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HEAT TRANSFER RATES IN A HORIZONTAL TUBE BY MEANS OF VARYING WIDTH OF TWISTED TAPE INSERTS

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Abstract- In this, investigations will be carried out to determine the heat transfer rates in a horizontal tube by means of varying width twisted tape inserts with air as the working fluid. Analysis is carried out for plain tube with and without twisted tape insert at constant wall heat flux and different mass flow rates calculated for Reynolds number 6000, 8000, 10000, 13500, five different widths 10mm, 14mm, 18mm, 22mm and 26mm. CFD analysis is performed for different cases to determine heat transfer coefficient, pressure drop, Nusselt number and friction factor and compared with that of plain tube.

Keywords- Twisted tapes, Reynolds number, Nusselt number, Heat transfer coefficient, Friction factor, pressure drop, CFD analysis.

I. INTRODUCTION

TWISTED TAPES

Figure: 1.Twisted tape

Twisted tape inserts increases the heat transfer coefficients with relatively small increase in the pressure drop as shown in figure.1. They are known to be one of the earliest swirl flow devices employed in the single phase heat transfer processes. Because of the design and application convenience they have been widely used over decades to generate the swirl flow in the fluid. Twisted tapes with multitube bundles are easy to fit and remove, thus enables tube side cleaning in fouling situations. Inserts such as twisted tape, wire coils, ribs and dimples mainly obstruct the flow and separate the primary flow from the secondary flows. This causes the enhancement of the heat transfer in the tube flow. Inserts reduce the effective flow area thereby increasing the flow velocity. This also leads to increase in the pressure drop and in some cases causes' significant secondary flow. Secondary flow creates swirl and the mixing of the fluid elements and hence enhances the temperature gradient, which ultimately leads to a high heat transfer coefficient.

II. LITERATURE SURVEY

Eiamsaard et al [1] carried out an experimental investigation on heat transfer and friction factor Characteristics in a double-pipe heat exchanger fitted with regularly spaced twisted tape insert. Two types of tube inserts consisting of a full-length typical twisted tape at different twisted ratios

And a twisted tape with various free space ratios were used in their experiments. The results Shows that the heat transfer coefficient increases by decreasing the twist ratio. However, they Illustrated that decreasing the free space ratio can increase both the heat transfer coefficient and Friction factor.

Rahimi et al [2] carried out a CFD modeling in order to find the heat transfer in a tube equipped with different modified inserts fabricated based on a twisted tape insert. The operational Performances of these inserts were compared experimentally and theoretically with that obtained from the classic twisted tape insert. The CFD predicted results have been used to explain the Experimental observations.

The present work shows the results obtained from experimental investigations of the augmentation of turbulent flow heat transfer in a horizontal tube by means of varying width twisted tape inserts with air as the working fluid. In order to reduce excessive pressure drops associated with full width twisted tape inserts, with less corresponding reduction in heat transfer coefficients, reduced width twisted tapes of widths ranging from 10 mm to 22 mm, which are lower than the tube inside diameter of 27.5 mm are used. Experiments were carried out for plain tube with & without twisted tape insert at constant wall heat flux and different mass flow rates. The twisted tapes are of three different twist ratios (3, 4 and 5) each with five different widths (26-full width, 22, 18, 14 and 10 mm) respectively. The Reynolds number varied from 6000 to 13500. Both heat transfer coefficient and pressure drop are calculated and the results are compared with those of plain tube. It was found that the enhancement of heat transfer with twisted tape inserts as compared to plain tube varied from 36 to 48% for full width (26mm) and 33 to 39% for reduced width (22 mm) inserts. Correlations are developed for friction factors and Nusselt numbers for a fully developed turbulent swirl flow, which are applicable to full width as well as reduced width twisted tapes, using a modified twist ratio as pitch to width ratio of the tape.

III. MASS FLOW RATE CALCULATIONS

$Re = \rho v L / \mu$ and $\rho v = \dot{m}$

ρ = Density (Kg/m^3),

V=Velocity (m/s),

L = length of the tube (m),

μ = viscosity (kg/ms)

$\mu = 1.789\times10^{-5}\ m^2/s$, L = 2m, Re = 6000, 8000, 10000, 13500

For Re = 6000 → $6000 = \dot{m}\times2/1.789\times10^{-5} \rightarrow \dot{m} = 0.05367$ kg/s

For Re = 8000 → $8000 = \dot{m}\times2/1.789\times10^{-5} \rightarrow \dot{m} = 0.07156$kg/s

For Re = 10000 → $10000 = \dot{m}\times2/1.789\times10^{-5} \rightarrow \dot{m} = 0.08945$ kg/s

For Re = 13500 → $13500 = \dot{m}\times2/1.789\times10^{-5} \rightarrow \dot{m} = 0.0241515$ kg/s

IV. RESULTS

CFD ANALYSIS ON HEAT TRANSFER ENHANCEMENT IN HORIZONTAL TUBE WITH TWISTED INSERTS

From the analysis of a twisted tape insert with width 10 mm, it is observed that the pressure and heat transfer coefficient increases with increase in a Reynolds number as shown in figures 1 to 5.

PRESSURE **HEAT TRANSFER COEFFICIENT**

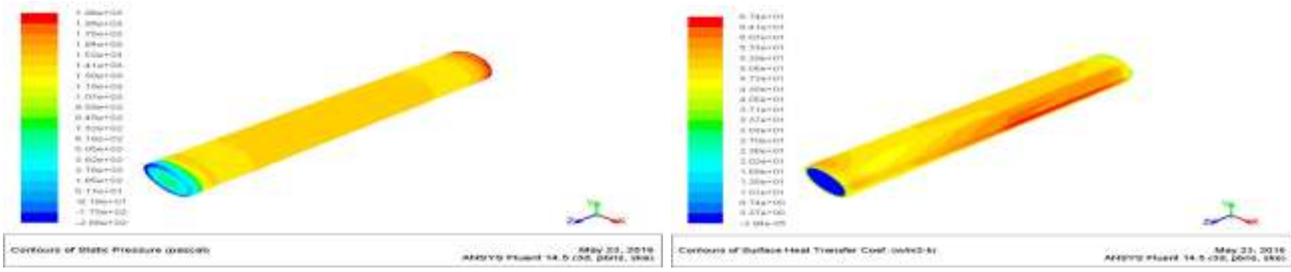


Figure: 2.Twisted tape width 10mm, Reynolds number – 6000, Mass flow rate 0.05367kg/s

PRESSURE **HEAT TRANSFERCOEFFICIENT**

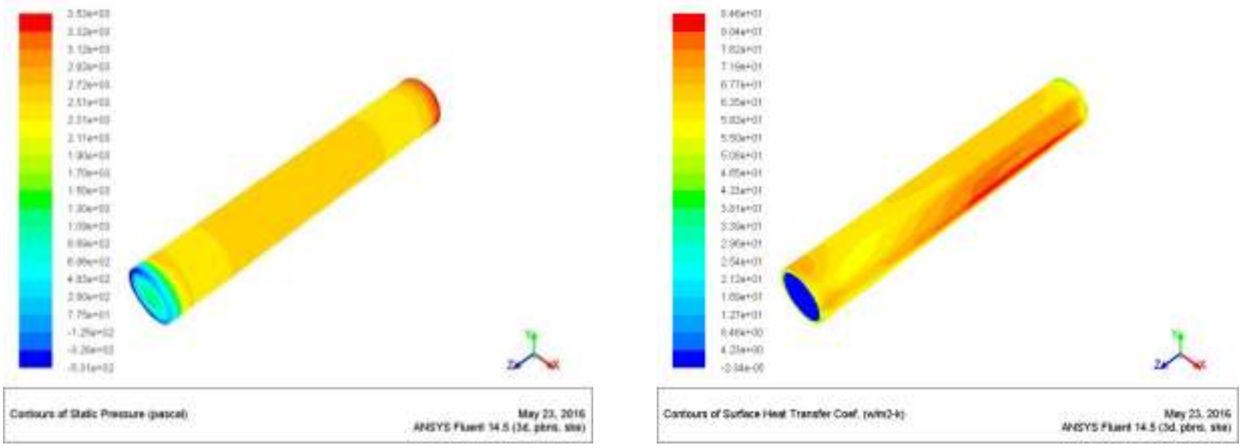


Figure: 3.Twisted tape width 10mm, Reynolds number – 8000, Mass flow rate 0.07156kg/s

