Enhancement of Heat Transfer in Micro-Channel with Twisted Tape Insert

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Abstract- A 3D micro channel in transient condition with hydro dynamically fully developed was investigated. The main aim to increase the turbulence of fluid with a helical twisted tape insert and compare with the channel without twisted tape. Since the more the turbulence in fluid more the convective heat transfers. A commercial CFD package is used for investigation. An isothermal wall condition with Re equal to 100 which is equal to inlet velocity of 0.67m/s is taken as boundary condition. The main aim is to compare the heat transfer rate, axial wall shear stress, skin friction coefficient, Nusselt number, wall fluxes and heat transfer coefficient for the channel with twisted tape with respect to the without twisted tape. It is found that the increase in turbulence occurs in microchannel due to the twisted tape insert. Also it is found that heat transfer characteristics like axial wall shear stress, skin friction coefficient, surface Nusselt number and surface heat transfer coefficient are greater in with twisted tape with respect to without twisted tape. The result revealed that when we use micro channel with twisted tape as compare micro channel with straight tape convective heat transfer increase, convective heat transfer increases because of turbulence in the twisted tape increase. The increased value we can calculate with the help of commercial computational fluid dynamic or commercial CFD. Micro channels are micro in size and have much application in micro electro mechanical system, integrated circuit, biochemical application because it is most suitable method for removing heat flux.

Keywords: CFD, Twisted tape, Nusselt number, Reynold number, Micro-channel, Turbulence.

I. INTRODUCTION

It is a technique used to increase the thermo hydraulic properties of the heat exchanger devices. It can be classified into three ways i.e.

Active Technique

From manufacturing point of view these techniques are very complex and some external power is needed for desired flow to improve the heat transfer rate. Because of external power needed to manufacture is has very limited application

Different active techniques are as

Mechanical aids: Scrapped heat exchanger and rotating tube heat exchanger are manufactured by mechanical aid techniques. Working principle of these techniques is stirring the fluid by means of rotating the surfaces.

Surface vibration: Mostly it has been used in single phase flow. To obtain a higher convective heat transfer coefficient a frequency of low or high amplitude is applied to the surface.

Fluid vibration: As a replacement for applying vibration at the surface in the fluid pulsation are created. This technique is applied for single phase flow.

Electrostatic fields: This technique is uses electrostatic field from an AC or DC sources to increase the heat transfer by mixing of fluid. It uses dielectric fluid of heat transfer process.

Injection: By injecting the same fluid or another fluid into the main fluid by the means of a porous interface of the section of the heat transfer area increases the heat transfer rate.

Suction: This technique is appropriate for both single phase flow and two phase flow heat transfer. Removal of vapour by means of porous heated surface in two phase flow and removal of fluid by means of porous heated surface in single phase flow is done by this technique.

Jet impingement: This technique is also appropriate for both single phase flow and two phase flow heat transfer**.** This method employs the cooling or heating the fluid perpendicularly or obliquely to increase the heat transfer rate at the surface.

Passive technique

These techniques use the power from itself rather than external source which results in increase in pressure drop of fluid. Some modification in geometry or surface cause higher heat transfer rate by disturbing the behavior of fluid.

Different passive techniques are as

Treated surface: This technique includes alteration of the surfaces like pits, cavity or scratches at the heat transfer area. This method is mainly used in boiling and condensation purposes.

Rough Surface: By employing this method a disturbance is created in the region of viscous sub layer. This method is mainly used in single phase turbulent flows.

Extended surfaces: The most commonly used extended surfaces are plain fins which is mainly used in heat exchanger. In the present era finned surfaces become very popular due to their ability to interrupt the flow field which in turns the increase the heat transfer rate.

Displaced enhancement devices: this method is mainly used in forced convection. They enhance the heat transfer indirectly at the surface of the heat exchanger by shifting the fluid from the surface which is heated or cooled with the bulk fluid.

Swirl Flow devices: they create the swirl flow in the axial direction of the channel. The common example of swirl flow devices are helical twisted tape and twisted ducts. it can be used in both type of flow i.e. single phase flow and double phase flow.

Coiled Tubes: In single phase flow generation of vortices are caused by curvature of coiled which results in higher heat transfer coefficient. This phenomenon is mainly occurs in regions of boiling.

