Academic Journal of Science and Technology
ISSN: 2771-3032 | Vol. 6, No. 3, 2023

Review on Current Application of Microchannel Heat Exchanger

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Abstract: This paper considers various applications of heat exchangers in refrigerators, air conditioning, and nuclear power plants in recent years, current issues and trends, including the required capacity of refrigerator heat exchanger and the corresponding advantages of microchannel heat exchanger, refrigerator application of frost problems, ash problems and improve the performance of the relevant research; Examples of application of microchannel heat exchanger in air conditioning, comparison with traditional heat exchanger, and improvements to problems such as frost, the distribution of fluids, corrosion found in experiments; Study on advantages of compact microchannel heat exchanger in nuclear power plant. The purpose of this paper is to fill the gap in the application of microchannel heat exchanger and provide reference for future research.

Keywords: Micro channel heat exchanger, Refrigerator, Air conditioning, Refrigeration.

1. Introduction

Microchannel heat exchangers have been concepts for the first time since 1981 from TUCKERMANDB and PEASERFW[1]，In recent years, the research on it develops very rapidly. Compared with other traditional heat exchangers, the micro-channel heat exchanger has a good application prospect in petrochemical industry, machinery manufacturing, low temperature refrigeration and other industries, and has been paid more and more attention.

At present, most reviews of micro-channel heat exchanger at home and abroad focus on heat exchange characteristics, structure optimization and other aspects, while there are few reviews in the application. This paper will summarize the application status, existing problems and development trend of micro-channel heat exchanger in refrigerator, air conditioning and nuclear power plant in recent years, fill in the gaps in the application of which and provide reference for future research.

2. Application of Microchannel Heat Exchanger in Refrigerator

2.1. Application advantage of microchannel heat exchanger

The refrigerator mainly uses steam compression refrigeration. Heat exchanger is a key factor affecting the volume of refrigerator, refrigeration effect and energy consumption, it can not only determine the size of the refrigerator, the irreversible loss caused by the heat transfer temperature difference is also the main factor affecting the energy efficiency of the refrigerator, And the reduction of the volume of heat exchanger is conducive to the improvement of the volume of the refrigerator, improving the heat exchange capacity and heat exchange rate of the heat exchanger is conducive to the improvement of the refrigerator performance, reducing the fluid resistance in the heat exchanger is conducive to reducing noise and energy saving.

Micro-channel heat exchanger has the following advantages, which can meet the needs of refrigerator heat exchanger: high heat exchange efficiency, simple structure and low cost, strong corrosion resistance and pressure resistance.

2.2. The application of microchannel heat exchanger in refrigerator

The micro-channel heat exchanger has good potential and prospect in the application of refrigerator evaporator and condenser. BOENG [2] et al. designed a new type of micro-channel evaporator for household refrigerator. The performance of 16 kinds of prototype models with different geometric characteristics was evaluated by experiments, and the variation law of total thermal conductivity and air side pressure drop with wind speed was obtained. By comparing with traditional frost-free finned tube evaporator, the application potential of this model in household refrigeration equipment was demonstrated.

There are still some problems to be solved in the application of micro-channel heat exchanger in refrigerator. Due to the small fin spacing of micro-channel heat exchanger, its application is limited by the frost blocking problem of evaporator. ShengWei et al. observed the surface temperature distribution of evaporator under frosting conditions by using infrared thermal imager and tested the system performance. W. Sheng[3] et al. reviewed the research progress of frost prevention technology of refrigerator low temperature heat exchanger. ZhengMin et al. established a three-dimensional numerical model of frost formation based on OpenFOAM platform and proposed that future studies should consider the flow distribution of refrigerant in flat tubes and simulate frost growth in complete micro-channel louver fin heat exchangers. The factors affecting the frost formation of micro-channel heat exchanger and the research on the frost suppression design of micro-channel heat exchanger is summarized in FIG.1.

