Optimization of Heat Transfer Coefficient through Microchannel using CFD

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Abstract. This paper provides a computational examination of the 3D (three-dimensional) heat flow and heat transfer moving in a rectangular smaller scale channel and utilizing water as a cooling liquid. The miniaturized scale channel utilized is having a width of 57 μm, profundity of 180 μm and length of 10000 μm. The work is engaged to build the heat transfer rate in a smaller scale channel utilizing expanded surfaces called blades and the examination is done at various Reynolds number. Computationally work is approved through the expectation and correlation with the current work. The augmented estimation of Reynolds number shows the decrement in the heat transfer. The examination of coefficient of heat transfer has been completed over the miniaturized scale channels, which demonstrate the surmised variety of temperature along the course of stream. Exact presumptions introduced in the balance technique give a brief look at genuine circumstance and the whole work is anticipating another thought of blade on the channel to build the heat transfer rate. In addition, other blade structures examination over the channel demonstrated the variety of heat transfer and the last work is engaged to discover the best effective approach to expand the heat transfer rate.

Keywords: Computational Fluid Dynamics (CFD), ANSYS, Heat Transfer, Cooling fluid, Heat transfer rate, Micro-channels, Reynolds number.

1. Introduction

These days the fast development in execution of focal preparing unit, utilization of realistic cards, power enhancers, high procedure speed and other phenomenal execution electronic chip framework are watched, every one of these components are decided by the elevated level of warmth increment reason [1]. Incredible test comes to oversee warm properties in the framework and to beat this better and elite cooling framework is required [3]. Among others, the smaller scale channel heat sink has been demonstrated to be a superior cooling strategy. An enormous number of stream channels with trademark measurements extending from 10 to 1000 μm are manufactured in a strong substrate which for the most part has high warm conductivity. An electronic portion is then placed on the bottom area of the warmth sink. The warmth produced by the part is first moved to the channels by heat conduction through the strong, and expelled by the cooling liquid which is compelled to course through the channels. The warmth sink in the miniaturized scale channel includes surface territory per unit volume, high warmth moves coefficient and the cooling liquid which is utilized. The favorable position that is acquired has pulled in impressive considerations from analysts. Small scale channel heat sinks with different plans and shapes were displayed and tentatively tried, and predominance of the cooling strategy utilized was affirmed by trial results [4–8]. In expansion to the different exploratory works, numerous investigative examinations are found in the existing literature [10]. The examination relating to balance was generally
utilized in these investigations. Fundamentally, there is a strong area isolating two channel streams and this locale contains a slender balance. The outcomes acquired from the blade investigation are then straightforwardly applied to structure the warmth move process in the warmth sinks. The worldwide warmth move attributes are assessed by utilizing this strategy. Be that as it may, various significant presumptions are typically utilized and the conclusive outcomes are determined. A portion of the strategies may go amiss from the genuine circumstance situation and thus will lessen the precision of the systematic model [10-14]. Study of smaller scale channel has been done broadly over the most recent couple of decades since a portion of their exceptional property like high warmth move rate [2]. This miniaturized scale size cooling framework diminishes the weight as well as expel a lot of warmth than that of enormous scope cooling framework. Knowing the way that the stream in enormous scope channel is perceived by Nusselt number which is equivalent to $hD/L$, Where D is the width of channel, $k$ is the warm conductivity and $h$ is the coefficient of convective warmth move. If water driven breadths are under 1mm and volumetric limit is in smaller scale liters at that point channels are reflected to be as Micro-Channel [1]. Physical properties of small scale channel incorporates there size, besides they are predominantly utilized for electronic cooling framework.

As the size of channel diminishes to small scale size, the warmth move coefficient will increment and this augmentation in the estimation of warmth move rate through channel makes it intriguing subject to investigate [3]. There is huge contrast between the warmth move and the stream trademark in huge scope channel and small scale channel. Miniaturized scale channel has additionally expanded interest in the zone like vehicle airbags, inkjet printers and airplane. The exertion of cooling has been cultivated by the immediate and roundabout cooling strategies in miniaturized scale channel [9]. Although the warmth sinks are intended for disseminating huge warmth motions, the little stream rate makes a huge temperature ascend toward both the strong and cooling liquid stream, which can harm the temperature detecting electronic segments. In this manner, a progressively precise forecasts identified with the temperature field are basic for a successful plan of a small scale channel heat sink. A progressively summed up depiction of warmth move rates and its attributes must be acquired by direct numerical reenactment of three-dimensional liquid stream [1].

