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Experimental Investigation on Condensation Performance of Brazed Type Parallel Flow Condensers

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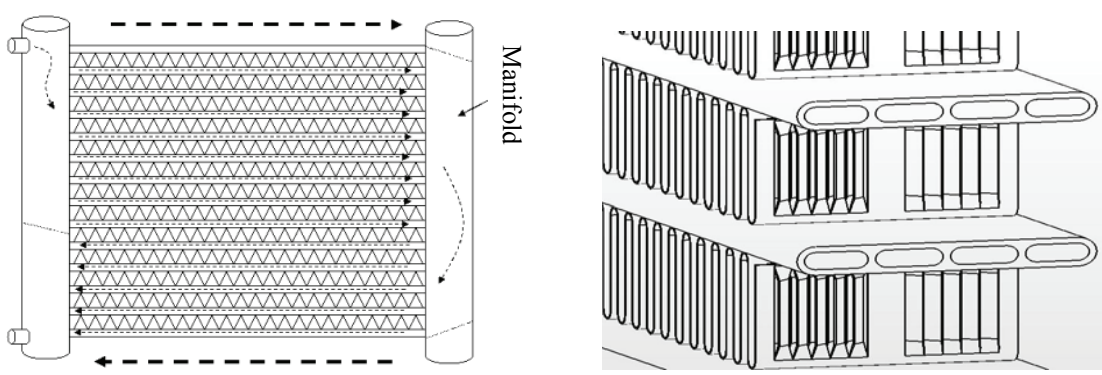
ABSTRACT

Condensation heat transfer performance of six brazed type parallel flow condensers (PFHXs) were investigated, and were compared with a double-row φ9.52mm fin-and-tube heat exchanger (CTHX) under the same testing condition. Pressure drop of airside, condensation capacity and comprehensive condensation performance were plotted in curves for comparison. The test results showed that: PFHXs had the characteristics of high comprehensive condensation performance and high condensation capacity per unit volume, the condensation capacity per unit face area of the PFHXs was higher than or equivalent to that of the CTHX under the same testing condition.

1. INTRODUCTION

In recent years, the brazed type parallel flow heat exchanger (PFHX), also called microchannel heat exchanger (MCHX), was paid more attention to in HVAC&R since it has many attractive advantages such as compactness, high efficiency, little internal volume and lightness when compared with traditional fin-and-tube heat exchangers(CTHX). The application of PFHX was extended from automotive air conditioner (AC) in the past to residential and commercial AC at present. In fact, the PFHX became popular research topic worldwide in air conditioning factories, colleges and institutes (Yun et al., 2006).



(a) Unit (b) Partial view

Figure 1: Sketch of PFHX

The PFHX mainly consists of manifolds, multiport extrusion tubes (MPE tubes) and fins, as shown in figure 1 (a), with all joints metallic bond through welding in a vacuum or nitrogen-charged atmosphere brazing furnace. The serpentine fin is usually louver type. As shown in figure 1 (b), the cross section MPE tube has rectangular, circular

or triangular channels with hydraulic diameter ranging from 0.5mm to 1.6mm. The tube height usually ranges from 1mm to 3mm, tube width from 12mm to 26mm, fin height from 5mm to 10mm, fin pitch from 1mm to 2mm and fin thickness from 0.05 to 0.1 mm (Chang and Wang, 1997, Kim and Bullard, 2002, Park and Jacobi, 2009). The close up view of the metallic bond joint between fin and tube, thus the contact thermal resistance of the fin to tube joint is nearly zero.

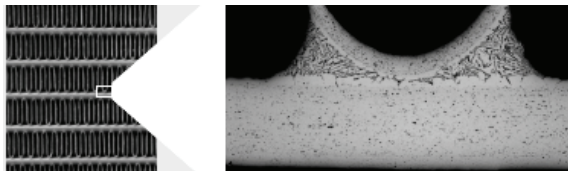


Figure 2: Close up view of the joint between fin and tube

Condensation heat transfer performance of six brazed type PFHXs were experimentally investigated and compared with a double-row φ9.52mm CTHX under the same testing condition. Pressure drop of airside, condensation capacity and comprehensive condensation performance were plotted in curves for comparison. The test results showed that the condensation capacity per unit face area of the PFHXs was higher than or equivalent to that of the CTHX under the same testing condition.