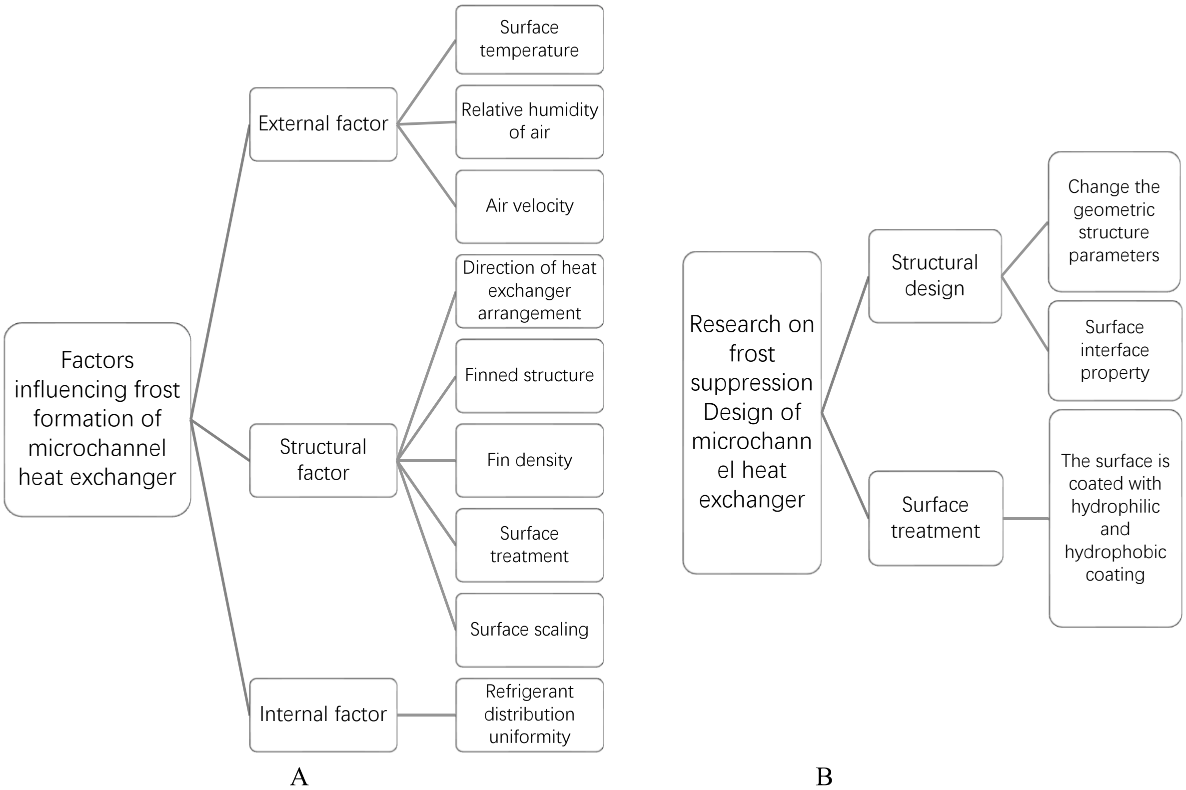

Figure 1. The factors affecting the frost formation of micro-channel heat exchanger (FIG. 1 (A))
The research on the frost suppression design of micro-channel heat exchanger (FIG. 1 (B))

In addition, long-term use of the refrigerator will lead to ash accumulation, increase the air side pressure drop, and reduce the working performance of the refrigerator. ZHANG[4] et al. took dust composition, dust volume and scaling speed as factors affecting air side scaling, tested the performance changes of exchanger with different structure sizes in household refrigerators before and after scaling, and observed and analyzed the formation of scaling.

At present, scholars have carried out surface treatment of heat exchanger, adopted phase change material for cold storage, optimized the fin structure of heat exchanger and other measures to strengthen heat exchange, reduce energy consumption of refrigerator and improve the overall working performance of refrigerator. Many other researchers have applied numerical simulation methods to the design, optimization, and evaluation of micro-channel heat exchangers, and have achieved many results, such as computational fluid dynamics (CFD) models for heat exchanger design and optimization, which have the advantage of testing multiple designs without actual verification[5]. BOENG [6] et al. established a mathematical model of the working performance of the micro-channel condenser in household refrigerator, evaluated the impact of the geometric shape of the micro-channel condenser on the energy consumption of the refrigerator. GUPTA[7] et al. used numerical simulation to study the influence of fins with perforated rectangular fins on heat transfer and flow resistance characteristics of finned tube heat exchangers. ELAREM et al. proposed a new design scheme of PCM heat exchanger in order to improve the energy efficiency of household refrigerators. The above is summarized in Table 1.

