Purdue University
Purdue e-Pubs

International Refrigeration and Air Conditioning Conference

School of Mechanical Engineering

2010

Experimental Investigation on Condensation Performance of Fin-and-Flat-Tube Heat Exchanger

Xiangfei Liang
Gree Electric Appliances

Shumin Xing
Gree Electric Appliances

Rong Zhuang
Gree Electric Appliances

Bo Zheng
Gree Electric Appliances

Experimental Investigation on Condensation Performance of Fin-and-Flat-Tube Heat Exchanger

Xiangfei LIANG*, Shumin XING, Rong ZHUANG, Bo ZHENG

Refrigeration Institute of Gree Electric Appliances, Inc. of Zhuhai,
Jinji West Rd., Zhuhai City, 519070, P. R. China
Phone: +86-756-8668924, Fax: +86-756-8668982, E-mail: liangxf@gree.com.cn

* Corresponding Author

ABSTRACT

Condensation heat transfer performance of louvered fin-and-flat-tube heat exchanger (FTHX) in single slab and in residential air-conditioning system were experimentally investigated, and were compared with fin-and-circular-tube heat exchangers (CTHX) under the same testing conditions. The test results showed that: FTHX had the characteristics of low pressure drop of air side, high pressure drop of refrigerant side and less refrigerant charge; the overall heat transfer performance of copper FTHX was higher than that of φ7mm CTHX but a little lower than that of φ9.52mm CTHX; the cooling capacity and EER of the residential air-conditioning system with FTHX were a little lower than those of the system with φ9.52mm CTHX.

1. INTRODUCTION

The rising price of the original material and the upgrading EER of the AC are accelerating the R&D on high efficient heat exchangers. The tube outer diameter of the fin-and-tube heat exchanger tends to decreasing with the good effects such as lower air-side pressure drop and less refrigerant charge, and the other trend which has the same effects is to flatten the circular tube. Wilson et al (2001) reported that when the φ9.52mm×0.3mm circular tube was flattened to 2.57mm height, the condensation heat transfer enhancement factor of smooth tube reached 1.7~2.3 and that of internal grooved tube reached 3.5-4.5.

When a circular tube was flattened, the flat cross section sketched in fig. 1 will be formed. The ratio of cross section area of the flattened tube to that of the circular tube with equal inner perimeter will decrease sharply with the height of the flat tube decreasing, as showed in fig. 2. Therefore, the refrigerant charge related to internal volume will decrease sharply, too. The internal volume of the flattened tube will be 28.9% the volume of φ9.52mm×0.3mm circular tube and 39% the volume of φ7mm×0.3mm circular tube when they were flattened to 2mm height.

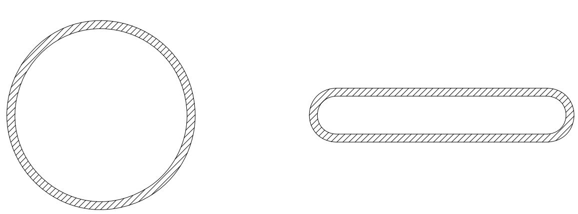


Figure 1: Sketch of circular tube and flattened tube in cross section view

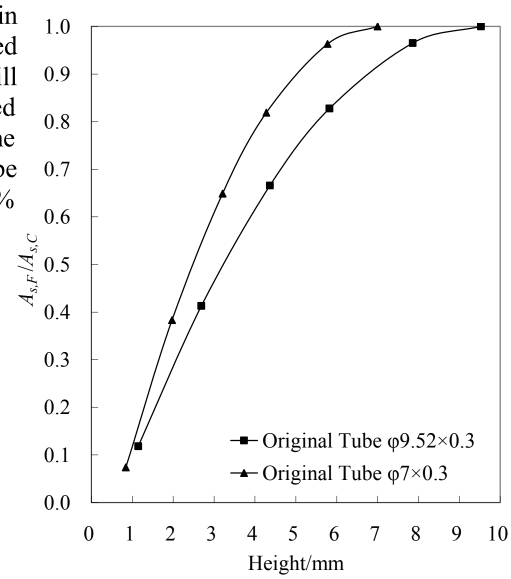


Figure 2: Cross section area ratio varies with the flattened tube height

The air-side friction drag of the fin-and-flat-tube heat exchanger will decrease due to the smaller form drag of the flat tube. The wake region of flat tube shrinks greatly and the fin efficiency increases due to smaller longitudinal tube pitch and longer fin-to-tube contact line in the air flow direction, compared to circular tube with equal outer perimeter, which will contribute to improve the heat transfer performance. However, the application feasibility of the new type heat exchanger to residential air-conditioning should be estimated through experiment and comparison to the traditional heat exchanger.

