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Review on Applications of Micro Channel Heat Exchanger

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Abstract – *With advancement in almost all technology sectors, the world is moving towards miniaturization. Hence, it becomes necessary to remove high heat flux from highly compact systems such as high performance computer chips, laser diodes and nuclear fusion and fission reactors for ensuring their consistent performance with long life. Micro-channels and mini-channels are naturally well suited for this task, as they provide large heat transfer surface area per unit fluid flow volume. Hence, facilitating very high heat transfer rate. Use of micro-channels can be explored in various applications i.e. turbine blades, rocket engine, hybrid vehicle, hydrogen storage, refrigeration cooling, thermal control in microgravity and capillary pump loops. Heat flux removal requirement varies significantly based on the type of application. Heat dissipation requirement will continue to rise with more advancement in technologies and further reduction in the size of these applications. Considering facts, it can be concluded that microchannel heat sinks seem to be the plausible solution of twenty first century cooling problems. In the recent years' micro channel heat exchangers have been applied in refrigeration and air conditioning because they provide larger heat transfer area per unit volume and they are smaller and lighter than those obtained from conventional heat exchanger. We know that micro channel heat exchanger is more effective for a performance enhancement than cross fin and tube heat exchanger in residential air-conditioner. And micro channel heat exchanger helps to reduce refrigerant quantities in residential air-conditioner systems for the purpose of replacing all aluminum parallel flow heat exchangers as a heat exchanger for all kinds of air conditioner, the improvement of anti-corrosion technology and degree of flexibility for product application should be done.*

Key Words: Microchannel Heat Exchanger, Air conditioning, Electronic cooling, cooling Capacity, Coefficient of Performance.

1. INTRODUCTION

Heat exchanger with reliable and high performance has been the study focus of the refrigeration and air conditioning system. In recent years, with increasing demand for light weight and rising copper prices, copper substitution is also a widespread concern. Under the premise of meeting the heat exchange remand, micro-channel heat exchanger can reduce equipment weight, improve the device compact. The manufacturing costs can be reduced and the product competitiveness can be improved by using aluminium. Micro-channel heat exchanger has been extensive researched and applied in cooling of electronic equipment. Along with the improving of process technology, micro-channel technology is gradually used in household air conditioning and automotive air conditioning system. The concept of micro-channel heat exchanger was first proposed and used by Tuckerman and Pease in 1981.Micro-channel heat exchanger is defined by Mehendale. S. S as if the hydraulic diameter of heat exchanger is less than 1mm. Micro-channel heat exchangers for heat exchanging between two different fluids was first developed out by the Swift in 1985. 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, then appeared 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. And micro-channel heat exchanger began to enter the refrigeration and air conditioning industry. At present, the micro-channel heat exchanger has been applied in automotive air conditioning system. In household air conditioner field, technology of micro-channel heat exchanger applied in single-cold air-conditioner condenser has gradually matured, however, this technology faces big challenges, such as complex gas liquid two-phase uniform streaming. The conventional micro-channel heat exchanger represents non uniform behaviour and also increasing pressure loss. A similar trend is found in straight micro-channel heat sink (MCHS), a low temperature at inlet and a high temperature at outlet and an increasing temperature along the longitudinal direction. To overcome the above problem, i.e., to get the uniform thermal behaviour, introducing secondary flows at many locations along the primary flow is one of the alternatives. The introduction of branching network in microchannel analysis has stirred this field and attracted increased attention in branching micro-channel heat sink. Micro-channels analysis reveals that a new branching channel has increased heat transfer and also the lesser pumping loss as compared to traditional parallel micro-channel heat sink.

Secondary flow is employed in micro channel heat sink (MCHS) by introducing slanted passage in the channel wall between the adjacent channels in alternating orientation. The intervallic passage causes disruption in the hydrodynamic boundary layer and redevelopment at the leading edge of the following wall. This phenomenon decreases the average thermal boundary layer thickness, thus enhances the heat transfer performance with minor pressure drop due to combined effect of thermal boundary layer re-development and flow mixing. The heat transfer coefficient is inversely proportional to hydraulic diameter. Decreasing the diameter of MCHS increases the heat transfer coefficient. Thus the temperature field can be made uniform. Natural branching network can be used to overcome the disadvantage of micro-channel heat sink. Natural branching network consists of a general form, a primary channel of decreasing hydraulic diameter and it branches out at many locations in two or more sub channels of decreasing diameter. For flow of liquid through the channel a pump is used to force the flow through the narrow passages. During the flow some losses incurred. The challenge is to minimize the pumping loss incurred in the channel. Branching network offers a promising solution. It reintroduces the boundary layer that increases the heat transfer rate. The scope of MCHS is increasing day- by-day.

1.1 MICROCHANNEL HEAT EXCHANGER USED IN AIR CONDITIONING

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. 3 COP comparison for both Heat Exchanger Fig. 2 comparison of cooling capacity testing the base unit condenser was replaced by a micro channel a micro channel 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 micro channel heat exchanger and results in increase in refrigeration effect. Cost of micro channel 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. 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 aluminium micro channel heat exchanger, consist of multi louvered fin.

