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A Review on Performance Enhancement of Microchannel Condenser in Refrigeration System

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Abstract

This review paper presents the work on the performance of condenser used in refrigeration system by the various researches. Micro channel condenser used to enhance the performance of various parameters like heat transfer, pressure drop, energy efficient ratio, COP and refrigerant effect of the system. In refrigeration system condenser is a vital part. Micro channel heat exchanger has been increasingly applied in HVAC&R (Heating, ventilation and air conditioning & refrigeration) field due to its higher efficiently heat transfer rate more compact structure.

Keywords: Micro channel condenser, refrigeration system, heat transfer rate, refrigerant Effect.

1. INTRODUCTION

Micro channel condenser is an effective enhancement technique for its relatively high heat transfer coefficient and low pressure drop penalty. micro channels bring to the overall performance of the heat exchanger include the increase in compactness, possible reduction of the air-side pressure drop, improvement of the heat transfer, and the Reduction of the refrigerant charge. It is also frequently used in automotive refrigerant condensers, which use aluminum tubes. It can reduce equipment weight, improve the device compactness, also reduced the manufacturing cost &competitiveness can be improved by using aluminums. Air conditioning and refrigeration system plays an important role in industry, infrastructure and household. The industry sectors include the food industries, textiles chemicals, printings, transports and others. Infrastructure includes banks, restaurants, schools, hotels and recreational facilities. The micro channel condenser is made to have nearly an identical face area, depth and fin density as the round tube condenser which is the baseline. Micro channel condenser should provide higher capacity and system COP. The objective of this paper is to summarize the benefits of micro channel coils in air conditioning applications. The flat shape of the micro channel reduces the power necessary to move the air through the heat exchanger (air-side pressure drop), compared to round-tube heat exchangers. The shape of the micro channel tubes and fins also increases the air side heat transfer coefficient. Decreasing the hydraulic diameter of the micro channel tube and increasing the number of ports, increases the local heat transfer coefficients. Increasing the local heat transfer coefficient on both sides decreases the required size of the heat exchanger therefore reducing the amount of tubing necessary for a specific heat load. Decreasing the hydraulic diameter of the tube also decreases the volume of the tube and the refrigerant quantity. The only disadvantage causes due to reduction of the hydraulic diameter in the micro channel tube is that the refrigerant pressure drop increases for the Same mass flux or even worse for the same number of tubes never the less increasing the number of tubes one could Mitigate the problem to some extent. Higher pressure drops require more pumping power and higher energy Consumption resulting in reduction in COP (Coefficient of Performance).

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2. Literature Review

Weilin Qu, Issam Mudawar [2003], The study presented a water-cooled two-phase micro-channel heat sink containing 21 parallel 231×713 μm micro-channels explores pressure drop and hydrodynamic instability . Two phase hydrodynamic instability of two types were identified: mild parallel channel instability and severe pressure drop. It is shown that severe pressure drop oscillations, which can trigger pre-mature critical heat flux, which eliminated simply by throttling the flow upstream of the heat sink. For predicting two-phase pressure drop are assessed for suitability to micro-channel heat-sink design different methods. Generalized two-phase pressure drop correlations are examined first, developed for both macro- and mini/micro-channels 10 correlations are include. Effects of channel size and coolant mass velocity incorporated by new correlation which shows better accuracy than prior correlations. A theoretical annular two-phase flow model comes under second method which aside from excellent predictive capability, possesses the unique attributes of providing a detailed description of the various transport processes occurring in the micro-channel, as well as fundamental appeal and broader application range than correlations [1].

