CFD ANALYSIS OF MINI CHANNEL HEAT EXCHANGER USING WATER AS A WORKING FLUID

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ABSTRACT

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 the conventional heat exchangers, pipes are larger in size which makes heat exchanger bulky. But in some typical applications such as closed loop gas turbine heat exchangers, cryogenic applications, heat exchangers used in PWR power plants, nuclear submarines, etc., size and weight are critical design constraints on the heat exchanger. Also for high pressure applications tubes are subjected to high bending stresses. To overcome these difficulties, compact heat exchangers can be employed. Mini channels heat exchanger is a type of compact heat exchanger in which minichannels are machined on metal plates and then such plates are bonded together. Such an arrangement provides high strength so that it can be used for high pressure applications. In present work, a mini channel heat exchanger is designed with assuming inlet and outlet of hot temperature, inlet of cold water temperature and also the mass flow rates of cold and hot water. This compact heat exchanger can be used for cooling purpose of electronics device like silicon chip which would be used for microprocessor. In order to cool down silicon chip, it is kept in place of hot fluid plate. Cooling of silicon chip is required to prevent from damage and subsequently failure.

Keyword: - *CFD, Mini channel, Heat exchanger*

1. INTRODUCTION

Fluid flow inside the channel is heart of many natural and manmade systems. Heat and mass transfer is accomplished across the channel walls in biological system, such as brain, lungs, kidneys, intestines, blood vessels, etc., as well as many manmade systems, such as heat exchanger, nuclear reactor, desalination units, air separation units, etc. With the advancements in computing technology in the past few year decades, electronics have become faster, smaller and more powerful. This results in ever increasing heat generation rate from electronic devices. In most case, the chips are cooled through forced air flow. However, when dealing with components that contain billions of transistors working at high frequency, the temperature can reach a critical level where standard cooling methods are not sufficient. In addition to high performance electronic chips, diode arrays and high energy mirrors. 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 [1]. In heat exchanges, there are usually no external heat and work interactions. Typical applications involve heating or cooling of fluid stream of concern and evaporation or condensation of single- or multi-component fluid streams.

In other applications, the objective may be to recover or reject heat, or sterilize, pasteurize, fractionate, distill, concentrate, crystallize, or control a process fluid. In a few heat exchangers, the fluids exchanging heat are in direct contact. In most heat exchangers, heat transfer between fluids takes place through a separating wall or into and out of a wall in a transient manner. In many heat exchangers, the fluids are separated by a heat transfer surface, and ideally they do not mix or leak. Such exchangers are referred to as direct transfer type, or simply recuperation. Common examples of heat exchanger are shell- and tube exchanger, automobile radiators, condensers, evaporators, air pre-heaters, and cooling towers. Fluid flow and mass transfer in the human body, for example, utilize the high heat and mass transfer coefficients associated with micro channels. Following nature's lead, many heat transfer devices are utilizing micro-channels in emerging novel applications, such as high heat flux cooling of lasers and digital micro-processors [2].

2. LITRETURE REVIEW

Nizar Ahammed et al. [3] has performed experiment on thermoelectric cooling of electronic devices with nanofluid in a multiport minichannel heat exchanger. In this study the performance of thermoelectric cooling of electronic devices with nanofluid in a multiport minichannel heat exchanger is experimentally investigated. The power transistor in the circuit board usually operates with the electric power ranging from 20W to 400W which is considered as the input power to the TEC. The Reynolds number is varied from 200 to 1000. The thermal effectiveness of the cooling system increases with increase in volume concentration which makes the nanofluids as a promising coolant for electronic cooling applications.

