A Review of Air Conditioning with the Use of Mini-Channel and Micro-Channel Heat Exchanger

Shemal K. Parmar[1], Krunal N. Patel[2], Avdhoot N Jejurkar[3]

Abstract— Use of micro-channel and mini channel heat exchangers are significantly increased in air conditioning applications due to its favorable characteristics like higher heat and mass transfer, compact system and lower cost etc. In this review paper, characteristics of air conditioning system with minichannel and micro channel heat exchangers are analyzed. Mini-channel and micro-channel heat exchangers have higher surface contact area to volume ratio. Minichannel and micro-channel heat exchangers are lighter in weight because they are made of aluminum only. Also the cost of mini channel heat exchanger is less because of aluminum structure. Mini channel uses less power and refrigerant charge so it is also good for environment. Effectiveness of mini channel heat exchanger is increased by using fin at internal and external both the side. Mini-channel heat exchanger and micro-channel heat exchanger can be used in refrigeration and air conditioning system. In air conditioning system at both mini channel and micro-channel heat exchanger can be applied as both the condenser and evaporator. As mini and micro-channel heat exchangers are compact in size they are very much suitable for the automotive air conditioning system. Mini-channel and micro-channel heat exchanger the sensible and latent both cooling capacity increases and overall efficiency of air conditioning system increases.

Index Terms— Air Conditioning, Mini-channel heat exchanger, Micro-channel heat exchanger, Coil Effectiveness, Compact System, Heat transfer, Higher surface contact area.

1 Introduction

MINICHANNEL AND MICROCHANNEL HEAT EXCHANGERS

A heat exchanger is a device that is used to transfer thermal energy (enthalpy) between two or more fluids, between a solid surface and a fluid, or between solid particulates and a fluid, at different temperatures and in thermal contact. In heat exchangers, there are usually no external heat and work interactions.

If the ratio of surface contact area to volume is higher than it is called as compact heat exchanger. Mini and micro channel heat exchanger are compact type of heat exchangers. According to kandlikar they are distinguishing by their fundamental tube diameter. Diameter ranging from 0.01 to 0.2 mm is a microchannel heat exchanger, channel diameter ranging from 0.2 to 3 mm is Minichannel heat exchanger, and above 3 mm conventional type heat exchanger [4]. The ability to produce tubes with external or internal fins and with smaller wall thicknesses allows higher heat transfer area per unit volume of a tube. Therefore, mini- and microchannel tubes are ideal for use in compact and light weight heat exchanger.

Every air conditioning system contains at least two heat exchanger, usually they are called condenser and evaporator. Generally, in air conditioning system Mini and microchannel heat exchanger use in both the place at evaporator and condenser. In the case of condenser, the hot, high pressure refrigerant gas must be condensed to sub cooled liquid. So condenser work at high pressure. In the case of evaporator, sub cooled liquid passes into the heat exchanger. This refrigerant absorbs heat from the evaporating place and convert to the vapor form. This cools the air and boils the refrigerant.

Few advantages of Mini and microchannel heat exchangers over conventional heat exchangers are, Minichannel and microchannel has higher surface contact area than conventional heat exchanger,Higher heat transfer rate, Uses less refrigerant charge, For same cooling effect require less space, System become lighter in weight, Less costly. These advanatges show usefulness of the system.

2 Use of Mini-Micro Channel Heat Exchanger in Air Conditioning

In the year of 2012, S. Senaye, M. Dehghandokht have done thermal modeling of mini-channel and

- *Shemal Parmar is doing Masters in Thermal Engineering at Mechanical Engineering Department, Dr. Jivraj Mehta Institute of Technology, Mogar, Anand shemal1791991@gmail.com, +91-8128554595*
- *Krunal N Patel is a faculty at Mechanical Engineering Departmen, Institute of Technology and Management Universe, Vadodara, krunal_2191@yahoo.com, +91-9558650461*
- *Avdhoot N. Jejurkar is a faculty at Dr. Jivraj Mehta Institute of Technology at Mogar, Anand*

laminated types evaporator in mobile air conditioning system. The performance of mini-

