# EXPERIMENTAL STUDY ON THE ANALYSIS OF HEAT ENHANCEMENT IN CORRUGATED TWISTED PIPES

G.Veerendra Kumar[1] and B Chandra Shekar [2]
[1]Department of mechanical Engineering, ASRCE, Tanuku, JNTU Kakinada, India
[2] Assistant Professor, ASRCE, Tanuku, JNTU Kakinada, India

***ABSTRACT***

*In heat exchanger, the enthalpy is transferred between two or more fluids, at different temperatures. The major challenge in designing a heat exchanger is to make the equipment more compact and achieve a high heat transfer rate using minimum pumping power. In recent years, the high cost of energy and material has resulted in an increased effort aimed at producing more efficient heat exchange equipment. Furthermore, as a heat exchanger becomes older, the resistance to heat transfer increases owing to fouling or scaling. The heat transfer rate can be improved by introducing a disturbance in the fluid flow thereby breaking the viscous and thermal boundary layer. However, in the process pumping power may increase significantly and ultimately the pumping cost becomes high. Therefore, to achieve a desired heat transfer rate in an existing heat exchanger at an economic pumping power, several techniques have been proposed in recent years and are discussed under the classification section.*

*In this work, a study of transient heat transfer in double tube heat exchanger has enhanced. The inner tube of the setup was made with corrugation on both inner and outer walls by twisting the pipe from one end, which gives the more swirling motion to the fluid particles flowing over it. The flow inside the pipe was considered as turbulent, and the analysis was done experimentally and theoretically by using the ANSYS workbench. The experimental results were compared with the experimental values taken in the setup done by considering the inner tube as normal pipe. In both heat exchangers the values were taken and compared with the theoretical analysis. Temperature distribution and heat transfer rate were calculated and the details of the study have been discussed in this paper.*

***KEYWORDS:*** *Heat Transfer, Heat Exchangers, Transient Heat, corrugated twisted pipes.*

## I. INTRODUCTION

Now days, the atmospheric conditions are at hot conditions due to releasing of hot gases and wastage from the machines, vehicles and mainly from the industries even we are using the heat exchangers. To cool those hot gases the design considerations are playing a vital role in present days. The ways to maintain those fluids at lower temperatures, they have to maintain more time in heat exchangers with water as coolant or the surface area of the fluids which are subjected to heat rejection process has to increase. Maintaining the fluid inside heat exchanger for a long time, it may increase the maintenance cost. So it is preferred to increase its surface area by increasing the length of pipes inside the heat exchanger as increasing the size. But it may also take some maintenance cost or it may increase the area of the plant or industry.

By changing the design of the pipe in heat exchanger without increasing its length, we can transfer heat from hot fluids in higher values and will increase the effectiveness of heat exchanger. Using corrugated pipes in the place of normal pipes in double tube heat exchanger, they increase the effectiveness. The corrugation of the pipe is taken by means of addition of extended rib sections on inner and outer side of the pipe or by adding the twisted tapes for the walls of the pipe. These two methods have high initial cost and maintenance cost. Using of corrugated twisted pipe in the place of them, it will give the corrugation to the pipe, which can increase effectiveness of the heat exchanger. The initial cost and maintenance cost for these pipes are less comparing to the previous one.

## II. LITERATURE REVIEW

Steady heat transfer enhancement has been studied in helically coiled-tube heat exchangers. The outer side of the wall of the heat exchanger contains a helical corrugation which makes a helical rib on the inner side of the tube wall to induce additional swirling motion of fluid particles. Numerical calculations have been carried out to examine different geometrical parameters and the impact of flow and thermal boundary conditions for the heat transfer rate in laminar and transitional flow regimes. Comparison of the flow and temperature fields in case of common helical tube and the coil with spirally corrugated wall configuration are discussed [1].

The fuzzy logic expert system (FLES) for heat transfer performance investigation in helically coiled heat exchanger with spirally corrugated wall operated with water and CuO/water nanofluids. Compared with traditional logic model, fuzzy logic is more efficient in connecting the multiple units to a single output and is invaluable supplements to classical hard computing techniques. Hence, the main objective of this analysis is to investigate the relationship between heat exchanger working parameters and performance characteristics, and to determine how fuzzy logic expert system plays a significant role in prediction of heat transfer performance. Analytical values are taken in helically coiled heat exchanger with spirally corrugated wall operated with water and CuO/water nanofluids for investigation of heat transfer performance [2-5].

