"A Review on CFD Analysis of Square Microchannel Heat Exchanger"

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ABSTRACT: *This paper presents the numerical analysis of a 3D Square Microchannel Heat Exchamger in transient condition with hydrodynamically fully developed flow. The turbulence is increased with a helical twisted tape and is compared with the channel without twisted tape. The ANSYS FLUENT 15.1 code is used to solve the governing equations. An isothermal wall condition is maintained with Reynold number equals 100 and inlet velocity of 0.6m/s. The parameters like the heat transfer rate, axial wall shear stress, Nusselt number and heat transfer coefficient for both the types of channel are compared. It is found that the increase in turbulence occurs in channel with twisted tape arrangement and due to that the heat transfer characteristics like axial wall shear, skin friction; surface nusselt number and surface heat transfer coefficient are greater in with twisted tape as compared to that without twisted tape.*

(Key Words: ANSYS FLUENT, MICROCHANNEL, NUSSELT NUMBER, SKIN FRICTION, AXIAL WALL SHEAR)

1. INTRODUCTION

Micro channel heat exchangers, or microstructured heat exchangers are heat exchangers in which (at least one) fluid flows in lateral confinements with typical dimensions below 1 mm. The most typical such confinement are microchannels, which are channels with a hydraulic diameter below 1 mm. Micro channel heat exchangers can be made from metal, ceramic. The concept of micro channel heat exchangers was proposed and used by Tuckerman & Pease in 1981. The first micro heat exchanger was developed by Swift in 1985.

1.1. Classification of Micochannel

It is a very debatable topic between the researchers to define a definition of micro channel. Mehendale et al. (2000) used a classification technique which is based on manufacturing to obtain various varieties of channel dimensions, where D is the smallest channel dimension.

1 $\mu m < D < 100$: Micro channels

100 µm < D < 1 mm: Minichannels

1 mm < D < 6 mm: Compact Passages

6 mm < D: Conventional Passages

Kandlikar and Grande (2003) adopted a different classification based on the rarefaction effect of gases in various ranges of channel dimensions, "D" being the smallest channel dimension:

1 µm <D < 10 µm: transitional Micro channels

10 µm < D < 200 µm : Micro channels

200 µm < D < 3mm: Mini channels

3mm < D: Conventional Passages

1.2 Twisted Tape:

The Twisted Tape is historically well known heat transfer enhancement mechanism. It offers moderate enhancement at relatively pressure increase for laminar, transition and turbulent flow .The stream line and velocity of flow field for a swirl flow induced by the twisted tape is higher than the plain tube. This phenomenon affects the heat transfer coefficient by increasing the turbulence higher tangential velocity near the walls.

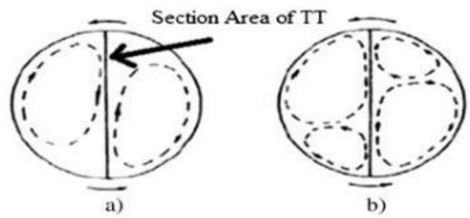

Figure 1.1The secondary induced flow patterns by twisted tape

2. Literature Review

Orhan Aydin, Mete Avci (1723-1730) : They examined analytically for a Newtonian fluid flow from two parallel plates for forced convection heat transfer in laminar condition. They investigated the slip velocity, viscous dissipation effect, and temperature jump. While performing the experiment they consider hydro dynamically and fully developed condition. The condition for wall is constant heat flux and constant temperature. They gave the result of several of Nusselt number with respect to Brinkman number.

Pfahler (1990) : His main focus was on calculating the length of scale at which the layer separation occurs He calculated & found that the Fluid Flow In a rectangular cross section micro tube channel with an cross section of 80 to 7200 micron/m2 .the assumption of navier –stokes equation was directly related by him. Even for the tiniest of the channel large fall of was noticed from the equation. For a Micro tube filled with nitrogen, H was found to be on larger side for the macro tube then to the micro tube. He Calculated value of turbulent heat flow transfer coefficient, And found out that it was seven times greater than the value obtained by equation.

