NUMERICAL AND EXPERIMENTAL ANALYSIS OF HEAT TRANSFER COEFFICIENT WITH OPTIMUM PRESSURE DROP IN TURBULATOR FITTED PIPE

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Abstract: Purpose of this investigation is to augment HTC with minimum pressure drop inside pipe carrying cold water surrounded by hot water using passive technique with turbulent flow. The passive technique used in this paper is helical coil wire as turbulator. The CFD Analysis is done for Divergent Convergent Turbulator in simulation software and the turbulator is analyze for various wire diameter of 0.7, 1.0, 1.5, 2.0, 2.5 and 3 mm and also by varying the mass flow rate of working fluid. From the results obtained by this analysis the most optimum dimension of the turbulator is selected for manufacturing and further experimentation is performed for validation with simulation software results. Also, the experimental result of Divergent Convergent Turbulator is compared with Twisted Tape Turbulator for same boundary condition and comparison has proven that Divergent Convergent Turbulator increases the HTC by 33% more than Twisted Tape Turbulator on expense of 25% more Pressure Drop than Twisted Tape Turbulator.

Index Terms: Pressure drop, HTC (Heat Transfer Coefficient), Divergent Convergent Turbulator, Twisted Tape Turbulator, CFD

I. INTRODUCTION:

Current world energy scenario reveals the declination of non-renewable energy sources which leads to conservation or efficient utilization of resources. The thermal industries which are mainly dependent on coal required proper utilization of this energy. The most usable mechanical component in the thermal industries is heat exchanger which is use for heat exchange between two fluids. To increase the efficiency of plant the optimization of various components is required. Optimization of Heat exchanger design is of large interest now days; basically to improve heat transfer turbulence is required within a flow. Most known techniques to increase heat transfer in heat exchanger are active and passive method. Active method comprises of surface vibration, electric field and acoustics which require external power supply and passive method technique generally use projection or surface that generally disturbs the fluid motion. Research done in this paper is on passive technique.

Passive method generally involves:
1. Inserts
2. Extended surfaces
3. Surface modification

Inserts are inserted inside the pipe to create obstruction to flow which produces turbulence and led to increase HTC on expense of increase in pressure drop. Widely use inserts are twisted tape turbulator and helical coil wire turbulator. Extent investigation has been carried out on simple helical coil turbulator with working medium as air but in this research study has been oriented on modification in design of helical coil turbulator with working medium as water.

II. LITERATURE REVIEW:

Yang San et al. [1] experimentally investigated the heat transfer and fluid friction correlations for circular tubes with coiled wire inserts for both water and air as the working fluid. It is found that Nusselt number increases with the e/d value, whereas it increases with decrease of p/d value.
An experimental study on heat transfer and pressure drop of multi-walled carbon Nano tube – water Nano fluid inside a horizontal

tube fitted with coiled wire was conducted by Behabadi et al. [2]. The effect of various parameters like pitch, wire diameter, Reynolds number on heat transfer coefficient and pressure drop was studied. It was seen that heat transfer augmentation takes place in coiled wire inserted tube.

Gunnes et al. [3] reported an experimental analysis for a tube fitted with coiled wire for two different distances between the coiled wire and tube wall. It was concluded that both heat transfer and pressure drop increases with reducing distance between them.

Gracia et al. [4] experimentally investigated the use of different helical coil wire and twisted tape turbulator in a flat tape solar water collector. For all types of inserts the absorber temperature reduced more as compared to the plain pipe. But off all the inserts helical coiled wire gave best results.

Salimpour and Gholima [5] used coiled wire inserts in a plain tube for convective condensation of R404A vapor. Pressure drop up to 1200% increases due to this wire coiled inserts as compared to plain tube. Akhavan-Behabadi et al. [6] carried out the heat transfer augmentation of heating engine oil inside a horizontal tube with coiled wire inserts. Two empirical correlations were found to determine the Nusselt number which was within the error band of ±20% with that of experimental Nusselt number.