Thanhtrung Dang et al. [4] in 2011 has done their experimental work on the effects of configurations on the performance of microchannel counter-flow heat exchangers. In this work the influences of configurations on the performance of microchannel heat exchangers were studied experimentally. The parameters associated with geometrical configuration consist of inlet/outlet locations.(1) case no.1 is for the case of increasing the inlet temperature of the hot side: the inlet temperature and the mass flow rate at the cold side were fixed at 22.5ºC and 0.2135 g/s respectively, at the hot side the mass flow rates were fixed at 0.2308 g/s and the inlet temperature were varying from 45 to 70 ºC (2) case no. 2 is for the case of increasing the mass flow rate of the cold side: the inlet temperature and the mass flow rate at the hot side were fixed at 70 ºC and 0.2308 g/s respectively, at the cold side the inlet temperature were fixed at 22.5 ºC and the mass flow rates were varying from 0.2135 to 0.401 g/s. Regarding the effects of inlet/outlet locations, for two types (I-type and S-type) of the microchannel heat exchangers, the heat flux obtained from the S-type are higher than those from the I-type even though the performance indexes of both heat exchangers are essentially the same. The lowest pressure drop of 506 Pa was achieved for the heat exchanger with the I-type, as compared to those with the S-type.

Jyh-tong Teng et al. [5] has performed experiment on effect of flow arrangement on the heat transfer behaviors of a microchannel heat exchanger. In this study the results were obtained by both numerical simulations and experimental data. For the experiments carried out in this study, the inlet temperature and the mass flow rate of the cold side were fixed at 22.5 ºC and 0.2043 g/s, respectively. For the hot side, the mass flow rate was fixed at 0.2321 g/s and the inlet temperatures were varying from 45 to 70 ºC. The results obtained from this experiment indicate that heat flux obtained from the counter-flow arrangement is always higher than that obtained from the parallel-flow one: the value obtained from the counter-flow is 1.1 to 1.2 times of that obtained from the parallel-flow.

Reiyu Chein et al. [6] has done their research work on numerical study of the inlet/outlet arrangement effect on microchannel heat sink performance. In this study, fluid flow and heat transfer in microchannel heat sinks are numerically investigated. The three-dimensional governing equations for both fluid flow and heat transfer are solved using the finite volume scheme. The computational domain is taken as the entire heat sink including the inlet/outlet ports, inlet/outlet plenums, and microchannels. The heat sink material is silicon and the working fluid is deionized water. The particular focus of this study is the inlet/outlet effects on the fluid flow and heat transfer inside the heat sinks. The microchannel heat sinks with various inlet/outlet arrangements are investigated in this study. Six types of micro channel heat sink D-, N-, S-, U-, I-type and V-type are used for investigation. The results obtained from this research work indicates that for the heat sinks with horizontally fluid supply and collection, i.e., the I-, N-, D-, and S-type heat sinks, the velocity maldistribution is more serious than heat sinks with vertically fluid supply and collection, i.e., the U- and V-type heat sinks. Because of velocity maldistribution, the flow rate in each heat sink channel is different. As a result, temperature nonuniformity is more serious in the heat sinks with horizontally fluid supply and collection. Using the overall heat transfer coefficient to evaluate the heat sink performance, it is found that the V-type heat sink has the best performance among the heat sinks studied.

Nguyen Ba Chien et al. [7] has done their research works on convective heat transfer characteristics of single phase liquid in multiport minichannel tube: experiment and CFD simulation. This study demonstrated the single phase boiling heat transfer of water in horizontal multiport minichannels. The experimental data were observed in aluminum tube of 7.9 x 2.5 mm (width x high) with 7 rectangular channels and the length of 500 mm, the Reynolds number of 1400 – 4200, and heat fluxes of 3 – 6 kW/m^2. The result shows that the frictional factor is slightly higher for lower heat flux while the Nusselt number is higher with higher heat flux. Moreover, the transition of fractional factor was observer when the Re > 3000. The Nusselt number is high when x* < 0.06 and decrease and keep constantly as theory. The trend also shows that the Nusselt increase with the increasing of heat flux.

