EFFECT OF TWISTED TAPE INSERTS IN DOUBLE PIPE HEAT EXCHANGER USING AL2O3/WATER NANO FLUIDS

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ABSTRACT

The effect of various twist ratio's of twisted tape inserts to enhance the rate heat transfer with Al2O3/water nanofluid. The investigation has been carried out with different twist ratio's of (Yw= 3.4, 4, 4.5) with 0.3% volume concentration, were 5% higher than water. These experiments were carried out for double pipe concentric heat exchanger. This experiment was conducted at Reynolds number ranges from 250 to 760 with the temperature ranges 27^{0}C to 40^{0}C. The twist ratio of 3.5 counter flow increase heat transfer rate compared to other twist values. The numerical results proved that increase of thermal performance of nanofluid with modified twisted tape. The turbulent kinetic energy is increased very much and also increased by the twisted tape insert.

***Keywords**: Al_2O_3/water nanofluid, double pipe heat exchanger, twisted tape insert , heat transfer enhancement.*

NOMENCLATURE

A	Cross sectional area (m2)
S	Surface area (m2)
D	Test section diameter (m)
L	Test section length (m)
m	Mass flow rate (kg/s)
Re	Reynolds number, 4m/πμD
Pr	Prandtl number, μcp/k
cp	Specific heat (J/kg K)
f	Friction factor
h	Convective heat transfer coefficient (W/m2K)
k	Thermal conductivity (W/m K)
Nu	Nusselt number, hD/k
T	Temperature (oC)
v	Fluid velocity (m/s)

Q Heat input (W)

Greek symbols

μ Dynamic viscosity (kg/m2 s)

ρ Density (kg./m3)

φ Volume concentration (%)