PRESSURE **HEAT TRANSFER COEFFICIENT**

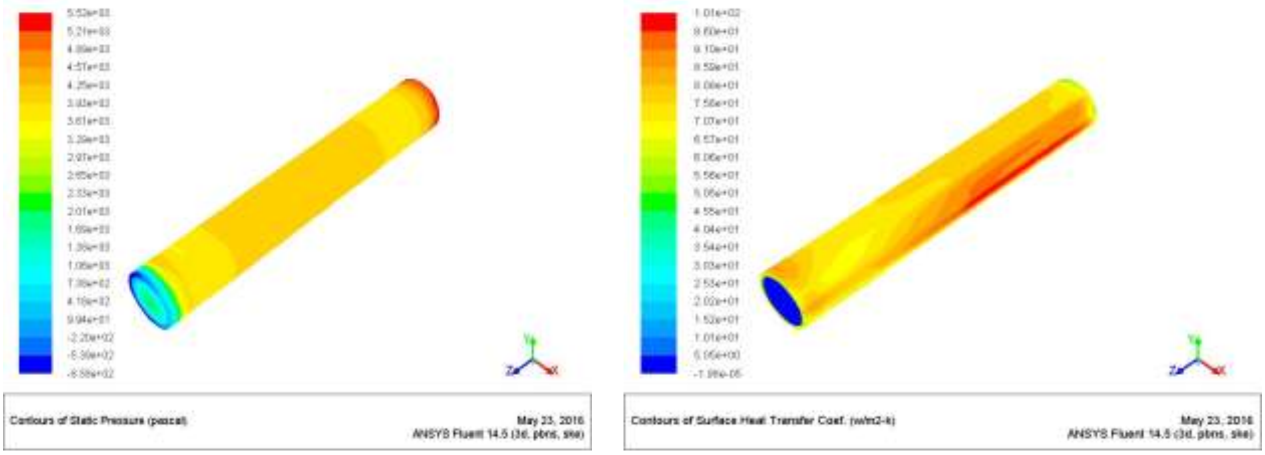


Figure: 4.Twisted tape width 10mm, At Reynolds – 10000, Mass flow rate 0.08945kg/s

PRESSURE **HEAT TRANSFER COEFFICIENT**

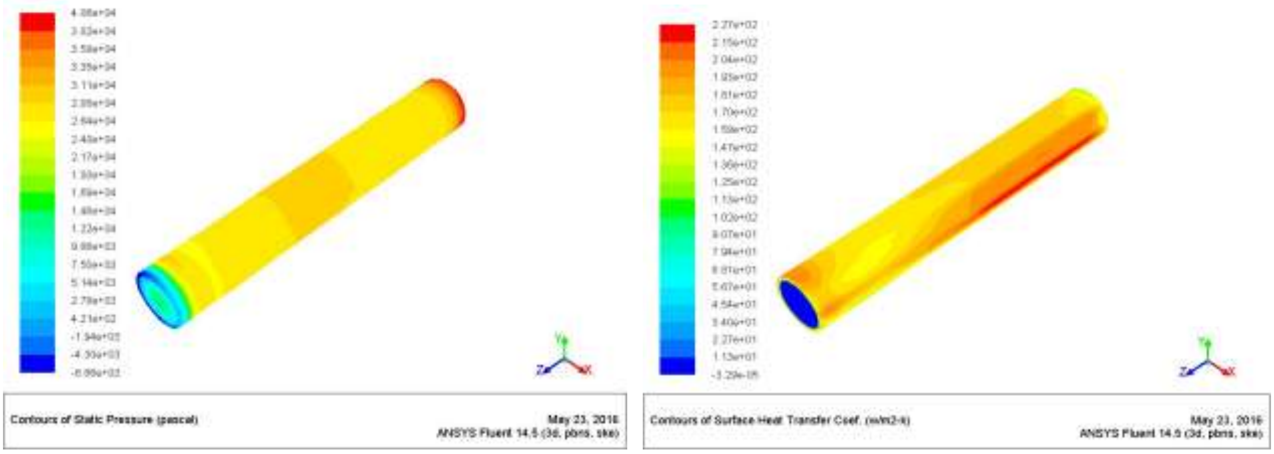


Figure: 5.Twisted tape width 10mm, Reynolds number – 13500, Mass flow rate 0.0241515kg/s

From the analysis of a twisted tape insert width 14 mm, it is observed that the pressure and heat transfer coefficient is increased up to Reynolds number 10,000 and beyond that there is a sudden drop in a pressure and heat transfer coefficient as shown in figures 6 to 9.

PRESSURE **HEAT TRANSFER COEFFICIENT**

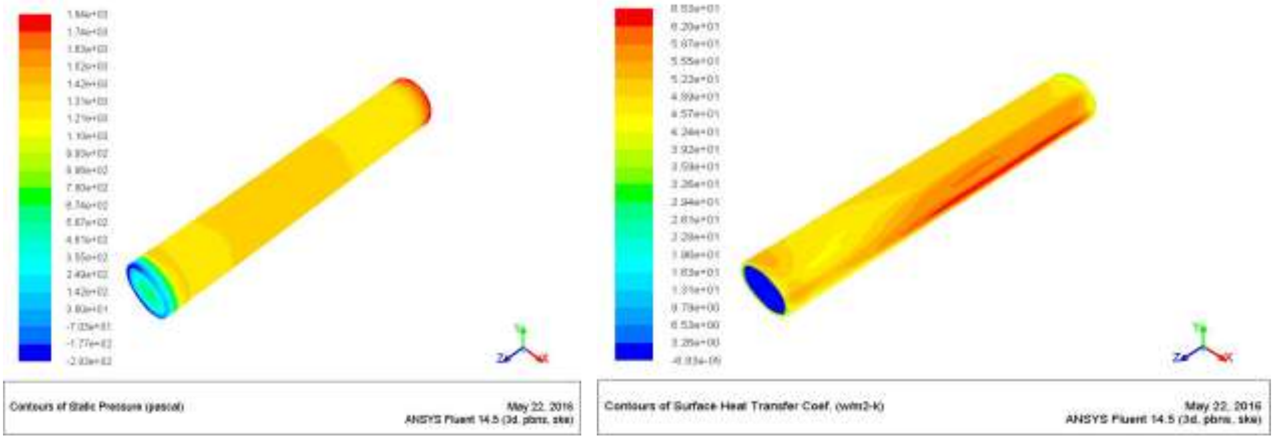


Figure: 6. Twisted tape width 14mm, Reynolds number - 6000, Mass flow rate 0.05367 kg/s

PRESSURE **HEAT TRANSFER COEFFICIENT**

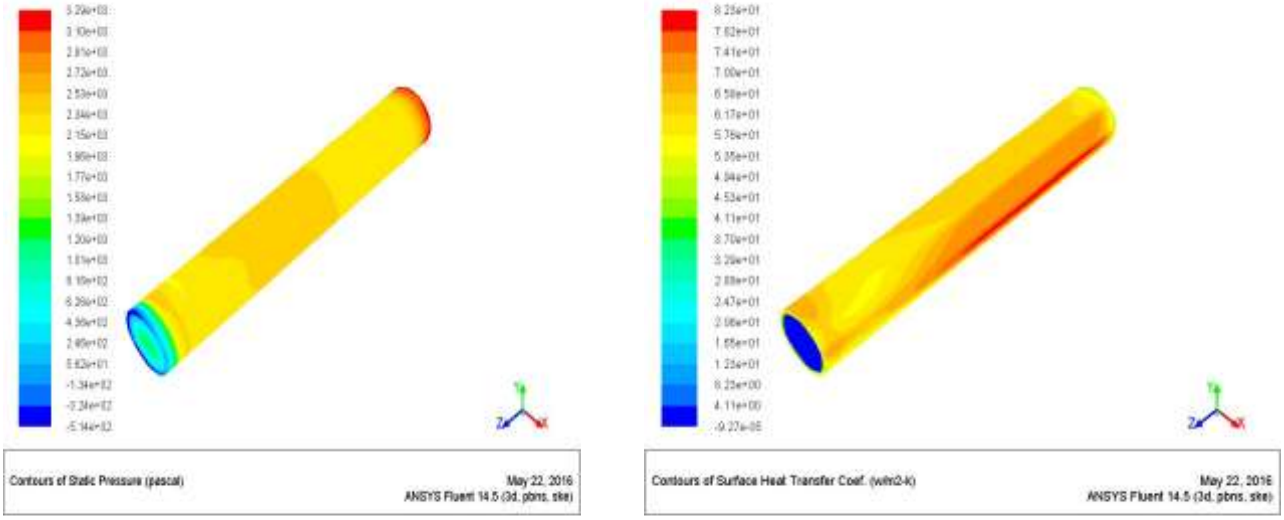


Figure: 7. Twisted tape width 14mm, Reynolds number – 8000, Mass flow rate 0.07156kg/s

PRESSURE **HEAT TRANSFER COEFFICIENT**

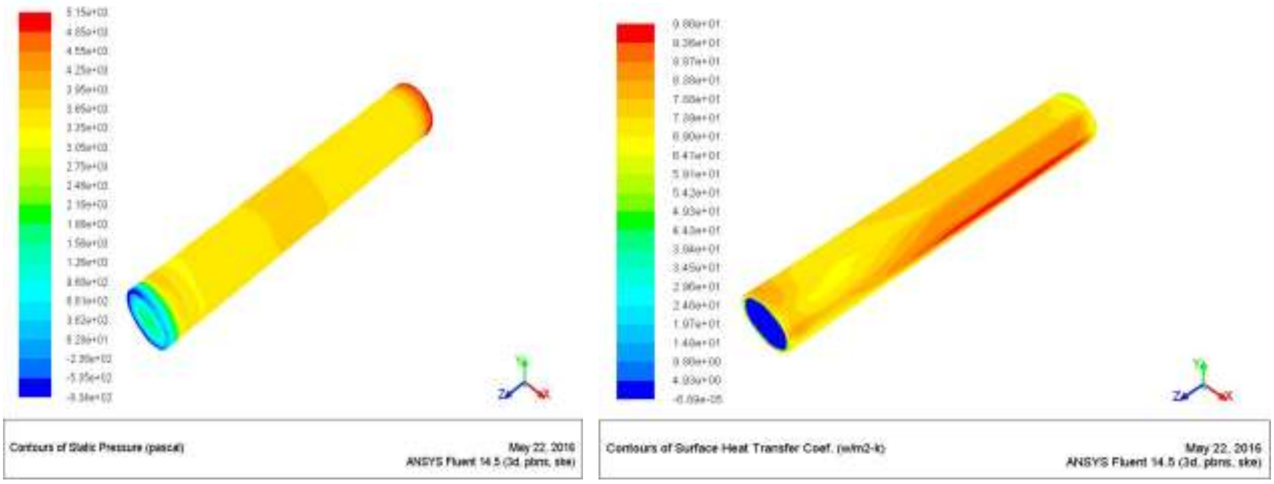


Figure: 8. Twisted tape width 14mm, Reynolds number – 10000, Mass flow rate 0.08945kg/s