2. TEST SAMPLES AND METHOD

2.1. Test samples

The geometric parameters of the six test samples were listed in table 1. PFHX-2.0*20 stands for height and width (2.0mm*20mm) of the sample's MPE tube. MPE tubes of the 3rd sample in table 1 have microfin rectangular channels, those of the other samples have smooth rectangular channels. The number of MPE tubes in parallel in each pass was listed in table 2. The flow circuit arrangement in PFHX-1.4*16 was illustrated in figure 3.

The test sample for base line is a double-row φ9.52mm CTHX. The transversal and longitudinal tube pitch is 25.4 mm and 22 mm, respectively. The fin type is louvered fin and fin pitch 1.6mm. The flow circuit is a common type used in the outside unit of a heat pump. All the test samples were in plate form.

Table 1: The geometric parameters of the test samples (units: mm)

No.	Sample symbol	Fin type	Fin height	Fin pitch	Number of tubes
1	PFHX-1.9*16	louver	8	1.3	50
2	PFHX-2.0*20	louver	8	1.15	49
3	PFHX-3.0*16A	louver	8	1.3	44
4	PFHX-3.0*16B	louver	8	1.25	40
5	PFHX-1.4*16	louver	5	1.2	77
6	PFHX-2.0*25.4	louver	8.5	1.4	47

Table 2: Number of MPE tubes in parallel in each pass of the test samples

No.	Sample symbol	1st pass	2nd pass	3rd pass	4th pass	5th pass	6th pass
1	PFHX-1.9*16	22	14	8	6	-	-
2	PFHX-2.0*20	14	10	9	7	5	4
3	PFHX-3.0*16A	13	9	7	6	5	4
4	PFHX-3.0*16B	15	12	8	5	-	-
5	PFHX-1.4*16	33	23	12	9	-	-
6	PFHX-2.0*25.4	19	14	9	5	-	-

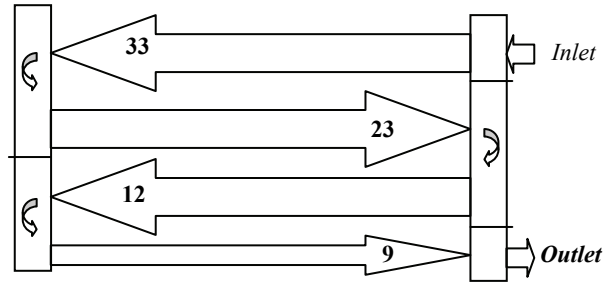


Figure 3: Flow circuit arrangement in PFHX-1.4*16

2.2. Test method

The experiments were carried out in an Air-conditioning and Heat Exchangers Laboratory which described by Liang et al (2006). The refrigerant is R-22.

Some parameters of the operating conditions were controlled as following for better comparison:

Inlet air dry bulb temperature: 35℃
Inlet air wet bulb temperature: 24℃
Inlet air frontal velocity: 1.4~2.5m/s
Inlet absolute pressure of refrigerant: 1.729~2.033MPa
Inlet superheat of refrigerant: 20℃
Outlet subcooling of refrigerant: 8℃

3. RESULTS AND DISCUSSION

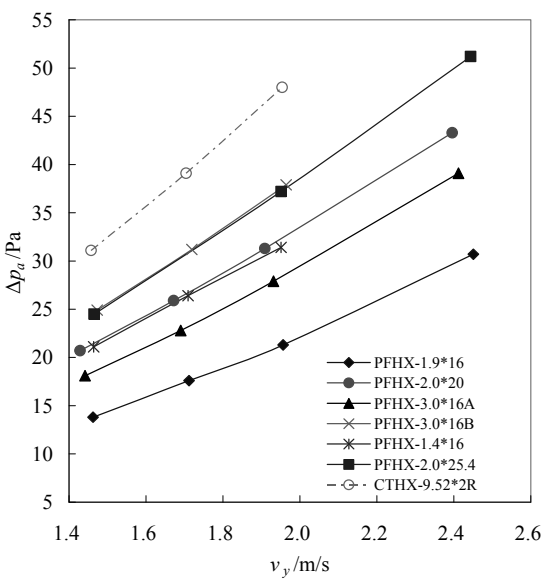


Figure 4: Airside pressure drop varying with inlet air velocity (T_{DB}/T_{WB}=35/24℃)