Subscripts

nf nanofluid

bf basefluid

1. INTRODUCTION

Several researchers were carried out using the twisted tape inserts. In this study Double pipe heat exchangers and experimented. This work yields the results of high performance heat transfer coefficient. It is very useful to Textile, Refrigeration industries. Nanofluids enhance the heat transfer rate by adding is with different concentrations, dispersion of the nanoparticles into the distilled water increases the thermal conductivity and viscosity of the nanofluid, this augmentation increases with the increase in particle concentrations [1, 2]. At a particle volume concentration of 2% the use of Al_2O_3/water nanofluid gives significantly higher heat transfer characteristics. For example at the particle volume concentration of 2% the overall heat trasfer coefficient is 700.242 W/m2 K and for the water it is 399.15 W/m2 K for a mass flow rate of 0.0125 L/s so the enhancement ratio of the overall heat transfer coefficient is 1.754, this means the amount of the overall heat transfer coefficient of the nanofluid is 57% greater than that of distilled water. As for Nusselt number, the value of Nusselt number for 2% volume concentration is 587 and for the distilled water it is 367.759 so the maximum enhancement ratio at 0.0125 L/s is 1.596, this means that Nusselt number of the nanofluid is 62.6% greater than that of distilled water by Jaafar Albadr [3].The turbulent flow through double pipe heat exchanger equipped with modified twisted tapes has been performed for a range of Reynolds number (5000 to 21,000) with a wide range of solid volume fraction (0.2% to 0.9%).The influences of the geometrical progression ratio, twist ratio and volume concentration on the heat transfer rate and friction factor characteristics have effects on the heat transfer enhancement and friction factor respectively 1.03 to 4 and 1.4 to 2.8 times Heydar Maddah[4].And increasing the particle concentrations increases the thermal conductivity, viscosity and friction factor of the nanofluid investigated experimentally in a horizontal shell and tube heat exchanger about the convective heat transfer performance and flow characteristics of Al2O3 nanofluid. Jaafar Albadr[5]. The numerical simulations for turbulent forced convection heat transfer in a circular tube having louvered strip inserts with constant heat flux condition. Among the nanofluids SiO_2 nanofluid has the highest Nusselt number and skin friction coefficient values, followed by Al_2O_3, ZnO, and CuO and finally pure water has the lowest Nusselt number. The Nusselt number is slightly improved with the increase of nanoparticle concentration. H.A. Mohammed et al [7].The V-cut twisted tape with twist ratios 2.0, 4.4 and 6.0 offered a higher heat transfer rate, friction factor and also thermal performance factor compared to the plain twisted tape in all Reynolds number. P. Murugesan et al [8]. At different air and liquid volumetric flow rates the overall heat transfer coefficient decreases with increasing inlet temperature of the nanofluid. The overall heat transfer coefficient enhances with the addition of nanoparticles to the base fluid experimental investigated the overall heat transfer coefficient in the automobile radiator using CuO/water nanofluid**.** M. Naraki et al [11].The heat transfer behaviors of the nanofluids are highly dependent on the particle concentration and the flow conditions and weakly dependent on the temperature S.M. Peyghambarzadeh et al [12]. A.A. RabienatajDarzi et al [13], Found that by increasing the concentration of γ-Al2O3- water nanofluid in double tube heat exchanger nanofluid, the heat transfer and the pressure drop simultaneously increase, and the concluded that adding the nanoparticles to the base fluid has better result at higher Reynolds number. The thermophysical properties like thermal conductivity and viscosity of Al2O3 nanofluid is determined through experiments at different volume concentrations and temperatures. Heat transfer coefficients and frication factor Reynolds number of 10,000 and 22,000 with nanofluid of 0.5% volume concentration is higher when compared to water in a plain tube. L. Syam Sundar et al [14], the aspect ratios of longitudinal strip inserts in different conditions and found the use of longitudinal strip inserts is advantageous at higher Reynolds either for water or nanofluid. The use of nanofluid enhances heat transfer coefficient with no significant enhancement in pressure drop compared to water. L. SyamSundar et al [15]**.**Smith Eiamsa-ard et al [16], investigated experimentally and numerically of TiO2/water nanofluid with multiple twisted tapes and found that TiO2 nanoparticles exhibited a continual increase in thermal performance with increasing concentration. By increasing a number of twisted tapes provide a better fluid mixing as results of more consistent swirl flows. The numerically about the behavior of water- and ethylene glycol-based Al2O3 nanofluids in turbulent and laminar flow regimes in a flat tube. Found that numerical results were the same as for the experimental data, which increasing the concentration of nanoparticles in the base fluid increased the heat transfer coefficient and the Nusselt number. Nanofluids are a promising solution for optimal design of a heat exchange system.VahidDelavari et al [17].

2. EXPERIMENTAL SETUP

Fig 2.1 shows the schematic diagram of the experimental setup. It is a double pipe heat exchanger consisting of a calming section, test section, rotameters, water tank for supplying cold water, nicrome coils, nanofluid tank and. The test section is a smooth copper tube with dimensions of 1500mm length, Inner tube-12mm ID, and 15mm OD; Outer ID pipe-34mm ID, and 38 mm OD. The outer pipe is well insulated using asbestos rope to reduce heat losses to the atmosphere. Two calibrated rotameters, with the flow ranges 1 to 5 LPM are used to measure the flow of hot water and nanofluid. The water, at room temperature is drawn from an tank using pump. Similarly a rotameter is provided to control the flow rate of hot water from the inlet hot water tank. Two pressure tapings- One just before the test section and the other just after the test section are attached to the U-tube manometer for pressure drop measurement. Mercury is used as the manometric fluid. Seven RTDs measure the inlet & outlet temperature of nanofluid (T1 –T7) through a multipoint digital temperature indicator. And two RTD for each inlet and outlet hot water and nanofluid.