The condensation heat transfer performance and air-side pressure drop of a new type heat exchanger with louvered fin and flat smooth copper tube were tested and compared with φ9.52mm and φ7mm traditional heat exchangers with louvered fin and internal grooved copper tube under the same working conditions in the paper. The cooling capacity and EER were tested and compared in a split type residential air conditioner just with the condenser altered among the three heat exchangers under the rated operating condition.

2. EXPERIMENT SETUP AND PROCEDURE

2.1 Test facility

The experiments of heat exchanger condensation heat transfer performance were carried out in Air-conditioning and Heat Exchangers Laboratory which described by Liang et al (2006). The lab had an air enthalpy method calorimeter, so the split type residential air conditioner with three different condensers to be compared can be tested in the lab.

2.2 Test section

The parameters of the three different condensers are listed in table 1. The picture and the refrigerant circuit of the fin-and-flat-tube heat exchanger (FTHX) were showed in fig. 3 and fig. 4, respectively. There were thirty flat tubes flattened from φ7mm×0.3mm circular tube in the FTHX, but only twenty-nine tubes were actually used into the refrigerant circuit. The longitudinal tube pitch of the FTHX which is 17mm was the shortest among the three HXs. Each HX in table 1 has the same length of frontal area and the closely equal height.

Table 1: The geometric parameters of the condensers

HX Symbol	Tube	Material	Rows	Fin Type	Fin Pitch	Longitudinal Tube Pitch	Transversal Tube Pitch
FTHX	φ7S (Flattened)	Copper	Single	Louvered	1.63mm	17mm	21.65mm
CTHX-7	φ7G	Copper	Single	Louvered	1.6mm	19.05mm	12.7mm
CTHX-9.52	φ9.52G	Copper	Single	Louvered	1.6mm	25.4mm	22mm

(Note: S-Smooth, G-Grooved)

Figure 3: Picture of FTHX

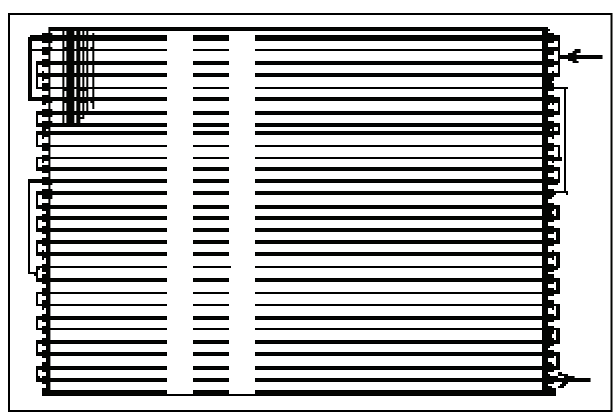


Figure 4: Refrigerant circuit of FTHX

2.3 Test procedure

The three single-slab condensers were tested firstly to gain the condensation capacity, air side and refrigerant side pressure drops, then tested to get the cooling capacity and power consumed after they were bended and installed in a split type residential air conditioner.

The single-slab condensers were tested under the following working conditions controlled for comparison purpose: dry bulb temperature, wet bulb temperature and frontal velocity of inlet air, refrigerant pressure and superheat at inlet and refrigerant subcooling at outlet of the condenser. When air side pressure drop was tested, only the foregoing three parameters of the inlet air were controlled, the refrigerant loop shut down and there was no refrigerant in the condenser. The operating condition specified for condensers as follows,

Refrigerant: R-22	Inlet refrigerant absolute pressure: 1.729-2.033MPa
Inlet air dry bulb temperature: 35 ℃	Inlet refrigerant superheat: 20℃
Inlet air wet bulb temperature: 24 ℃	Outlet refrigerant subcooling: 2-8℃
Inlet air frontal velocity: 0.5-2.8m/s	

The cooling capacity and EER were tested and compared in a split type residential air conditioner under the rated operating condition just with the condenser altered among the three heat exchangers. The refrigerant charge and the opening of the same electronic expansion valve (EEV) were adjusted to optimize the cooling capacity and EER of the residential air conditioner. The operating condition specified for residential air conditioner as follows,

Inside room dry bulb temperature: 27 ℃	Outside room dry bulb temperature: 35 ℃
Inside room wet bulb temperature: 19 ℃	Outside room dry bulb temperature: 24 ℃