Randall f.Barron, X.M.Wang and Roberto Warington (1991) : Gratez formulated to include the effect of slip flow of in a low pressure gas & the general problem of formulating thermally the heat transfer flow through a micro tube. The eigen value was calculated through different method. For Solving the hydro-dynamically formulated laminar flow inter relation was made with help of integral transformation method which a used at first with a constant heat flux & isothermal wall a stable state flow in a micro tube was considered. For both heating & cooling case Viscous heating was implemented .temperature Jump effect was found to be vanishing the Nusselt number was increase thus it was proved that at high prandlt number the temperature jump phenomenon was not found.

Nicolas G. Hadjiconstantinou, Olga Simek (2002) : For a nano channel and 2 D microchannel the convective heat transfer coefficient for a gaseous flow for constant wall temperature they investigated slip flow regime. The flow condition is hydro-dynamically fully developed thermally fully developed. For calculating the nusselt number they used the axial heat conduction condition.

Gokturk tunc, Yoldiz Bayazitoglu (2002) : They have also examined for rectangular microchannel the slip flow heat transfer for thermally fully developed and hydro dynamically fully developed. At the wall of the micro channel the H-2 boundary is applied.

Tuckerman and Pease (2006): They asserted that h for turbulent flow through conventionally sized micro-channels is lower than the laminar flow via micro-channels Bas on the calculation the determined that 790W/cm2 heat flux dissipation is possible that too without a phase change.

3. Mathematical Modeling

Case 1

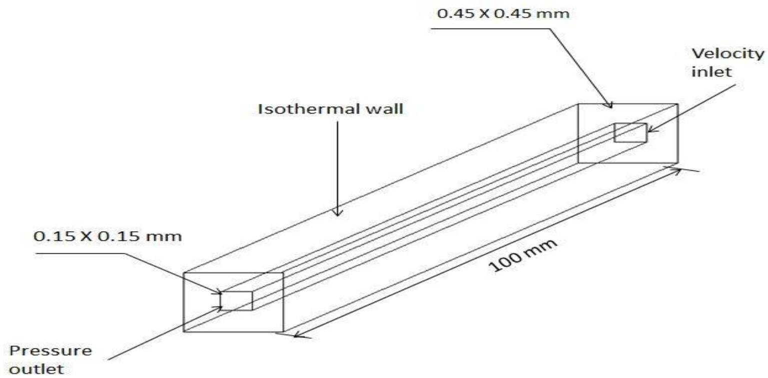

Figure 3.1- Square Micro channel without twisted tape

Case 2

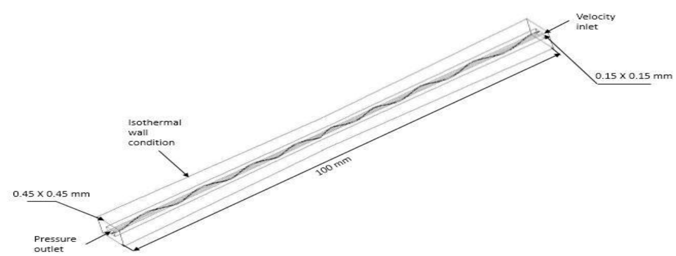

Figure 3.2- Square Micro channel with twisted tape

3.1. Assumptions

The physical and geometrical assumptions are following.

(1) The flow is 3-D, laminar, incompressible and steady state.

(2) Water is the working fluid.

(3) Thermo-physical properties are taken constant.

(4) There is no gravity effect.

(5) Viscous dissipation is zero.

Based on the above assumptions, the governing equations are following Governing Differential Equations

Continuity equation

$$\frac{\partial \rho}{\partial t} + \frac{\partial (\rho u)}{\partial x} + \frac{\partial (\rho v)}{\partial y} + \frac{\partial (\rho w)}{\partial z} = 0$$