The inner tube of the concentric-tube heat exchanger has a sinusoidal, wavy surface in the longitudinal direction, which enables heat-transfer enhancement. The tube can be stretched to a certain extent and thus change the corrugation of the heat-transfer surface area. We designed an experiment in which we used the Wilson-plot method to separately determine the convective heat-transfer coefficient on the inside and outside of the inner tube of the concentric-tube heat exchanger with different corrugation ratios. Based on the measurements correlation equations were developed to calculate the convective heat-transfer coefficient for any corrugation ratio, which allows us to simplify the design of local ventilation devices [6-9].

Heat transfer coefficient and entropy generation rate of helical coil heat exchanger were analytically investigated considering the nano-fluid volume fractions and volume flow rates in the range of 1–4% and 3–6 L/min, respectively. During the analyses, the entropy generation rate was expressed in terms of four parameters: particle volume concentration, heat exchanger duty parameter, coil to tube diameter ratio and Dean Number [10-15].

In many industrial applications, it is found that heat exchangers are one of the most important equipments. The heat transfer rate through different heat exchangers was discussed by using the device with better effectiveness (mainly shell and tube, tube in tube type [16]). To increase the effectiveness of the heat exchanger the study was considered in it with nano-fluidsand was discussed that the rate of heat transfer through pipes was increased by arranging the blocks to the walls of the tubes as extended surfaces[17][18]. The experimental studies given that heat transfer through the heat exchangers increases, when using the nano-fluids as coolants. In plate type heat exchangers, the analysis of pressure drop, heat transfer, boiling and condensation were discussed to know the characteristics and factors playing for the effectiveness [19]. In coil tube heat exchangers the studies have been conducted to analyse the heat transfer rate by considering the flow inside the pipe as laminar and turbulent [20-22]. The numerical analysis was done on the pipes by considering the flow as laminar and turbulent. The analysis was done by several authors by adding the extra surface to the pipe like corrugation for more effectiveness in straight pipes [23-25].

## III. DESIGN OF HEAT EXCHANGER PIPE

The general heat exchanger of type double tube can be designed in Ansys, by using the extrude options. But in this project, the model has to design, double tube heat exchanger with twisted pipe as inner one. So, I preferred the software Rhinoceros to complete the design by using the command twist. Heat exchanger of normal pipe double tube was done in the Rhinoceros with dimensions as 0.0254m inner pipe diameter and 0.0508m with a thickness of 2mm for a length of 0.609m. The same dimensions were used for the double tube heat exchanger with corrugated twisted pipe inside. Fig.1 shows the normal pipe design considered inside the heat exchanger, as the Fig.2 shows the Corrugated Twisted pipe design.

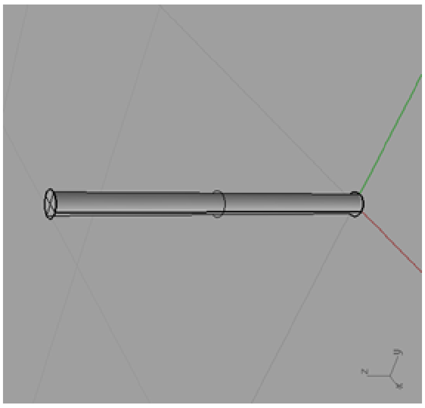


**Fig.1**Normal Pipe Geometry

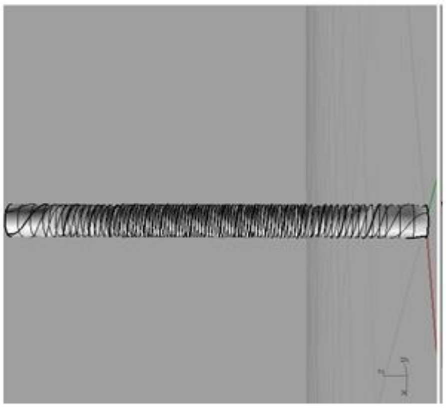


**Fig.2** Twisted Pipe Geometry

### 3.1. Meshing of Heat Exchanger*:*

The pipe drawn in Rhinoceros was saved in IGES format and was imported to Ansys Fluent Workbench. The geometry was modified to define the object as heat exchanger with fluid flows.

