Numerical Investigation of Microchannel Heat Exchanger Having Rectangular Channel With Convex Ribs

Ganesh C[1], Kulandaivel D[2], Ramesh K[3]
[1]Dept of Mechanical Engineering – PG
[2]Assistant Professor, Dept of Mechanical Engineering
[3]Professor, Dept of Mechanical Engineering
[1, 2, 3] Government College of Technology, Coimbatore -641 013, Tamilnadu, India

Abstract- *Multiport micro channel aluminum tubes are becoming more popular as components in heat exchangers. These heat exchangers are widely utilized in industrial settings and are reasonably priced due to their enormous production volume and wide variety of lengths and geometries. Micro channel tubes are therefore perfect for usage in small and lightweight heat exchangers. This paper presents thermal performance of a microchannel heat sink with convex ribs. To achieve good thermal performance, the Geometrical parameters of microchannel heat sink were optimised. Reynolds number 50 is used to assume the laminar flow regime. The findings demonstrate that the convex ribs significantly impact the thermal performance of microchannel. In comparison to a plain microchannel, the microchannels including convex ribs with a diameter of 0.4 mm have a greater Nusselt number. Nonetheless, there was a rise in the pressure decrease. Therefore, more research is needed to lessen pressure drop. Overall, efforts were made to improve heat transfer performance of microchannel, and the microchannel with convex ribs had the highest thermal performance.*

Keywords- Microchannel heatexchangers, Convex ribs, Heat transfer rate, Tapered head, active convective turbulence.

I. INTRODUCTION

Humans have used heat as an energy source for a wide range of applications. As a consequence of increasing industrial needs and expanding production operations, humanity has discovered a broad range of gadgets and manufactured them according to their demands. In the modern world, a variety of heat exchanger types are used to manage heat in a wide range of applications. The growing need for controlled settings has led to exchangers becoming more specialised and varied. Heat exchangers are used in the chemical, petrochemical, and end-user industries. Increase deamnd in energy sector motvited reserchers to conduct studies to enhance understanding on the heat transfer in many applications[1,2]

In general, heat transmission is proportionate to surface area; however, in recent decades, material utilisation has decreased while energy efficiency has increased, and space constraints have made it necessary to enhance mass and heat exchangers. Reducing the size and volume of energy exchange is one of the projects that have been brought about by more than 40 years of study. Various studies have been conducted on the heat transfer improvement in cooling applications to further understand the physical concept of cooling in microchannels Based on current extensive study, micro-channels have become the revolutionary breakthrough using several techniques.

When micro-channels were designed appropriately and used with the right topics, it was discovered that high surface-area-to-volume ratios might result in relatively high heat transfer coefficients. Pressure decreases between the channels may also lower these coefficients concurrently, which might lead to abnormalities in flow. Additionally, it has been shown that it decreased the circulation of flow inside the channels. Overall, these findings showed that micro-channels have been one of the most reliable research methods for addressing the problems mentioned above. According to recent research, the use of micro-channels in a variety of sectors may yield more benefits than they do now and spark new revolutions. Because of this, production costs are progressively going down, and rapid fixes are being found for these factors, which are primary restrictions of micro-channels.