Navier-stoke equation

$$\rho\left(\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}\right)=-\frac{\partial P}{\partial x}+\mu\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2}\right)+F_x$$

$$\rho\left(\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}\right)=-\frac{\partial P}{\partial y}+\mu\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}+\frac{\partial^2 v}{\partial z^2}\right)+F_y$$

$$\rho\left(\frac{\partial w}{\partial t}+u\frac{\partial w}{\partial x}+v\frac{\partial w}{\partial y}+w\frac{\partial w}{\partial z}\right)=-\frac{\partial P}{\partial z}+\mu\left(\frac{\partial^2 w}{\partial x^2}+\frac{\partial^2 w}{\partial y^2}+\frac{\partial^2 w}{\partial z^2}\right)+F_z$$

Energy equation

$$\rho c_p\left(\frac{\partial T}{\partial t}+u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}+w\frac{\partial T}{\partial z}\right)=k\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}+\frac{\partial^2 T}{\partial z^2}\right)+\Phi$$

Where Φ is viscous dissipation factor

$$\Phi=2\mu\left[\left(\frac{\partial u}{\partial x}\right)^2+\left(\frac{\partial v}{\partial y}\right)^2+\left(\frac{\partial w}{\partial z}\right)^2+\frac{1}{2}\left(\frac{\partial v}{\partial x}+\frac{\partial u}{\partial y}\right)^2+\frac{1}{2}\left(\frac{\partial v}{\partial z}+\frac{\partial w}{\partial y}\right)^2+\frac{1}{2}\left(\frac{\partial w}{\partial x}+\frac{\partial u}{\partial z}\right)^2\right]$$

4. Problem Formulation

4.1. Problem Description

- A 3D laminar and unsteady state flow through a square micro channel has been analyzed. Dimension of the micro channel are in micro meter. The cross section of micro channel is 0.15*0.15mm and length of the channel is 100 mm and the thickness of the channel is 0.15mm along all four side of the wall over the entire length. The side wall of the micro channel is considered to be isothermal condition i.e. constant temperature.
- At the inlet fluid is entering at ambient temperature i.e. 298 K and leaving at the outlet where the gauge pressure is zero. Pressure driven flow is considered. The isothermal wall considered as a temperature of 330 K.
- The geometry is created in ANSYS WORKBENCH and simulation is done with the help of FLUENT. Flow variable like velocity, temperature and pressure have been analyzed at different cross section of pipe. For convective heat transfer Nusselt number plays a very significant role are plotted. Main aim to investigate the compare Nusselt number, skin friction coefficient, axial wall shear stress, convective heat transfer for the two cases.

4.1.1. Simulation Approach:

The above stated 3D geometry of 2 cases is created by using ANSYS WORKBENCH 15.0. Total number of meshed cell is equal to 160000. The detailed meshed geometry is shown in fig. Apply all the boundary condition and initialize the problem by choosing a suitable solver iterate the problem. The convergence of residual is shown in fig