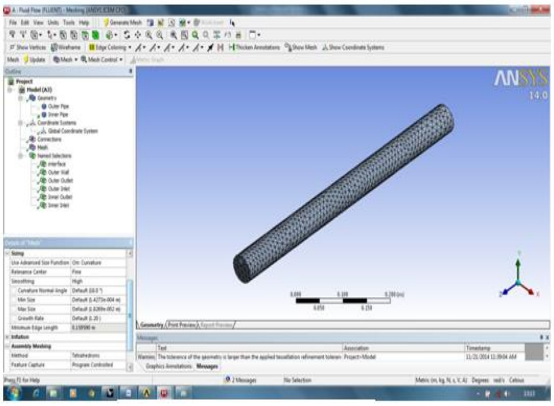


**Fig.3.** Mesh of Normal Pipe

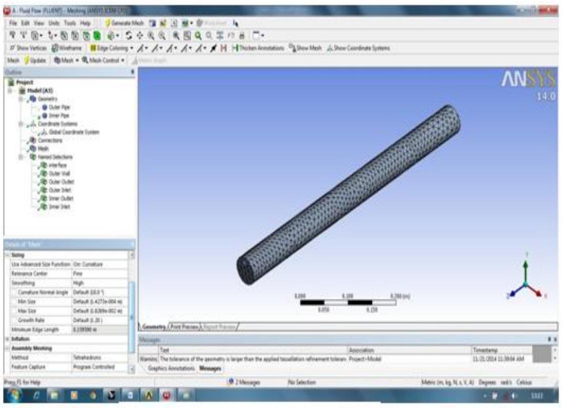


**Fig.4.** Mesh of Corrugated Twisted Pipe

The enclosure was created in the geometry modelling panel for the outside pipe with dimension mentioned in 3.1. In geometry the pipe were assigned to fluid. If we want to study the analysis through the pipe, then we have to Boolean the inner pipe with the enclosure. Naming of Inlet, outlet and wall for both the pipes in heat exchanger were given with a pre term inner and outer for both heat exchangers. The surface subjected to the convection process was named as interface inner surface and interface outer surface.

## IV. EXPERIMENTAL SETUP

- ✓ **In this project the materials used are**

| | | |
|---|---|---|
| Inner pipe | : | Stainless steel 202 grade |
| Outer pipe | : | Iron gauge 15 |

- ✓ **Dimensions are**

| | | |
|---|---|---|
| Inner pipe diameter | : | 0.0254m |
| Inner pipe length | : | 1.0000m |
| Outer pipe diameter | : | 0.0508m |
| Outer pipe length | : | 0.6090m |

### 4.1.Equipment Arrangement:

The heating coil pipe was connected to the inner pipe of the test equipment to maintain the hot water flow rate inside. The outer pipe of the equipment was connected from the water tank to maintain the normal water directly. The flow rates of hot and cold water were maintained by arranging and adjusting the regulating (controlling valves) valves at the outlets of the pipes as shown fig.12. As shown in the fig.5, RTD indicator was connected to the hot water inlet from the temperature controller. Digital thermometers were arranged to measure the temperatures at the inlet and outlet of both inner outer pipes as shown in fig.1.

**Fig.5.** Experimental setup of heat exchanger with corrugated twisted pipe

### 4.2.Heat Exchanger:

The media may be separated by a solid wall to prevent mixing or they may be in direct contact. They are widely used in space heating, refrigeration, air conditioning, power plants, chemical plants, petrochemical plants, petroleum refineries, natural gas processing, and sewage treatment.

## V. OBSERVATIONS AND CALCULATIONS

### 5.1 Observation Table:

### Normal Pipe:

**Table 1** Experimental values of temperature in Normal pipe heat exchanger

| Sl. No. | Inner inlet temperature (ºC) | Outer inlet temperature (ºC) | Inner outlet temperature (ºC) | Outer outlet temperature (ºC) | Flow rate in inner pipe Kg/s | Flow rate in outer pipe Kg/s |
|---|---|---|---|---|---|---|
| 1 | 100 | 30 | 93.6 | 35.5 | 0.194 | 0.582 |
| 2 | 100 | 30 | 90.8 | 37.2 | | |
| 3 | 100 | 30 | 96.5 | 33.6 | | |
| 4 | 100 | 30 | 93.9 | 35.2 | | |
| 5 | 100 | 30 | 91.8 | 36.5 | | |

## Corrugated Twisted Pipe:

**Table.2** Experimental values of temperature in corrugated twisted pipe heat exchanger

| Sl. No. | Inner inlet temperature (°C) | Outer inlet temperature (°C) | Inner outlet temperature (°C) | Outer outlet temperature (°C) | Flow rate in inner pipe | Flow rate in outer pipe |
|---|---|---|---|---|---|---|
| 1 | 100 | 30 | 85.7 | 42.6 | 0.18 | 0.536 |
| 2 | 100 | 30 | 86.4 | 42.5 | | |
| 3 | 100 | 30 | 90.2 | 40.8 | | |
| 4 | 100 | 30 | 83.3 | 45.2 | | |
| 5 | 100 | 30 | 81.6 | 47.4 | | |