3. CFD MODELING AND SETUP

Multiport mini channel heat exchangers are usually built of thin plate. Mini channels are machined on surface of the plate by means of micro-fabrication technologies. Cold & hot plates are placed one over one such a way that C-H-C configuration is made so hot water gets cool faster & type of flow is counter flow. Total number of cold plates and hot plates are six & three respectively and top most plate is fixed plate. Material of plate is copper and working fluid is water. Depth of the channel is 1 mm and thickness of plate is 3 mm. Other specifications of the plate are shown in Fig. 1 & computational model of multiport minichannel heat exchanger of C-type is shown in Fig. 2.

Fig. 1: 2D geometry of plate (C-type)

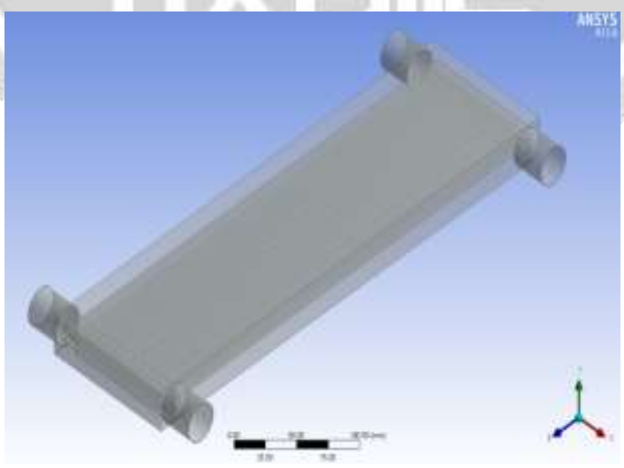

Fig. 2: Computational model of multiport minichannel heat exchanger (C-type)

3.1 Inlet Condition

The inlet boundary condition was "mass flow rate inlet". The mass flow rate and temperature values were specified at the inlet of channel domain. The direction of the inlet mass flow rate was normal to surface. Percentage turbulence intensity and hydraulic diameter were also specified while solving the turbulence equation. The value of the hydraulic diameter was specified as per the equation . Turbulence intensity of 1% was generally considered to be low, while 10% was considered to be high. The values of turbulence intensity were estimated based on an empirical correlation provided in Ansys CFX for fully developed duct flow, which were in the range of 4% to 6%. These values were in agreement with the range specified by Ansys CFX for complex flows.

3.2 Outlet Condition

At the outlet, the "pressure outlet" boundary condition was specified as a constant Value equal to zero gauge pressure. Back flow total temperature, percentage turbulence intensity and hydraulic diameter were also specified.

3.3 Meshing of Computational Model

The computational domains are meshed with unstructured Tet/Hybrid grids. They are meshed by the CFX software, a geometric modelling and grid generation tool used with ANSYS CFX. Mesh diagram of minichannel heat exchanger are shown in Fig. 3