PRESSURE **HEAT TRANSFER COEFFICIENT**

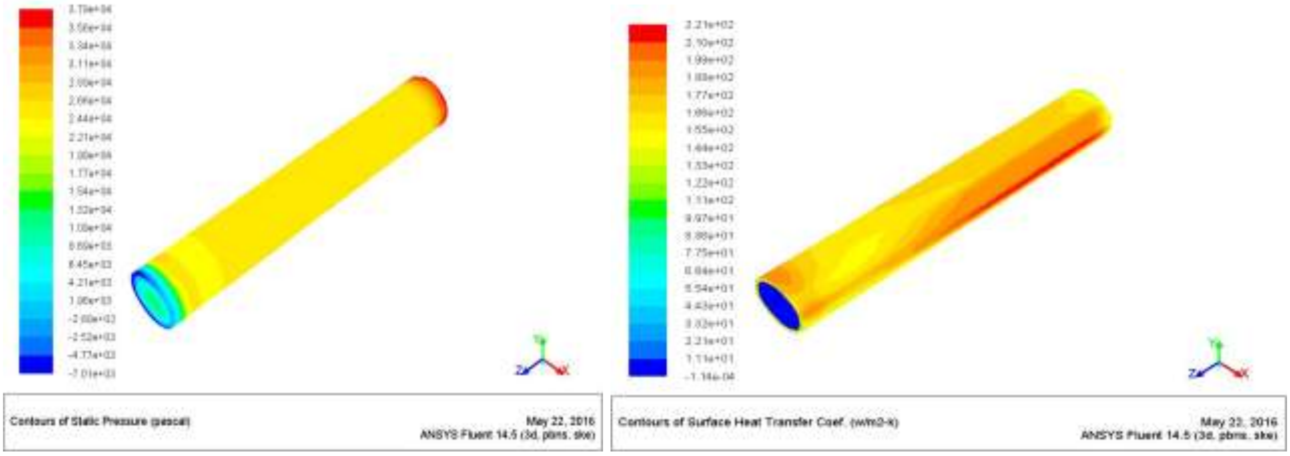


Figure: 9. Twisted tape width 14mm, Reynolds number – 13500, Mass flow rate 0.0241515kg/s

From the analysis of a twisted tape inserts with width 18 mm, it is observed that the pressure increases up to Reynolds number 10,000 and beyond that there is a sudden drop in a pressure and heat transfer coefficient increase up to Reynolds number 8000 and beyond that there is a drop in a heat transfer coefficient as shown in figures 10-13.

PRESSURE **HEAT TRANSFER COEFFICIENT**

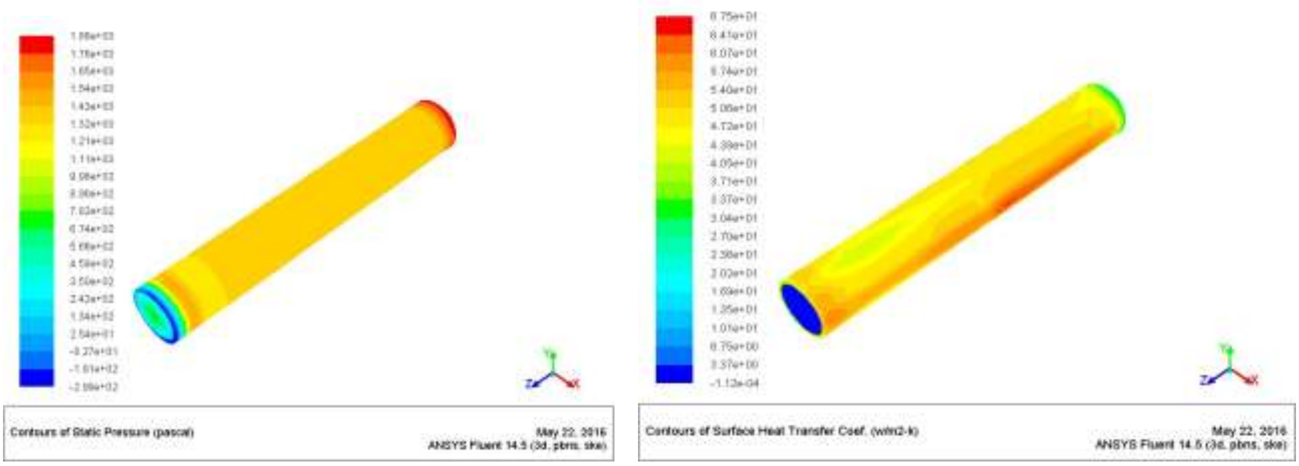


Figure: 10. Twisted tape width 18mm, Reynolds number - 6000, Mass flow rate 0.05367 kg/s

PRESSURE **HEAT TRANSFER COEFFICIENT**

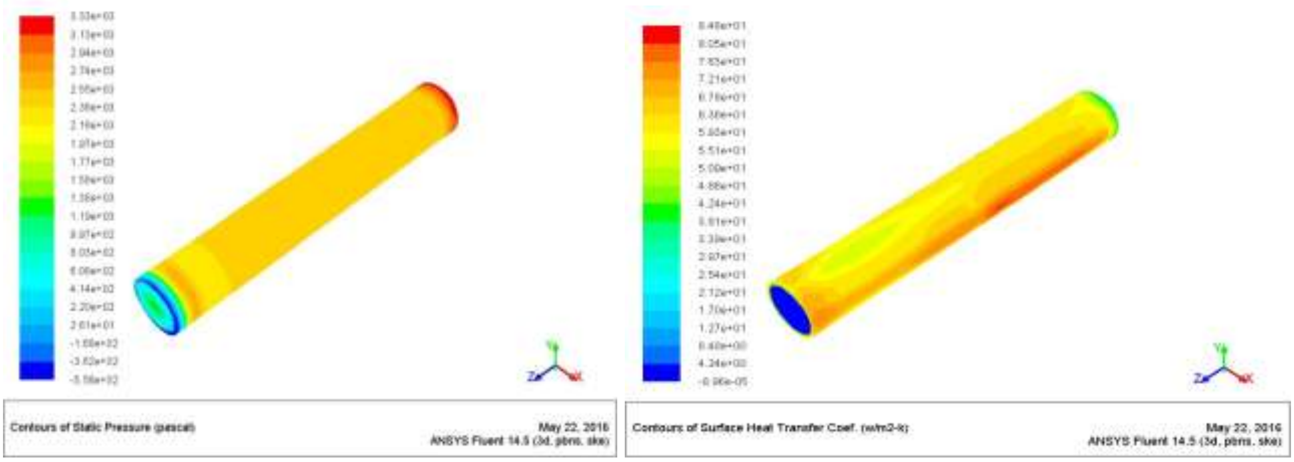
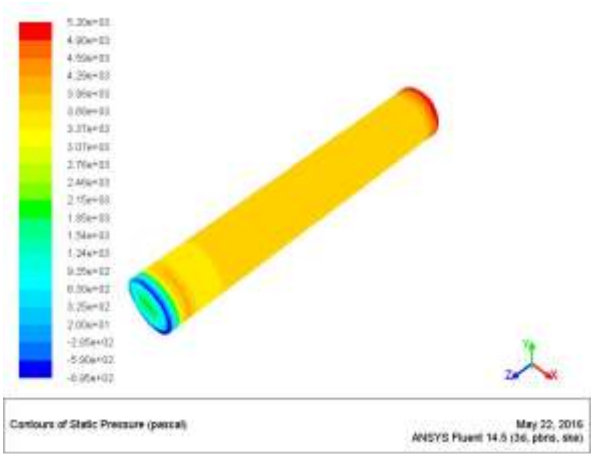


Figure: 11. Twisted tape width 18mm, Reynolds number - 8000, Mass flow rate 0.07156kg/s