## 5.2. Model Calculations:

$$Re_s = \frac{\rho_s U_s D_e}{\mu_s} = \frac{G_s D_e}{\mu_s}$$

$$C_h = c_h m_h$$

$$C_c = c_c m_c$$

Overall heat transfer coefficient: $U = \frac{1}{\left(\frac{1}{h1}\right)+\frac{r1}{k}\ln\frac{r2}{r1}+\frac{1}{h2}}$

$h_1$=hot water convective heat transfer coefficient
$h_2$=cold water convective heat transfer coefficient

$$Nu = \frac{\frac{f}{8}(Re-1000)(Pr)}{1+\frac{f^{\frac{1}{2}}}{8}\left(Pr^{\frac{2}{3}}-1\right)} \qquad f = [(0.79\ln Re)-1.64]-2$$

$$3000 \le Re_D \le 5\times 10^6$$
$$0.5 \le Pr \le 2000$$
$$Nu_D = 0.023\,Re_D^{4/5}\,Pr^n$$

D is the inside diameter of the circular pipe

Pr is the Prandtl number

N=0.4 for heating of the fluid, and n=0.3 for cooling of the fluid.

$$0.6 \le Pr \le 160$$
$$Re_D \gtrsim 10\,000$$
$$\frac{L}{D} \gtrsim 10$$

Form the data of heat transfer tables, for the water at temperatures 30 and 100 degrees, the properties are:

**Table.3** Water properties at different temperatures

| Temperature $^0$C | Density Kg/m$^3$ | Specific heat J/ Kg-K | Thermal conductivity W/m-K | Viscosity Kg/m-s | Prandtl number |
|---|---|---|---|---|---|
| 30 | 995.7 | 4179 | 0.617 | 797.56 | 5.46 |
| 100 | 958 | 4219 | 0.68 | 252.61 | 1.8 |

#### 5.2.1. Inner Pipe:

$$Nu=\frac{hd}{K} \qquad h_1=2740.88\ W/m^2K$$

#### 5.2.2. Outer Pipe:

$$U=\frac{1}{\left(\frac{1}{2740.88}\right)+\frac{0.0127}{16.7}\ln\frac{0.0254}{0.0127}+\frac{1}{1743.68}}$$

$U=683.06\ W/m^2K$

$C_h=c_h m_h= 4.219*0.194=0.818=C_{min}$

$C_c=c_c\ m_c = 4.179*0.582=2.532$

### 5.3. Normal Pipe:

$Q_{avg}$ = $h_1A\ (\Delta T)$

= $2740.88*\pi*0.0254*0.6096(373-366.32)$

= 832.303W

### 5.4. Corrugated Twister Pipe:

$Q_{avg}$ = $h_1A\ (\Delta T)$

= $2740.88*\pi*0.0254*0.6096\ (373-358.44)$

= 1942.02W.

## VI. FIGURES

### 6.1. Normal Pipe Heat Exchanger:

#### 6.1.1. Velocity:

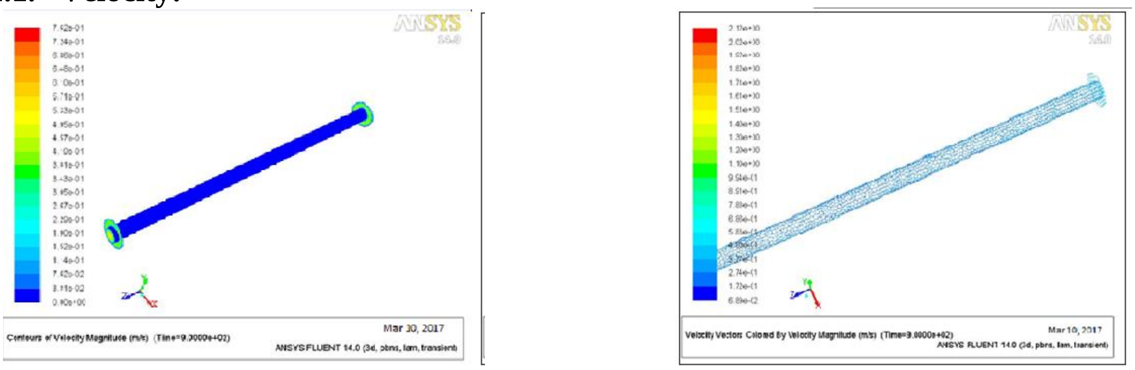
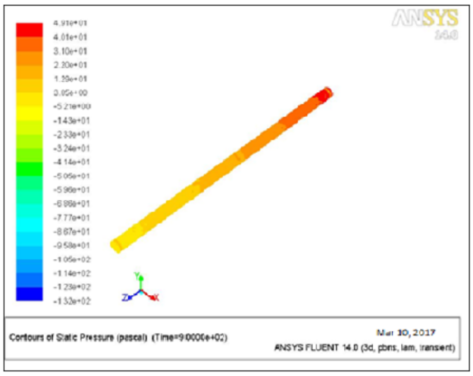
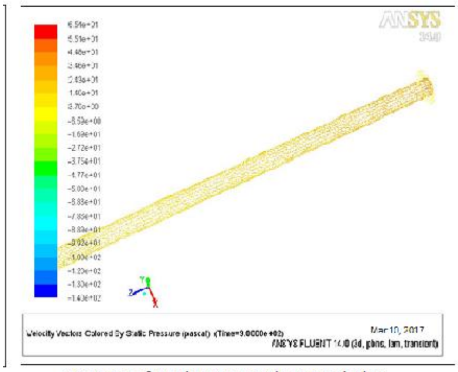


