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Comparative performance of an automotive air conditioning system using micro-channel condensers with and without liquid-vapor separation

Wenxian Zheng[a], Ying Chen[a,]*, Nan Hua[a], Tianming Zhong[a], Yulie Gong[b]

[a]*School of Material and Energy, Guangdong University of Technology, Guangzhou 510006, China*
[b]*Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, Guangzhou, 510640, China*

Abstract

This paper experimentally investigated the performances of an automotive air conditioning (AAC) system with the liquid-vapor separation micro-channel condenser (LSMC) and a common parallel flow micro-channel condenser (PFMC), respectively. The performances of the two systems were compared under nomal running condition of IMACA. The cooling capacity of the LSMC system was 5.18% higher than that of the PFMC and the EER value of the LSMC system was 3.73% higher than that of the PFMC. The further investigation on the performance of the two systems were measured under the outdoor dry bulb temperature varying from 29℃ to 41℃ while the indoor dry bulb and wet bulb temperature fixed at 27℃ and 19.5℃. In addition, under the standard condition of IMACA, the thermodynamic performance of two systems under the condenser air face velocity varying from 1.5 to 4.5m/s was investigated. Compared with the PFMC system, the cooling capacity and EER of the LSMC system were improved by 1.79%~8.49% and 1.43%~7.18%, respectively.

Keywords: Liquid-vapor separation baffle; Microchannel condenser; Automotive air conditioning system; Cooling capacity; EER

1.Introduction

New technologies and refrigerants have been developed in automobile air conditioning (AAC) industry to improve system performance and reduce the effect of AAC on environment. Micro-channel tube with heat transfer enhancement characteristics is taken as one potential solution for system performance improvement. Recently, Peng [1] and Chen [2] presented a novel condenser named liquid-vapor separation condenser (LSC). They designed a kind of multi-pass flow condenser with an integrated orifice baffles in the header, which separated the liquid refrigerant during the condensation process in the headers and made the refrigerant circuitry in the tube. The advantages of using LSCs in refrigeration systems have been reported by Chen et al. [3]. A well-designed condenser can meet the requirements of energy saving, compactness, and cost reduction. For the parallel flow condenser using micro-channel tube technology firstly appeared about 20 years ago when R134a was used to replace R12 in AAC system. In

* Corresponding author. Tel.: +86-020-39322581; fax: +86-020-39322581.
E-mail address: chenying@gdut.edu.cn.

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this paper, the liquid-vapor separation micro-channel condenser (LSMC) and a common parallel flow micro-channel condenser (PFMC) were proposed to replace the currently used AAC heat exchangers. The component and system performance are experimentally studied on enthalpy difference chamber.

2.Novel structure design and description

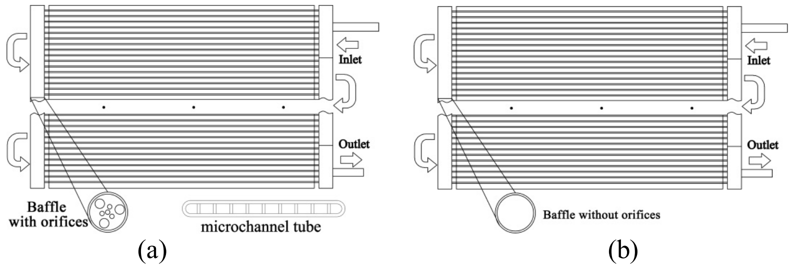

Fig.1 (a) (b)Structure diagram of the LSMC and the PFMC

As shown in Fig.1 (a), the LSMC condenser consists of a micro-channel tube bank and a pair of headers at both ends. Some aluminous baffles with diameter 1~2mm round holes called liquid-vapor separators are equipped in the headers and the positions of the liquid-vapor separators were showed in the figure. These liquid-vapor separators divide the refrigerant route into several passes with different tube numbers in per tube pass. Fig.1 (b) demonstrates a PFMC with the same tube structure parameters to the LSMC, except the baffles without holes in headers. In this paper, the PFMC was chosen as a baseline and the tube number of both condensers is 19-12-9-8 for each tube pass, totally 4 tube passes.