Case 1

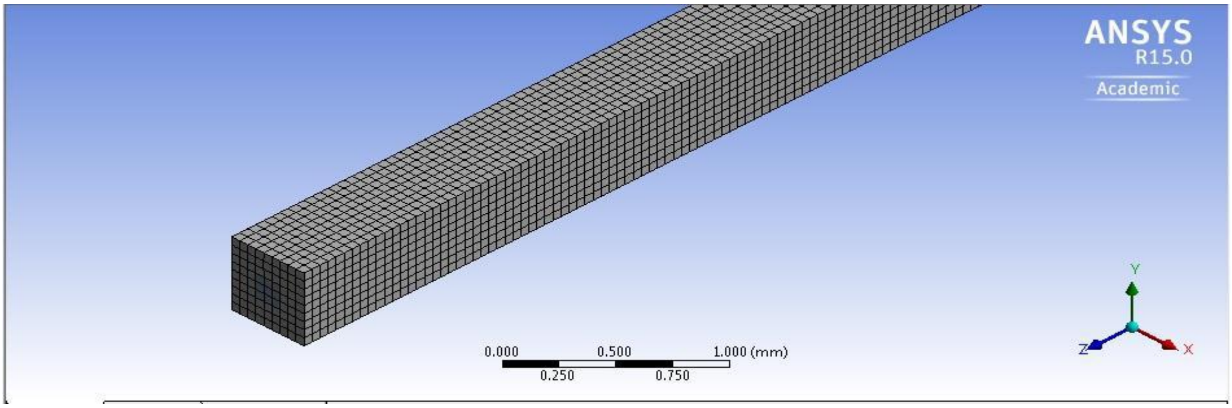

Figure 4.1 - Completed meshed geometry of micro channel without twisted tape

Case 2

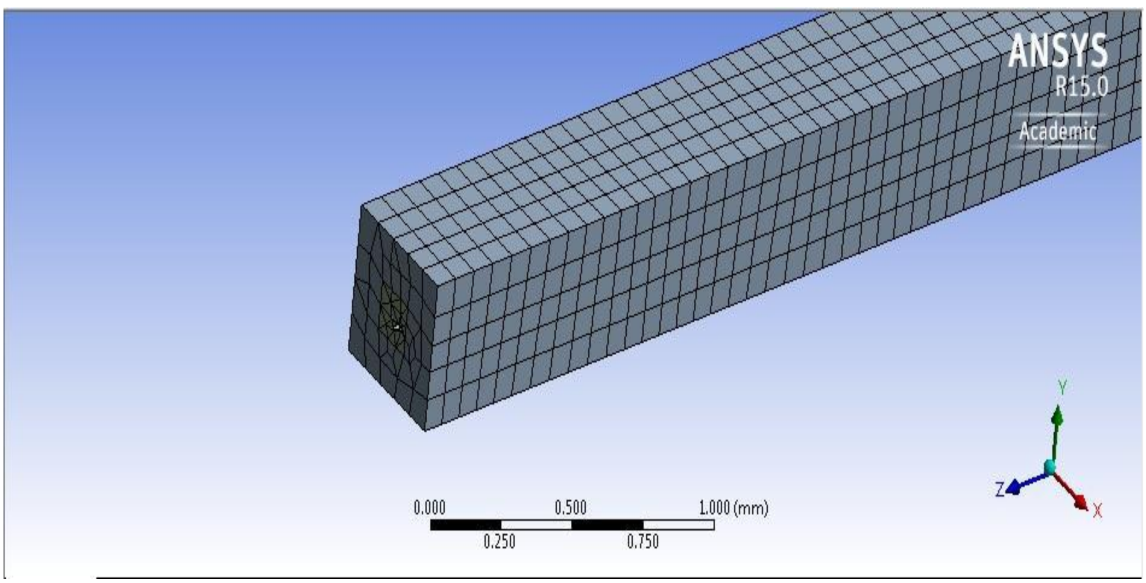

Figure 4.2 - Completed meshed geometry of micro channel with twisted tap

4.2. Velocity Simulation

Water is considered as a working fluid with pressure at outlet of 1atm.

- The velocity at the inlet is 0.6 m/s which are equals to a Reynolds number equal to 100.
- At the wall no slip boundary condition is considered.

Pressure correction based iterative SIMPLE algorithm with the 2nd order upwind scheme is for discretization. Initialization is done at the velocity inlet and performed the iteration.

