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Experimental investigation of Micro-Channel Heat Exchanger

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ABSTRACT - Microchannel Evaporator now a days can be effectively used due to its compact size in refrigerators for its performance, refrigeration setup design to detect experimental performance of microchannel evaporator. In this paper performance analysis of microchannel evaporator is compared with round tube and coil tube. In analysis of micro channel evaporators, it can be found more effective at various loads and operating condition. For review, same size of micro channel and round tube evaporator and microchannel are considered. From experiment the micro channel evaporator is made to have nearly identical face area, depth and fin density as the round tube evaporator which is the baseline. Also varying the refrigerants, COP & efficiency of micro channel the various reviews of microchannel evaporator can be efficient and also refrigerator system requires less power.

Keywords :- Refrigerator, Round tube evaporator, Microchannel evaporator, COP, Heat transfer rate

I. INTRODUCTION

The main aim is to understand the heat exchangers with microchannel flow and heat transfer from an refrigerating point of view, in conjunction with the global trends in cooling technologies and the requirements of the refrigerating industry.Heat exchanger with reliable and high performance has been the study focus of refrigeration and air conditioning system. In recent years, with increasing demand for lightweight and rising copper prices, copper substitution is also a widespread concern.Micro-channel heat exchanger can reduce equipment weight, improve device performance and make it compact. The product competitiveness can be improved by using aluminiums. Micro-channel heat exchanger has been extensive researched and applied in cooling of electronic equipments. Along with the improving of process technology, micro-channel technology is gradually used inautomotive air conditioning system ,household air conditioning, and refrigeration systems.

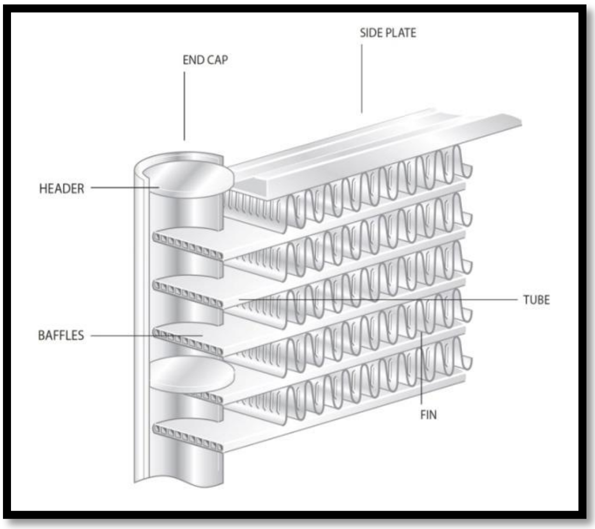

Fig.1.Sectional Microchannel Heat Exchanger

Microchannel in microtechnology is a channel with a hydraulic diameter below 1 mm.Microchannels are used in fluid control and heat transfer.Fig.1 shows the sectional view of MCHE. The concept of the microchannel was proposed for the first time by Tuckerman and Pease.They suggested an effective method for designing microchannels in the laminar and fully developed flow.

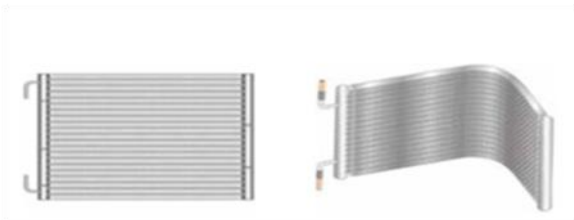

Fig.2. MCHE

II. LITERATURE REVIEW

The literature review is carried out in order to see present research in this area which is elaborated under the present status. Further review will be carried out for following purpose by referring journals like International Journal of Refrigeration, Applied Thermal Engg.ASHRAE Journal, Renewable and sustainable Energy Review, Journal of Industrial andscientific Research, etc.Many researchers have attempted experimental and theoretical work on micro channel evaporator some of this work is focused on the use of micro channel evaporators in Refrigeration System.

1. GundaMader, Georg P.F. Fosel, Lars F.S. Larsen [3] presented comparison of the transient behavior of microchannel and fin-and-tube evaporators. The development of control algorithms for refrigeration systems requires models capable of simulating transient behavior with sensible computational time and effort. The most pronounced dynamics in these systems are found in the condenser and the evaporator, especially the transient behavior of the evaporator is of great importance when designing and tuning controllers for refrigeration systems. Various so called moving boundary models were developed for capturing these dynamics and showed to cover the important characteristics. A factor that has significant influence on the time constant and nonlinear behavior of a system is the amount of refrigerant charge in evaporator which is considerably reduced when microchannel heat exchangers are utilized. Here a moving boundary model is used and adapted to simulate and compare the transient behavior of a microchannel evaporator with a fin-and-tube evaporator for a residential air-conditioning system. The results are validated experimentally on a test rig.