3.Experimental Apparatus And Test Conditions

3.1 Experimental apparatus

A series of experiments were conducted to investigate the performance of the air conditioning systems in two chambers showed in Fig.2. The automobile air conditioning was composed of a compressor, a compressor driving motor, a condenser, a receiver, a mechanical expansion valve, an evaporator and other accessory parts, The dry and wet bulb temperatures of air were measured by Pt100 thermocouples with accuracy of 0.1℃. The air volume flow was measured by a nozzle flow meter, whose accuracy was within 0.1% in the full scale. The pressure of the refrigerant was measured by pressure transducers with an accuracy of ±0.5%. The compressor rotational speed can be measured by a reflective photoelectric whirl measuring apparatus with an accuracy of ±0.2%. The accuracy of compressor consumption power meter was with ±0.05%.

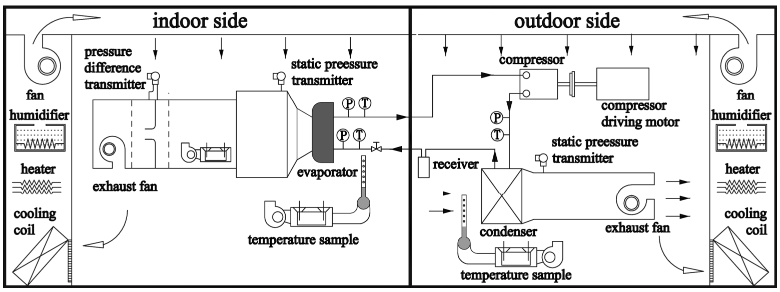

Fig.2 A layout of the experimental system apparatus

3.2. Test conditions

Two parallel flow micro-channel condensers with and without header were investigated experimentally, which with the same tube and fin structure and heat transfer area. The test ambient conditions are listed in Table 1.

Table 1 The test ambient conditions

	Unit	1	2	3	4	5	6	7	8	9	10
Evaporator	T_dry (℃)	27	27	27	27	27	27	27	27	27	27
	T_wet (℃)	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5
Condenser	T_air (℃)	35	35	35	35	29	32	35	38	41	35
	V_face (m/s)	1.5	2.5	3.5	4.5	2.5	2.5	2.5	2.5	2.5	1.5
	RPM_comp (r/min)	1800	1800	1800	1800	1800	1800	1800	1800	1800	900

4.Experimental Result And Discussion

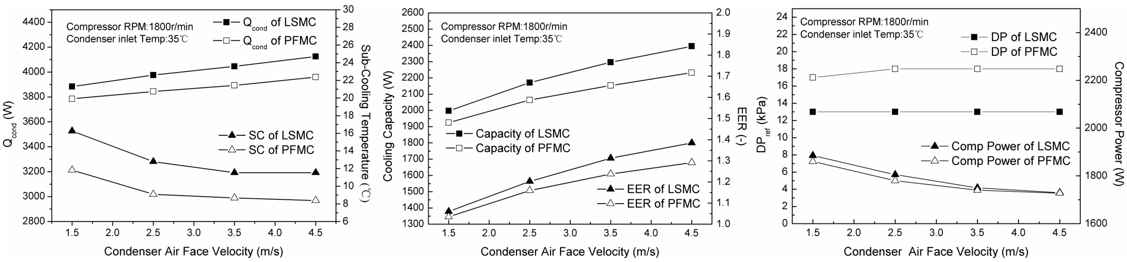

Fig. 3. (a) Condensation heat &Sub-cooling temp; (b) Cooling capacity & EER; (c) pressure drop & Compressor power.

The thermodynamic performances of the LSMC and the PFMC at different condenser air face velocities are shown in Fig.3(a),(b),(c). They shows the cooling capacity, EER and condenser heat increase with the increase of the condenser air face velocity both of systems. Fig.3(a) shows that the heat load of the LSMC is 2.5% to 6.2% higher than that of the PFMC at different condenser air face velocities. For the LSMC, over 10℃ sub-cooling temperature is observed, although all test conditions are the same as the PFMC. Fig.3(b) shows the LSMC system has 3.79% to 7.3% larger cooling capacity in car compartment than those of the PFMC system under the same conditions. The EER in LSMC system is 2.42% to 7.18% higher than which in the PFMC system, because the compressor consumption power of the LSMC system is larger. The refrigerant pressure drop of two condensers at different condenser air face velocity is shown in Fig.3(c), the pressure drop of the LSMC is lower than those of the PFMC obviously.