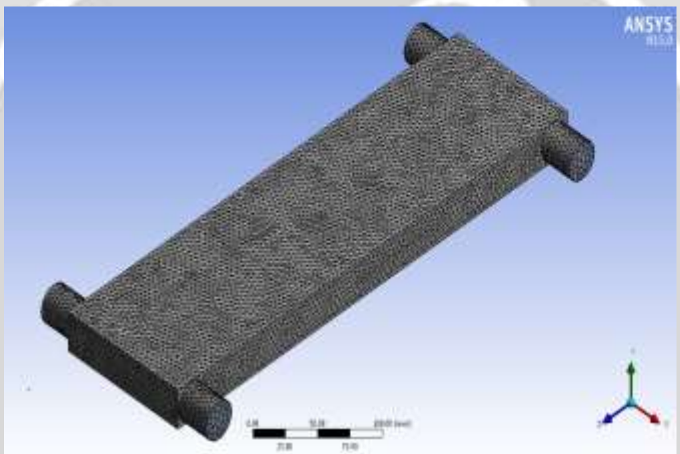

Fig. 3: Mesh diagram of mini channel heat exchanger

4. RESULT

Different set of numerical simulation are performed on the ANSYS with fluid (water) in channel side along with different mass flow rate and maintaining the same inlet temperature on channel. In all the cases, water is used as working fluid on channel plate. The numerical simulation is performed with three dimensional, steady state and turbulent flow system, segregated solver and standard k- model are employed and energy equation is included. For flow analysis here Ansys CFX is used as a post processor. Comparing the results obtained by numerical simulation with experimental analysis on paper is used for validation of numerical simulation results are done and numerical simulation for different temperature. As shown below, different contours of temperature, these contours are plotted with different mass flow rate, which are taken according to the experimental data. These contours are plotted at the mid plane of the model of channel type heat exchanger. Temperature distribution for different mass flow rate is shown in Fig. 4 and Fig. 5. Temperature distribution of cold fluid is shown in Fig. 4, in which cold fluid temperature increase from 305 K to 323.499 K at mass flow rate 0.08 kg/s cold side. CFD simulation results are shown in Table 1 and Table 2 for counter and parallel flow minichannel heat exchanger.

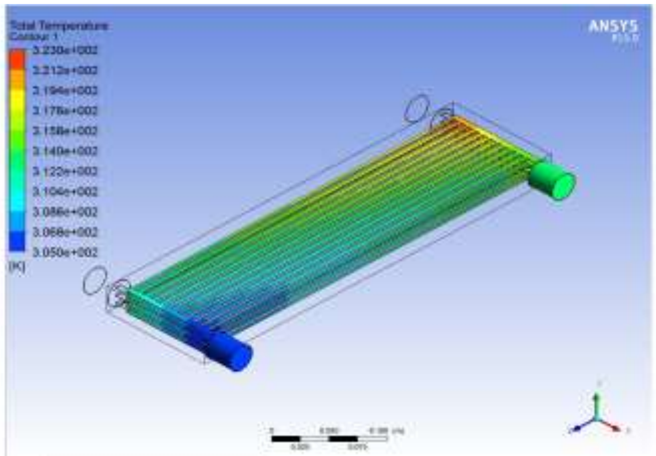

Fig. 4: Cold fluid temperature contour

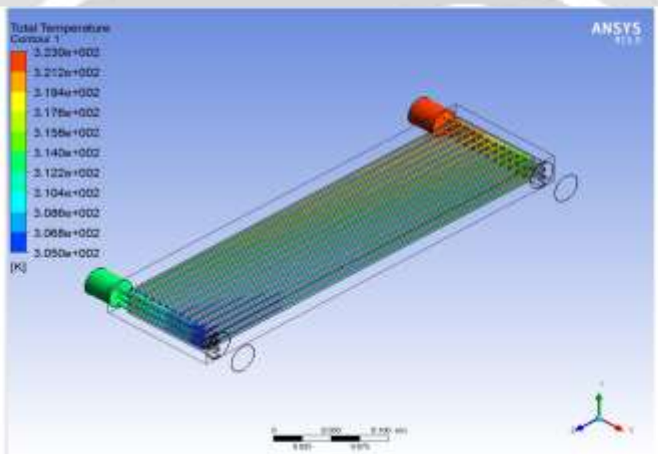

Fig. 5: Hot fluid temperature contour

Table 1: CFD results of counter flow minichannel heat exchanger

Sr. No.	Hot fluid				Cold Fluid			
	ṁ(kg/s)	Thi	Tho	ΔT	ṁ(kg/s)	Tci	Tco	ΔT
1.	0.08	343	324.498	19.502	0.08	305	323.499	19.499
2.	0.08	343	320.68	22.32	0.09	305	326.155	22.155
3.	0.08	343	320.503	22.497	0.1	305	326.052	22.053
4.	0.08	343	323.499	19.501	0.11	305	323.501	19.501
5.	0.08	343	320.241	22.759	0.12	305	325.828	21.828
6.	0.09	343	321.171	21.829	0.08	305	326.243	22.243
7.	0.09	343	320.934	22.066	0.09	305	323.205	22.205