Case 1

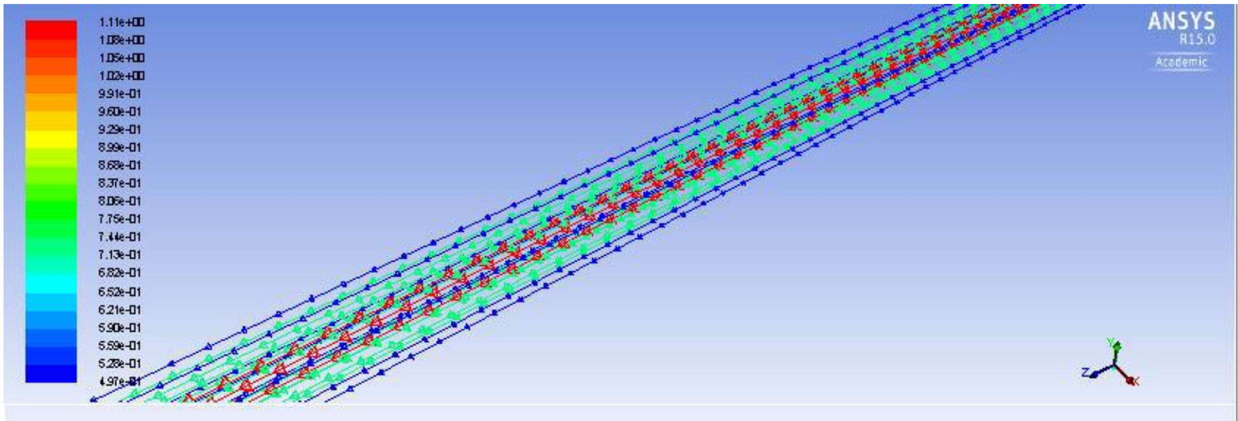

Figure 4.2 - Velocity vector of micro channel without twisted tape

Case 2

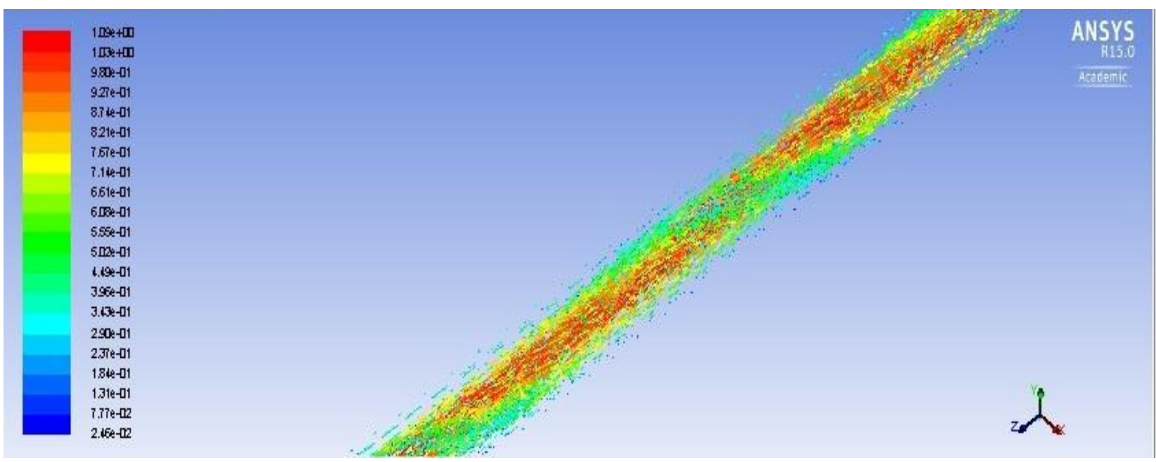

Figure 4.4 - Velocity vector of micro channel with twisted tape

4.3. Temperature Simulation

For the same geometry of micro channel we consider the temperature at the wall is to be constant temperature Twall = 330 K. The temperature of the fluid at the inlet is Ti= 298K. These boundary condition are solved by fluent and temperature contours are shown in fig