Micro-channel heat exchangers have been extensively used in automotive air conditioning systems but never been used in residential air-conditioners. Hence researchers first studied the automobile air conditioners. Researchers have done thermal modelling of micro-channel and laminated type's evaporator in automobile air conditioning system. The performance of micro-channel heat exchanger is compared with the laminated evaporator which was used in automotive industries. The numerical results of thermal modelling of laminated and mini-channel evaporators was validated with corresponding experimental data which was obtained from experiments performed on automobile air conditioning system in calorimeter test bench. The performance of laminated and mini-channel were also compared under various operating conditions. Researchers used ϵ- NTU method for evaluating and comparing the system under different conditions. After these 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 reduces the time period as well as power/fuel consumption for reaching the comfortable cabin temperature.

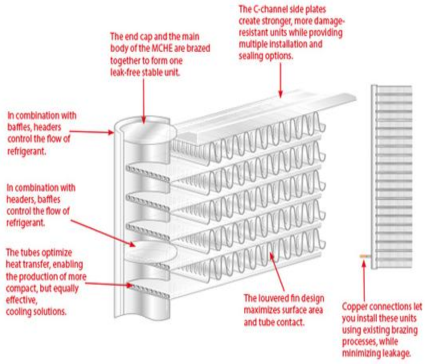

Fig 1: Microchannel Heat Exchanger

2. Comparison of cooling capacities in both cases

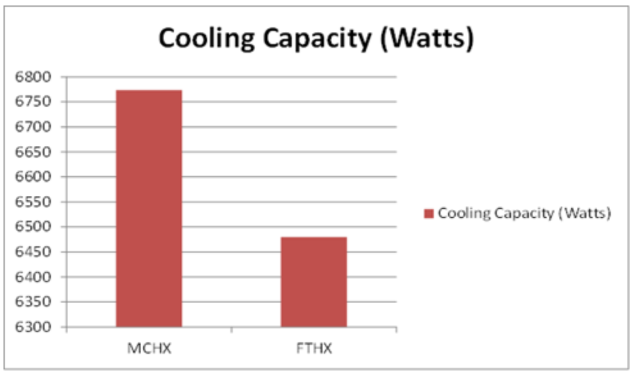

Fig 2: Cooling capacity comparison

Thus from the above results, it is observed that as refrigerant charge in the system decreases, the refrigeration effect increases. Micro-channel heat exchanger has a higher cooling capacity as compared to the conventional finned tube type heat exchanger. There is 4.5% increase in the cooling capacity with the use of micro-channel heat exchanger in the air-conditioning system.

3. Comparison of COP of system in both cases

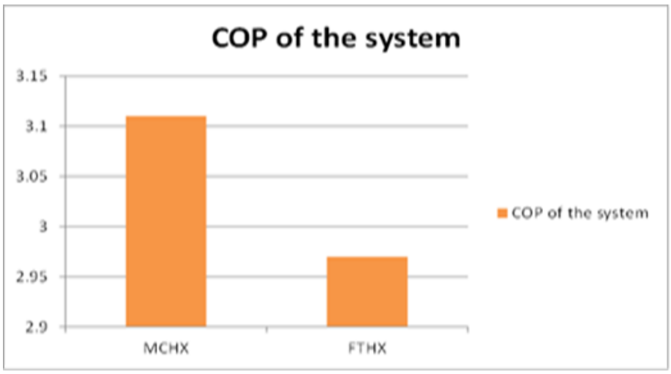

Fig 3: System COP Comparison

From the above results it is indicated that the COP of the system increases if micro-channel heat exchangers are used in place of conventional finned tube type heat exchangers. There is a 4.7% rise in COP of the system in case of micro-channel heat exchangers. Thus from this experiment it is proven that, micro-channel heat exchangers have higher performance as compared to finned tube type heat exchangers and hence can be viewed as a potential replacement for the conventional heat exchangers in HVAC industry due to rising energy efficiency standards.