**Fig.6.** Velocity of Normal Pipe Heat Exchanger

### 6.1.2. Pressure:



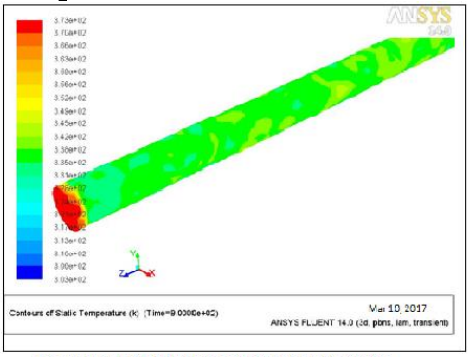

Contours of static pressure in normal pipe



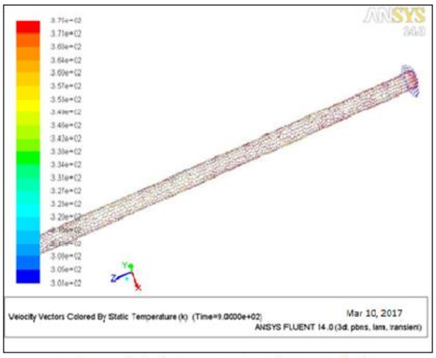

Vectors of Static pressure in normal pipe

**Fig.7.**Pressure of Normal Pipe Heat Exchanger

### 6.1.3. Temperature:




Contours of static temperature in normal pipe

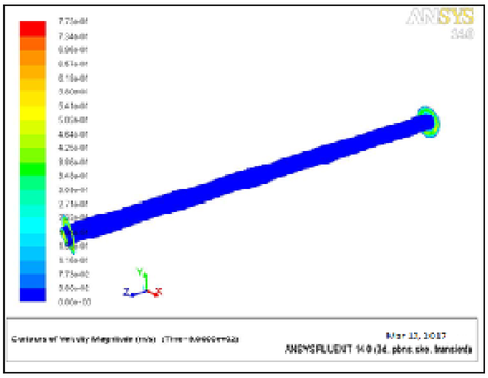



vectors of static temperature in normal pipe

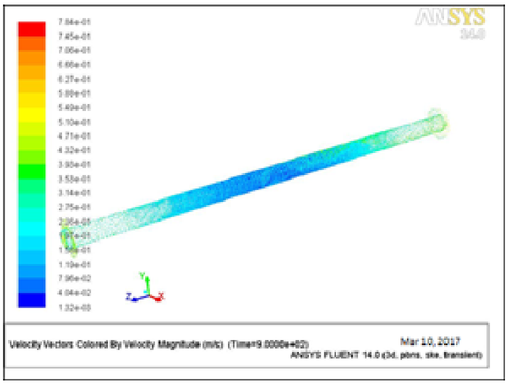
**Fig.8.**Temperature of Normal Pipe Heat Exchanger