8.	0.09	343	320.749	22.254	0.1	305	326.126	22.126
9.	0.09	343	320.587	22.413	0.11	305	326.036	22.036
10	0.09	343	320.453	22.507	0.12	305	325.938	21.938
11	0.1	343	321.49	21.51	0.08	305	324.825	20.825
12	0.1	343	321.184	21.816	0.09	305	326.207	22.207
13	0.1	343	320.975	22.026	0.1	305	326.168	22.168
14	0.1	343	320.806	22.194	0.11	305	326.096	22.096
15	0.1	343	320.662	22.338	0.12	305	326.015	22.015
16	0.11	343	326.176	16.824	0.08	305	321.655	17.655
17	0.11	343	321.411	21.589	0.09	305	326.188	22.188
18	0.11	343	320.934	22.066	0.1	305	326.205	22.205
19	0.11	343	321.013	21.927	0.11	305	326.132	22.132
20	0.11	343	320.861	22.139	0.12	305	326.066	22.066
21	0.12	343	321.872	21.128	0.08	305	326.121	22.121
22	0.12	343	321.621	21.379	0.09	305	326.194	22.194
23	0.12	343	320.937	22.066	0.1	305	326.205	22.205
24	0.12	343	321.217	21.783	0.11	305	326.133	22.133
25	0.12	343	320.543	22.457	0.12	304	326.255	22.255

Table 2: CFD results of parallel flow minichannel heat exchanger

Sr. No.	HOT Fluid				COLD Fluid			
	ṁ(kg/s)	Thi	Tho	ΔT	ṁ(kg/s)	Tci	Tco	ΔT
1	0.08	343	323.498	19.502	0.08	304	323.499	19.499
2	0.08	343	323.499	19.501	0.09	304	323.499	19.499
3	0.08	343	323.491	19.509	0.1	304	323.499	19.499
4	0.08	343	323.501	19.499	0.11	304	323.499	19.499
5	0.08	343	323.501	19.499	0.12	304	323.499	19.499

6	0.09	343	323.498	19.502	0.08	304	323.499	19.499
7	0.09	343	323.498	19.502	0.09	304	323.499	19.499
8	0.09	343	323.500	19.500	0.1	304	323.499	19.499
9	0.09	343	323.501	19.499	0.11	304	323.499	19.499
10	0.09	343	323.501	19.499	0.12	304	323.499	19.499
11	0.1	343	323.503	19.495	0.08	304	323.499	19.499
12	0.1	343	323.498	19.552	0.09	304	323.499	19.499
13	0.1	343	323.498	19.552	0.1	304	323.499	19.499
14	0.1	343	323.500	19.500	0.11	304	323.499	19.499
15	0.1	343	323.501	19.499	0.12	304	323.499	19.499
16	0.11	343	323.519	19.481	0.08	304	323.498	19.498
17	0.11	343	323.503	19.497	0.09	304	323.498	19.498
18	0.11	343	323.498	19.502	0.1	304	323.498	19.498
19	0.11	343	323.498	19.502	0.11	304	323.498	19.498
20	0.11	343	323.500	19.500	0.12	304	323.499	19.499
21	0.12	343	323.549	19.451	0.08	304	323.498	19.498
22	0.12	343	323.515	19.485	0.09	304	323.498	19.498
23	0.12	343	323.502	19.498	0.1	304	323.498	19.498
24	0.12	343	323.501	19.499	0.11	304	323.498	19.498
25	0.12	343	323.498	19.502	0.12	304	323.498	19.498

5. CONCLUSIONS

CFD analysis were performed for parallel and counter flow mini channel heat exchanger for constant inlet temperature on hot and cold side. Results obtained from simulation indicates that by varying mass flow rate on hot and cold side, heat transfer obtained from counter flow heat exchanger is higher than that obtained from parallel one. So hot side temperature drop achieved for counter flow heat exchanger is higher than parallel flow mini channel heat exchanger.

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