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Long-term performance of air-side heat transfer and pressure drop for finned tube evaporators of air conditioners under intermittent operation conditions

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ABSTRACT

In this study, the effects of long-term intermittent operations on the air-side heat transfer and pressure drop performance of finned tube evaporators of air conditioners were investigated by experiments on an aluminum-fin evaporator and a copper-fin evaporator. In order to simulate intermittent operations of on–off controlled air conditioners, the temperatures of the two evaporators changed to $5 \pm 0.5\,^{\circ}C$ at first and then to $27 \pm 0.5\,^{\circ}C$ repeatedly. The repetition number was up to 4800, and the air-side heat transfer and pressure drop of the two evaporators were tested after every 300 repetitions. The test results indicate that after long-term intermittent operations, the air-side heat transfer coefficient decreases and the pressure drop increases. The variations of the heat transfer coefficient and the pressure drop are more obvious at lower inlet air velocity, and the influence of long-term intermittent operations on the aluminum-fin evaporator is greater than that on the copper-fin evaporator.

Evaporateurs à tubes ailetés des systèmes de conditionnement d’air sous des conditions de fonctionnement intermittent : performance dans le long terme sous l’angle du transfert de chaleur côté air et de la chute de pression

Mots clés : Conditionnement d’air ; Évaporateur ; Tube aileté ; Expérimentation ; Transfert de chaleur ; Chute de pression ; Paramètre

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Nomenclature

A	area (m^2)
b'	slop of the air saturation curve
C_p	specific heat ($J\ Kg^{-1}\ K^{-1}$)
D	diameter (m)
D_c	fin collar outside diameter (m)
f	friction factor
F	correction factor
F_p	Fin pitch (m)
h	heat transfer coefficient ($W\ m^{-2}\ K^{-1}$)
i	enthalpy ($J\ kg^{-1}$)
Δi_m	logarithmic-mean enthalpy difference ($J\ kg^{-1}$)
j	Colburn factor
k	thermal conductivity, ($W\ m^{-1}\ K^{-1}$)
m	mass flow rate ($kg\ s^{-1}$)
N	number of intermittent operations
N_t	number of longitudinal tube rows
Δp	pressure drop (Pa)
P_l	longitudinal tube pitch (m)
Pr	Prandtl number
P_t	transverse tube pitch (m)
Q	heat transfer rate (W)
Re_{Dc}	Reynolds number based on tube collar diameter
Re_{Di}	Reynolds number based on tube inside diameter
T	temperature (K)
u	velocity ($m\ s^{-1}$)
u_{max}	maximum velocity across heat exchanger ($m\ s^{-1}$)
$U_{o,w}$	overall heat transfer coefficient ($W\ m^{-2}\ K^{-1}$)
x_p	thickness of tube wall (m)
y_w	thickness of condensate water film (m)

Greek symbols

$\eta_{f,wet}$	wet fin efficiency
$\eta_{f,fullywet}$	fin efficiency of a fully wet fin
$\eta_{f,partiallywet}$	fin efficiency of a partially wet fin
θ	wavy angle (°)
μ	dynamic viscosity of air (Pa s)
ρ	density ($kg\ m^{-3}$)

Subscripts

a	air
act	actual
ave	average value
Al	aluminum
Cu	copper
exp	experiment
f	fin
i	inner
in	inlet
m	mean value
o	outer
out	outlet
p	tube
w	water

1. Introduction

Room air conditioners with finned tube evaporators are widely used and can be used over a long period (e.g. 10 years). The performance of such air conditioners may obviously deteriorate in its life cycle, and the deterioration may mainly result from the degradation of evaporator performance. The refrigerant circuit of an air conditioner is closed and the performance variation of the refrigerant-side is very small compared with that of the air-side. Therefore, the investigation on the long-term performance of finned tube evaporators should be focused on the variation of the air-side performance, including heat transfer and pressure drop.

Most of room air conditioners are on–off controlled and operated intermittently. After long-term intermittent operations, the air-side heat transfer and pressure drop performance of a finned tube evaporator changes obviously. The air-side heat transfer performance is affected by the thermal contact resistance between tubes and fins, and the thermal resistance between the airflow and fins. For a new and well made evaporator, the thermal contact resistance between tubes and fins is quite limited (Jeong et al., 2004, 2006), and it is much smaller than the thermal resistance between airflow and fins. However, for an intermittently operated air conditioner, the thermal contact resistance between tubes and fins becomes more and more important with the increase of operation time. Therefore, both the variation of the thermal contact resistance between the airflow and fins and the thermal resistance between tubes and fins contribute to the long-term air-side heat transfer performance of a finned tube evaporator under intermittent operations. At the same time, the hydrophilicity of fin surfaces may degrade after the long-term intermittent operations, resulting in a pronounced change of the air-side heat transfer and pressure drop performance (Min et al., 2000).

There is no published research directly focusing on the long-term air-side heat transfer performance of finned tube heat exchangers. However, there are researches on the contact angle of fins after long-term operations (Hong, 1996; Min et al., 2000; Min and Webb, 2002). These researches show that the contact angle is affected by dry/wet cycles under intermittent operation conditions, and the effect of dry/wet cycles on contact angle of fins with hydrophilic coating is smaller than that without hydrophilic coating. Considering the relationship between the contact angle and the air-side heat transfer performance, it can be concluded from these researches that the air-side heat transfer performance of finned tube heat exchangers will change after long-term intermittent operations.

The effects of plasma treatment (Kim et al., 2007), dust deposition (Yang et al., 2007) and microorganism growth (Pu et al., 2009) on the long-term pressure drop performance of finned tube heat exchangers have been studied. However, these studies do not reflect the influence of intermittent operations.

The purpose of this study is to experimentally investigate the variation of air-side heat transfer and pressure drop of