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Analysis of Microchannel Heat Exchanger with and without twisted tape

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ABSTRACT

The numerical study of a 3D square microchannel heat exchamger under transient conditions with hydrodynamically fully developed flow is presented in this research. A helical twisted tape is used to increase the turbulence, and the results are compared to the channel without twisted tape. The governing equations are solved using the ANSYS FLUENT 15.1 algorithm. With an input velocity of 0.6 m/s and a Reynolds number of 100, an isothermal wall condition is maintained. The Nusselt number, heat transfer coefficient, axial wall shear stress, and heat transfer rate are among the metrics that are compared between the two types of channels. It is discovered that a channel with twisted tape arrangement experiences an increase in turbulence, and as a result, the heat transfer characteristics, such as axial wall shear and skin friction, as well as the surface nusselt number and surface heat transfer coefficient, are higher in the channel with twisted tape than in the one without.

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

1. INTRODUCTION

Heat exchangers having (at least one) fluid flowing in lateral confinements that are typically smaller than 1 mm are known as micro channel heat exchangers or microstructured heat exchangers. Microchannels, which are channels with a hydraulic diameter less than 1 mm, are the most common type of confinement. Ceramic and metal are two possible materials for microchannel heat exchangers. Tuckerman & Pease introduced and employed the idea of micro channel heat exchangers in 1981. Swift created the first tiny heat exchanger in 1985.

Classification of Micochannel

The definition of a micro channel is a very contentious issue among experts. Mehendale et al. (2000) obtained several types of channel dimensions using a manufacturing-based categorisation approach, with D being the lowest channel dimension.

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1 μm < D < 100: Micro channels
100 μm < D < 1 mm: Minichannels
1 mm < D < 6 mm: Compact Passages 6 mm < D: Conventional Passages

With "D" being the smallest channel diameter, Kandlikar and Grande (2003) used a different categorisation based

on the rarefaction impact of gases in different ranges of channel dimensions:
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:

A well-known heat transfer improvement method from history is the twisted tape. For laminar, transitional, and turbulent flow, it provides a considerable improvement at a comparatively high pressure rise.When the twisted tape creates a swirl flow, the stream line and flow field velocity are higher than when the plain tube is used. By increasing the turbulence and tangential velocity close to the walls, this phenomenon has an impact on the heat transfer coefficient.

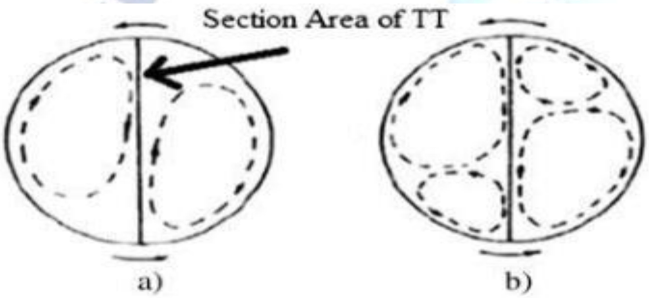

Figure 1.1The secondary induced flow patterns by twisted tape

2. LITERATURE REVIEW

Orhan Aydin, Mete Avci (1723-1730) : They looked at forced convection heat transfer in laminar conditions analytically for a Newtonian fluid flow from two parallel plates. They looked at the temperature jump, viscous dissipation effect, and slide velocity. They take into account the hydrodynamically and completely formed state when conducting the experiment. Constant temperature and heat flow are prerequisites for walls. In relation to the Brinkman number, they provided the results of several Nusselt numbers.

Pfahler (1990) : His primary goal was to determine the scale length at which layer separation takes place. He determined that the fluid flow in a microtube channel with a rectangular cross section that ranges from 80 to 7200 microns/m2.He made a clear connection to the Navier-Stokes equation assumption. The equation showed a significant fall off, even for the smallest of the channels. H was discovered to be on the bigger side for the macro tube compared to the micro tube for a nitrogen-filled microtube. He determined that the turbulent heat flow transfer coefficient was seven times higher than the value derived from the equation.

Randall f.Barron, X.M.Wang and Roberto Warington (1991) : The influence of slip flow in a low pressure gas and the overall issue of thermally forming the heat transfer flow via a microtube were both included in Gratez's formulation. A different approach was used to compute the eigen value. A steady state flow in a microtube was initially studied with a constant heat flux and an isothermal wall in order to solve the hydrodynamically stated laminar flow inter relation using the integral transformation approach. Viscous heating was used for both the heating and cooling cases.temperature It was demonstrated that the temperature jump phenomena was absent at high Pandlt numbers as the jump effect vanished as the Nusselt number increased.

Nicolas G. Hadjiconstantinou, Olga Simek (2002) : They looked into the slip flow regime for a nano channel and a 2D microchannel to determine the convective heat transfer coefficient for a gaseous flow at constant wall temperature. The flow state is thermally and hydrodynamically completely developed. The axial heat conduction condition was utilised to get the nusselt number.