Using a microchannel with an embedded fins structure inside the microchannels enhances the thermal performance due to enhancing the turbulent flow inside the channels. Also, perforation increases the heat transfer area and heat dissipation from the surface and boosts cooling performance [3]. When compared to the plate-fin microchannel, the enhanced designs' thermal resistance was reduced by 30% at various fluid velocities. A perforated microchannel increases the heat transfer performance in comparison to the plain microchannel with the addition of pressure losses [4]. The heat transfer is enhanced due to the increase in the conventional area. Increasing the perforation diameter increased the heat transfer performance while a notice of the pressure drop was increased. The thermal performance of microchannel that is air-cooled and microchannel that is air-cooled with perforations in power electronic applications is discussed [5]. The perforated microchannel can keep the electronic devices in the temperature criteria since it dissipates more heat than the air microchannel. Surface microchannel's thermal performance has been improved as a result of the changes in flow behaviour and heat transfer area. The use of knurling on the channel surface improves the heat transmission performance of microchannels [6]. The enhancement of heat transfer of Nu was 255% compared to the smooth surface due to an increase in surface roughness. The roughness causes the separation of the boundary layers and fluidmixing. Moreover, the performance of heat transfers in microchannels improved using the hybrid wettability bottom surface of elliptical patterns [7]. The surface wettability is controlled using sandblasted and smooth surfaces. The heat transfer increased using hybrid patterns and fully sandblasted surfaces compared to the smooth surface. The effect of modifying the cross-sectional shape of the fins (rectangular, trapezoidal, and triangle) on the thermal performance of the microchannel was investigated [8]. The microchannel with triangle fin cross-section has the best performance compared to the fins cross-section. In addition, different perforation shapes which are (square, triangle and circle) are conducted on triangle fin cross-section for optimizing thermal performance. Triangular perforation advances the heat transfer performance compared to square and circle perforation. Heat transfer and pressure drop analysis of serpentine microchannels in laminar flow was investigated [9]. The thermal resistance and pressure drop losses were reduced at ranges of Reynolds number of (200–1000) which enhanced the thermal performance. To study the effect of the geometry of the pin-fin on thermal performance and friction losses, different pin fin-shaped were configured [10]. The performance enhances with the use of cone pin fin heat sink while Nusselt number with friction losses increase in case using rectangular pin fin heat sink.

II. NUMERICAL MODEL AND METHOD

Micro-channel heat exchangers are getting more and more interest for refrigeration systems, especially when compactness and low refrigerant charge are desired. Numerous research looked into the functionality and performance of these systems. Numerous authors provided relationships between pressure reductions and heat transmission.

At the field of computational fluid dynamics (CFD), numerical investigations and studies have been carried out at the beginning. In particular, since the programme produces findings that are fairly near to experimental values, the new design theory offers a more efficient way to employ CFD software. But strong computers are all that are needed for such software—not specialised sensors, valves, thermocouples, or other hardware. The advancements in CFD software have enabled researchers to produce more appropriate designs.

CFD can be used to determine pressure decreases, heat transfer rates, design mass-flow rates, and fluid dynamic forces like lift and drag. It uses the discretization method known as the finite element method, which is applied in thermal and structural analysis. The key idea in the physical interpretation of the finite element method is the partitioning of the mathematical model into non-overlapping basic geometric components.

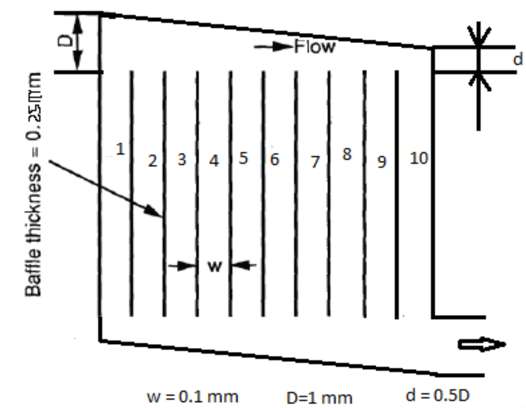

Figure 2.1. Reference Geometry

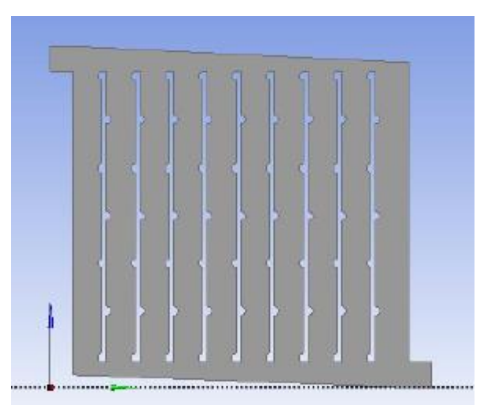

Figure 2.2 Modeled Geometry

The boundary conditions

Region	**Boundary condition**	**Expression**
Inlet	Velocity	u = 0.25 m/s, T = 293
Outlet	Pressure	P = 0
Wall	Constant heat flux adiabatic	Q = 1000 W