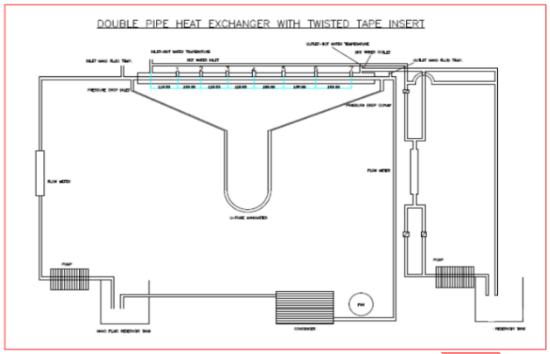


Fig.1 experimental setup

2.1SPECIFICATION SOF HEAT EXCHANGER USED

The experimental study is done in a double pipe heat exchanger having thespecifications as listed below:-

Inner pipe ID	12mm
Inner pipe OD	15mm
Outer pipe ID	34mm
Outer pipe OD	38mm
Material of construction	Copper
Heat transfer length	1.5m

Table.1 Specifications of Heat Exchanger

2.2 TYPES OF INSERTS USED

Three types of twisted tape inserts made from stainless steel strips of thickness 1.80 mm were used

Strip	**Twist ratio Yw**
1	3.5
2	4
3	4.5

Table.2 Twist ratio of strip inserts

The present work deals with finding the friction factor and the heat transfer coefficient for the various types of twisted tapes with twist ratios (yw=3.5, 4, 4.5) and finally finding the heat transfer enhancement by using nanofluid.

3.NANOFLUID PREPARATION

In order to prepare the nanofluids by dispersing the nanoparticles in a basefluid, proper mixing, and stabilization of the particles is required. Basically three different methods are available to attain stability of nanofluids. The methods are listed as follows: (1) Acid treatment of base fluids (2) Dispersants addition, (3) use of Ultrasonic Vibration. All of these techniques intend at changing the surface characteristics of a system and suppressing settlement to obtain stable suspensions. In the present study, Al_2O_3 nanoparticles of size 20–22 nm were mixed with distilled water and stabilizers and then sonicated continuously by ultrasonic vibrator (Toshiba, India) generating ultrasonic pulses of 100W at 36 ± 3 kHz for 5 h to break down agglomeration of the nanoparticles, prior to being used as the working fluid.

Fig.2 nanofluid immersed in bath

Fig.3 time set in ultrasonic vibrator

4.NUMERICAL METHOD

4.1 BOUNDARY CONDITIONS

At the inlet and outlet, a periodic condition is specified and theupstream temperature is kept constant at 299 K.

Boundary conditions	Velocity Magnitude	Turbulent Kinetic Energy	Turbulent Dissipation Rate	Temperature
Velocity Inlet hot water	0.5 m/s	0.01 m2/s2	0.1 m2/s3	348 K
Pressure Outlet	-	-	-	-
Velocity Inlet nanofluid	0.67 m/s	0.01 m2/s2	0.1 m2/s3	283 K
Pressure Outlet	-	-	-	-

Table.3Boundary conditions given

The inlet velocity and temperature profiles are obtained via the following scheme. In the beginning, uniform inlet velocity and temperature profiles for the plain tube and enhanced tube were used. Then, re-computation was performed using the outlet velocity and temperature profiles of the previous step. After several times of computation applying this approach, fully developed flow and temperature profiles can be obtained. The enhanced wall function method is adopted for the treatment of tube wall and surfaces of multiple twisted tapes. At the outlet, an outlet pressure condition is used. The boundary condition between the fluid and the twisted tape surface is adiabatic condition. Only 360twist length is applied, due to the requirement of a periodic flow. The Reynolds number used for the computation is referred to the inlet one which kept constant at10,000. The constant heat flow condition is specified on the tube wall with a value of 1000 W m^2.

5.MESH

Initially a relatively coarser mesh is generated. This mesh contains mixed cells (Tetra and Hexahedral cells) having both triangular and quadrilateral faces at the boundaries. Care is taken to use structured hexahedral cells as much as possible. It is meant to reduce numerical diffusion as much as possible by structuring the mesh in a well manner, particularly near the wall region. Later on, a fine mesh is generated. For this fine mesh, the edges and regions of high temperature and pressure gradients are finely meshed.

6.DATA REDUCTION

The thermo-physical properties (Density, Specific heat, Viscosity and Thermal conductivity) of Al_2O_3/water nanofluid were evaluated based on the properties of the base fluid and nanoparticles. It was assumed that nanoparticles were well dispersed in the base fluid (water).