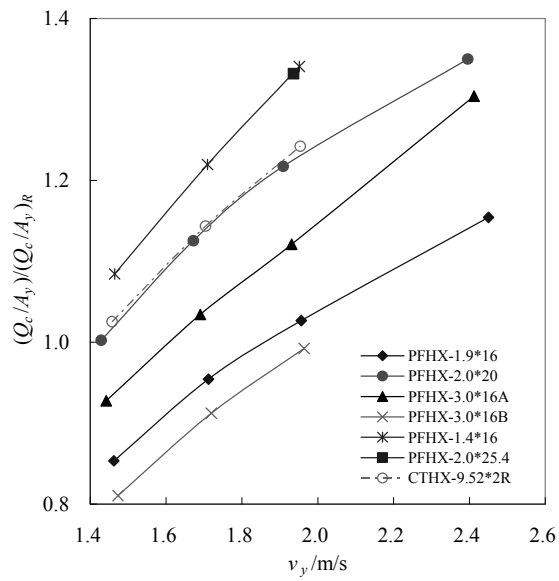


Figure 5: Relative condensation capacity per unit frontal area varying with inlet air velocity (T_{DB}/T_{WB}=35/24℃, p_{in}=1.856MPa, T_{sh}=20℃, T_{sc}=8℃)

The airside pressure drop of all the test samples were showed in figure 4, it can be seen that the pressure drop of φ9.52mm CTHX is the highest mainly due to the longer depth and the bigger form drag. The airside pressure drop of PFHX-2.0*20 is almost the same as that of PFHX-1.4*16, but is about 15.5% lower than that of PFHX-2.0*25.4 and is about 10.7% to 14.4% higher than that of PFHX-3.0*16A. The pressure drop of PFHX-3.0*16A is 27%~31% higher than that of PFHX-1.9*16 mainly caused by form drag of MPE tube.

As listed in table 1, the geometric parameters of PFHX-3.0*16B is very similar to those of PFHX-3.0*16A, but its airside pressure drop of the former is abnormally 31%~35% higher than that of the latter. It was found that the fins

of PFHX-3.0*16B were irregularly louvered and distorted, and excess solder remained in fin spacing by carefully examined. All of the foregoing factors caused the higher air pressure drop.

The condensation capacity of all the samples tested was reduced for better comparison. Relative condensation capacity per unit frontal area $(Q_c/A_y)/(Q_c/A_y)_R$ defined as ratio of the target condenser's condensation capacity per unit frontal area to a constant. The relative ratios varying with inlet air frontal velocity is shown in figure 5. The condensation capacity of PFHX-1.4*16 is almost equal to that of PFHX-2.0*25.4, and is about 5.7%～7.9% higher than that of CTHX-9.52*2R, the capacity of which is a little higher than that of PFHX-2.0*20. The capacity of PFHX-3.0*16A, PFHX-1.9*16 and PFHX-3.0*16B is roughly 9.5%, 17% and 20% lower, respectively, compared to that of CTHX-9.52*2R. The condensation capacity of PFHX-3.0*16B is the lowest because of the distorted fins and excess solder remained. Besides, it has no enhanced internal structure so the condensation capacity of PFHX-3.0*16B is about 12% lower than that of PFHX-3.0*16A.

By calculating the condensation capacity per unit volume, it can be seen that the condensation capacity per unit volume of PFHX-1.4*16 is about 200% higher than that of CTHX-9.52*2R under the test condition.

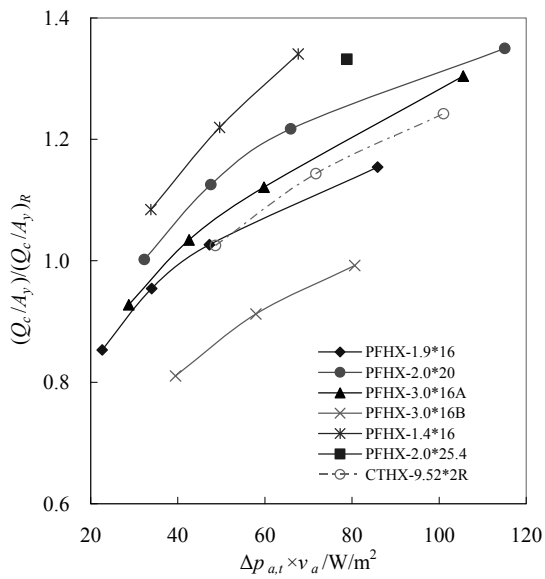


Figure 6: Relative condensation capacity per unit frontal area varying with pump power per unit frontal area (T_{DB}/T_{WB}=35/24℃, p_{in}=1.856MPa, T_{sh}=20℃, T_{sc}=8℃)