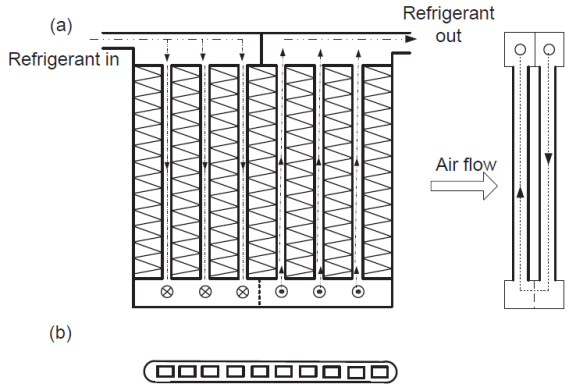

Fig. 1 mini channel Heat exchanger

channel heat exchanger is compared with the laminated evaporator which was used in automotive industries. The numerical results of modeling he laminated and mini-channel evaporators validated with corresponding experimental data which was obtained from experiments performed on mobile air conditioning system in calorimeter test bench. The performance of laminated and mini-channel were also compared under various operating conditions. They used ϵ- NTU method for evaluating and comparing the system under different conditions. After this experiments and results they concluded that the mini-channel evaporator had higher cooling capacity (7.2 %) and higher refrigerants pressure drop (45%) in comparison with the corresponding values in laminated evaporator assuming the same external geometry. The outlet air temperature and enthalpy of mini-channel evaporator was also lower (11%) and (8%) respectively, than that for laminated evaporator. This cause to reduce the time period as well as power/fuel consumption for reaching the comfortable cabin temperature [1].

In the year of 2013 Shambhu Prasad Shukla and Dr. D. B. Zodpe have compared the performance of residential air conditioning system having either a fin and tube condenser or a microchannel *condenser is experimentally investigated. For determining the capacity and performance characteristics of the unit under standard climate condition followed methods of testing specified by ISHRAE standard IS1391. As per the test standards, air side and refrigerant side measurements are used to determine performance, particularly cooling capacity and energy efficiency ratio (EER). For this investigation, a commercially available capacity residential air conditioning system having fin and tube condenser served as the base system. After*

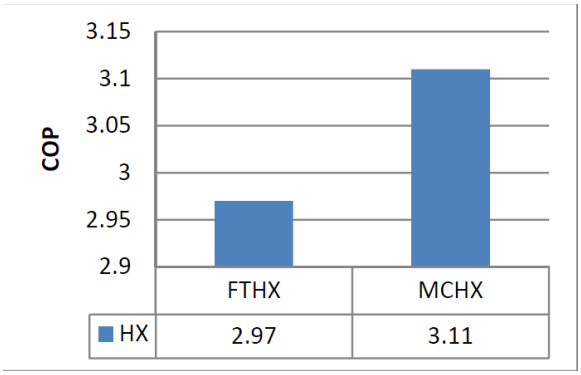

Fig. 2 COP comparison for both Heat exchanger [2]

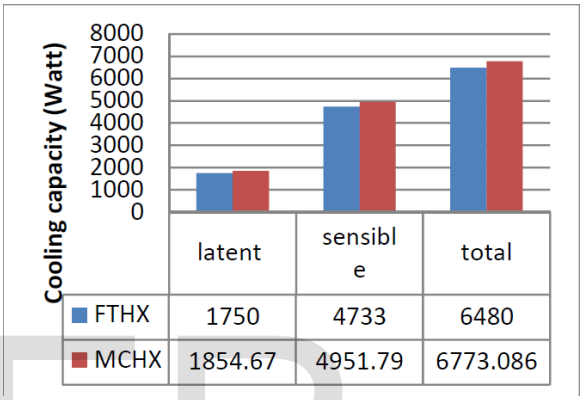

Fig. 3 comparison of cooling capacity [2]

testing the base unit condenser was replaced by a microchannel a microchannel heat exchanger with the same face area under identical test conditions. From test they concluded that sub-cooling of the liquid side is achieved for microchannel heat exchanger and results in increase in refrigeration effect. Both the latent capacity and sensible capacity increased considerably in microchannel heat exchanger. Cost of microchannel heat exchanger is less as no copper is used. For same cooling capacity the refrigerant charge reduces up to 18, thus reducing the refrigerant cost. So, Overall performance can be enhanced by using micro channel heat exchanger [2].