PRESSURE **HEAT TRANSFER COEFFICIENT**



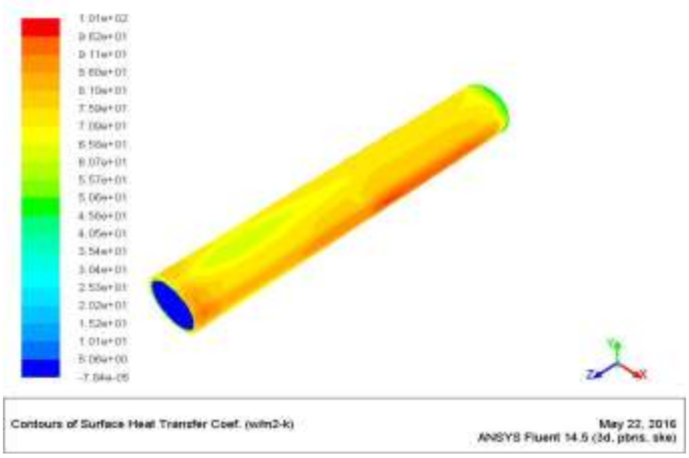
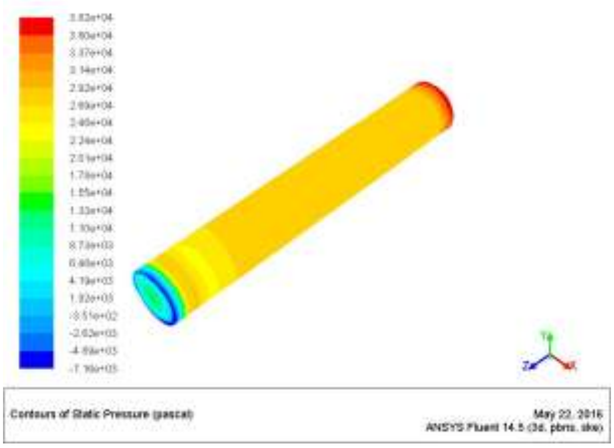


Figure: 12. Twisted tape width 18mm, Reynolds number – 10000, Mass flow rate 0.08945kg/s

PRESSURE **HEAT TRANSFER COEFFICIENT**



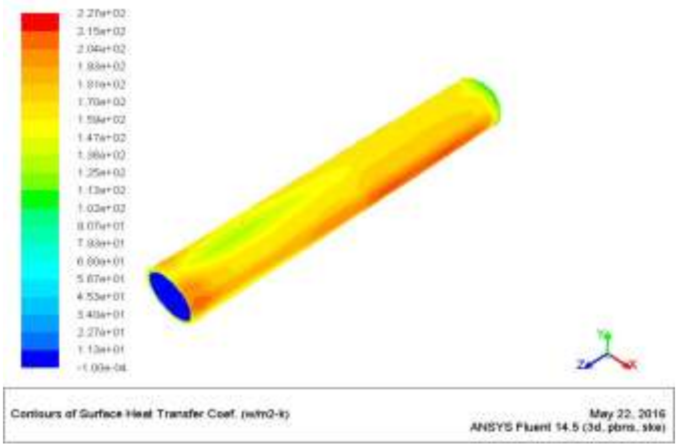
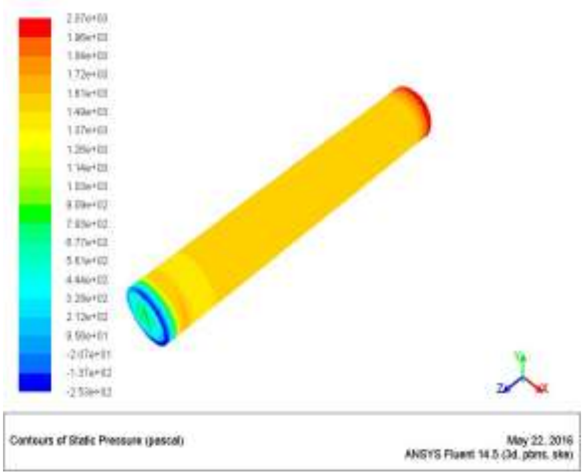


Figure: 13.Twisted tape width 18mm, Reynolds number – 13500, Mass flow rate 0.0241515kg/s

From the analysis of a twisted tape inserts with width 22 mm, it is observed that the pressure increases up to Reynolds number 10,000 and beyond that there is a sudden drop in a pressure and heat transfer coefficient increase up to Reynolds number 8000 and beyond that there is a drop in a heat transfer coefficient as shown in figures 14-17.

PRESSURE **HEAT TRANSFER COEFFICIENT**



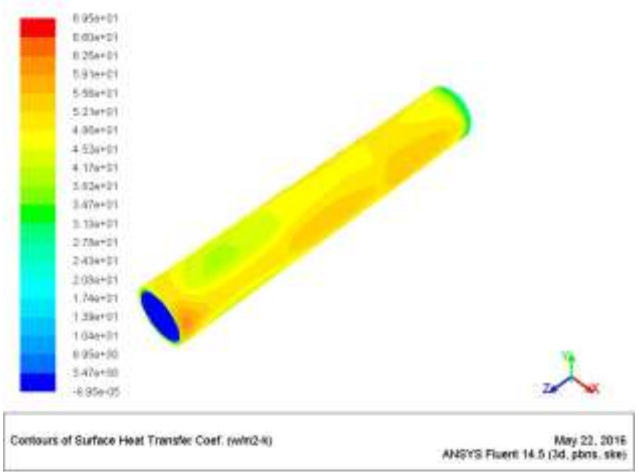


Figure: 14.Twisted tape width 22mm, Reynolds number – 6000, Mass flow rate 0.05367kg/s

PRESSURE **HEAT TRANSFER COEFFICIENT**

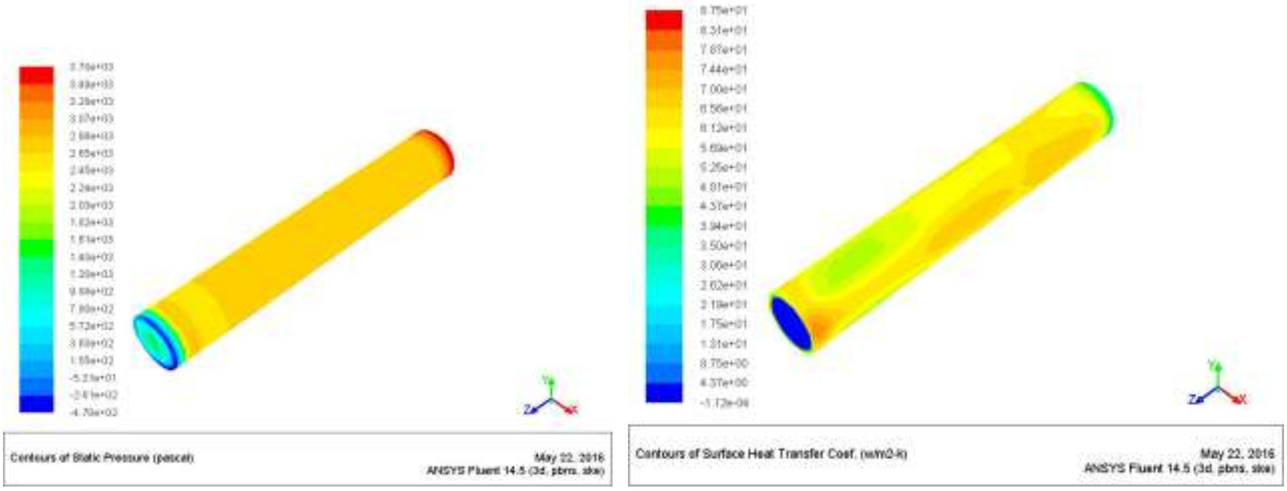


Figure: 15.Twisted tape width 22mm, Reynolds number – 8000, Mass flow rate 0.07156kg/s

PRESSURE **HEAT TRANSFER COEFFICIENT**

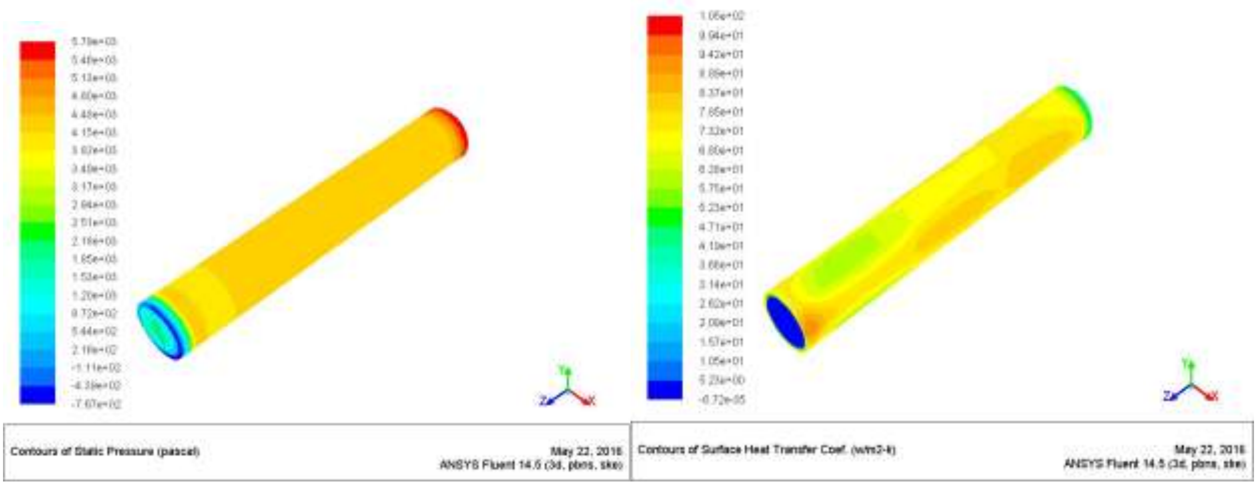


Figure: 16.Twisted tape width 22mm, Reynolds number – 10000, Mass flow rate 0.08945kg/s