Table 1. Summary of simulation method to improve refrigerator performance

	Method	Conclusion
BOENG [6]	Mathematical model	The model fits well with the working performance of refrigerator condenser
GUPTA[7]	Numerical simulation	The perforated fin enhances the heat transfer performance
ELAREM [8]	CFD	The PCM device for household refrigerator is beneficial to the rapid stabilization and homogenization of temperature, but there are some limitations

Compactness and miniaturization are the development direction and trend of today's refrigerator heat exchanger. The use of micro-channel heat exchanger in most cases can achieve the performance of the original heat exchanger, and even make the overall performance of the system has been greatly improved. However, there are also some technical difficulties, which bring challenges to the practical application, such as small fin spacing makes the air side resistance increase, easy to accumulate ash, not easy to exhaust frost, etc., also to meet the challenges, scholars have explored many solutions to improve the overall performance of refrigerator heat exchanger.

3. Application of Microchannel Heat Exchanger in Automobile Air Conditioning

3.1. The application of microchannel heat exchanger in automobile air conditioning

Micro-channel heat exchangers are gradually used in refrigeration and air conditioning because of their high heat transfer performance, strong corrosion resistance, compact structure and price advantages. Li Haijun studied the difference in thermal performance between the micro-channel heat exchanger and the traditional tube fin heat exchanger(FIG. 2) in the electric bus heat pump air-conditioning system, and the experimental results show that the electric bus heat pump system using the micro-channel heat exchanger has better heating effect. Guo Xialin replaced the 5mm micro-channel heat exchanger with fin-tube heat exchanger as the condenser and used it in the 1.5HP R290 household air conditioning system. Zhao Xiaodan et al. constructed a 2HP micro-channel split home air conditioner experimental system. The experimental results show that compared with conventional household air conditioning, the cooling capacity of micro-channel household air conditioning refrigeration system is increased by 3.85%, the compressor power is reduced by 2.50%, and the COP is increased by 6.46%. Xie Bingbing et al. improved the refrigeration performance of subway air conditioning units by changing the forward and reverse installation methods of micro-channel condenser on subway vehicle air conditioning units. The above is summarized in Table 2.

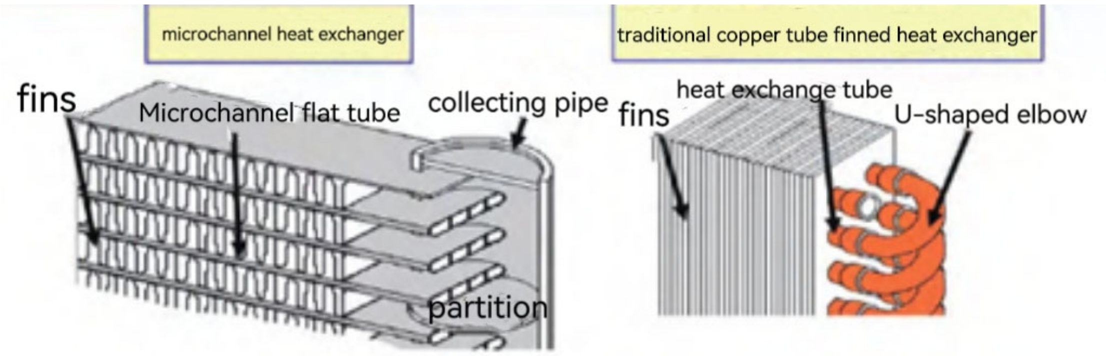

Figure 2. Comparison between microchannel heat exchanger and traditional finned heat exchanger

Table 2. Comparison and summary of practical application of micro-channel heat exchanger and traditional heat exchanger

	Application scenario	Compared with traditional heat exchanger
Li Haijun	Electric bus	The heating effect of heat pump system is better
Guo Xialin Zhao Xiaodan	Household air conditioning	Ideal match with R290 home air conditioning system cooling capacity, COP increase, compressor power reduction
Xie Bingbing	Subway vehicle air conditioning	Improved refrigeration performance of subway air conditioning units

At present, the main research trend of the micro-channel heat exchanger in automobile air conditioning is to improve the efficiency of heat exchange, reduce size and improve the heat exchange area, mainly by improving the structure and materials of the exchange and other technical means. There are also some problems in the practical application of micro-channel heat exchanger.