Raviwat Srisomba et al. have carried out their study on effect of operating conditions on the air side heat transfer, and pressure drop of a micro channel heat exchanger under wet surface conditions were studied experimentally. The test section was an aluminum microchannel heat exchanger, consist of multi louvered fin and multiport Mini channels. They stuied the effect of inlet humidity, air frontal velocity, air inlet temperature and refrigerant temperature on air side performance. To analyze experimental data the mean enthalpy difference method is used. The test was performed at relative air humidity raging between 45% and 80%, air inlet temperature ranges

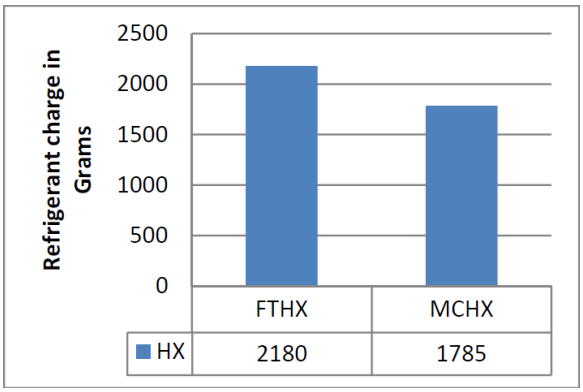

Fig. 4 Refrigerant charge for both heat exchangers

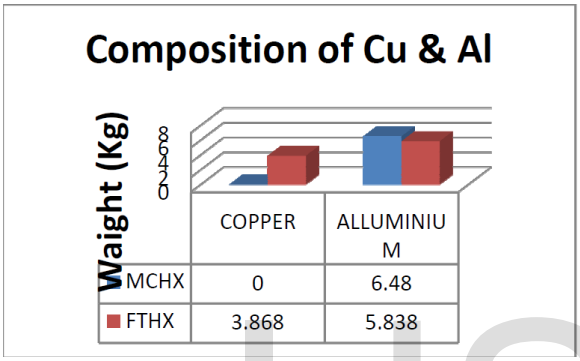

Fig. 5 Composition of Cu and Al [2]

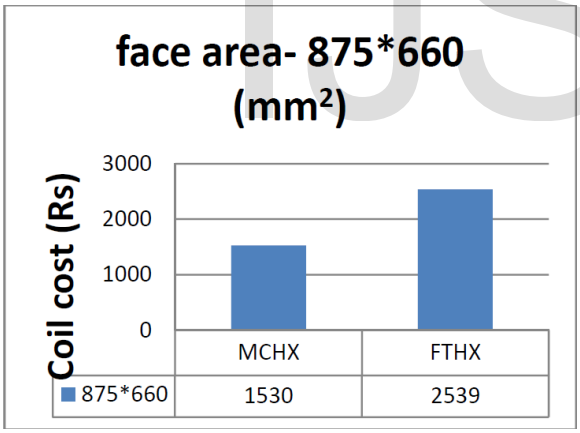

Fig. 6 Comparison of face area required [2]

of 27, 30 and 33 ˚C, refrigerant saturated temperature ranging from 18 to 22 ˚C and Reynolds number between 128 to 166. After experiment they concluded that the wet fin efficiency rapidly decreases with the increase in inlet relative humidity and air inlet temperature. The dehumidification capacity increases as the air frontal velocity, inlet relative humidity and air inlet temperature increases, and refrigerant's saturated temperature decreases. The heat transfer coefficient increases as the inlet relative humidity

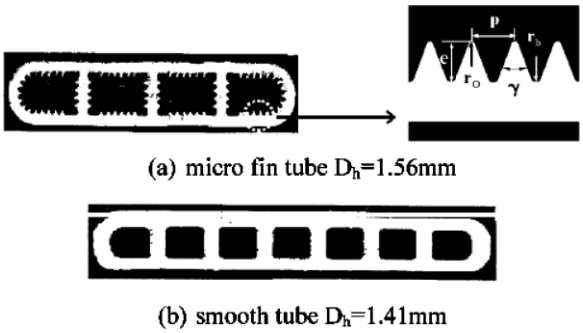

Fig. 7 mini channel with or without micro fins [4]

and air inlet temperature increase, and as the refrigerant's saturated temperature decreases. The relative humidity and air frontal velocity have significant effects on the air-side pressure drop for the smaller fin pitch, louver pitch, and flow depth heat exchanger cases, whereas air and refrigerant temperatures have small effects [3].