4. MICROCHANNEL HEAT EXCHANGER USED FOR ELECTRONIC COOLING

When a lot of electro-mechanical systems have been miniaturized and integrated by compact design, thermal management in a small volume should be simultaneously considered. As the devices or systems become smaller, heat flux increases in general. Therefore, an effective cooling strategy for the micro-devices is required especially when the cooling target is made from microfabrication processes. The microfluidic heat exchanger is one of the most promising devices for cooling down the electronic systems because it can be also made by the microfabrication processes. This device which is also called microchannel heat sink has been considered as an effective heat removal tool and has caught much attention during the past decades, due to its advantages including high heat transfer performance, mild pressure loss and easy fabrication. It is evident that the former electronic cooling systems majorly employ heat pipes, fins and a combination of both. The use of the fin and heat pipe based cooling system manages to occupy large volume and appeals a huge setback from the perspective of compactness of the device. For example, a normal heat pipe combined with a fan can dissipate (300W/m2K) energy and at lower magnitude with only fins (80W/m2K)3. But these cannot dissipate the latest range 2000W/cm2K, due to this, the above devices have limitations for recent electronic components. Increasing the surface area and using appropriate liquid coolant is one of the better options to move further. The concept of the microchannel heat sink was first coined by Tuckerman and Pease. His path-breaking work initiated many other researchers to compare their numerical and experimental work with other microfluidic heat exchanger shapes. The geometry of inlet and outlet manifolds which are responsible for distributing and gathering of fluid in channels is an important factor for designing microfluidic heat exchangers. Accordingly, the basic manifold designs are conservative and bifurcation type, as shown in Fig. 1. In a conservative design, there is a single manifold region directly connected to the channels distributing the flow. The dashed line in the manifold shows an alternative for improving flow uniformity and consequently temperature gradient by making the manifold non-uniform or triangular. In bifurcation type, the flow from the inlet is divided into two streams; each is then further subdivided into two more till the number of divisions matches the number of channels 4.

Beside this, channels geometry, channels porosity, the fluid type, using ribs in channels and etc. are the parameters which have a significant effect on microfluidic heat exchangers efficiency.

Since it was first proposed by Tuckerman and Pease the micro-channel cooling has gradually been accepted in electronic industry. The key to achieving high heat transfer coefficient is due to use of microscopic channel dimensions. For example, such small channels (i.e., small hydraulic diameters) make use of the constant Nusselt number in the case of laminar fully developed flow to provide very large heat transfer coefficients. Thermal resistance of flow in a tube or over a plate mainly concentrates in the thermal boundary layer. Therefore, a small thermal resistance is expected due to an extremely small thermal boundary layer in the micro-channels. Heat transfer and friction in microchannel have received a considerable attention in recent years. Experimental studies are performed on gases, liquids, and two phase boiling. Based on the results from the above studies, the general features of heat transfer and flow friction of micro channels can be summarized as follows:

1.Conversion from laminar to transition regimes occurs at much smaller Reynolds numbers, and the transition region is limited in a smaller Reynolds number zone than for conventional channels.

2. The friction and heat transfer correlations often deviate from the conventional one for large tubes.

3. The geometric parameters of micro channels, especially the hydraulic diameter and the aspect ratio of the channel, have critical effects not only on the flow transition Reynolds number but also on the friction factor and the heat transfer coefficient. As the characteristic diameter approaches the molecular or substructure level, an analysis based on the classical continuum

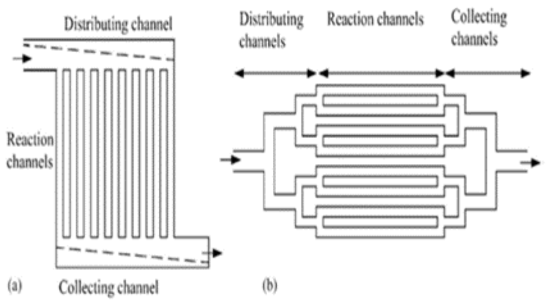

Fig 4: Schematic for (a) conservative and (b) bifurcation type manifold structures

Besides the above well-established benefits and application of the microchannel, it has also its own operational limitations as follows:

1. Due to the increased surface area, friction factor increases in micro channels leading to higher pressure drop and it further intensifies while introducing high viscous fluids.

2. The use of Nano fluids or two-phase fluid develops corrosion in the channels and causes a decrement in heat transfer due to fouling effects.

3. The non-uniformity of fluid flow distribution in microchannel leads to the development of hot spots on the electronic device and decreasing its lifespan.

4. Identifying an effective manufacturing process for microchannel that provides near zero surface roughness is difficult.

5. If point 4 is reality then the concern about early turbulence effects and higher pressure drop can be solved. But, most importantly the primarily responsible factor that influences heat transfer in the microchannel can be cornered.

5. CONCLUSIONS

In recent years, micro-channel heat exchanger has been more widely applied in the refrigeration and air conditioning industry due to its significant advantages over conventional fin & tube type heat exchangers. For the purpose of replacing all aluminum parallel flow heat exchangers as a heat exchanger for all kinds of air-conditioner, the improvement of anti-corrosion technology and degree of flexibility for product application should be done. In addition, refrigerant distribution characteristics should be improved. On the other hand, refrigerant flow mal-distribution is one of the main problem deteriorate heat transfer rate of air-conditioner. Hence, before designing the micro-channel, the pressure loss and heat transfer characteristics must be accurately predicted, while the theoretical basis which can accurately guide the design is not yet mature and there is no uniform industry standard in manufacturing. However, it is believed that with the study of micro-channel heat exchanger performances in-depth, optimization of heat transfers and existing problems in manufacturing and applications will be resolved & micro-channel heat exchanger will be more widely used in the HVAC industry.

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