Yun Wook Hwang, Min Soo Kim (2006) in this paper R-134a used for investigate the pressure drop characteristics in micro tubes. The test tube diameter was circular stainless steel tube with inner diameters of 0.244, 0.430, and 0.792 mm. Although some of the existing studies reported the early flow transition at the Reynolds number of less than 1000, it was not found in the single-phase flow pressure drop tests. The conventional theory predicted the friction factors well within an absolute average deviation of 8.9%. The two-phase flow pressure drop increased with increasing mass flux, increasing quality, and decreasing tube diameter. The existing correlations failed to predict the two-phase friction multipliers in the micro tubes of this study. A new correlation to predict the two-phase flow pressure drop in micro tubes was developed in the form of the Lockhart–Martinelli correlation. It includes the effect of the tube diameter, surface tension effect, and the effect of the Reynolds number on the two-phase flow pressure drop in micro tubes. The new correlation developed in this study predicted the experimental data within an absolute average deviation of 8.1%. **[2]**

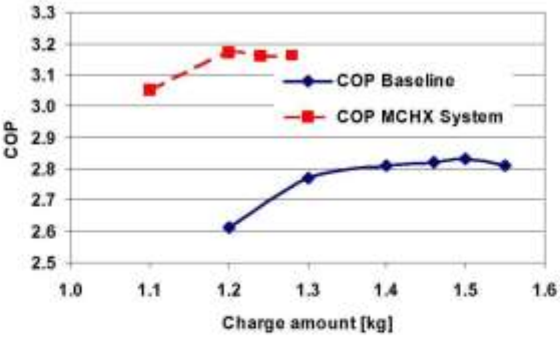

Figure: 1 COP vs. Refrigerant Charge Amount

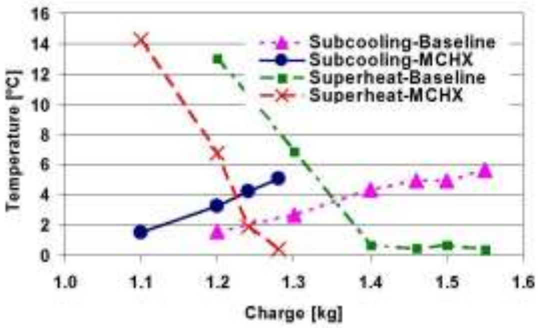

Figure: 2 Degree of Superheating and Sub cooling V/s. Refrigerant Charge Amount

Rin Yun, Yunho Hwang, Reinhard Radermacher, Rebeka Zecirovic (2006) in this study the seasonal performance of a residential air conditioning system having either a fin-and-tube condenser or a micro channel condenser is experimentally investigated. Micro channel heat exchangers offer a higher volumetric heat exchange capacity and a reduced refrigerant charge amount. However, the operating

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characteristics and the seasonal energy efficiency ratio (SEER) of the residential air conditioning system using a micro channel condenser have not been well known. For this investigation, a commercially available 7 kW capacity residential air conditioning system having a fin-and-tube condenser served as the base system. After testing the base unit with the fin-and-tube condenser, the condenser was replaced by a micro channel heat exchanger with the same face area under identical test conditions. The test results show that the system with a micro channel heat exchanger has a reduced refrigerant charge amount of 10%, the coefficient of performance increased by 6% to 10%, and the SEER increased by 7% as compared with those of the base system. Moreover, the condensing pressure of the system is decreased by 100 kPa and the pressure drop across the condenser is decreased by 84%. The micro channel heat exchanger enhances the SEER of the residential air conditioning system by providing better heat transfers at reduced pressure drops. [3]

Pega Hrnjak, Andy D. Litch (2008) this paper presents a prototype ammonia chiller with an air-cooled Condenser and plate evaporators are used for experimental results. The main objectives were compactness of the system and charge reduction. In the chiller Two aluminum condensers were evaluated: one a single serpentine ‘‘macro channel’’ tube (D_h ¼ 4.06 mm) and other with a parallel tube arrangement between headers and ‘‘micro channel’’ tubes (hydraulic diameter D_h ¼ 0.7mm). The charge is reduced to 20 g/kW (2.5 oz/Ton).The performances of condense and chillers are compared based on various criteria to other available ammonia chillers. From the experimental data taken, the micro channel parallel Flow condenser appears to outperform the macro channel Serpentine condenser. The overall heat transfer coefficient for a given face velocity is 60–80% higher than for the serpentine Condenser; and the charge is an average of 53% less. Existing air-cooled ammonia chillers could greatly benefit from micro channel technology. The charge would be significantly reduced while maintaining the same heat transfer capability. In addition, the external volume of the chiller could be reduced because the external volume of a micro channel design is small. It can be about 30% of the volume of the standard round tube, plate fin condenser. **[4]**