PRESSURE **HEAT TRANSFER COEFFICIENT**

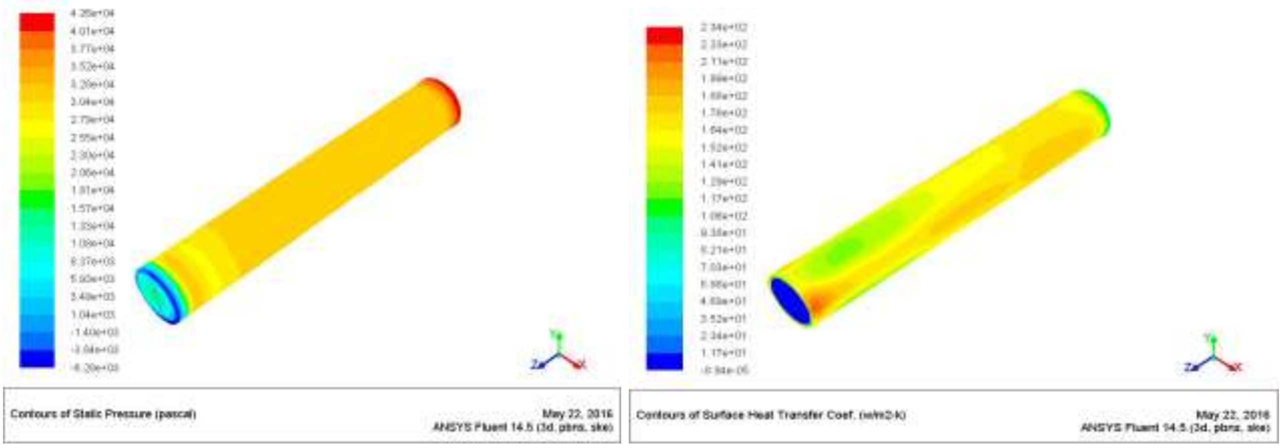


Figure: 17.Twisted tape width 22mm, Reynolds number – 13500, Mass flow rate 0.0241515kg/s

From the analysis of a twisted tape inserts with width 26 mm, it is observed that the pressure increases up to Reynolds number 10,000 and beyond that there is a sudden drop in a pressure and heat transfer coefficient increase up to Reynolds number 8000 and beyond that there is a drop in a heat transfer coefficient as shown in figures 18-21.

PRESSURE **HEAT TRANSFER COEFFICIENT**

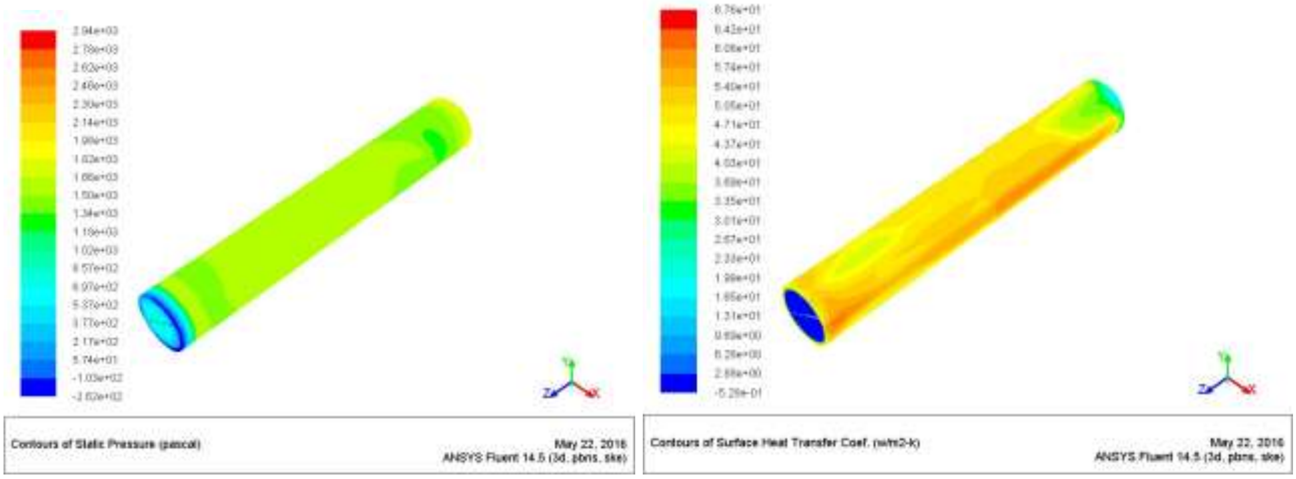


Figure: 18.Twisted tape width 26mm, Reynolds number – 6000, Mass flow rate 0.05367 kg/s

PRESSURE **HEAT TRANSFER COEFFICIENT**

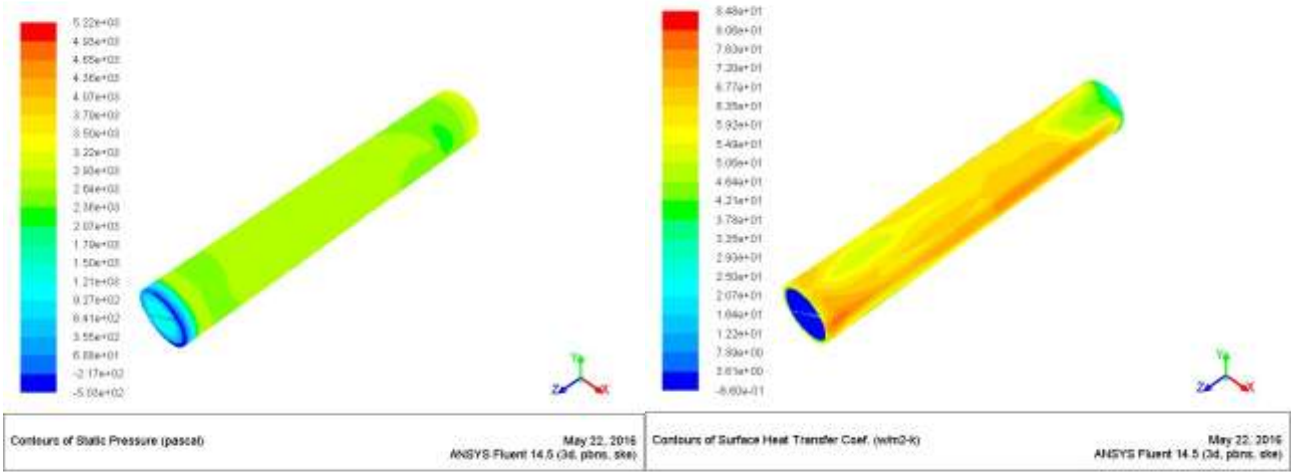


Figure: 19.Twisted tape width 26mm, Reynolds number – 8000, Mass flow rate 0.07156kg/s

PRESSURE **HEAT TRANSFER COEFFICIENT**

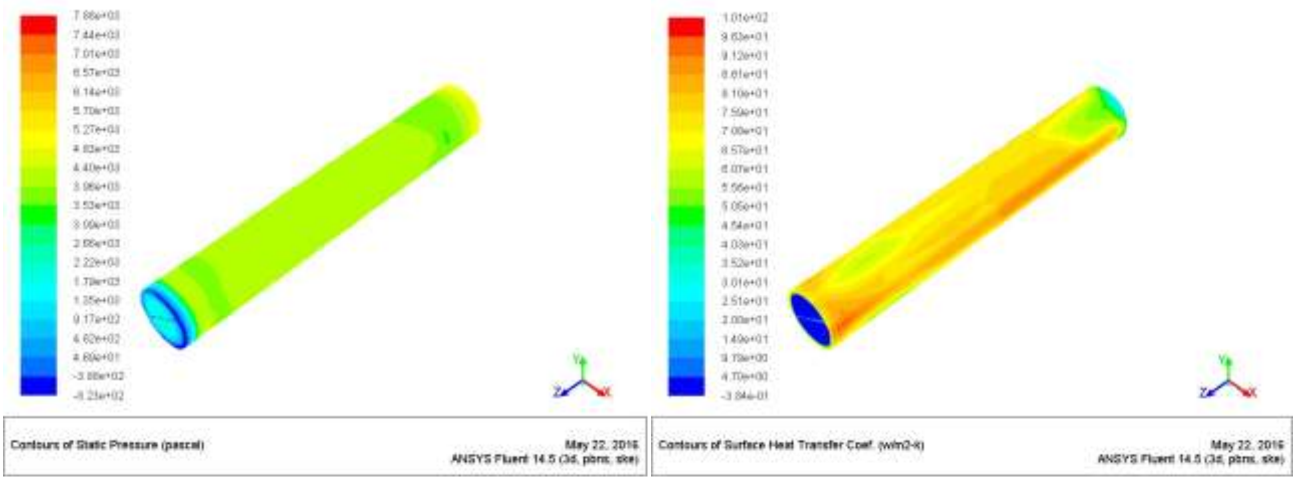


Figure: 20.Twisted tape width 26mm, Reynolds number – 10000, Mass flow rate 0.08945kg/s