Gokturk tunc, Yoldiz Bayazitoglu (2002) : Additionally, they have investigated the slip flow heat transfer for both hydrodynamically and thermally completely formed rectangular microchannels. The H-2 border is applied at the microchannel wall.

Tuckerman and Pease (2006): They claimed that laminar flow via microchannels had a higher h than turbulent flow through normally sized microchannels. According to the computation, 790W/cm2 heat flow dissipation is feasible, and it can do so without undergoing a phase transition.

3. MATHEMATICAL MODELING

Case 1

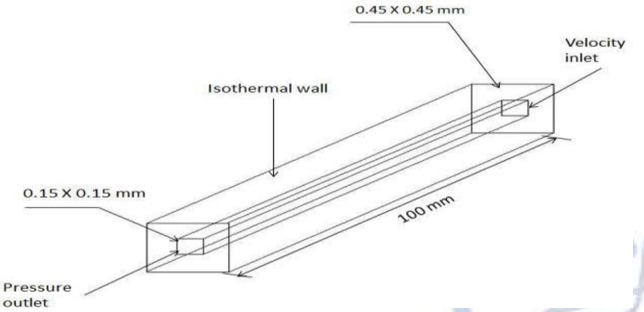

Figure 3.1- Square Micro channel without twisted tape

Case 2

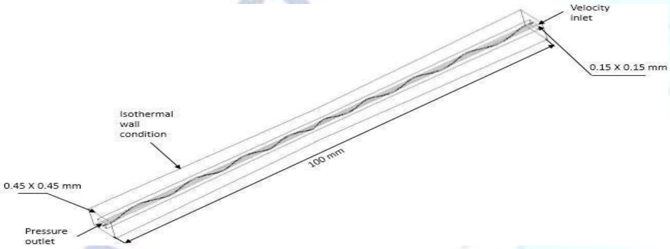

Figure 3.2- Square Micro channel with twisted tape

Assumptions

The following are the geometrical and physical presumptions.

(1) The flow is incompressible, laminar, three-dimensional, and steady state.

(2) The operating fluid is water.

(3) Thermophysical characteristics are assumed to be constant.

(4) The impact of gravity does not exist.

(5) There is no viscous dissipation.

The governing equations are as follows, predicated on the assumptions: Differential Equations Under Control

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

• Analysis has been done on a 3D laminar and unsteady state flow via a square microchannel. The micro channel's dimensions are measured in micrometres. The microchannel's dimensions are as follows: its length is 100 mm, its cross section is 0.15*0.15 mm, and its thickness is 0.15 mm along each of the wall's four sides. The microchannel's side wall is regarded as being in an isothermal state, or having a constant temperature.

• The fluid enters the system at room temperature (298 K) at the inlet and exits at the outlet, where the gauge pressure is zero. Pressure-driven flow is taken into account. The temperature of the isothermal wall is 330 K.

•ANSYS WORKBENCH is used to construct the geometry, while FLUENT is used to do the simulation. Variables of flow, such as temperature, pressure, and velocity, have been examined at various pipe cross sections. Plotting of the Nusselt number is crucial for convective heat transfer. The primary goal is to compare the two examples' axial wall shear stress, skin friction coefficient, Nusselt number, and convective heat transfer.

The 3D geometry of the two scenarios mentioned above was produced using ANSYS WORKBENCH 15.0. There are 160000 meshed cells in total. Fig. displays the meshed geometry in detail. Set up the problem by selecting an appropriate solver and applying all the boundary conditions. Figure illustrates the convergence of the residual.

Case 1

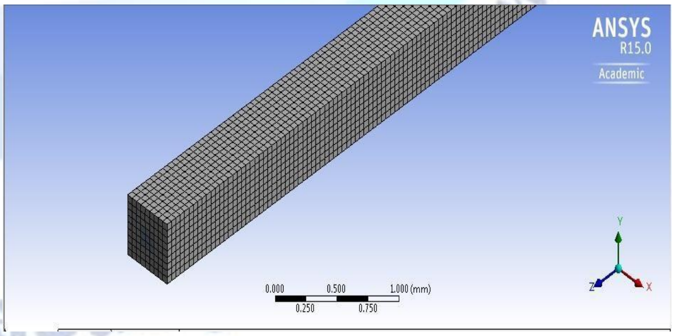

Figure 4.1 - Completed meshed geometry of micro channel without twisted tape

Case 2

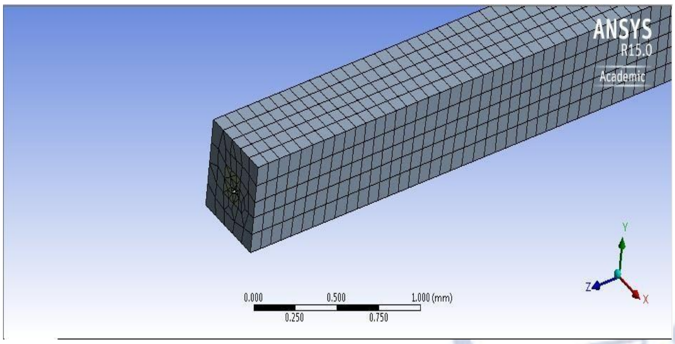

Figure 4.2 - Completed meshed geometry of micro channel with twisted tap

Velocity Simulation

Water is regarded as a working fluid when its output pressure is 1 atm.