## 6.2. Corrugated Twisted Pipe:

### 6.2.1. Velocity:



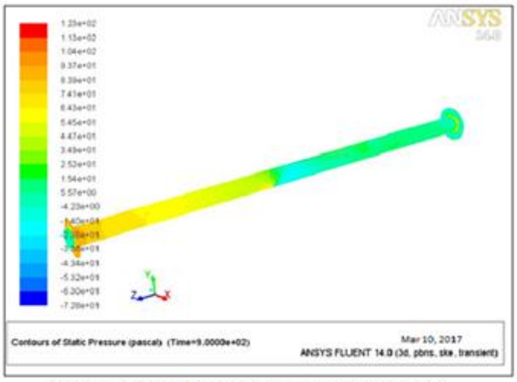

Contours of velocity magnitude in corrugated twisted pipe



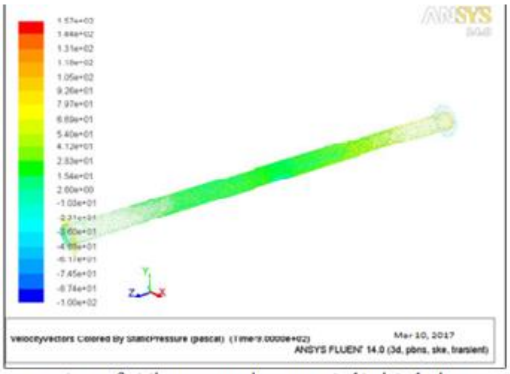

vectors of velocity magnitude in corrugated twisted pipe

**Fig.9.** Velocity of Corrugated Twisted Pipe

### 6.2.2. Pressure:



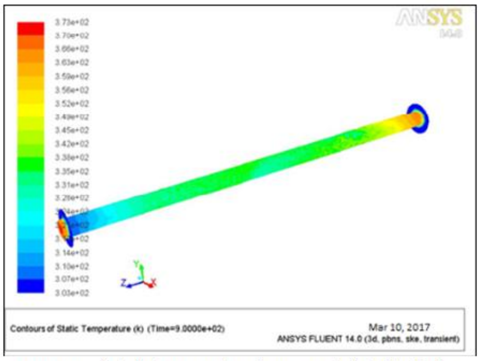

Contours of static pressure in corrugated twisted pipe



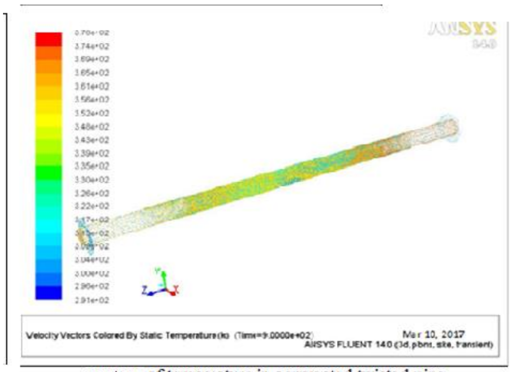

vectors of static pressure in corrugated twisted pipe

**Fig.10.**Pressure of Corrugated Twisted Pipe

### 6.2.3. Temperature:




contours of static temperature in corrugated twisted pipe