2. Computational Investigation

The idea of miniaturized scale is utilized to play out the computational investigation and compared with the findings of Kawano et al.'s. test work [9]. The warmth sink is produced using copper and water is utilized as the cooling liquid. A steady warmth motion limit condition is considered on the electronic part at the top mass of the warmth sink. Exploiting eveness, a unit cell comprising of just one channel and the encompassing strong is picked as appeared by the ran lines in Fig. 1. The fundamental goal is centered around the warmth move process happening in the picked unit cell. The computational outcomes got can be effortlessly applied to the whole warmth sink. Fig. 1 shows the unit cell, the arrange framework and some physical documentations. Measurement of the warmth sink unit cell are given in Table 1. Representation of the physical area with the assistance of numerical condition drives the displaying of a small-scale channel and the conduct of various arrangement of condition shows reaction of framework in the wake of contributing a few unique boundaries [10]. Demonstrating and examination of physical framework is prime worried of computational investigation, the two stages include movement of liquid stream and with the assistance of direct numerical arrangement strategies got the outcomes gives the conduct of liquid in computational examination [10]. Essential factor is the disturbance rules that effects in the liquid stream, however since the stream is started with a low Reynolds number so any stream system can be taken [12]. The boundary that is utilized to characterize which sort of stream system is the Reynolds number which is given by condition (2.1) equations considered for the analysis of the convective heat transfer coefficient through the flow over cylinder are as follow.
\[ Re = \frac{\rho VcD_h}{\mu_f} \]  \hspace{1cm} (2.1)

Where \( \rho \) is the coolant density, \( \mu \) is the coolant dynamic velocity, \( V_c \) is the average coolant velocity and \( D_h \) is the hydraulic diameter

Numerous assumptions are being considered during the computational analysis of this proposed study. The major assumptions are:

- Negligible heat transfer through radiation.
- Steady state heat transfer.
- Properties of fluid and solid are constant.
- Laminar flow
- Incompressible flow
- Negligible superimposed natural convective heat transfer.
- There is no slip at wall.
- The walls are straight.
- Wall of micro-channel are smooth.
- Knudsen number is very small so that the fluid is of continuous medium

Based on the above approximations, the governing differential equations considered to describe the fluid flow and heat transfer in the unit cell are noted. The momentum equation is written as

\[ \rho_f (V \cdot \nabla V) = -\nabla P + \mu_f \nabla^2 V \]  \hspace{1cm} (2.2)
The energy equation is
\[ \rho_f C_{p_f} (V \cdot \nabla T) = k_f \nabla^2 T \] (2.3)

For the solid, the momentum equation is simply
\[ V = 0 \] (2.4)

And the energy equation is
\[ k_s \nabla^2 T = 0 \] (2.5)

The velocity is zero for the hydraulic case at the boundary walls, except the inlet and outlet. A uniform velocity is applied at the channel inlet.
\[ u = \frac{Re}{\mu_f D_h} v = 0, w = 0 \] (2.6)

The flow is fully developed at the channel outlet.
\[ \frac{\partial u}{\partial x} = 0, \frac{\partial v}{\partial y} = 0, \frac{\partial w}{\partial z} = 0 \] (2.7)

For applying the thermal boundary conditions, adiabatic boundary conditions are applied to all the boundaries of the solid region except the heat sink top wall, where a constant heat flux is assumed.
\[ -k_s \frac{\partial T}{\partial z} = q'', \text{ for } 0 \leq x \leq L \text{ or } 0 \leq y \leq W, z = H \] (2.8)

At the inlet, the fluid temperature is equal to a given constant inlet temperature.
\[ T = T_{in}, \text{ For } x=0 \] (2.9)

At the outlet the flow is assumed to be fully developed
\[ \frac{\partial^2 T}{\partial x^2} = 0, \text{ For } x=L \] (2.10)
Fig 2.2: Isometric view of meshed micro-channel without fin

Fig 2.3: Front view of meshed micro-channel with fin

Fig 2.4: Isometric view of meshed micro-channel with rectangular fin
Above demonstrated figure 2.1, 2.2 displays the work perspective on without balance miniaturized scale channel, figure 2.3, 2.4 displays the fit perspective on same smaller scale channel with rectangular blade and figure 2.5, 2.6 displays the coincided see with triangular balance. Framework Independent investigation was one of the primary worries during the computational examination. A uniform network game plan in the X-heading, Y-bearing and changing game plan in Z course with an enormous number of matrix focuses is utilized to determine the stream creating district.