Surface tension devices: This technique enhances the flow of liquid to boiling surface from the condensing surface. Wicked or grooved surface are the best example of this technique.

Compound Technique

When two or more techniques used simultaneously to improve the heat transfer rate which is greater than either technique is called compound technique.

II. BACKGROUND

In order to augment heat transfer and to increase thermal performance of the heat exchangers heat transfer enhancement techniques are widely used. These techniques are classified in two groups, active and passive techniques. For active techniques heat transfer rate is improved by supplying extra energy to the system while in passive techniques the purpose is solved without use of any extra energy. The passive techniques include surface area extension (extended surfaces: fins), rough surfaces, inserts, tabulators also called swirl flow devices and coated surfaces.

The tabulators are of different types like wire coil inserts, twisted tapes and their combination. Out of all inserts are most popular devices used for improving heat transfer performance of heat exchangers used in industries. The purpose of inserting these swirl flow devices is to improve heat transfer rate by decreasing the thickness of thermal boundary layer, disturbing velocity boundary layer and allowing core fluid to mix with peripheral fluid. The wire coil inserts and twisted tape inserts are easy to manufacture and install, their cost is too less.

KhwanchitWangcharee[2020] in their paper, have made the Techniques to augmentheattransfer. They end up with the detailed analysis of heat transfer applications. This introductory chapter on the augmentation of convective heat transfer provides background for the many applications of this “second generation heat transfer technology” cited throughout this volume. The many available augmentation techniques are described, and some representative performance data and correlations are given for the popular passive techniques.

A. A. RabienatajDarji[2019] also have discussed the comparison of wire coil inserts and twisted tape in their work. It was observed and noted that to disturb the central core flow the twisted tapes are the solution but if peripheral annular flow is to be mixed with core flow the wire coil inserts perform better. In context with heat transfer rate they have concluded that twisted tape perform better than the wire coil inserts. In process industries the fluids used have high density because of high viscosity and dirt and thus they need high pumping power. In such cases the pumping power is the important element and is drive to put constraints on selection of passive device. When pumping power is an issue pressure drop adds limitation on type of insert, as twisted tape cause more pressure drop than wire coil inserts.

C. Thianponget. Al [2018] works in the condition of force convection by using twisted tape insert of width 16 mm thicknesses 1.2mm, length 0.5m and twist ratio 5.5, 6.5, 8.5 with circular holes of diameter 6mm and conclude that for Re no.range 2000 to 12000, the Nussult number for twisted tape insert with twist ratio 8.5,6.5 and 5.5 was found to be 23.99%, 25.64% and 29.32% respectively also the Friction factor is increased approximately by 0.20%, 0.2673 % and 0.4545 % with twist ratio 8.5, 6.5 and 5.5 respectively.

A. E. Kabeel et. al [2017] Give a Analysis of Heat Transfer in Pipe with Twisted Tape Inserts to understand the effect of change in pitch of twisted tape on the flow physics, results of Re no.800 and twist ratio 2, 3, 4 and 5 are considered and conclude the variation of twist ratio and Re no.on heat transfer and flow characteristics using twisted tape inserts and also the heat transfer increases with decrease in twist ratio and increase in Reynolds number.

M. M. K. Bhuiya et. al [2016] found in double pipe heat Exchanger of diameter 0.015 m and length of 2.5 m with variable twisted type insert in ANSYS fluent that a trend of increase in heat transfer with the provision of insert on the heat exchanger. The heat transfer was found to increase as the Re no.was varied over the range. The result shows that effect of insert on the enhancement of heat transfer depends on both the pattern of insert and Re no.of the flow.

III. PROBLEM IDENTIFICATION

From the study of various research papers we have obtained the fallowing problems:

- Geometry was not suitable for higher heat transfer.
- Size and cost of heat transfer equipments was more.
- The main concern for the equipment design is to minimize the flow resistance while Enhancing the heat transfer coefficient.
- Performance of heat exchangers can be improved by many augmentation techniques but Increase in pressure drop is always a barrier for heat transfer enhancement

IV. OBJECTIVES

Heat transfer can also be enhanced by using twisted tapes & inserts. These coiled inserts acts as a turbulence generator. The use of this generated turbulence is expected to create the tangential velocity to prolong residence time of the flow and to enhance the tangential and radial fluctuation, therefore leading to increase in heat transfer inside the test tube.