vectors of temperature in corrugated twisted pipe

**Fig.11.**Temperature of Corrugated Twisted Pipe

## VII. RESULTS

### 7.1 Theoretical Results:

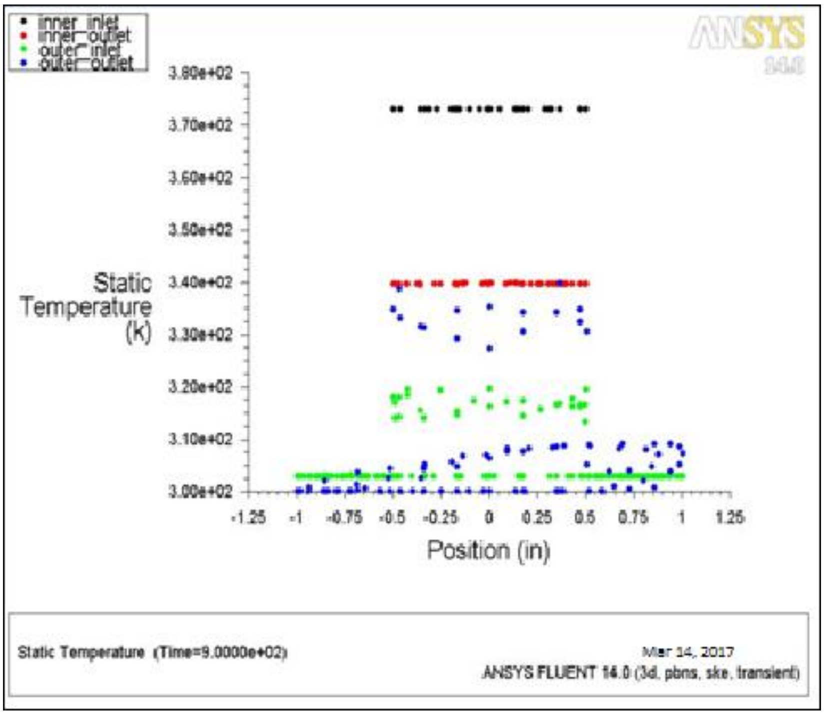



**Fig.12.**Temperature distributions in Corrugated Twisted Pipe Heat exchanger

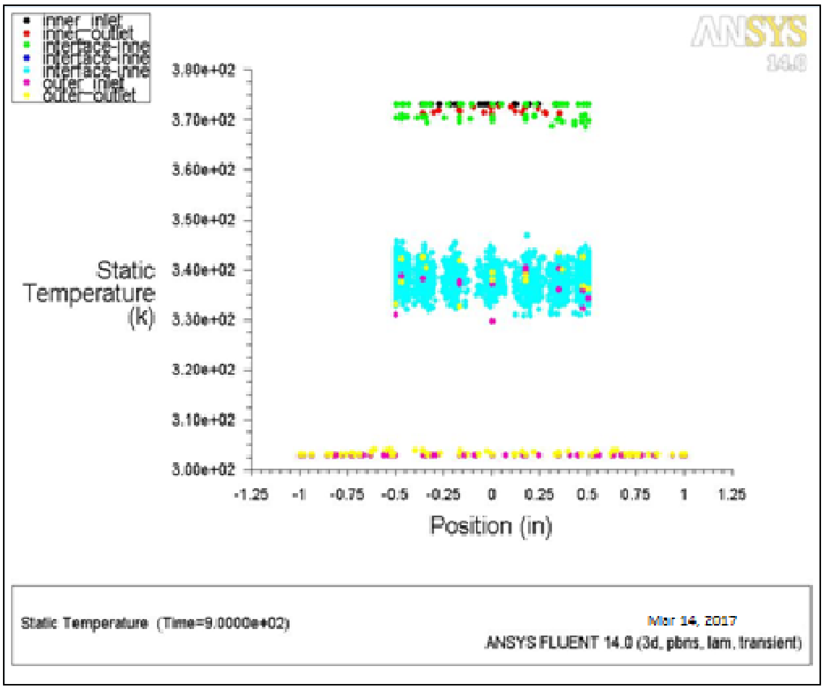



**Fig.13.**Temperature Distributions in Normal Pipe Heat Exchanger

### 7.2 Experimental Results:

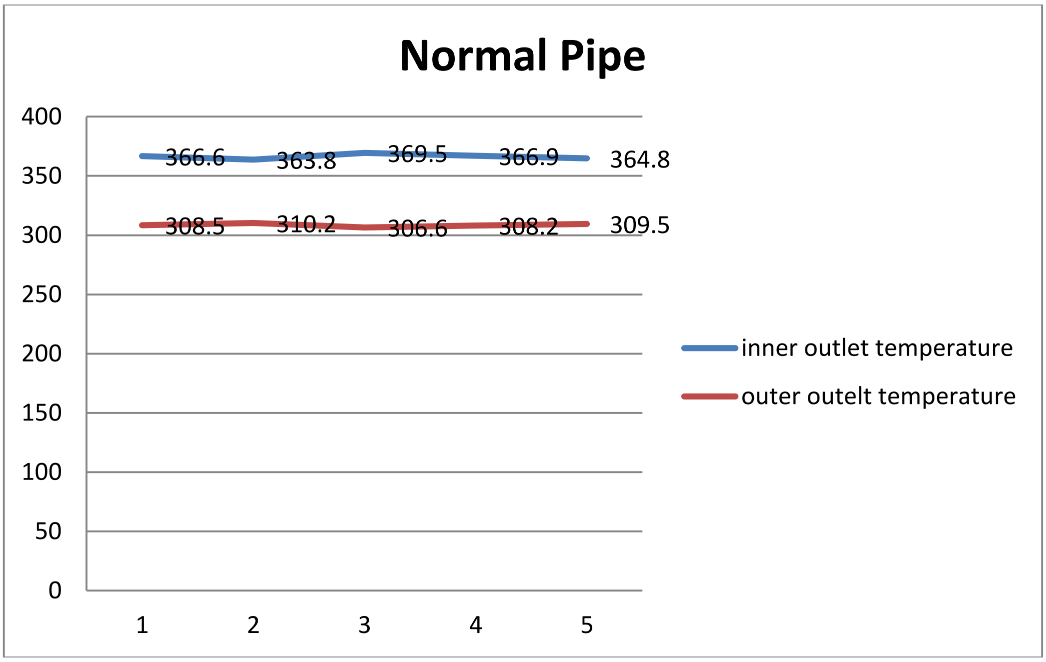



**Fig.14.**Temperature Distributions in Normal Pipe Heat Exchanger as inlet Temperatures at Inner Pipe are 373K and Outer Pipe is 303K.