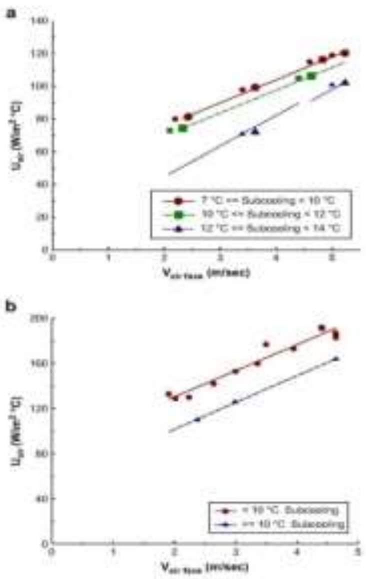

Figure: 3 overall heat transfer coefficients in (a) serpentine and (b) Microchannel parallel flow condenser based on air Side surface area

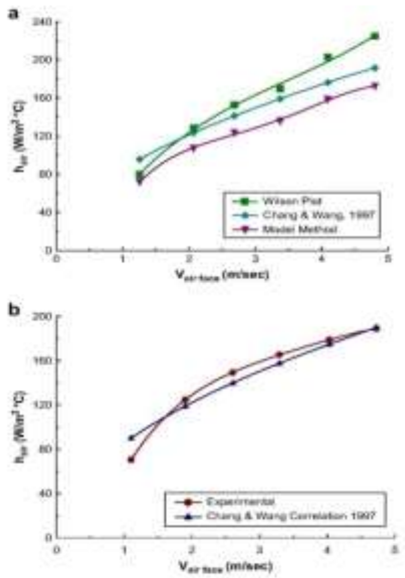

Figure: 4 air side heat transfer results (a) serpentine and (b) Microchannel condenser

Chang Yong Park, Pega Hrnjak (2008) This study investigates effects of two condensers (micro channel and round tube) on the performance of R410a residential air conditioning system was

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experimentally examined. In various conditions two systems were operated in separate environmental chamber and their performance was measured. Both cooling capacity and COP of the system with micro channel condenser were higher than those for the round tube condenser in all test conditions. A numerical model for the micro channel condenser simulated with consideration given to the refrigerant distribution in the headers and non uniform air distribution at the face of the condenser. This result showed that refrigerant distribution and effect of the air was not a significant parameter in predicting the capacity of the micro channel condenser experimentally examined in the study. These two condensers had almost identical frontal area and depth because the purpose of this study was to measure performance improvement using the micro channel condenser had an almost identical package volume as the round-tube condenser. The COP of the system with the micro channel condenser was 13.1% higher than that with round tube condenser, using a micro channel condenser resulted in a 2.5 C lower conditioning temperature and decreased the refrigerants pressure drop from166kpa in round –tube condenser to 57kpa in the micro channel condenser. The refrigerant charge amount for the system with the micro channel condenser was 9.2% smaller than that with the round tube condenser even though the micro channel condenser showed better heat transfer performance of capacity and system COP than the round tube condenser. [5]

ZHANG Huiyong, LI Junming, LI Hongqi(2010) This paper introduces a microchannel condenser 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. Compared with the original condenser, 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. [6]

Milnes P. David, Josef Miler, Julie E. Steinbrenner, Yizhang Yang, Maxat Touzelbaev, Kenneth E. Goodson(2011) In the present work we design, model and experimentally characterize a two-phase vapor venting parallel micro channel heat exchanger capped with a 220 nm pore, hydrophobic PTFE membrane that vents the vapor phase into separate vapor transport channels. We compare the performances of a traditional no venting heat exchanger and the vapor-separating version operating at heat fluxes of up to 820 kW/m2 and water mass fluxes of between 102 and 420 kg/s m2. We find ~60% improvement in the normalized pressure drop and up to 4.4 °C reduction in the average substrate temperature between the control and vapor venting device under similar operating conditions. [7]

