer coefficient.

With specific reference to refrigerant super-heated vapour condensation Goto et al. [5] measured the heat transfer coefficient during CFC-113 film condensation on a horizontal tube and they found a 5% of heat transfer coefficient enhancement with respect to saturated vapour condensation for 40 °C of super-heating. Huebesch and Pate [6] experimentally investigated HFC-236ea and CFC-114 condensation on plain and integral fin tubes and they found a 3–5% enhancement with 3–5 °C of super-heating. Longo [7,8] measured the heat transfer coefficients of HFC-134a and HFC-410A saturated and super-heated vapour (10 °C) inside a brazed plate heat exchanger. The super-heated vapour heat transfer coefficients are 8–10% higher than those of saturated vapour under the same refrigerant mass flux both for HFC-134a and HFC-410A.

The present paper investigates the effect of vapour super-heating on hydrocarbon refrigerant 600a (Isobutane), 290 (Propane) and 1270 (Propylene) condensation inside a brazed plate heat exchanger.

2. Experimental set-up and procedures

The experimental facility, as shown in Fig. 1, consists of a refrigerant loop, a water-glycol loop and two water loops. In

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