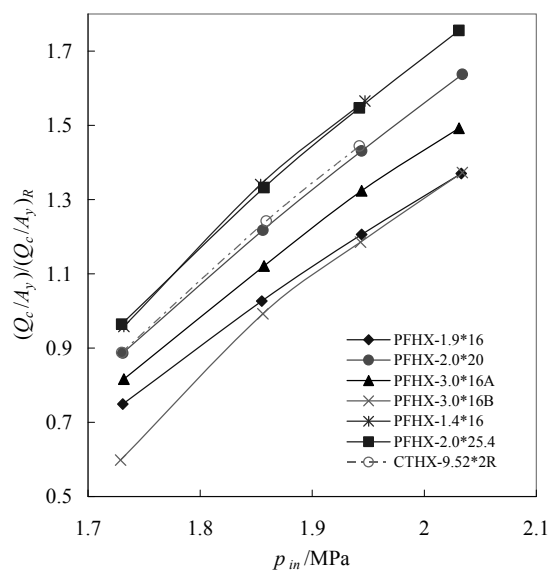


Fig.7. Relative condensation capacity per unit frontal area varying with inlet refrigerant pressure (T_{DB}/T_{WB}=35/24℃, v_{in}=2.0m/s, T_{sh}=20℃, T_{sc}=8℃)

The airside pressure drop is different at the same frontal velocity, so the relative trend between different samples is not agree with the real effect in practice. The comprehensive condensation curves, which take the pump power into consideration, plotted in figure 6 can reflect the real effect. The pump power per unit frontal is $\Delta p_{a,t} \times v_a$, and $\Delta p_{a,t}$ is the total pressure drop produced by blower. The comprehensive condensation capacity of PFHX-1.9*16 and PFHX-3.0*16B are lower than and those of the other four PFHXs are higher than that of CTHX-9.52*2R under the same pump power. The comprehensive condensation capacity of PFHX-1.4*16 is the highest and is about 18% higher than that of CTHX-9.52*2R, then PFHX-2.0*25.4, PFHX-2.0*20 and PFHX- 3.0*16A in turn.

The relative condensation capacity per unit frontal area of all the samples varying with inlet refrigerant pressure are illustrated in figure7. The inlet refrigerant saturation temperature, corresponding to the inlet refrigerant pressure tested, is 45℃, 48℃, 50℃ and 52℃, respectively. As shown in figure 7, the condensation capacity increases linearly with inlet refrigerant pressure under the controlled condition. It is very helpful for choosing and sizing PFHX in design phase.

Compared with conventional CTHX, PFHX has the following characteristics: larger heat transfer area per unit volume, metallic bond fin-to-tube joint, smaller hydraulic diameter multiport channels and thinner MPE tube height. Therefore, PFHX has the attractive advantages such as lower airside pressure drop, smaller refrigerant charge and higher condensation heat transfer performance.

It is worthy to point out that the fins of PFHX could be denser than that of CTHX because of the lower airside pressure drop characteristic. Dense fins can usually improve thermal performance under dry condition, but it is unsuitable in wetting or frosting condition. Actually, it was observed that the condensate drained difficultly and the refrigerant distributed unevenly when the PFHX was used as an evaporator, which affected the thermal performance greatly (Kim et al., 2007, Kim et al., 2008, Hwang et al., 2007). The inherent problems are currently caused by PFHX structure and manufacture technics. Xia et al. (2006), Padhmanabhan et al. (2008), Zhang and Hrnjak (2008) pointed out frosting was another great problem which limited the application of PFHX to condenser in HVAC&R.

4. CONCLUSIONS

Condensation heat transfer performance of six brazed type PFHXs were experimentally investigated, and were compared to a double-row φ9.52mm CTHX. The test results shows that: PFHX has the characteristics of high comprehensive condensation heat transfer performance and high condensation capacity per unit volume. The comprehensive condensation capacity of PFHX-1.4*1.6 is 18% higher than the double-row φ9.52mm CTHX and the condensation capacity per unit volume of the former is 200% higher than that of the latter under the same test condition.

PFHX has very perfect comprehensive condensation heat transfer performance, it can used as condenser and can replace fin-and-tube condenser in air-conditioning currently. However, there still exist the engineering problems such as condensate drainage, refrigerant distribution and frosting control to be solved in order to extend PFHX's application to evaporator and heat pump in future.

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