Guan-Qiu Li, Zan Wu, Wei Li, Zhi-Ke Wang, Xu Wang, Hong-Xia Li, Shi-Chune Yao (2012) An experimental investigation was performed for single-phase flow and condensation characteristics inside five micro-fin tubes with same outer diameter 5mm and helix angle 18^0data are for mass fluxes ranging from about 200 to 650kg/m^2s.The nominal saturation temperature is 320k, with inlet and outlet qualities of 0.8 and 0.1, respectively. The results suggest that tube 4 has the highest condensation heat transfer coefficient and also the highest condensation pressure drop penalty, while tube 5 has the highest enhancement ratio due to its lowest pressure drop penalty and intermediate heat transfer coefficient. Condensation heat transfer coefficient flattens out gradually as G decreases when G<400kg/m^2s for tube 2 and tube 4. This nonlinear mass-flux effect may be explained by the complex interactions between micro fins and fluid, including liquid drainage by surface tension and interfacial turbulence. In addition, the experimental data was analyzed using seven existing pressure drop correlations and four heat transfer models to verify their respective accuracies. [8]

G.B. Ribeiro, J.R. Barbosa Jr., A.T. Prata (2012) in this paper the thermal-hydraulic performance of micro channel condensers with open-cell metal foams to enhance the air-side heat transfer is investigated. Three different copper metal foam structures with distinct pore densities (10 and 20 PPI) and porosities (0.893 and 0.947) were tested. A conventional condenser surface, with copper plain fins, was also tested for performance comparison purposes. The experiments were performed at a condensing temperature of 45°C. The air-side flow rate ranged from 1.4 x 10^{-3} to 3.3 x 10^{-3} m^3/s (giving face velocities in the range of 2.1- 4.9 m/s). The heat transfer rate, the overall thermal conductance, power were calculated as part of the analysis. **[9]**

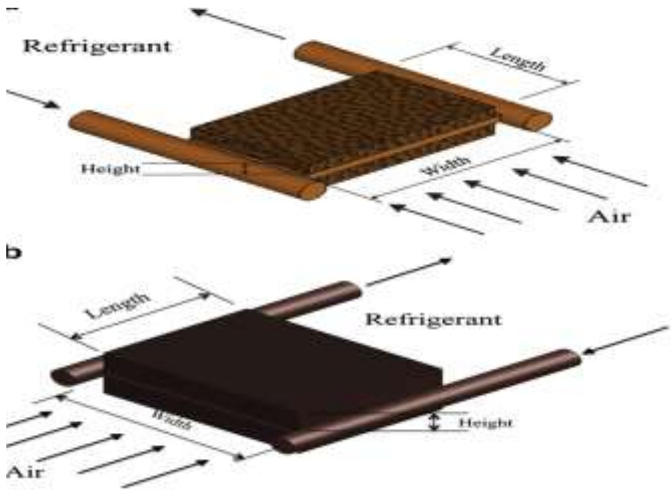

Figure: 5 Illustration of a metal foam condenser [9]

Gopinath R. Warrier z, Chang-Jin Kim, Y. SungtaekJu (2013) was analyzed a novel two-phase micro channel cooling device that incorporates perforated side walls for potential use as an embedded thermal management solution for high heat flux semiconductor devices. A dense array of perforated side walls separate alternating liquid and vapor micro channels, allowing the vapor generated through evaporation of liquid supplied through micro-perforations to flow only in the dedicated vapor channels. By separating the liquid and vapor flows, these ‘‘perspiring’’ sidewalls enable us to circumvent flow instabilities and other challenges associated with conventional two-phase micro channel cooling while at the same time effectively take advantage of the large extended surface areas available in high-aspect-ratio micro channels. One implementation of our design is parametrically analyzed using finite element modeling, demonstrating the potential of our proposed device for handling high heat flux electronic and optoelectronic semiconductor devices. [10]