The density and specific heat of nanofluid were evaluated from Eqs. Respectively

$$\rho_{nf} = \varphi.\ \rho_p + (1-\varphi).\ \rho_w \qquad 5$$

$$c_{p,nf} = \frac{\phi\rho_{n,p}\, c_{p,np} + (1-\phi)\rho_w.c_{p.w}}{\rho_{nf}} \qquad 6$$

The thermal conductivity and viscosity is found from the below equation

$$\frac{k_{nf}}{k_w} = \frac{k_{np}+2k_w+2\phi(k_{np}-k_w)}{k_{np}+2k_w-\phi(k_{np}-k_w)} \qquad 7$$

$$\mu_{nf} = \mu_w(1+\eta\phi) \qquad 8$$

The average heat transfer coefficient defined by the following formula

$$h = \frac{q''}{T_w - T_f} \qquad 9$$

The average Nusselt number was calculated as

$$N_u = \frac{hD}{k} \qquad 10$$

Volume concentration

$$\phi = \frac{\left(\dfrac{W_{Al2O3}}{\rho_{Al2O3}}\right)}{\left(\dfrac{W_{Al2O3}}{\rho_{Al2O3}} + \dfrac{W_{water}}{\rho_{water}}\right)}$$

7. EFFECT OF TWISTED TAPE IN DOUBLE PIPE HEAT EXCHANGER

The heat transfer of tubes equipped with tape increases the swirl flow seen in the figure :the Reynolds number is available over the range750-200, and water was used as the working fluid. Fig. shows that Nusselt number considerably increased with increasing Reynolds number. This was attributed to a stronger turbulent intensity and thus a better fluid mixing. At a given Reynolds number, Nusselt number in the tube Yw=3.5 twisted tapes was significantly higher than those in the other two and plain tube. This can be explained that at lower Reynolds number, a thermal boundary becomes thicker; therefore the swirl flows induced by twisted tapes possess more significant effect on disruption of thermal boundary. This can be explained by the fact that more tape 3.5 induces higher number of swirl flows imparted to an axial flow than 4 and 4.5,resulting in more uniform fluid mixing between the core and the tube wall regions, throughout the tube

Part number	Part Of The Model	State Type
1	Inner_Fluid	Fluid
2	Inner_Pipe	Solid
3	Outer_Fluid	Fluid
4	Outer_Pipe	Solid

Fig.4 Twisted tape inserts

8.CFD ANALYSIS

Computational fluid dynamics (CFD) study of the system starts with the construction of desired geometry and mesh for modeling the dominion. Generally, geometry is simplified for the CFD studies. Meshing is the discretization of the domain into small volumes where the equations are solved by the help of iterative methods. Modeling starts with the describing of the boundary and initial conditions for the dominion and leads to modeling of the entire system. Finally, it is followed by the analysis of the results, conclusions and discussions.

8.1 GEOMETRY

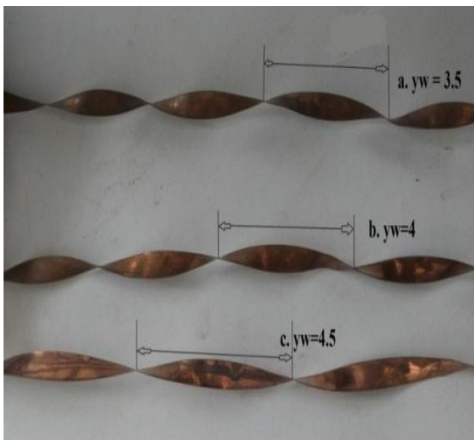
Heat exchanger is built in the GAMBIT 3.2.16 design. It is a parallel-flow heat exchanger. In the operation tool bar geometry is selected with positive-z.

Table.4 Naming of various parts of the body with state type

Out of 3 planes, viz, XY-plane, YZ-plane and ZX-plane, the YZ-plane is selected for the first sketch. A 1000mm length and 6 mm radius cylinder is created using volume command and insert volume v1 is subtracted form volume v2. And volume v3 of 950 mm length and thickness 4mm is created and moved 50 mm in z-axis.