Case 1

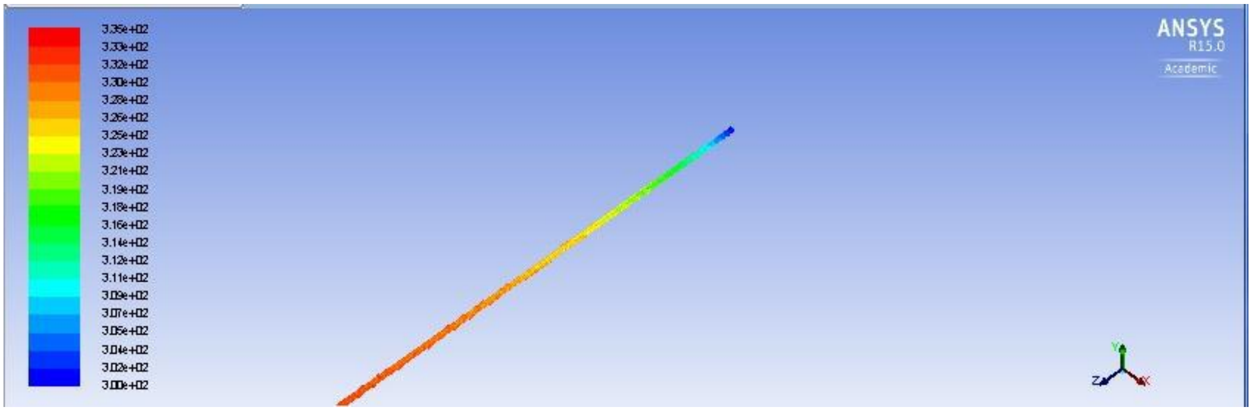

Figure 4.5 - Temperature contour of micro channel without twisted tape

Case 2

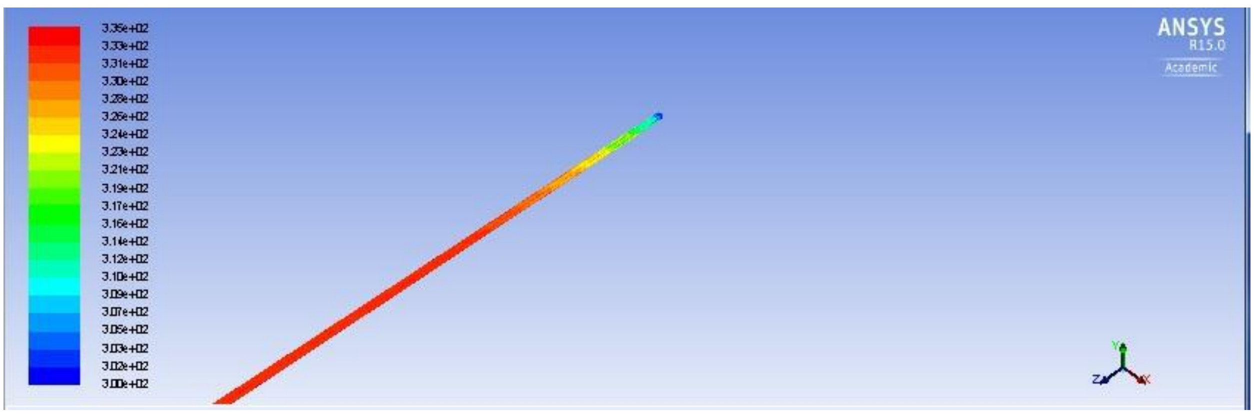

Figure 4.6 -Temperature contour of micro channel with twisted tape

5. Conclusions

In this paper heat transfer in the square micro channel heat exchanger with twisted tape and without twisted tape have been investigated by CFD FLUENT R15 code. From the present work following results are concluded

1. It is found that the axial wall shear stress increases when the twisted tape insert is employed with the conventional micro channel.

2. It can be concluded that the skin friction coefficient increases when the twisted tape insert is employed with the conventional micro channel.

3. From the above results it is found that surface nusselt number increases when the twisted tape insert is employed with the conventional micro channel.

4. Also Surface heat transfer coefficient increases when the twisted tape insert is employed with the conventional micro channel.

5. Due to twisted tape insert the increase in turbulence occurs which results in higher convective heat transfer.

REFERENCES

[1] D.B. Tuckerman, R.F. Pease, High performance heat sinking for VLSI, IEEE Electron. Dev. Lett. EDL 2 (1981) 126–129.

[2] S.S. Mehendale, A.M. Jacobi, R.K. Ahah, Fluid flow and heat transfer at micro and meso-scales with application to heat exchanger design, Appl. Mech. Rev. 53(2000)175–193.

[3] Errol B. Arkilic, Martin A. Schmidt & Kenneth S. Breuer, Slip flow in MicroChannels, Dynamics Symposium Oxford UK, July 1994.

[4] S.Yu, T.A. Ameel, Slip-flow heat transfer in rectangular micro channels, Int. J. Heat Mass Transfer 44 (5) (2001) 4225-4234.

[5] M. Gad-el-Hak, "The fluid mechanics of microdevices" – The Freeman Scholar Lecture, Trans. ASME, J. Fluids Engineering, 121, 5-33 (1999).