The objectives of this work are:

- Enhance the heat transfer with respect to plain tube.
- Reduce the size and cost of heat exchanger.
- The equipment design is to minimize the flow resistance while enhancing the heat Transfer coefficient.
- Decrease pumping power requirement.

V. METHODOLOGY

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 0.15×0.15 mm and length of the channel is 100 mm and the thickness of the channel is 0.15 mm 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. 300 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 335 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.

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

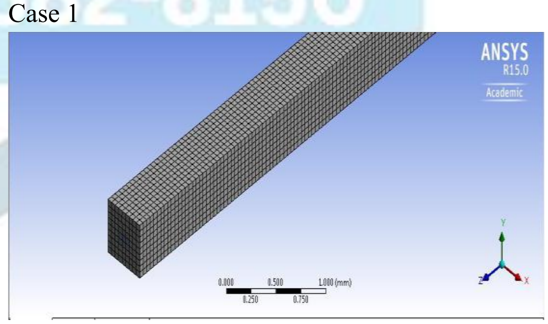

Figure 1: Completed Meshed Geometry of Micro Channel Without Twisted Tape

Case 2

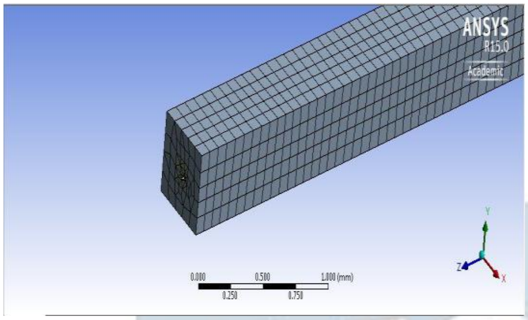

Figure 2: Completed Meshed Geometry of Micro Channel With Twisted Tape

Convergence Limit

Case 1

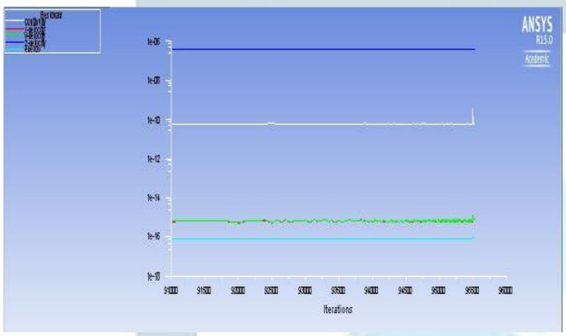

Figure 3: Convergence Residual of Microchannel without Twisted Tape

Case 2

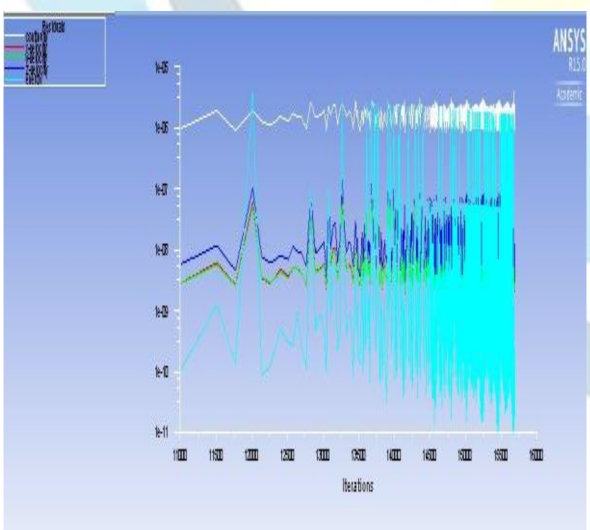

Figure 4: Convergence Residual Of Microchannel With Twisted Tape

VI. RESULTS AND ANALYSIS

Axial Wall Shear Stress

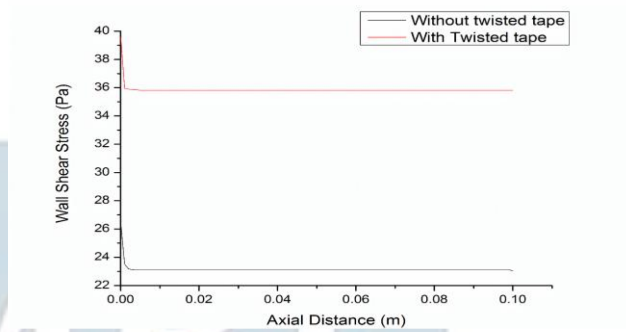

Figure 5: Wall Shear Stress Vs Axial Distance

Table 1: Wall Shear Stress And Axial Distance With Twisted Tape

S.NO.	AXIAL DISTANCE(m)	WALL SHEAR STRESS(Pa)
1	0.00	39
2	0.00125	37
3	0.0025	36
4	0.04	36

Table 2: 1 Wall Shear Stress and Axial Distance without Twisted Tape

S.NO.	AXIAL DISTANCE(m)	WALL SHEAR STRESS(Pa)
1	0.00	25
2	0.00125	24
3	0.0025	23
4	0.04	23

Skin Friction Coefficient

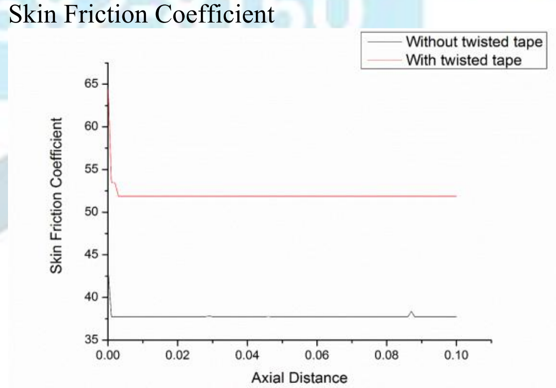

Figure 6: Skin Friction Coefficient Vs Axial Distance