In the year of 2007, Satish G. Kandlikar have presented the road map of implementing mini channel heat exchanger in refrigeration and air conditioning. Characteristics of mini channel heat exchangers and their components were analyzed. How the mini channel heat exchanger is advantageous over conventional heat exchanger? The different parameters and component of mini channel heat exchanger which is helpful in improving the heat transfer and efficiency is discussed. The mini channel heat exchanger can be used in different applications. Refrigeration and air conditioning is one of those application. This paper provides the road map for implementing Minichannel heat exchanger in refrigeration and air conditioning system. After all analysis he concluded that the surface area and heat transfer coefficient enhancements associated with mini channel flow can be exploited effectively to make the refrigeration equipment smaller in size. Significant refrigerant charge reductions are also possible due to the higher surface area-to-volume ratio for the mini channels. Additional advantages include capital cost reductions, reduced environmental impact due to lower refrigerant inventory, and possible improvements in COP of the system. The mini channel heat exchangers currently being considered for refrigeration applications are modeled after the existing heat exchangers in automotive applications. A new initiative is recommended to develop new types of heat exchangers that fully exploit the advantages of mini channel flow passages on both sides of refrigerant-to-water or refrigerant-to-secondary refrigerant heat exchangers [4].

In the year of 2013, Thanhtrung Dang and Minhhung Doan have investigated experimentally condensation heat transfer of two microchannel heat exchangers. The heat transfer rate of a microchannel heat exchanger was achieved 272.9 W for the vapor having the inlet temperature of 101 ^{o}C and the mass flow rate of 0.123 g/s and for the cooling water having the inlet temperature of 32^{o}C and mass flow rate of 3.1133 g/s. It was also observed that the heat transfer rate obtained from the counter flow arrangement is always higher than that obtained from the parallel one: the value obtained from the counter flow arrangement is 1.04 to 1.05 times of that obtained from the parallel flow. The results for two phases are in good agreement with the results for single phase. In addition, the condensation heat transfer coefficient in the microchannel heat exchangers decreases as increasing the inlet cooling water temperature [5].

In the year of 2014, Davide del Col, Macro Azzolin, Stefano Bortolin, Alberto Cavalini have presented their study. To reduce effect of global warming it is necessary to develop new HVAC (heating, ventilation and air conditioning) technologies with low environmental impact. When considering the impact, both direct impact and indirect impact should take into account. The energy consumption, and consequent carbon dioxide emissions caused by the electricity production process is considered in indirect impact. And leakage of refrigerant is considered as direct impact. The refrigerant charge reduction in the refrigerating systems, along with the substitution of HCFCs and high-GWP HFCs, is a goal for urgent need to reduce their contribution to greenhouse effect and reduce atmospheric emission. In this paper mini channels technology and various applications are presented. Mini channels are used in order to reduce the internal volume of the heat exchanger without compromising with the performance. The system with mini channel uses low refrigerant charge. So it is good solution for the direct impact for atmosphere.

3 Conclusion

Nowadays, Minichannel and Microchannel heat exchangers are extensively used and studied for their favorable characteristics. Mini channels are used in order to reduce the internal volume of the heat exchanger without compromising with the performance. The system with mini channel uses low refrigerant charge. So it is good solution for the direct impact for atmosphere. Few more characteristics show the usefulness of the system like they are lighter in weight. And no copper is used so the cost is also less of this heat exchangers. With all this advantages this heat- exchangers can be easily used in our air conditioning system. Mini and microchannel heat exchanger can be implemented in both places as condensed and evaporator. Latent and sensible both type of heat transfer increases in this type of heat exchanger. So all over COP is higher for this heat exchanger.