3.2. The application of micro-channel heat exchanger in new energy vehicle air conditioning

The frost formation of micro-channel heat exchanger is the main problem faced by exchanger as evaporator or heat pump system. Shortcomings such as fast frosting speed and long defrosting time limit its application in refrigeration systems. In addition, there are also problems such as uneven refrigerant distribution, condensate removal and corrosion resistance.

Scholars have carried out much research on frost problem. Zhao Xiaodan et al. studied the external factors affecting frost formation. Wei Xinghua studied a new chip micro-channel heat exchanger used as an outdoor heat exchanger. S.H.Hong[9] et al. found the performance of VMX in automobile air conditioning was better than HMX.

The problem of uneven fluid distribution is discussed. Flat tube protruding depth in this part of the collector can improve refrigerant distribution characteristics to some extent. Zhao Lanping et al. studied the performance difference of single-layer two-flow and double-layer four-flow in a three-heat exchanger automotive heat pump system when the upwind area and thickness of the internal condenser were equal. Liang Xixian et al. studied the distribution characteristics of the refrigerant flow in the vehicle-mounted micro-channel evaporator.

In terms of corrosion resistance, the zinc-sprayed extruded flat tube used in automobile air conditioning is easy to corrode under the harsh operating conditions of household air conditioning, which affects the reliability of the system. Liu Zhixiao et al. found heat exchange performance attenuation of micro-channel heat exchanger perform better than tube-fin heat exchanger. In terms of technology, Midea innovates the "multi-row slot front and rear punching technology of manifold", which is the first attempt in the industry to punch multi-row flat pipe slot holes on the manifold head, and ensure that the three rows of slot holes in the back row and front row are at the same level.

Table 3. Research summary of existing problems and improvement of heat transfer performance in application of micro-channel heat exchanger in automobile air conditioning

Research problem		Application scenario	Research results
Zhao Xiaodan	frosting	Refrigerated truck	Frost will reduce cooling capacity and COP
Wei Xinghua		Outdoor air conditioning	The thermal performance is still lower than that of existing copper fin heat exchangers
S.H.Hong[9]		Automobile air conditioning	Prolonged frosting period and increased peak capacity
Zhao Lanping	uneven fluid distribution	Automobile heat pump	The refrigerant side pressure drop of the double-layer four-flow condenser is increased
Liang Xixian		Vehicle air conditioning	The distribution characteristics of the refrigerant in the evaporator are optimized and analyzed. The distribution uniformity of the refrigerant in the three-stage evaporator is better
Liu Zhixiao	corrosion	/	The corrosion degree is obvious and the heat transfer performance attenuates obviously
MeiDi			Through the new technology, the corrosion and other technical problems have been overcome
Liu Xuyang	Sexual performance	Electric vehicle	A new heat exchange system is proposed to meet the heat demand of mini electric vehicles in winter and summer
Xue Zhen			The heat transfer capacity of air conditioning system of pure electric vehicle is improved by arranging flat pipe runner

In the term of heat transfer characteristics, CHENMH[10] et al. found that the distance and Angle of the pipes in the folded runner would have different influences on the heat transfer performance. Liu Xuyang et al. compared the heat transfer capacity of two micro-channel heat exchangers with different flow arrangements. Zhang Ping et al. studied the performance of the new folded flat-tube micro-channel heat exchanger under different working conditions. Xue Zhen et al. studied the plate tube, collector tube and fin structure of micro-channel heat exchanger. The heat transfer capacity is improved by arranging the flat pipe runner. The above is summarized in Table 3.

4. Application of Microchannel Heat Exchanger in Nuclear Power Plant

Compact microchannel heat exchanger (MCHX) has the advantages of simple structure and high heat transfer efficiency. Huang C [11] concluded that MCHX has the following advantages: high temperature and high pressure resistance. It can withstand the maximum pressure of more than 60mpa and the maximum temperature of 900℃. It has very high safety and reliability and is not affected by liquid shaking. Under the same heat load condition, its volume is about 1/5 of the traditional shell and tube heat exchanger, with a very high heat exchanger efficiency, up to 95%.