PRESSURE **HEAT TRANSFER COEFFICIENT**

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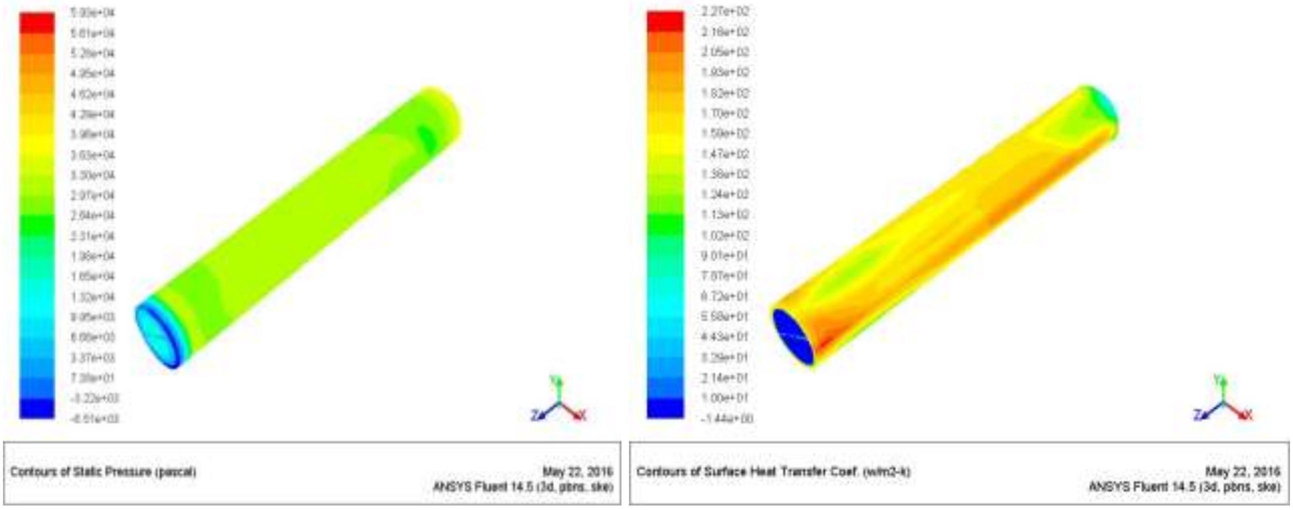

Figure: 21.Twisted tape width 26mm, Reynolds number – 13500, Mass flow rate 0.0241515kg/s

From the analysis of a plain tube, it is observed that the pressure and heat transfer coefficient is increased up to Reynolds number 10,000 and beyond that there is a sudden drop in a pressure and heat transfer coefficient as shown figures 22 to 25.

PRESSURE **HEAT TRANSFER COEFFICIENT**

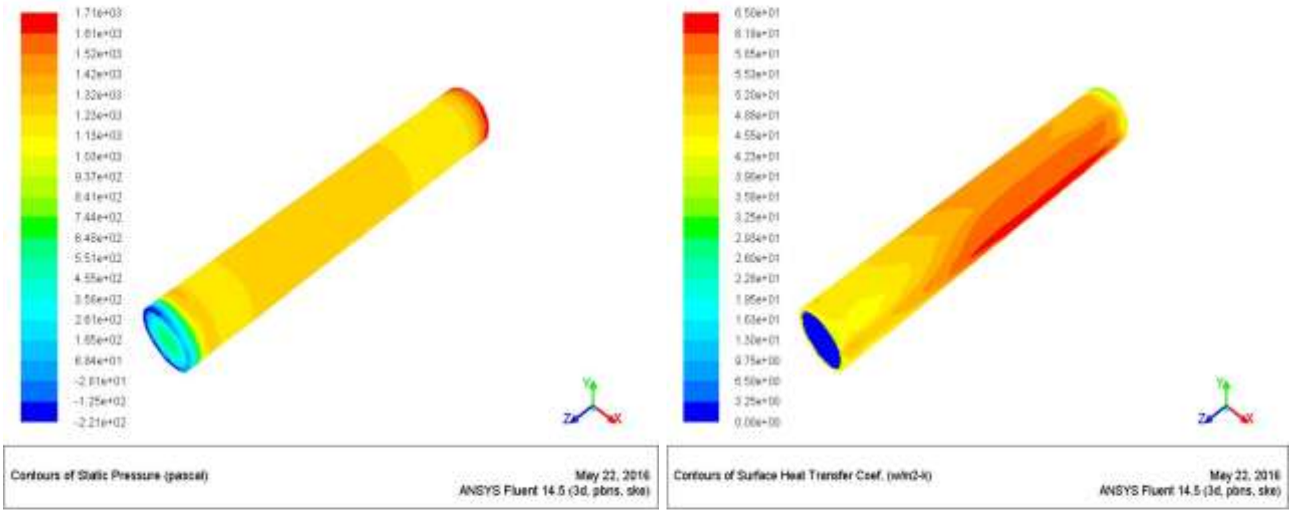

Figure: 22.Analysis of plain tube with Reynolds number 6000, Mass flow rate 0.05367Kg/s

PRESSURE **HEAT TRANSFER COEFFICIENT**

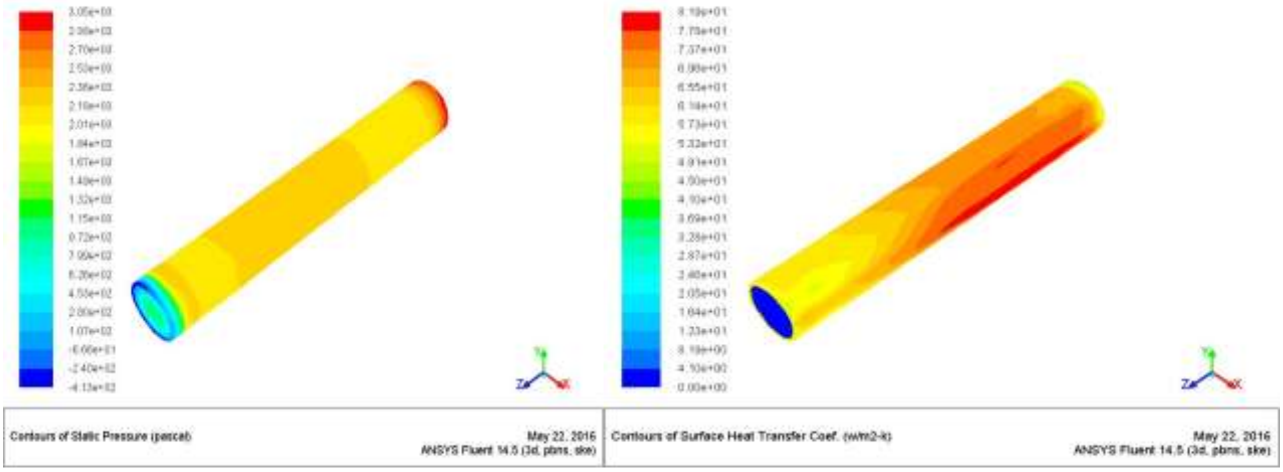

Figure: 23.Analysis of plain tube with Reynolds number 8000, Mass flow rate 0.07156kg/s

PRESSURE **HEAT TRANSFER COEFFICIENT**

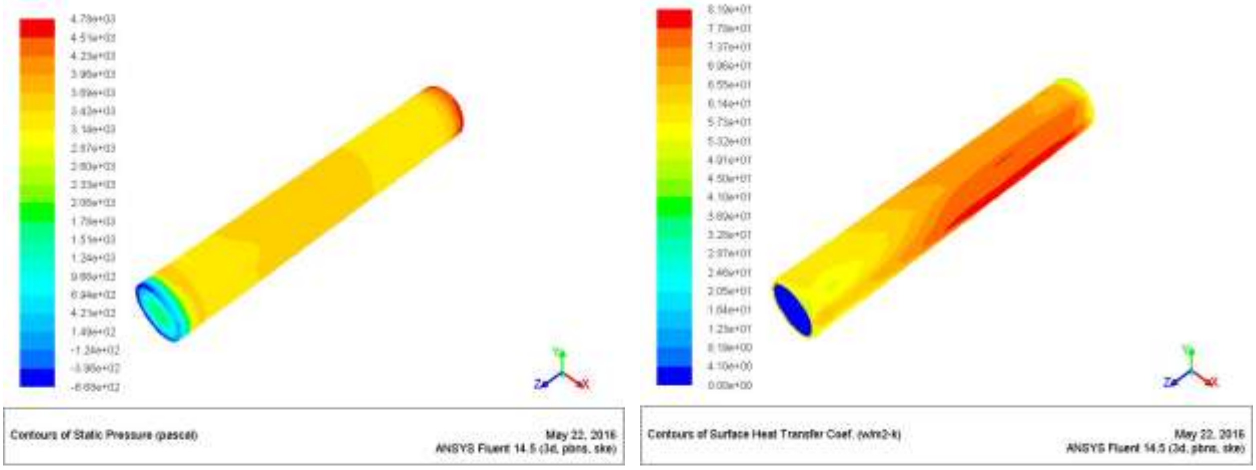

Figure: 24.Analysis of plain tube with Reynolds number 10000, Mass flow rate 0.08945kg/s