REFRENCES

[1] S. Senaye, M. Dehghandokht, "Thermal Modeling of Mini-Channel and Laminated Types Evaporator in Mobile Air Conditioning System," Internatinal journal of automotive engineering, volume 2, number 2, april 2012

[2] Shambhu Prasad Shukla , Dr. D. B. Zodpe, "Performance comparison of microchannel heat exchanger with fin and tub heat exchanger for split air conditioner," International creative research thought, volume 1 (2013), ISSN-2320-2882

[3] Raviwat Srisomba, Lazarus Godson Asirvatham, Omid Mahian , Ahmet Selim Dalkılıç, Mohamed M. Awad, Somchai Wongwises, "Air-side performance of a micro-channel heat exchanger in wet surface conditions"

[4] Kandlikar, Satish G.(2007) 'A Roadmap for Implementing Minichannels in Refrigeration and Air Conditioning Systems—Current Status and Future Directions', Heat Transfer Engineering, 28: 12, 973 — 985

[5] Thanhtrung Dang and Minhhung Doan, "An Experimental Investigation on Condensation Heat Transfer of Microchannel Heat Exchangers," International Journal of Computational Engineering Research, Vol, 03, Issue-12.

[6] Del Col, Davide; Rossato, Marco; Bernardinello, Stefano; and Zaramella, Luca, "Innovative Minichannel Condensers and Evaporators for Air Conditioning Equipment" (2014). International Refrigeration and Air Conditioning Conference. Paper 1527.

[7] Yanhui Han, Yan Liu, Ming Li, Jin Huang, "A review of development of micro-channel heat exchanger applied in air-conditioning system," 2011 2nd International Conference on Advances in Energy Engineering (ICAEE2011), Energy Procedia 14 (2012) 148 – 153.

[8] A Arteconi, G Giuliani, M Tartuferi and F Polonara. "Characterization of a mini-channel heat exchanger for a heat pump system", 31st UIT (Italian Union of Thermo-fluid-dynamics) Heat Transfer Conference 2013, doi:10.1088/1742-6596/501/1/012023

[9] Kamlesh Chhajed, Nilesh Patil, "Study and investigation of Refrigeration system using Microchannel condenser and round tube condenser," International journal of advanced research in science management and technology, Volume 1, Issue 7, 2015.

[10] Brix, W., Elmegaard, B., Carlsen, H., Hansen, M. O. L., & Jakobsen, A. (2010). Modelling refrigerant distribution in minichannel evaporators. Kgs. Lyngby, Denmark: Technical University of Denmark (DTU). (DCAMM Special Report; No. S114).

[11] Jiri Hejcik, Miroslav Jicha, "Single phase heat transfer in minichannels," PJ Web of Conferences 67 , epjconf / 201 02034 (2014), DOI : 10.1015/epjconf/20146702034
[12] Jay K. Dhulia. "A review of Design and Development of Minichannel and microchannel heat exchanger," 2015 IJEDR, volume 3, Issue 4, ISSN : 2321-9939.
[13] Ashraf, Mohammed Shan, Thoufeeq Azad, Bibin, Arun, " Experimental Analysis of Performance Characteristics of Mini Channel Heat Exchangers," International Journal of Research in Mechanical Engineering, Volume 4, Issue-3 (may-june 2016), pp. 39-43, ISSN Online: 2347-5188, Print: 2347-8772, DOA: 2705201
[14] Hailei Wang, Richard B.Peterson, " Performance Enhancement of a thermally activated cooling system using microchannel heat echangers."
[15] D.P. Patil, J.H. Bhangale, K.S. Deshmukh, "Experimental analysis of refrigeration system using microchannel condenser and round tube condenser,"
[16] John c. Hipchen, Robert D. Weed, Ming Zhang, Denis Nasuta, "Simulation based comparison of Optimized AC coil using small diameter Copper and aluminum Micro-channel tubes,"(2012), International Refrigeration and air conditioning conference, paper 1305

BIOGRAPHIES

Shemal Parmar is doing Masters in Thermal Engineering at Mechanical Engineering Department, Dr. Jivaraj Mehta Institute of Technology, Mogar at Anand which is affiliated to Gujarat Technological University. His field of interest is air conditioning and heat transfer.

Krunal N. Patel is a faculty at ITM Universe, an engineering college under Gujarat Technical University. He has done his M.E. in thermal engineering from Gujarat Technical University. His field of interests include refrigeration, air conditioning and energy conservation.

Avdhoot N. Jejurkar is a faculty at Dr. Jivraj Mehta Institute of Technolgoly at Mogar, near Anand. His area of interest includes solar energy and thermal engineering.