2. S.G. Kandlikar, W.J. Grande, "Evolution of microchannel flow passages-thermohydraulic

performance and fabrication technology[4] This paper is a synthesis of the design, operational and theoretical features of microchannel heat exchangers (MCHEX). The main contributions to the development of new design solutions and technologies in this field are presented. Differences by fluid flow and heat transfer between theoretical calculations and experimental results for MCHEX are shown. The influence of the wall velocity slip process on the flow and heat exchange in MCHEX is emphasized. The advantages of a very high thermal load using MCHEX are pointed out. This justifies the interest in their use, generally, in compact thermodynamic systems and, particularly, in cooling Micro-Electro-Mechanical Systems (MEMS). Traditional miniaturization technologies are the most accessible approach to produce micro-structures. These miniaturization techniques using traditional machine tools have been adapted to operate under miniature regimes. The domain of restricted use of machine tools becomes smaller as the lithography method is in expansion. Thus, the channel width of 25μm with an accuracy of order ± 4μm can be obtained with commercially available equipment

3 Tuckerman, D. B., and Pease, R. F.W., 1981, "High-performance Heat Sinking

for VLSI," IEEE Electron Device Lett.. [5] The present work is based on theoretical and computational investigations into microchannel heat exchangers. Microchannel heat exchangers have long been used as condensers but concerns regarding refrigerant maldistribution have so far prevented their use as evaporators.

The first part of the document is devoted to identifying causes of maldistribution and suggesting ways to reduce and eventually eliminate maldistribution. To reduce maldistribution caused due to header pressure gradient, short and fat radial headers were demonstrated to be better than longitudinal headers currently used in microchannel condensers.

The second part describes a way to avoid the problem associated with distributing two-phase refrigerant: passive vapor bypass. Immediately downstream of the expansion device, two-phase refrigerant is separated into vapor which is bypassed directly to the suction line through an adiabatic tube and liquid which is distributed into the evaporator. Computer simulation models were developed to explore the feasibility of this concept for a residential air-conditioning application using both sub- and transcritical cycles.

The last part of the document identified tradeoffs among the first cost, operating cost and compactness of microchannel heat exchangers. Variation of air-side parameters such as fin height, thickness and pitch were considered to identify a set of designs that have the lowest first cost and another having the highest energy efficiency.

4. Mudawar, I., 2001, "Assessment of High-Heat-Flux Thermal Management

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In the paper, micro channel heat exchangers are applied to residential and commercial Refrigeration systems.. The performance of heat pump system using micro channel heat exchangers is compared with that of baseline heat pump system using tube & fin heat exchangers. Experimental results show that the capacity of heat pump system can increase by 4% at most by using micro channel heat exchangers, and energy efficiency can increase by 4% at most. The weight of heat exchangers can be reduced by 45% at most, and the refrigerant charge can be reduced by 51% at most. In addition, the distribution of refrigerant becomes more uniform by distribution optimization.

5. Jianghong Wu, Guang Ouyang, Puxiu Hou, Haobin Xiao. [2] presented Numerical modeling of serpentine microchannel evaporators. Microchannel (or mini-channel) heat exchangers are drawing more attention because of the potential cost reduction and the lower refrigerant charge. Serpentine microchannel heat exchangers are even more compact because of the minimized headers. Using the serpentine microchannel condenser, some thermodynamically good but flammable refrigerants like R-290 (Propane) can be extended to more applications. To well size the serpentine microchannel condensers, a distributed-parameter model has been developed in this paper. Airside maldistribution is taken into account. Model validation shows good agreement with the experimental data. The predictions on the heating capacity and the pressure drop fall into 10% error band. Further analysis shows the impact of the pass number and the airside maldistribution on the condenser performance.

6. Ehsan Moallem, Sankar Padhmanabhan, Lorenzo Cremaschi, Daniel E. Fisher [8] Presented Numerical Simulations of a Micro-Channel Wall-Tube evaporator for Domestic Refrigerators in recent years, microchannel heat exchangers have begun to be used in refrigeration and air conditioning systems. This paper introduces a microchannel evaporator for domestic refrigerators with a theoretical model to evaluate its performance. The model was used to obtain the optimal design parameters for different numbers of tubes and tube lengths. The results show that the needed tube height of the downward section decreases with the number of tubes and the tube diameter. Compared with the original evaporator, the present optimal design parameters can reduce the total metal mass by 48.6% for the two wall two side design and by 26% for the two wall one side design. Thus, the present evaporator is much better than the evaporators usually used in actual domestic refrigerators.