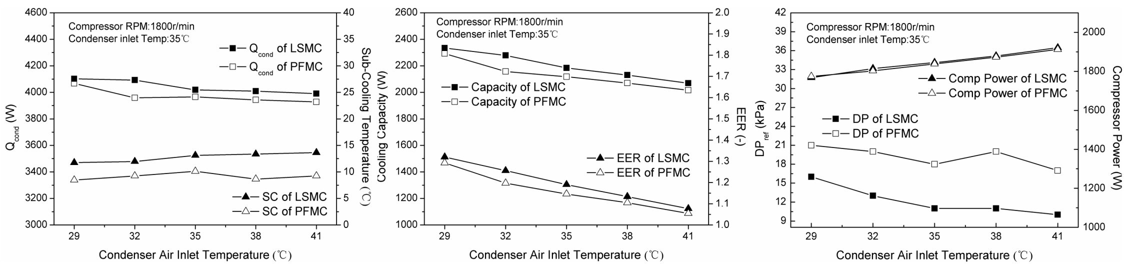

Fig. 4. (a) Condensation heat &Sub-cooling temp; (b) Cooling capacity & EER; (c) pressure drop & Compressor power.

Fig.4 (a),(b),(c) shows the thermodynamic performance of the LSMC and the PFMC at various outdoor air temperatures. They shows the cooling capacity and EER decrease when the condenser air inlet temperature increases. Fig. 4(a) shows that the heat load of the LSMC is 1.3% to 6.4% higher than that of the PFMC at different condenser air inlet temperatures. Fig.4 (b) shows the cooling capacity and EER LSMC are 1.79% to 8.49% and 2.13%~7.18% higher than those of the PFMC, respectively. The compressor powers of both systems are very close with each other at the different condenser air inlet temperatures.

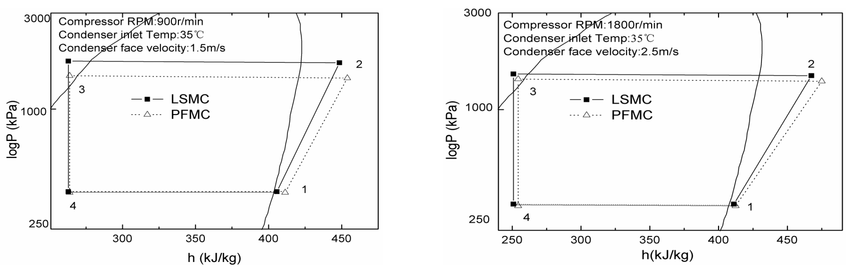

Fig. 5 (a) idle condition and (b) city condition P– h diagram for the LSMC and PFMC systems

As shown in Fig.5(a), (b), it is clear that the LSMC system has a larger cooling capacity and a better system performance than the PFMC system. The condensation pressure in the LSMC system is much higher than that of the baseline system, although the enthalpy difference between compressor suction and discharge ports for both systems are only have little difference. The compressor power of the LSMC system is a little higher, because of the higher refrigerant mass flow rate. Fig.5(a) shows the sub-cooling temperature at condenser exit of the LSMC system is larger than that of the PFMC system.

5.Conclusions

- The components test data comparisons show that the system performance of the LSMC system is better than the PFMC system.
- Under the standard rating conditions of IMACA, compared with the PFMC system, the cooling capacity and EER of the LSMC system were improved by 1.79% ~ 8.49% and 1.43% ~ 7.18%, respectively.
- Further study is necessary to optimize not only the structure of the LSMC but in several aspects of system such as evaporator, more efficient compressor and so on.

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Ying Chen

Ying Chen is a professor, Faculty of Material and Energy, Guangdong University of Technology. Her research interests include heat transfer enhancement in cooling applications, phase change phenomenon of nanofluids, and antiscale of heat exchanger.