The thermal calculations in microchannels can be obtained from numerical results. The hydraulic diameter of the channel is defined as:

$$D_h = \frac{4(W_1 \times H_f)}{2(W_1 + H_f)}$$

The indicator of the flow regime is conventionally controlled by Reynolds number and it is defined as:

$$R_e = \frac{\rho_f u_i D_h}{\mu_f}$$

The average heat transfer coefficient and Nusselt number is

$$h = \frac{Q_{ef}}{(T_w - T_f)}$$

The Nusselt number is:

$$Nu = \frac{h \times D_h}{k_f}$$

The reference geometry is presented in Figure 2.1. The reference geometry has ten channels with a tapered header. The channels have 0.25 mm baffle thickness between each other. Total heat exchanger size is shown in figure, including header diameter and the baffle thickness. In the reference study, Major diameter of tapered header was expressed as D, an abbreviation of diameter, Minor diameter of the tapered header is d. The Major diameter was chosen as 1 mm and minor diameter of the manifold was taken as 0.5 mm.The geometry was modeled with the DESIGN MODELER option of ANSYS software. The modeled geometry is shown in figure 2.2. The model was a 2D model and interfaces were defined as surface. ANSYS Workbench Mesher software was used for mesh generation of the model. In this work, the Ansys software was used to solve the governing equations for the solid and liquid domains using the finite volume method. The ANSYS DESIGN Modeler was used to build the geometry. The calculations of pressure, temperature, and velocity were simulated by using the SIMPLE algorithm. Furthermore, the consistency, In order to get the acceptable convergence of Navier-Stokes equations, For continuity, momentum, and energy equations, the residual is reduced to less than 10^{-6} and 10^{-9}, correspondingly.

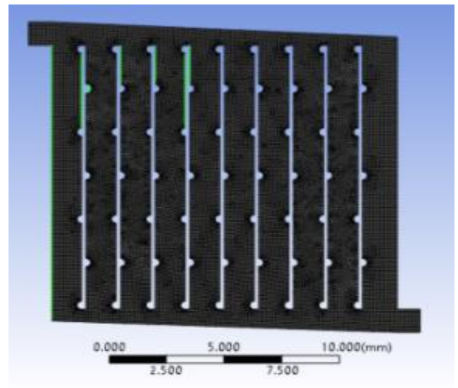

Figure 2.3. The mesh for microchannel

A mesh independence study is conducted to ensure that the mesh size does not influence the solution. The meshed geometry simulated a pressure-based steady state. The gravity forces were loaded in the -y-direction. The viscous model was chosen as laminar. The flow Reynold’s number was given in the references as 50. The fluid is water and the viscosity and density of water are constant, respectively as μ=0.01002 g/cm.s and ρ=0.9982 g/cm^3 at 20°C. The Convex ribs domains are analyzed with finer mesh than other solid and fluid domains to obtain accurate results. An analysis of Nusselt number calculation for case microchannel with convex ribs was achieved to ensure the mesh independence study. The 2D view of the mesh and grid for the microchannel is shown in figure 2.3.