PRESSURE **HEAT TRANSFER COEFFICIENT**

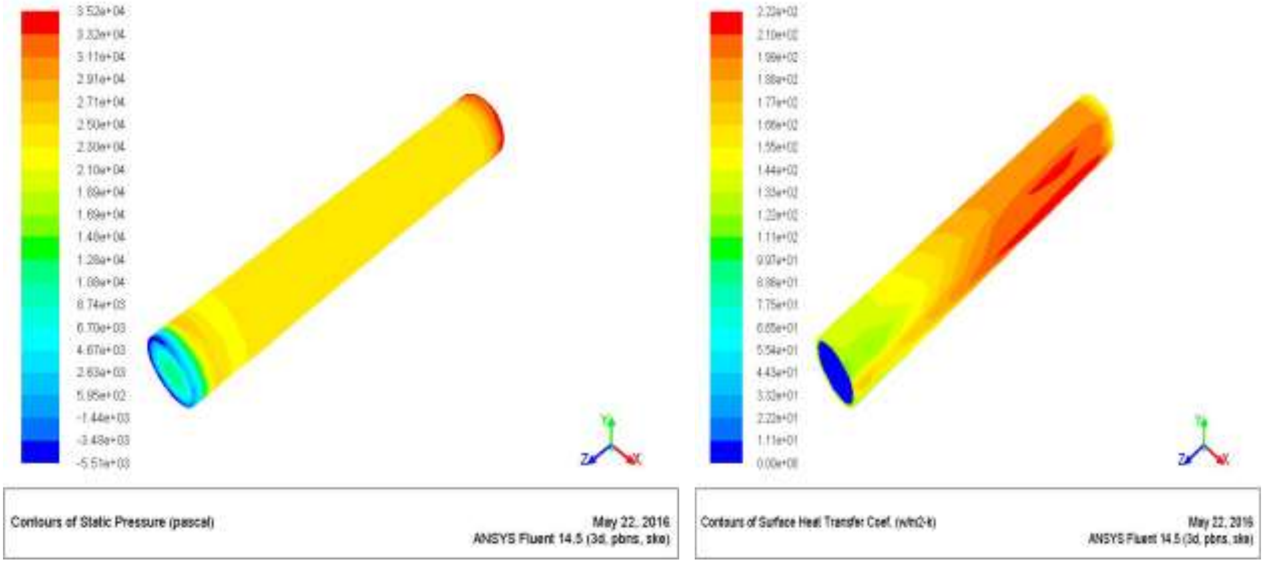

Figure: 25.Analysis of plain tube with Reynolds number 13500, Mass flow rate 0.0241515kg/sec

V. DISCUSSION

From the table.1,it is observed that, the with the insert width 10mm the heat transfer coefficient, pressure, Nusselt number increases with Reynolds number and heat transfer rate decrease with increase of Reynolds number.

Table: 1. INSERT WIDTH 10MM

Reynolds number	**Mass flow rate (Kg/s)**	**Pressure(Pa)**	**Nusselt number**	**Heat transfer coefficient (W/mm^2 K)**	**Total heat transfer rate (W)**			
					INLET	**OUTLET**	**WALL**	**NET**
6000	0.05367	2.34e-02	9.80e+01	2.37e+00	261.97226	-284.7849	22.602459	-0.21019363
8000	0.07156	2.34e-02	1.10e+02	2.67e+00	349.29654	-378.03076	28.42927	-0.30495262
10000	0.08945	2.34e-02	1.22e+02	2.95e+00	436.62076	-471.05591	34.001759	-0.43339157
13500	0.0241515	5.73e-02	1.92e+02	4.64e+00	1178.8766	-1256.0226	76.335182	-0.8108139

From the table.2, it is observed that, the with the insert width 14mm the heat transfer coefficient, pressure increases with Reynolds number up to 10,000 but the Nusselt number increases with Reynolds number and heat transfer rate decrease with increase of Reynolds number.

Table: 2. INSERT WIDTH 14MM

Reynolds number	Mass flow rate (Kg/s)	Pressure(Pa)	Nusselt number	Heat transfer coefficient (W/mm^2 K)	Total heat transfer rate (W)			
					INLET	OUTLET	WALL	NET
6000	0.05367	1.84e+03	2.7.e+03	6.53e+01	261.97238	-284.36102	22.215498	-0.17314339
8000	0.07156	3.29e+03	3.40e+03	8.23e+01	349.29651	-377.51169	27.93709	-0.27802849
10000	0.08945	5.15e+03	4.07e+03	9.86e+01	436.62067	-470.32526	33.409199	-0.29539108
13500	0.0241515	3.79e+04	9.15e+03	2.21e+02	1178.8765	-1254.2943	74.917412	-0.50043488

From the table.3, it is observed that, the with the insert width 18mm the heat transfer coefficient increases with Reynolds number up to 8,000 and pressure up to 10 ,000 but the Nusselt number increases with Reynolds number and heat transfer rate decreases with increase in Reynolds number.

Table: 3. INSERT WIDTH 18MM

Reynolds number	Mass flow rate (Kg/s)	Pressure(Pa)	Nusselt number	Heat transfer coefficient (W/mm^2 K)	Total heat transfer rate (W)			
					INLET	OUTLET	WALL	NET
6000	0.05367	1.86e+03	2.79e+03	6.75e+01	261.97098	-284.88687	22.676748	-0.23914528
8000	0.07156	3.33e+03	3.50e+03	8.48e+01	349.44125	-378.27896	28.51333	-0.32437706
10000	0.08945	5.20e+03	4.18e+03	1.01e+02	436.61868	-471.07736	34.073296	-0.38538361
13500	0.0241515	3.82e+04	9.37e+03	2.27e+02	1178.8719	-1255.8655	76.195313	-0.79821777

From the table.4,it is observed that, the with the insert width 22mm the heat transfer coefficient increases with Reynolds number up to 8,000 and pressure and Nusselt number increases with Reynolds number up to 10 ,000 and heat transfer rate decreases with increase in Reynolds number.

Table: 4. INSERT WIDTH 22MM

Reynolds number	Mass flow rate (Kg/s)	Pressure(Pa)	Nusselt number	Heat transfer coefficient (W/mm^2 K)	Total heat transfer rate (W)			
					INLET	OUTLET	WALL	NET
6000	0.05367	2.07e+03	2.87e+03	6.95e+01	261.97159	-284.63477	22.410139	-0.25303841
8000	0.07156	3.70e+03	3.61e+03	8.75e+01	349.29556	-377.77286	28.157721	-0.31957436
10000	0.08945	5.79e+03	4.32e+03	1.05e+02	436.61957	-470.60922	33.646229	-0.34342575
13500	0.0241515	4.26e+04	2.34e+02	2.34e+02	1178.874	-1254.9012	75.140129	-0.88758087

From the table.5, it is observed that, the with the insert width 26mm the heat transfer coefficient increases with Reynolds number up to 8,000 and pressure up to 10 ,000 but the Nusselt number increases with Reynolds number and heat transfer rate decreases with increase in Reynolds number.

Table: 5. INSERT WIDTH 26MM

Reynolds number	Mass flow rate (Kg/s)	Pressure(Pa)	Nusselt number	Heat transfer coefficient (W/mm^2 K)	Total heat transfer rate (W)			
					INLET	OUTLET	WALL	NET
6000	0.05367	2.94e+03	2.79e+03	6.76e+01	261.97073	-287.66492	25.506277	-0.25303841
8000	0.07156	5.22e+03	3.51e+03	8.48e+01	349.29456	-381.68878	32.204456	-0.31957436
10000	0.08945	7.88e+03	4.19e+03	1.01e+02	436.61829	-475.45996	38.784798	-0.34342575
13500	0.0241515	5.93e+04	9.40e+03	2.27e+02	1178.8711	-1267.4598	87.999123	-0.88758087

From the table.6, it is observed that, the with the plain tube the heat transfer coefficient and pressure increases with Reynolds number up to 10 ,000 but the Nusselt number increases with Reynolds number and heat transfer rate decreases with increase in Reynolds number.

Table: 6. PLAIN TUBE WITHOUT INSERTS

Reynolds number	Mass flow rate (Kg/s)	Pressure(Pa)	Nusselt number	Heat transfer coefficient (W/mm^2 K)	Total heat transfer rate (W)			
					INLET	OUTLET	WALL	NET
6000	0.05367	1.71e+03	2.69e+03	6.50e+01	261.97311	-285.78723	23.420017	-0.39410019
8000	0.07156	3.05e+03	3.38e+03	8.19e+01	349.29755	-379.21793	29.400047	-0.520333
10000	0.08945	4.78e+03	4.06e+03	8.91e+01	349.29755	-379.2459	29.400047	-0.548303
13500	0.0241515	3.52e+04	9.15e+03	2.22e+02	1178.8792	-1258.206	77.651375	-1.6757736

From the figure.26, it is observed that, the mass flow rates are increased with Reynolds number up to 10,000 and beyond that there is a drop in mass flow rate.