Surface Heat Transfer Coefficient

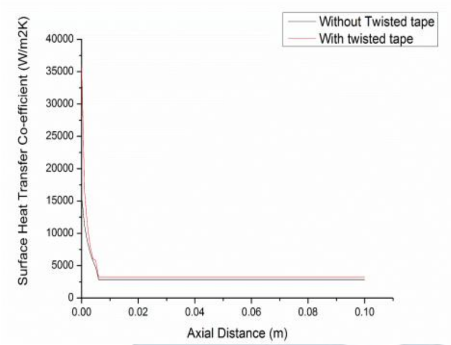

Figure 7: Surface Heat Transfer Coefficient Vs Axial Distance

Surface Nusselt Number

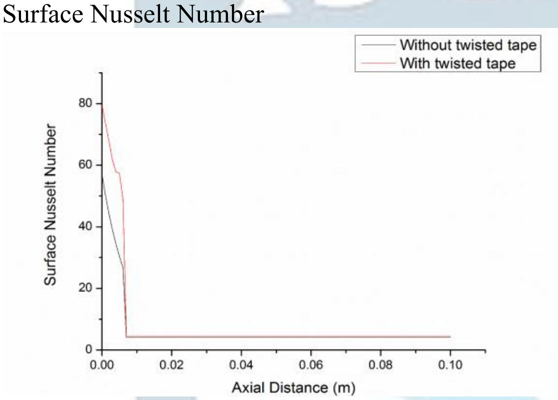

Figure 8: Surface Nusselt Number Vs Axial Distance

VII. CONCLUSIONS

1. It is found that the axial wall shear stress increases when the twisted tape insert is employed with the conventional microchannel.
2. It can be concluded that the skin friction coefficient increases when the twisted tape insert is employed with the conventional microchannel.
3. From the above results it is found that surface Nusselt number increases when the twisted tape insert is employed with the conventional microchannel.
4. Also Surface heat transfer coefficient increases when the twisted tape insert is employed with the conventional microchannel.
5. Due to twisted tape insert the increase in turbulence occurs which results in higher convective heat transfer.

It is observed that by inserting the twisted tape in conventional microchannel the parameters like wall shear stress. Skin friction coefficient, surface nusselt number, surface heat transfer coefficient increases along the axial distance. The reason is increase in turbulence by inserting the twisted tape which results in increase in turbulence. Due to this fluid is mixed properly which results more convective heat transfer. Present work is done with the water as working fluid, in which temperature jump and slip velocity does not play an important role. Can change working fluid as air in which temperature jump and slip velocity plays an important role. Change the property like temperature and pressure by implementing the UDF.

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