8.2 MESH

Initially a relatively coarser mesh is generated. This mesh contains mixed cells (Tetra and Hexahedral cells) having both triangular and quadrilateral faces at the boundaries. Care is taken to use structured hexahedral cells as much as possible. It is meant to reduce numerical diffusion as much as possible by structuring the mesh in a well manner, particularly near the wall region. Later on, a fine mesh is generated. For this fine mesh, the edges and regions of high temperature and pressure gradients are finely meshed.



8.3 MESH DETAILS

- Relevance center: fine meshing
- Smoothing: high
- Size: 4.033e-005m to 8.066e-005m
- Pinch tolerance: 3.6297e-005m
- Nodes: 586300
- Number of Elements: 53170
- Elements: Tet/Hybrid
- Mesh type: volume mesh
- Interval count: 15

8.4 BOUNDARY CONDITIONS

Boundary conditions are used according to the need of the model. The inlet and outlet conditions are defined as velocity inlet and pressure outlet. As this is a counter-flow with two tubes so there are two inlets and two outlets. The walls are separately specified with respective boundary conditions. No slip condition is considered for each wall. Except the tube walls each wall is set to zero heat flux condition.

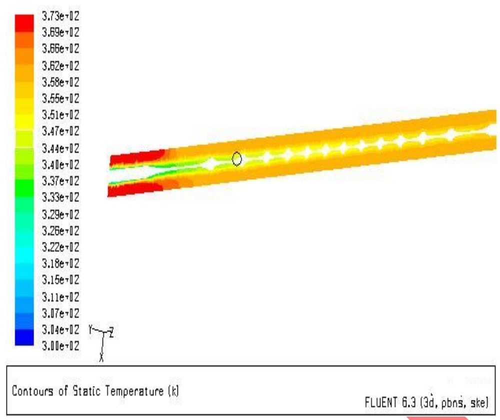


Fig.5 Static temperatures

In the Fig 5, the 2D contour of static temperature shows the convective heat transfer between both fluids in double pipe heat exchanger. The marked point shows the temperature the fluid in the pipe. The entry of the inner pipe temperature is 303K and outer pipe temperature is 343K.The outlet of the inner tube exits at 323K this shows Al_2O_3/water nanofluid shows 4.2% high rate of heat transfer than the water.

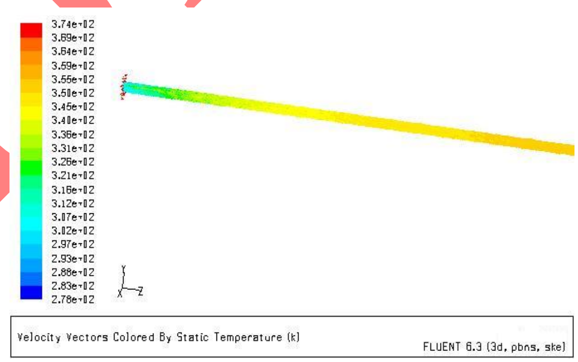


Fig.6 Velocity vectors

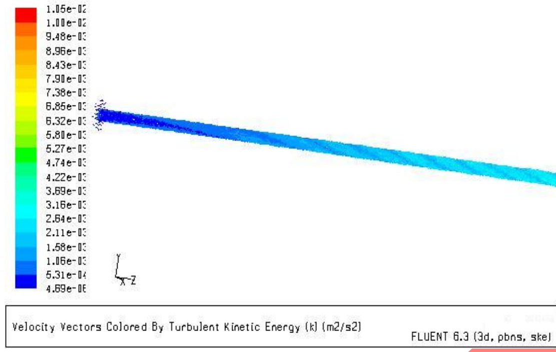


Fig.7 Turbulent kinetic energy

9 .RESULTS AND DISCUSSIONS

The use of twisted tape mixes the fluid well inside the tube and increases the pressure in the tube seen in fig: 7, this enhances the rate of heat transfer in the exchanger. The usage of the twisted tape inserts shows the swirl flow create high turbulent kinetic energy in the inner tube shown in vectors seen in fig: 7