III. NUMERICAL RESULTS AND DISCUSSION

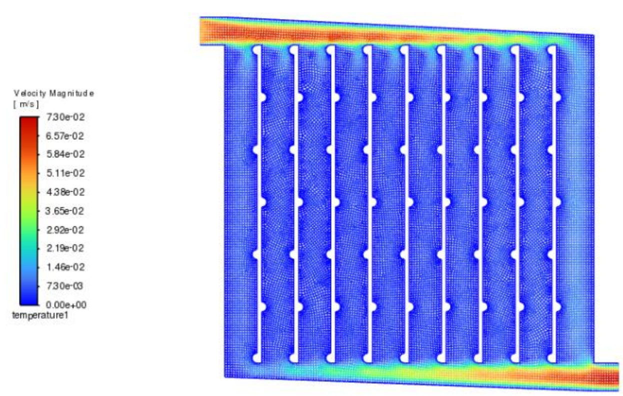

Figure 3.1. Velocity profile

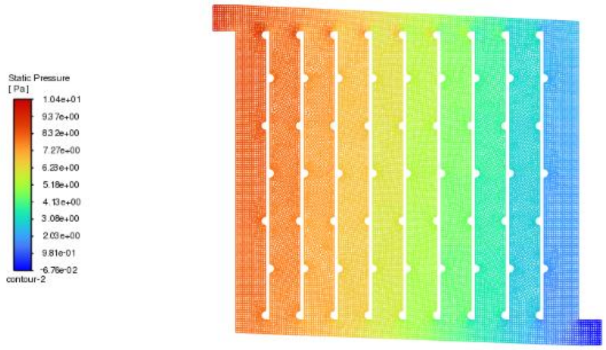

Figure 3.2. Static pressure

Figure 3.1 and 3.2 shows the velocity and the static pressure distribution in a tapered header and presents the results of referencegeometry. Microchannel was investigated with 0.4 mm diameter convex ribs. The boundary condition were applied as above mentioned values. The investigation was performed at laminar flow with Reynolds number 50. The Nusselt number was obtained for the given Reynolds number. Micrchannel heat sink with convex ribs gave the best thermal performance than normal microchannel. The size of the ribs had a significant effect on heat transfer performance because of increasing the flow circulation after fluid leaves the convex ribs. Thermal performance of the microchannel with convex ribs is shown in figure 3.3.

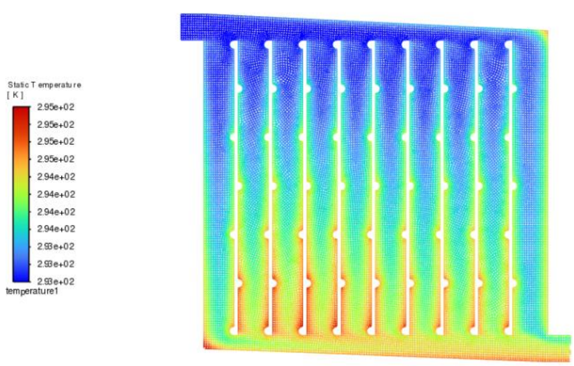

Figure 3.3 Thermal performance of Microchannel having rectangular channel with convex ribs

IV. CONCLUSION

In this paper, the reference geometry of the microchannel was simulated. The simulation results were in agreement with reference geometry and literature. The temperature distribution and flow rate of the geometry were obtained. From obtained numerical results, it can be concluded that microchannel heat exchanger with convex ribs had greater advantages than microchannel heat exchanger without ribs. Microchannel heat exchanger with convex ribs give more heat transfer for thesamemass flowoffluid when compared to normal microchannel. All in all, thermal performance of microchannel improved by introducing ribs in microchannel

Nomenclature

L - Themicrochannel'slength (mm), W - The microchannel's width (mm), Wl - The single channel's width(mm),H - The height of microchannel (mm), Hb - The microchannel base height (mm), v - Fluid velocity (m/s), Cp Specific heat (KJ/kg. K), k - Fluid thermal conductivity of the (W/m. K), Nu - Nusselt number, Tf Fluid temperature (K), ks - Solid thermal conductivity of (W/m. K), Ts - Surface temperature (K), P - Pressure (pa), Re - Reynold number, Dh - Hydraulic diameter (mm), U - overall velocity (m/s), Qeff - Effective heat transfer rate (W), Greek symbols: Δ – Difference, ρ - Fluid density (kg/m3), μ - Fluid dynamic viscosity (Pa s), Subscripts: f - Fluid in Inlet, s – Solid

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