7. **Bo Xu, Qing Han, Jiangping Chen, Feng Li, Nianjie Wang, Dong Li, Xiaoyong Pan [9]** The performance of the system with MCHEs in this studythe cooling capacity and EER of case 4 increases by 2% and 4% separately when compared. Meanwhile COP are same with baseline. Fig. 8 also shows that the weight of heat exchangers in case 4 is only 65% of case 3. And the refrigerant charge of case 4 is only 60% of case 3.

The MCHEs are 2 rows parallel-flow design which have different FPI for each row. The refrigerant flow velocity in the microchannel tubes is enhanced by using this 2 rows design, so the heat transfer coefficient in the tube is enhanced, and the oil return risk is reduced greatly. The first row which transfer heat with the air flow first is designed to be 8.5 FPI in order to avoid the blocks of air flow path by frost, and the second row is 16 FPI to increase the heat transfer area as much as possible. Though the refrigerant distribution optimization of 2 rows MCHE is much more difficult than 1 row MCHE when used as evaporator, a good distribution is gotten after optimization. There is no frost remain or drainage issue for the defrosting condition. The system heating capacity and HSPF can meet the target finally.

3.OBJECTIVES:

To compare performance of Refrigerator using Microchannel Heat Exchanger in place of evaporator with performance of Refrigerator with conventional evaporator using following points:

i.COP: We aim to improve the COP of refrigerator to make it more attractive for usage.

ii.Size: We aim to reduce the size of the assembly by making it more compact.

iii.Weight: The refrigeration system is too bulky. Its weight reduction is also one of the aims. It can be reduced by using polymers.

iv.Cost: Cost is the biggest barrier in implementation of refrigeration. We aim to minimize it as far as possible.

III. SCOPE

To meet the rapid development of modern microelectronic mechanical requirements of heat transfer, micro-channel heat exchangers began to be used in cooling high-density electronic devices in the 1980s, thenappeared in the MEMS(microelectronic mechanics system) industry in the 1990s. With studies on properties of micro-channel in depth and application in the promotion of electronic cooling,advantages of micro-channel heat exchanger which a traditional heat exchanger cannot match gradually appear.

MCHEs offer several major advantages in cold storage applications, for example in restaurants, food processing plants and supermarkets. These compact, efficient heat exchangers are very easy to keep clean, promoting the hygiene that is essential wherever food is involved. MCHEs also offer a 10% better COP than F&T coils of the same size. This means the frontal area of the unit can be 35% smaller without reducing its effect. So you can produce neat, efficient systems that can be relied upon to keep cold store rooms at the right temperature, year after year. Thanks to their low refrigerant charge, MCHEs also enable the production of more environmentally friendly products

IV. METHODOLOGY

Methodology is a very important concept to be considered to make sure the fluent working of the system and to get expected results. In other words, methodology which contains the elements of the work based on the objectives and scope of the project. A good methodology can present the overall view of the project and be used to arrange or extract the data easily. This includes the various steps involved such as literature study, introduction, fabrication of parts, testing phase, etc. Fig.2 shows the chart for methodology.

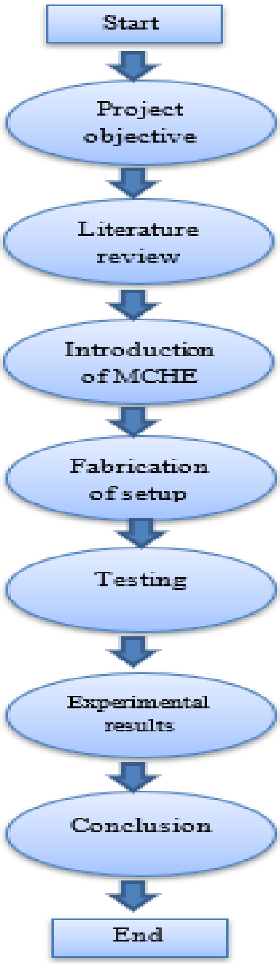

Fig. 2 Methodology

V. EXPERIMENTAL SETUP

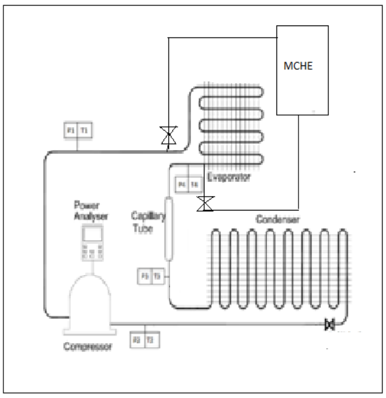

Fig. 3 Experimental setup

Fig.3 shows Experimental setup for refrigeration system in which round tube evaporators is replaced by MCHE. Refrigeration system is works on the principle of vapour compression cycle. Control valve is used to control flow either in round tube evaporator or MCHE.