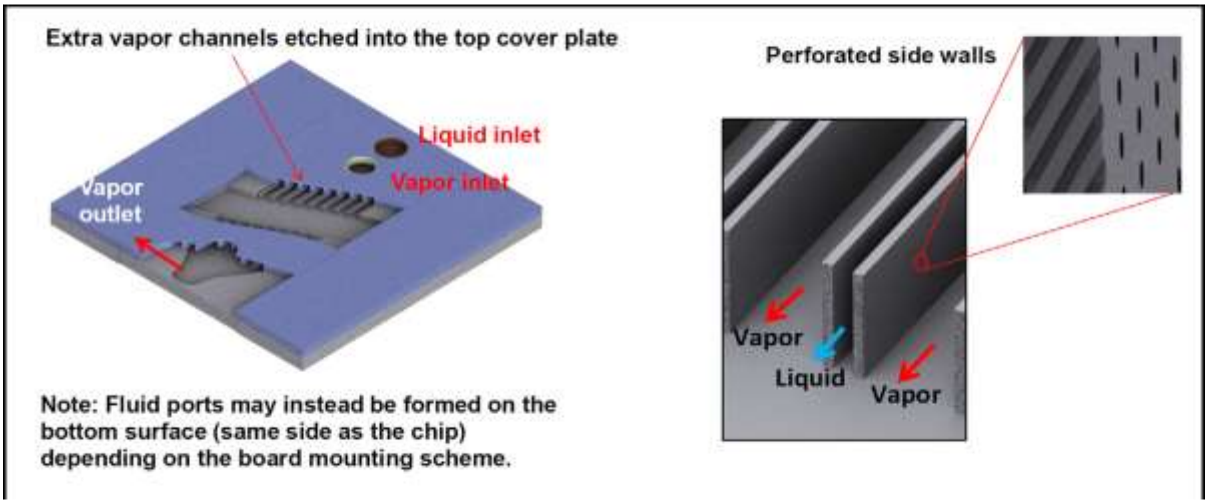

Figure: 6 A schematic of the proposed embedded evaporative cooling device featuring phase-separated micro channels with perforated side walls [10]

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Summary

Author name/ year	**Objective**	**Parameter used**	**Conclusion**
Weilin Qu & Issam Mudawar [2003]	Experiment conducted to measure pressure drop in a two phase micro channel heat sink.	21 Parallel 213×713µm Micro channels.	Pressure drop increases appreciably upon commencement of boiling in micro channels. At both moderate and high heat fluxes, the flow oscillates between the slug and annular patterns upstream and is predominantly annular downstream. Better accuracy is achieved using correlations specifically developed for mini/micro-channels.
Yun Wook Hwang & Min Soo Kim [2006]	Investigation of pressure drop in micro tubes and correlation development	d_i = 0.244,0.430,0.792mm Re<1000	Two phase flow pressure drop increase with increasing quality, increasing mass flux and decreasing tube diameter
Rin Yun et al [2006]	Comparison of performance of a residential air-conditioning system using Micro channel and fin-and-tube heat exchanger	a fin-and-tube condenser or a micro channel condenser, 7 kW capacity	reduced refrigerant charge amount of 10%, the coefficient of performance increased by 6% to 10%, and the SEER increased by 7%
Pega Hrnjak& Andy D. Litch [2008]	This paper presents experimental results from a prototype ammonia chiller with an air-cooled Condenser and a plate evaporator.	''micro channel'' tubes (hydraulic diameter Dh ¼ 0.7 mm), single serpentine ''macro channel'' tube (Dh ¼ 4.06 mm	The overall heat transfer coefficient for given face velocity is 60–80% higher than for the serpentine condenser; and the charge is an average of 53% less.
Chang Yong Park & Pega Hrnjak [2008]	The effect of different type of condensers on the performance of R410A residential air conditioning systems were investigated in this study.	The effect of different type of condensers on the performance of R410A residential air conditioning systems were investigated in this study.	COP and cooling capacity of the system with the micro channel condenser were higher than those for the round-tube condenser in all test conditions.
Milnes P. David et al [2011]	Hydraulic and thermal characteristics of a vapor venting two-	two-phase vapor venting parallel micro channel heat exchanger capped with a 220 nm pore,	We find~60% improvement in the normalized pressure drop and up to 4.4°C reduction in the average substrate temperature between the control and