3. RESULTS AND DISCUSSION

3.1 Test results of single-slab heat exchangers

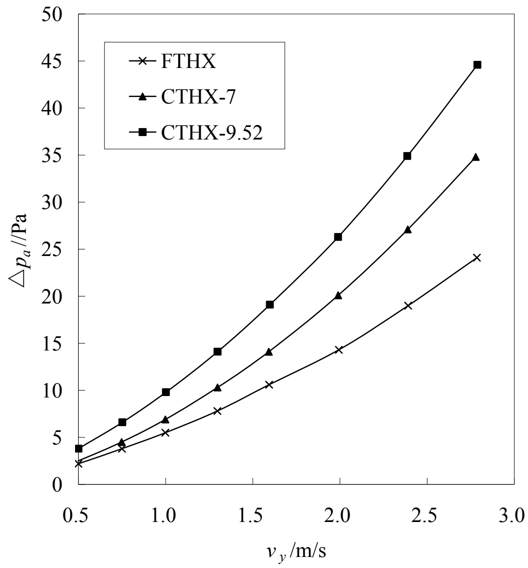
The air side pressure drop of the three heat exchangers tested is showed in fig. 5 and that of the FTHX is the lowest under the same frontal velocity. The air side pressure drop of FTHX is 14.3Pa, and is 29% and 46% lower than that of CTHX-7 and CTHX-9.52, respectively, at the frontal velocity 2m/s. The main reason is in that the flat tube has lower form drag than the original circular tube.

The condensation capacity of the three condensers tested was reduced for better comparison with each other. 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 FTHX's condensation capacity per unit frontal area was modified by multiplying the factor 1.0345 (=30/29) to take into account the unused 30th tube. The relative condensation capacity per unit frontal area of the three condensers were showed in fig. 6, that of FTHX is a little lower than or equivalent to that of CTHX-7, but about 10% lower than that of CTHX-9.52, when the inlet air frontal velocity v_y is in the range of 1.5~2.0m/s.

The relative trend showed in fig. 6 usually is not the trend in actual use since the condenser blower can not provide constant air volume flow rate when the condensers have different airside friction drag. To take the airside pressure drop into consideration, physical parameter for the abscissa in fig.6 was changed into fan power theoretically consumed per unit frontal area, thus fig. 7 formed. The theoretical fan power per unit frontal area is the product of outlet air velocity v_a and the total pressure $\Delta p_{a,t}$ which produced by the condenser blower. From fig. 7 we can see that, the relative condensation per unit frontal area of FTHX is obviously higher than that of CTHX-7, but a little lower than that of CTHX-9.52.

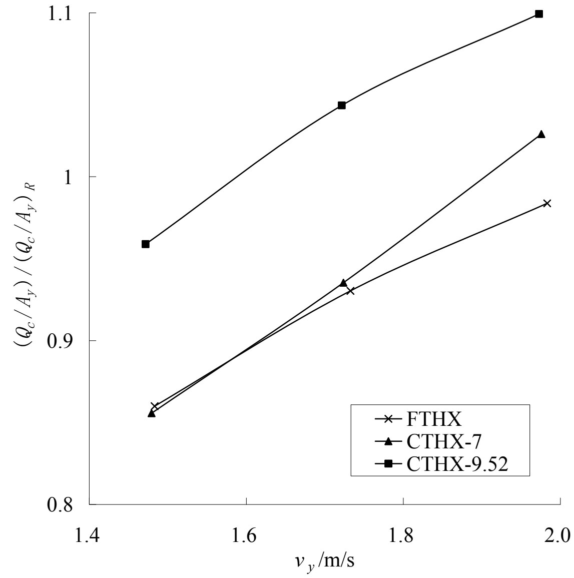
The refrigerant side pressure drop of the three condensers under different test conditions were showed in fig. 8, the abscissa of the figure is the ratio of the total mass flow rate to a constant. Obviously, the pressure drop of FTHX is greatly higher than that of CTHX-7 and CTHX-9.52. The smaller cross section area of flat tube caused higher refrigerant mass flow velocity, and the normal velocity gradient adjacent to the internal wall of the flat tube is much higher, the refrigerant circuit of FTHX has a very longer circuit, which are the main factors leading to higher pressure drop.

The FTHX has the characteristic of high pressure drop in refrigerant side, which greatly limits this type of heat exchanger's application to condenser just for cooling unit. It can not be used as evaporator or condenser for air source heat pump.