- At the intake, the velocity is 0.6 m/s, which corresponds to a Reynolds number of 100.
- No slide boundary condition is taken into account at the wall.

For discretisation, the second order upwind approach is used in an iterative SIMPLE algorithm based on pressure correction. The velocity intake is where initialisation and iteration are carried out.

Case 1

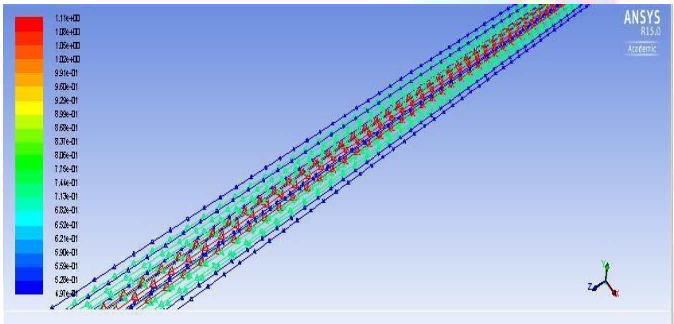

Figure 4.2 - Velocity vector of micro channel without twisted tape

Case 2

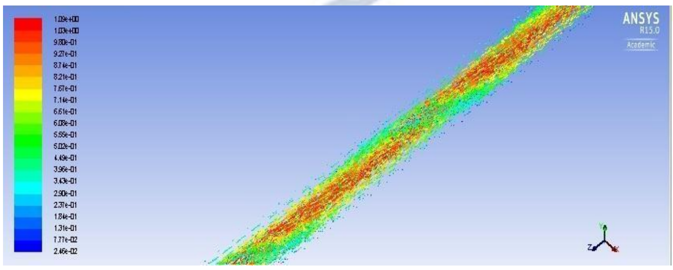

Figure 4.4 - Velocity vector of micro channel with twisted tape

Temperature Simulation

We assume that the temperature at the wall of a microchannel with the same shape is constant, Twall = 330 K. At the input, the fluid's temperature is Ti = 298K. Fluent solves these boundary conditions, and fig. displays the temperature contours

Case 1

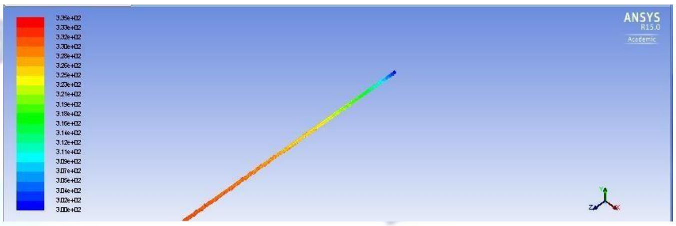

Figure 4.5 - Temperature contour of micro channel without twisted tape

Case 2

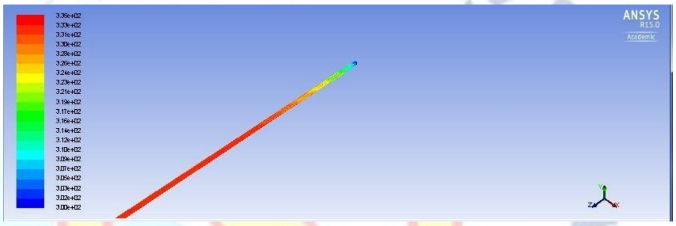

Figure 4.6 -Temperature contour of micro channel with twisted tape

5. CONCLUSIONS

This research uses the CFD FLUENT R15 code to examine heat transport in a square micro channel heat exchanger with and without twisted tape. The current work has led to the following conclusions.

1. When using the twisted tape insert with the traditional micro channel, it is discovered that the axial wall shear stress rises.
2. Using the twisted tape insert with the traditional micro channel results in an increase in the skin friction coefficient.
3. Based on the data above, it can be concluded that using a twisted tape insert with a traditional micro channel raises the surface nusselt number.
4. Additionally, using a twisted tape insert with a traditional micro channel results in an increase in the surface heat transfer coefficient.
5. The twisted tape insert causes turbulence to rise, which raises convective heat transfer.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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