In this project two types of evaporaters are used

1. Round tube evaporator
2. Micro channel evaporator

In this experiment using refrigerant R12 , COP of refrigerant is calculated. Compressor passes refrigerant to two evaporators separately and hence COP of both the system is thus calculated.

SPECIFICATIONS

1. Compressor: Hermetically sealed type
2. Air cooled condenser: copper coil with fins & cooling fan
3. Expansion device: capillary tube
4. Energy meter: one each for power supply to the measurement of compressor and evaporator heater.
5. Evaporator: Copper coil
6. Digital temperature indicator: To measure the temperatures at various points i.e. Evaporator inlet & outlet, condenser inlet & outlet temperatures of refrigerant.
7. Ammeter: 0- 15 Amps for compressor
8. Voltmeter: 230 V, A.C. for compressor
9. Switches: For various controls

PROCEDURE

1. Observe the existing setup.
2. Discharge the setup.
3. Fabricate the setup which consists of making the setup according to the design along with fitting of pressure and temperature gauges.
4. Charge the system with refrigerant R-12.
5. Run the refrigerator for suitable time period so that it will ensure smooth flow of refrigerant through the circuit and ensures desired outcome (usually 2 to 3 hours).
6. Take the observations of suitable pressure and temperature at certain points.
7. Perform calculations.

Basic parameters:

1. HP condenser pressure in KG/CM2
2. LP evaporator pressure in Kg/Cm2
3. Condenser inlet temperature Tci
4. Condenser outlet temperature Tco
5. Evaporator inlet temperature Tei
6. Evaporator outlet temperature Teo
7. Ammeter reading in Amp
8. Voltmeter reading in V

VI. OBSERVATIONS

c_p = 0.980 KJ/Kg^{0}K

Atmospheric Pressure - 1.01325Bar

Sr. No.	1	2	3
P1 (Bar)	1.289	1.3579	1.378
P2 (Bar)	10.390	10.735	11.231
P3 (Bar)	10.32	10.666	10.871
P4 (Bar)	1.358	1.3579	1.358
T1 (^{0}c)	16.4	16.6	14.2
T2 (^{0}c)	64.7	66.3	67.9
T3 (^{0}c)	41.3	42	43.3
T4 (^{0}c)	-14.6	-19	-19.2
T5 (^{0}c)	23.8	23.3	24.1
P_C(W)	125	126	126
Time(hr)	1	3	5

Table.1. Observation

Where,

P1& T1 - Compressor inlet pressure and temperature.
P2& T2 - Compressor outlet pressure and temperature.
P3& T3 -Condenser outlet pressure and temperature.
P4& T4 -Evaporator outlet pressure and temperature.
T5-Atmospheric temperature**.**
P_C- Compressor power.

VII. RESULTS

Sr. No.	m(kg/s)	COP	Q(Watt)
1	5.434*10^-3	5.565	132.95
2	5.478*10^-3	5.478	130.45
3	4.5*10^-3	5.071	108.48

Table.2. Result

Where,

m=Mass flow rate
COP=Coefficient of Performance
Q=Heat Transfer Rate

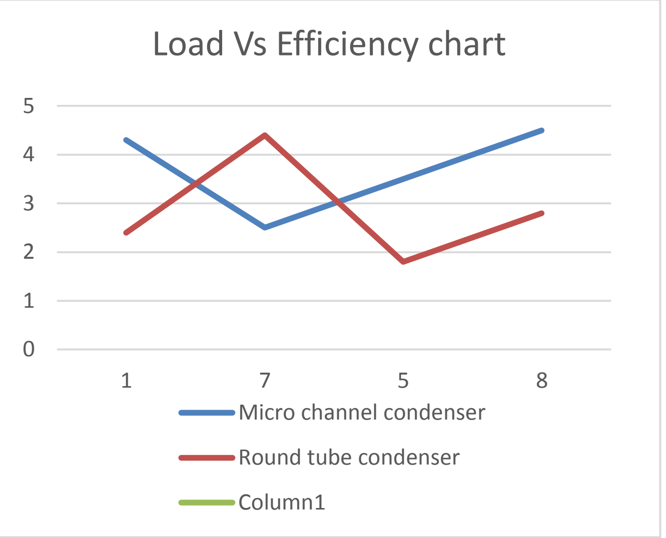

Fig.3. Load VS Efficiency

VIII. CONCLUSION

In this study, Refrigeration systems with a micro channel evaporator and a round tube evaporators were experimentally examined. These two evaporators had almost identical frontal area and depth because the purpose of this study was to measure performance improvement using the micro channel evaporator which had an almost identical package volume as the round tub evaporator. An economic issue such as heat exchanger cost was not considered. Significant performance improvement was presented for the system with microchannel condenser.

IX. REFERENCES

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