Experimental studies on heat transfer and friction factor characteristics of Al_2O_3/water Nano fluid in a circular pipe under laminar flow with wire coil inserts has been performed by M.Chandrasekar et al. [7]. Nusselt number increases from 15.91% to 21.53% when pitch to tube diameter ratio increases from 2 to 3.

V. Ozceyhan [8] used the CFD Analysis to numerically calculate the heat transfer and thermal stress in a tube with coiled wire insert. Various contours of pressure and temperature were plotted along with flow patter inside the pipe was also depicted. Heat transfer augmentation takes place along with increased pressure drop.

From the above literature survey, we found that most of the scientist have done experimental work and studied the effect of various parameters of coiled wire inserts like wire diameter, pitch to tube diameter ratio, cross section of the wire on the heat transfer coefficient and friction factor. The investigation on different shapes of helical coil inserts like diffuser, divergent convergent, convergent divergent and multiple helical coil (4 spring) is rarely been reported. Hence the aim of this work is to extend the data available on this different shape of turbulators in a turbulent flow with working fluid as water.

III. EXPRIMENTAL SETUP AND PERFORMANCE:

Simple Experimental setup is made to perform an experiment. The schematic diagram of setup is shown below in figure 3.1.which consist of Divergent Convergent Turbulator inside a pipe. The setup consist of a 0.5 hp of centrifugal pump, rotameter, by- pass valve, tank, thermocouple, heater, pressure gauge and pipe of 1500mm length and 27 mm inner diameter.

Table 1: Component Require to Perform Experiment

Sr no.	Component	Quantity
1	Pump (.5 hp)	1
2	By pass valve	1
3	Rota meter (0-20 lpm)	1
4	Pressure gauge (0-100 kPa)	2
5	Thermocouple	6
6	Heater (3 kW)	3

The working fluid in whole setup is cold water at ambient condition inside a sump and heated water inside a tank of 1500×500×500mm at uniform temperature of 70ºC which is maintained by the use of three heater of 3kW. Experimentation starts with turning on the pump which will pump the cold water from sump to the pipe inlet. The by-pass valve is provided to control the discharge of cold water passing through pipe. Volume flow rate of water is measured with a help of rotameter located at upstream of flow with capacity 0-20 lpm. The pipe carrying turbulator is well situated inside a tank which has hot water. Basic requirement to carry experiment is to maintain steady surface temperature of pipe at 70ºC. The temperature over the surface of pipe is measured by a K-type thermocouple in 4 nos. are provided at various surface location and to measure a pressure at inlet and outlet of a pipe a pressure gauge is provided with range of 0-100 kPa.