Printed circuit plate heat exchanger (PCHE) is a new type of micro-channel efficient compact plate heat exchanger, which can transfer heat under high temperature, high pressure and other harsh conditions. It is gradually active in oil, gas and nuclear energy fields. The working medium of light water nuclear power plants is water, which generally operates under turbulent conditions. The Korea Advanced Institute of Science and Technology has previously conducted experimental and numerical studies on the thermal and dynamic performance of PCHE in high-temperature gas-cooled reactors, and studied the thermal and dynamic performance of PCHE in different working media (helium-helium, helium-water, and helium-CO_2 mixture - water) at low Reynolds number Re [12]. kim studied on helium countercurrent heat transfer under laminar flow conditions in MCHX with Z-shaped flow channel, and the results showed that CFD technology can effectively simulate flow and heat transfer in MCHX. MA et al. conducted three-dimensional CFD simulation on MCHX of Z-shaped runner with different angles, and the results show that heat transfer and pressure drop increase with the increase of channel Angle, and the comprehensive performance of MCHX mainly depends on the operating conditions. Myavarapu et al. experimentally studied the cross-flow heat transfer of helium in MCHX under the conditions of laminar and laminar turbulent transition zones. It is pointed out that the boundary Reynolds number of the semicircular channel is about 1700.Based on this, Chen et al. designed a one-dimensional program and successfully predicted the dynamic response of MCHX. Zhou Xiang et al. used CFD method to conduct numerical simulation of fluid-structure coupling heat transfer in the three-dimensional dual-channel MCHX model, analyzed the flow and heat transfer characteristics of Z-channel under turbulent conditions, and put forward the heat transfer and flow criterion formula that can be used in engineering design. Deng Jing et al. analyzed the flow heat transfer performance of low-temperature regenerator, explored the influence of ZigZag Angle θ and axial length P of unit period flow channel in the cold side ZigZag microchannel of the low-temperature regenerator in the Bretton cycle system under supercritical carbon dioxide recompression on the flow heat transfer performance of SCO_2 under turbulent state, and conducted numerical simulation on its heat transfer and flow resistance.

Checking the strength of heat exchanger is as important in application as the heat transfer performance. Song Yu et al. conducted a numerical simulation study on the flow heat transfer of hot and cold fluids in the rectangular cross section micro-channel heat exchanger under the condition of large temperature difference, and studied the different variation trends of heat transfer coefficient under the condition of downflow and counterflow and the variation trend of flow pressure drop with the width of the channel. Zhang Xiaohui et al. studied the influence of the amount of splicing on the structural strength, found that when the channel is a Z-shaped channel, the stress gradually increases with the increase of the amount of splicing, and the maximum stress value of the Z-shaped channel with the same amount of splicing is higher than that of the straight channel.

Improving the comprehensive heat transfer performance and energy utilization efficiency of microchannel heat exchanger has become the main direction of equipment development. Compact and efficient heat exchangers are widely used in natural gas vaporization and liquefaction, offshore oil and gas treatment and other new energy and Marine fields, and in the field of hydrogen energy, photothermal power generation, nuclear reactor heat transfer and other aspects show great application prospects.

5. Conclusion

This paper mainly introduces the status of the application of micro-channel heat exchanger in the following aspects: heat exchanger is an important factor of refrigerator volume, refrigeration effect and energy consumption, not only can determine the size of the refrigerator, and the irreversible loss is the main factor affecting the energy efficiency of the whole machine. Microchannel heat exchangers are superior to conventional heat exchangers in terms of heat flow, volume heat transfer coefficient, flow resistance, economic cost and pressure. Energy saving is an important index of air conditioners. Compared with conventional heat exchangers, microchannel heat exchangers can produce products of high grade such as Class I energy efficiency standards.CO2 supercritical refrigeration system based on microchannel heat exchanger has become the mainstream system in the field of vehicle air conditioning. In recent years, with the development of nuclear reactor to modular and miniaturized direction, it is urgent to improve the efficiency and compactness of nuclear power plant heat exchanger. It has the advantages of simple and compact structure and high heat transfer efficiency, which has broad application prospect in nuclear floating liquefied natural gas and refrigeration industry.

In addition to the above three aspects, micro-channel heat exchanger has a wide range of application prospects in microelectronics, modern medical, materials science, aerospace, cryosurgery probe, micro and nano technology and many other fields.

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