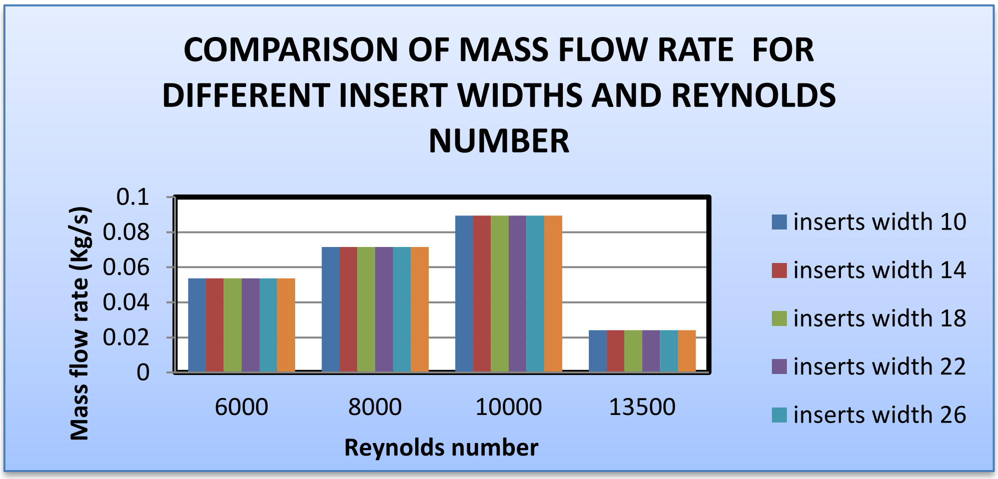

Figure: 26.Comparision of mass flow rate for different insert widths and Reynolds number

From the figure.27, it is observed that, the pressure increases with increase in Reynolds number and with twisted tape insert widths.

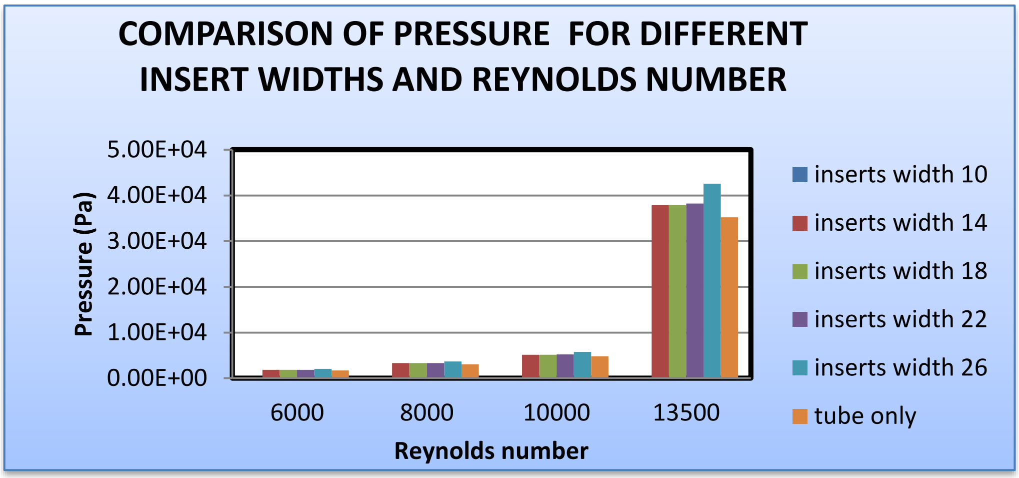

Figure: 27.Comparision of pressure for different insert widths and Reynolds number

From the figure.28, it is observed that, the Nusselt number increases with increase in Reynolds number and with twisted tape insert widths.

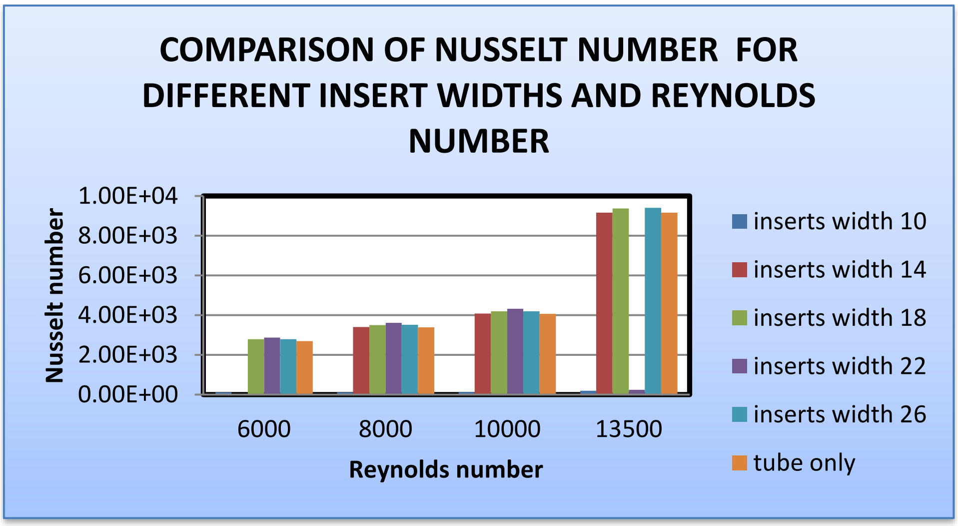

Figure: 28.Comparision Nusselt number for different insert widths and Reynolds number

From the figure.29, it is observed that, the heat transfer rate increases with increase in Reynolds number and with no twisted tape inserts. So, it is more for plain tube.

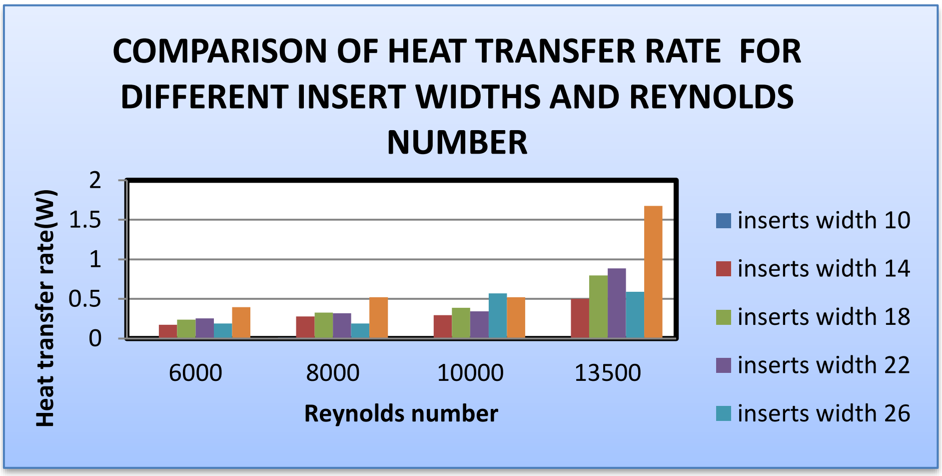

Figure: 29.Comparision of heat transfer rate for different insert widths and Reynolds number

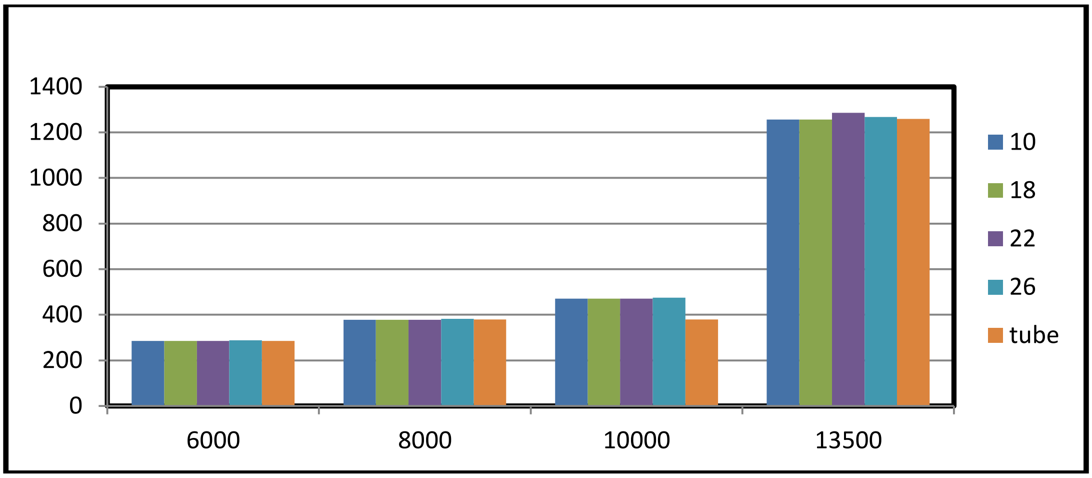

Figure: 30. Heat transfer rate plot

VI. CONCLUSION

By observing the analysis results, the heat transfer rate is increasing with increase of insert widths and Reynold's number and it is more for plain tube due to less area. The heat transfer coefficient, Nusselt number, Pressure gradient is increasing with increase of insert widths and Reynold's number and it is more for 26mm insert width. With increase of pressure gradient in tube increases heat transfer. So it can be concluded that by increasing insert width yields better results and also increase of Reynold's number is efficient.

VII. REFERENCES

[1] Enhancement of heat transfer using varying width twisted tape inserts
[2] Heat Transfer Enhancement with Al_2O_3 Nanofliud and Twisted Tapes in a Pipe for Solar Thermal Applications
[3] Experimental Investigations on Heat Transfer and Friction Factor of Silver Nanofliud in Absorber/Receiver of Parabolic Trough Collector with Twisted Tape Inserts
[4] Numerical and Experimental Comparison of Heat Transfer Enhancement in A 2-Pass Double Pipe Heat Exchanger with and without Inserted Twisted Tapes