3. Method of Solution

Utilizing ANSYS 14.5 where limited volume strategy is utilized and choosing SIMPLE calculation we fathomed the given smaller scale channel model utilizing the limit conditions given in Table 2. The limit condition in the channel is taken as the speed bay conditions. The Gauss–Seidal iterative procedure, with progressive over-unwinding strategy is chosen to improve the union time.
4. Validation

For approvals, results are approved in ANSYS-Fluent by contrasting and the code from Weilin Qu, Issam Mudawar 2002[1], and the computational examination of miniaturized scale channel without blade is checked in various manners to guarantee the legitimacy of investigation. In addition, the framework reliance test is first directed by utilizing a few distinctive work sizes. This test demonstrated that the outcomes dependent on the last framework introduced in this paper are free of work size. The computational consequences of this issue are contrasted and the assistance of diagram among position and surface nusselt number, as appearing in figure 4.1 and there is a fantastic understanding between the present computational expectation and arrangement got by Weilin Qu, Issam Mudawar 2002 [1]. The thing that matters is little to such an extent that the two unique outcomes are indistinguishable.

![Figure 4.1](image_url)

**Fig 4.1:** Comparison between computational predictions and solution obtained by coding for Surface Nusselt number in a rectangular channel.

5. Result and Discussion

The computational examination was finished for the rectangular small scale channel heat sink and the introduced outcomes shows, how viably heat move is expanding by adding balance to the surface. Familiar is utilized as a solver for this examination, in the wake of applying limit condition and watching the charts between the Nusselt number and position, gives the right clarification that temperature and Nusselt number both are expanded by expanding the estimation of Reynolds number. The diagrams which are plotted in figure 5.1 shows that the estimation of surface Nusselt number increments continually from delta to outlet as the estimation of Reynolds number increments when rectangular blades are utilized. As found in figure 5.1 at Reynolds number 140 the estimation of Nusselt number beginnings from 1.00e+4 and continue expanding. At the point when the estimation of Reynolds number is 700 as appeared in figure 5.1, the estimation of Nusselt number beginnings from almost 2.00e+4. Similarly figure 5.2 gives a similar clarification of the Nusselt number variety for the triangular fin. The heat transition dispersion can be seen clearly from the neighborhood Nusselt number circulation at the encased dividers of the channel. The circulations of Nusselt number at the top and base channel dividers are basically comparable. The estimation of Nusselt number at side divider is balanced about the center plane, however it is unquestionably not the same as the relating heat transition circulation. This is on the grounds that for laminar stream with steady properties, the Nusselt number is exclusively dictated by the channel geometry and nearby stream.
Table 2: Various properties that are employed in Computational Analysis

| $T_{\text{in}}$ (K) | $q''$ (W/cm²) | $k_{\text{water}}$ (W/mK) | $k_{\text{copper}}$ (W/mK) |
|---------------------|----------------|---------------------------|-----------------------------|
| 293                 | 90             | 0.61                      | 401                         |

Fig 5.1 Comparison between plots of Surface Nusselt Number and position vector when rectangular fins are used at Reynolds numbers is 140,400 and 700

Fig 5.2: Comparison between plots of Surface Nusselt Number and position vector when triangular fins are used at Reynolds numbers is 140,400 and 700
6. Conclusion

This paper is introducing the writing review, hypothetical angle, the three dimensional liquid stream and warmth move forms in a rectangular copper smaller scale channel, these were dissected computationally utilizing all the fundamental limit conditions, and the outcomes have been approved with the assistance of results got by coding. The impact of warmth move is mulled over and the estimations of warmth move rate are assessed at various estimations of Reynolds number with various sorts of blade geometry. It has been seen that the when rectangular balance just as the triangular blade are introduced in a smaller scale channel there is an expansion in the surface territory and dependent on the computational outcome this old style balance examination technique was researched and improved, this prompts show that the estimation of Nusselt number and along these lines the pace of warmth move increments as the Reynolds number increments.

Nomenclature

\( \rho \): Density of fluid flowing
\( u \): Velocity of flow in \( x \)-direction
\( v \): Velocity of flow in \( y \)-direction
\( p \): Pressure in the flow direction
\( X \): \( x \)-direction Body force
\( Y \): \( y \)-direction Body force
\( T \): Fluid temperature
\( T_\infty \): Free-stream Temperature
\( T_s \): Surface Temperature
\( c_p \): Specific heat of fluid at constant pressure
\( Nu \): Nusselt Number
\( h \): Convective heat transfer coefficient
\( L \): Characteristic Length
\( k \): Thermal Conductivity of the fluid
\( Re \): Reynolds Number
\( D \): Diameter of the cylinder
\( Pr \): Prandtl Number
\( \mu \): Dynamic Viscosity
\( \nu \): Kinematic Viscosity

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