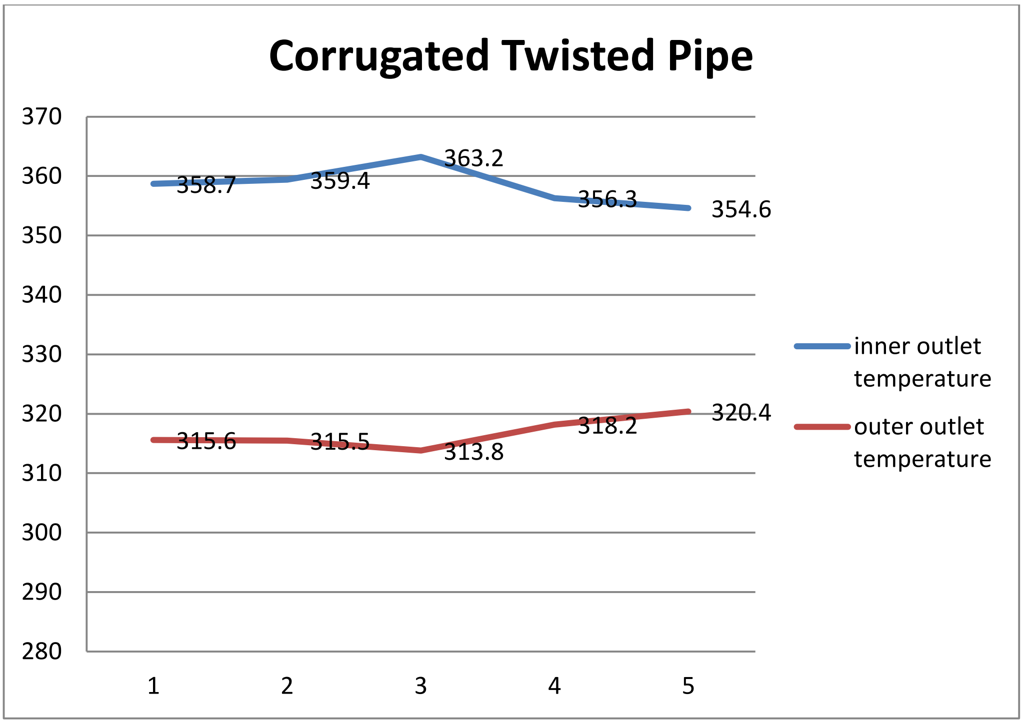



**Fig.15.**Temperature Distributions in Corrugated Twisted Pipe Heat Exchanger as Inlet Temperatures at Inner Pipe are 373K and Outer Pipe is 303K.

From the results it was observed that the temperature distribution in corrugated twisted pipe was high when comparing with that of the normal pipe heat exchanger.

## VIII. CONCLUSION

On the basis of work carried out under present thesis, it was concluded that, it was better to use the corrugated twisted pipes in place of the normal pipes. By using these corrugated twisted pipes the effectiveness of heat exchangers will increase, which can increase the efficiency of the industry or plant. Steady heat transfer enhancement has been studied in helically coiled-tube heat exchangers. The outer side of the wall of the heat exchanger contains a helical corrugation which makes a helical rib on the inner side of the tube wall to induce additional swirling motion of fluid particles.

## IX. FUTURE SCOPE

Here in this project, the material used for the equipment was stainless steel. By changing the material of the pipe with higher thermal conductivity and considering the coil type heat exchanger, it is better to give more efficiency. By considering the number of twists also increases the heat transfer rate of the pipe. This is applicable in all industries, power plants, automobiles, etc.

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## AUTHORS BIOGRAPHY

**G Veerendra Kumar** was born in prakasaraopalem, Andhrapradesh, India, in 1992. He receive the bachelor‘s degree in mechanical engineering from the university of Jawaharlal Nehru technological university, Kakinada, in 2014. He is currently pursuing the master degree in thermal engineering from the university of Jawaharlal Nehru technological university, Kakinada. His research interests include heat exchange in corrugated twisted pipes.