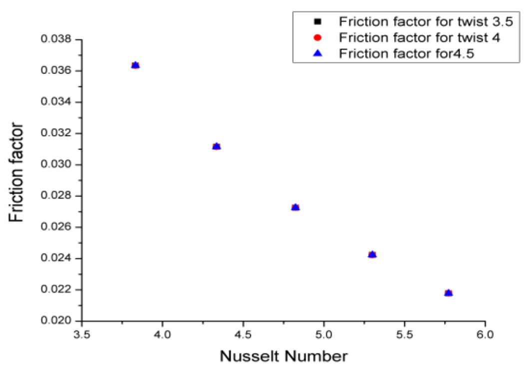


Fig.8 Friction factor (f) vs Nusselt number (Nu)

Friction factor decreases as Reynolds number increases and this decides the smoothness in the tube flow shown in fig.8The maximum value of the friction factor is 0.0363for flow Re= 440

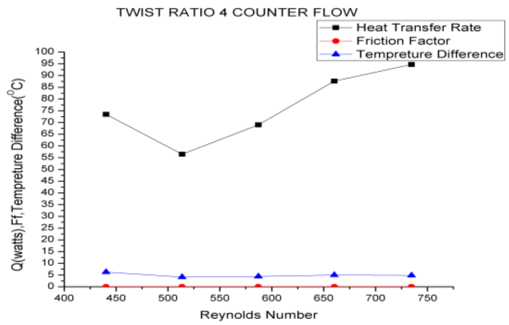


Fig.9 Reynolds number (Re) vs Heat transfer rate (Q),Ff,Temp(°C)

This shows the rate of heat transfer for twisted tape insets Yw=3.5, 4, 4.5both parallel and counter is done. In the fig: 9 Yw=3.5 counter flow has the high heat transfer rate followed by the Yw=3.5 paralel flow. The rate of heat transfer e f Al_2O_3increases when the Reynolds number increases.

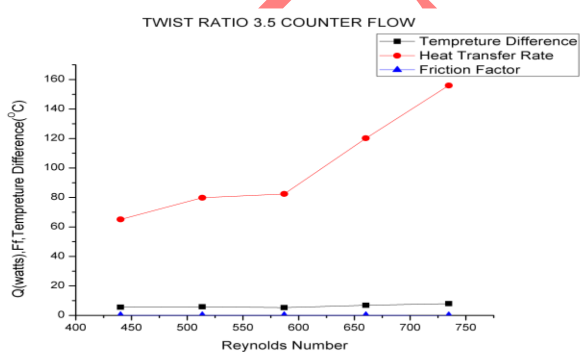


Fig.10 Change in temperature vs Reynolds number twist ratio

Yw= 3.5

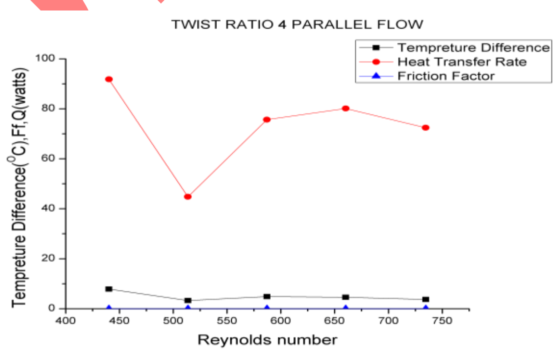


Fig.11 Change in temperature vs Reynolds number twist ratioYw= 4

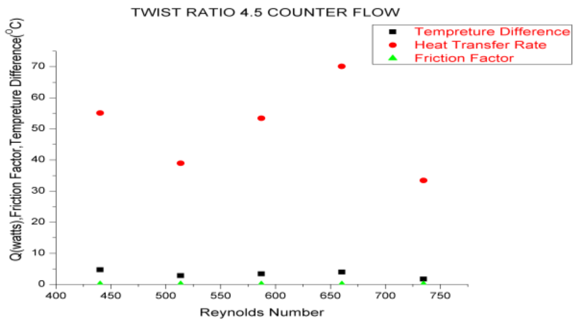


Fig.12 Change in temperature vs Reynolds number twist ratioYw= 4.5

The effect of twisted tape inserts influences the temperature change between the inlet and outlet in the inner tube. Of the three twisted tape Yw=3.5 has more temperature change compare to the Yw=4 and 4.5 seen in fig:12