	phase Micro channel heat exchanger	heat fluxes of up to 820 kW/m2and water mass fluxes of between 102 and 420 kg/s m2	Vapor venting device under similar operating conditions.
Guan-Qiu Li et al[2012]	Experimental investigation of condensation in micro fin tubes of different geometries	5 tubes each 5mm dia. and helix angle 18^0,mass fluxes ranging from 200-650 kg/m^2s Nominal saturation temperature 320 k	It observes that tube 4 has the highest condensation heat transfer coefficient and also the highest condensation pressure drop penalty. While Tube5 has the highest enhancement ratio due to its lowest pressure drop penalty and intermediate heat transfer coefficient.
G.B. Ribeiro et al [2012]	Performance analysis of micro channel condenser with metal foams on the air side.	Copper metal with distinct pore densities 10 and 20 PPI& porosities (0.893 & 0.947) R-600a Air flow rate : 1.4×10^{-3} to 3.3×10^{-3}	The air-side pressure drop is directly proportional to the pore density and inversely proportional to the metal foam porosity. And for a fixed pumping power, the overall thermal conductances of the metal foam condensers were lower than that of a plain fin condenser with similar characteristics.
Gopinath R. Warrier z, Chang-Jin Kim, Y. Sungtaek Ju[2013]	analysis a novel two-phase micro channel cooling device that incorporates perforated side walls for potential use.	two different micro-pore diameters (1 and 2 μm) and two different contact angles (5^0 and 10^0). For a fixed wall superheat of 7 K	When pore diameter, increasing the contact angle decrease in the effective evaporation heat transfer coefficient. And for a given contact angle, increasing the pore-diameter results in a decrease in the evaporation heat transfer coefficient.

3. Conclusions

The above literature review present that in many industries are actively investigating the use of micro channel tubes for many other heat transfer application in refrigerators, condensing units, and household air conditioning. A micro channel condenser consists of headers, Fins and the aluminum micro channel tubes. The goal of this paper is to explore the use of micro channel tube technology in the development of heat exchanger and to further utilize the properties of the refrigerant and advantages of the micro channel tube to reduce charge extruded aluminum multi port micro channel tubing is a technology that has become widely used as the condenser in automotive air conditioning.

Micro channel condenser improves COP, heat transfer rate, pressure drop, condenser capacity and evaporator capacity.

Nomenclature

ΔP	pressure drop (kPa)	M	Mach number
c_p	Specific heat	P	Pressure [Pa]
d	Diameter	Po	Poiseuille number
E	Activation energy	R	Universal gas constant
K	Thermal conductivity	Re	Reynolds number
Kn	Knudsen number	T	Temperature
Ks	Height of roughness	t	Time, s

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U	Velocity, m/s
x, y, z	Cartesian coordinates
Re	Reynolds number
t	Thickness
d_h	Hydraulic diameter of the tube, m
d_m	Mean inner diameter, m
d_o	Outside diameter of the tube, m
f	Friction factor
G	Mass flux, kg/ (m^2 s)
g	Gravitational acceleration, m/s^2
h	Heat transfer coefficient/(m^2 K)
Nu	Nusselt number
m	Mass flow rate, kg/s
Pr	Prandtl number
p_D	Pore density [PPI]
A	Area [m^2]

Greek symbols

α	Apex angle of the fin, degree
β	Helix angle, in degree
η	Dimensionless radius
θ	Dimensionless temperature
λ	Drag coefficient
μ	Dynamic viscosity (Pa s)
ν	Kinematic viscosity
ξ	Height to width ratio
ρ	Density (kg/m^3)
τ	Shearing stress at a wall
ϕ	Energy dissipation

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