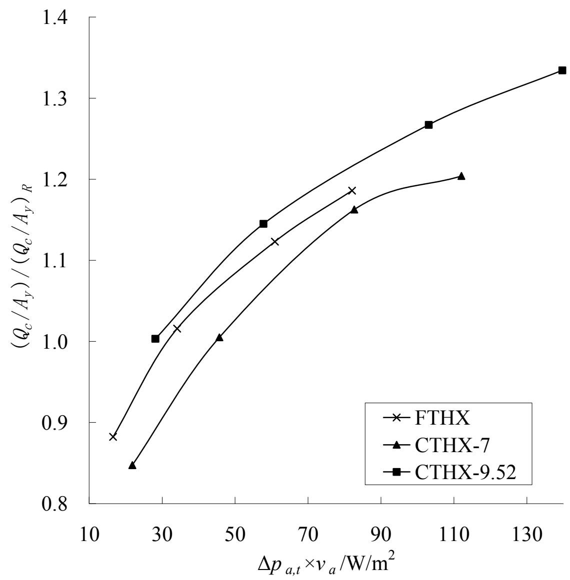
(35/24℃)

Figure 5: Air side pressure drop



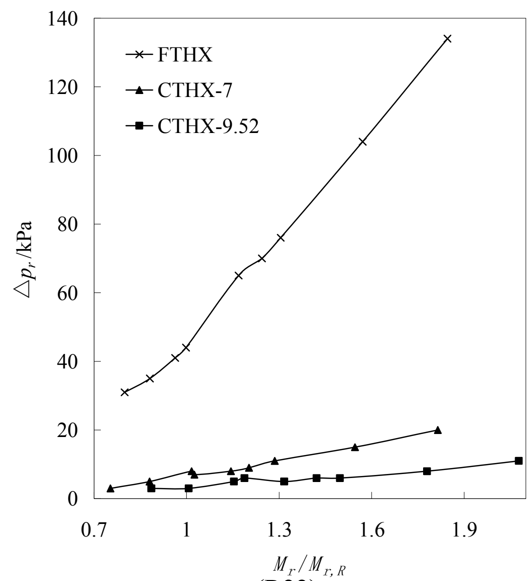
(35/24℃, R22, 1.856MPa, SH20℃,SC8℃)

Figure 6: Relative condensation capacity per unit frontal area



(35/24℃, R22, 1.73MPa, SH20℃,SC8℃)

Figure 7: Relative condensation capacity per unit frontal area



(R22)

Figure 8: Refrigerant side pressure drop

3.2 Test results of the residential air conditioner installed with heat exchanger as condenser

The split type residential air conditioner was charged with R22, the compressor displacement of which is 19.5cc/rev (motor rotate speed about 2880rev/min). EEV opening and refrigerant charge were adjusted to optimize the cooling system after target condenser was installed in the residential air conditioner. Test results were listed in table 2, from this table we can see that, the cooling capacity and EER of the system with FTHX is higher than those of the system with CTHX-7 but lower than those of the system with CTHX-9.52. The refrigerant charge of the system with FTHX is 18.7% and 27.8% lower than that of the system with CTHX-7 and CTHX-9.52, respectively.

If the 30th flat tube was in the refrigerant circuit of FTHX, the cooling capacity and EER would be more close to those of the system with CTHX-9.52. The comparison results in the cooling system obviously agree with the foregoing results in single-slab heat exchanger.

Table 2: Test results of the residential air conditioner

HX Symbol	R22 Charge/g	Cooling Capacity/W	Power/W	EER
FTHX	650	3167	1055	3.00
CTHX-7	800	3119	1064	2.93
CTHX-9.52	900	3182	1041	3.06

4. CONCLUSIONS

Condensation heat transfer performance of a new type louvered fin-and-flat-tube heat exchanger (FTHX) in single slab and in residential air-conditioning system were experimentally investigated, and were compared with fin-and-circular-tube heat exchangers (CTHX) under the same testing conditions. The test results showed that:

1) FTHX had the characteristics of low pressure drop of air side, high pressure drop of refrigerant side and less amount of refrigerant charged. The pressure drop of FTHX is 29% and 46% lower than that of φ7mm and φ9.52mm CTHX, respectively, at the frontal velocity 2m/s.

2) The overall heat transfer performance of FTHX was higher than that of φ7mm CTHX but a little lower than that of φ9.52mm CTHX.

3) The cooling capacity and EER of the residential air-conditioning system with FTHX were a little lower than those of the system with φ9.52mm CTHX, and the refrigerant charge is 27.8% lower than the system with φ9.52mm CTHX.

4) The application of the new type FTHX was limited to condenser for cooling unit in practice due to its refrigerant side high pressure drop.

The heat transfer performance of the new type FTHX will be improved by using internal grooved flat tube or grooved elliptical tube. The grooved elliptical tube will be helpful to reduce the refrigerant side pressure drop, thus the application arrange will probably extend to evaporator or condenser for air source heat pump.

REFERENCES

Liang, X., Zhai, L., Huang, H. and Zhuang R., 2006, Investigation of Inserts to Enhance Flow Boiling Heat Transfer in Tubes. *Proceedings of International Refrigeration and Air Conditioning Conference at Purdue*.

Wilson, J. W., Chato, J. C. and Newell, T. A., 2001, CDA Flattened Copper Tube Project Final Report. *ARTI Final Report*. CDA-Report2.