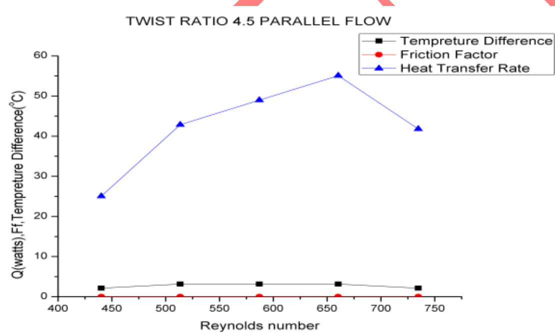


Fig.13Friction factor (f) vsNusselt number (Nu)

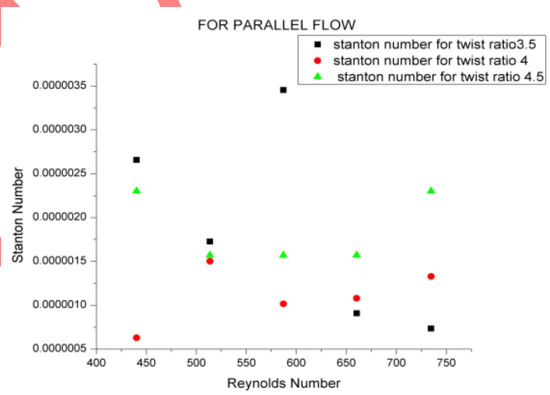


Fig.14Stanton Number (St) vs Reynolds number (Re)

The friction factor decreases with the increases in Nusselt number due to the viscosity in Al_2O_3/water nanofluid. Nusselt number increases when the Reynolds number increases seen in fig:14.

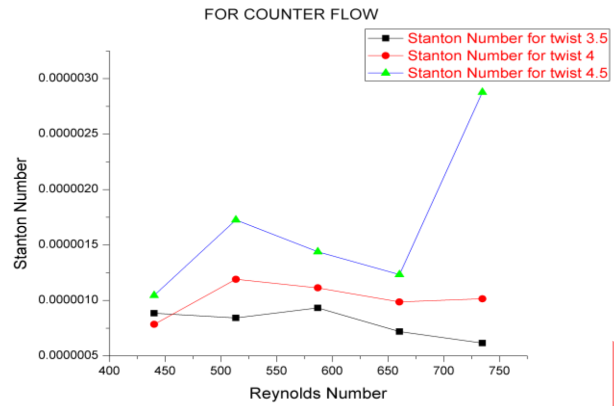


Fig.15Stanton Number (St) vs Reynolds number (Re)

9. CONCLUSION

The influences of twisted tapes with twist ratios (Yw= 3.5, 4, 4.5) and Al_2O_3 nanoparticles in water as a working fluid on heat transfer enhancement are described in this study. The conclusions are drawn below:

- Nusselt number, friction factor and thermal performance factor increased as the twisted tapes angle decreased.
- The tapes in counter arrangement provided higher thermal performance factor than that in parallel flow.
- The benefit of Al_2O_3 nanoparticles in water was significant in improving thermal performance.
- The thermal performance factors of the nanofluid with Al_2O_3 concentrations of 0.3% by volume were 5% higher than water.
- Compared with the other twisted tape Yw=3.5 counter flow has more heat transfer enhancement. The rate of heat transfer increases with the increase in flow rate in heat exchanger.
- Friction factor decreases with the increase in flow rate.

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