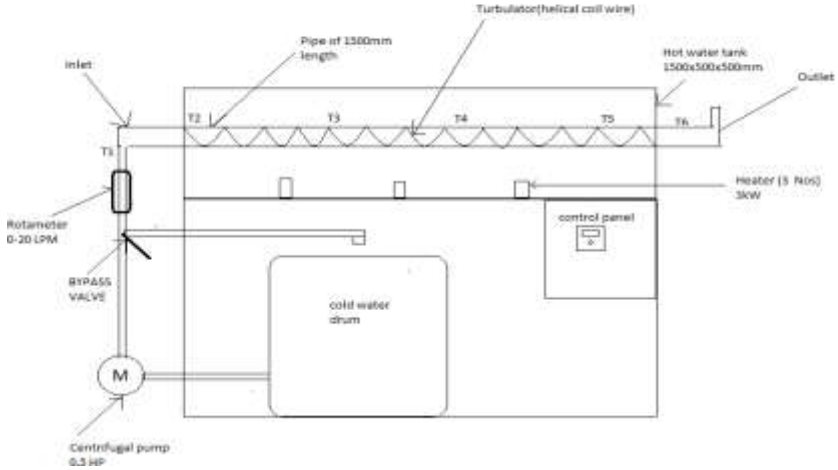


Figure 3.1: Schematic Diagram

Figure 3.2: Divergent Convergent Turbulator

Figure 3.3: Experimental setup

The readings are taken when uniform temperature of 70ºC is appearing over a pipe surface. As three heaters are provided inside the tank the heat distribution is localized near the heater because, the water inside a tank is still and not moving hence for uniform heating of water constant stirring is required. After a sump water is passed through turbulator fitted pipe, heat transfer occur between hot pipe and cold water by convection which causes rise in temperature of cold water at pipe outlet and hence this water is need to be drain out and cannot be reuse again as it will increase the temperature of cold water at inlet of pipe and this adversely affect the rate of heat transfer as temperature gradient reduces. Before starting the experiment the apparatus was checked, thermocouples were calibrated and checked for any leakages.

IV. MODELING AND ANALYSIS:

The modeling of turbulator involve in this study have modification in simple helical coil turbulator which led to Divergent Convergent Design, Convergent Divergent Design, Diffuser Design and 4 Spring Design. Out of this all design Divergent Convergent Turbulator provide good result from analysis and hence it is selected for manufacturing and experimentation. This turbulator has maximum diameter at center and minimum diameter at both ends. The pitch of the turbulator is 20mm and diameter at center and end are 27mm and 13mm respectively. Taper angle is kept as 0.5° and material use for manufacturing is mild steel. Divergent convergent turbulator is opposite to that of convergent divergent turbulator. At center it will have maximum diameter and at both end the diameter reduces to minimum size.

Figure 4.1: Assemble view

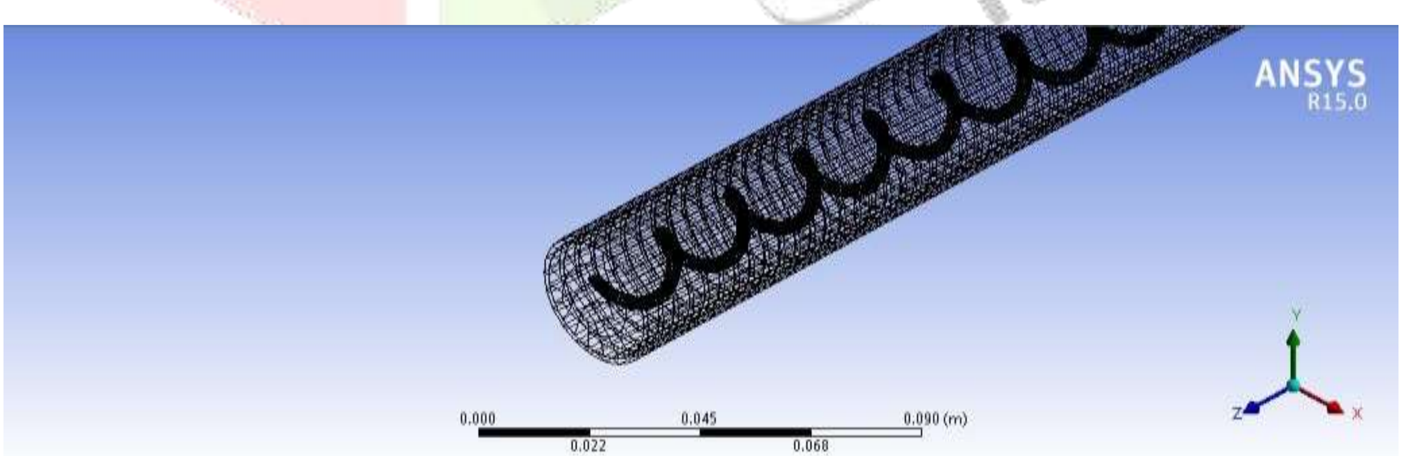


Figure 4.2: Mesh view

No. of Nodes = 185677 No. of Elements = 620791

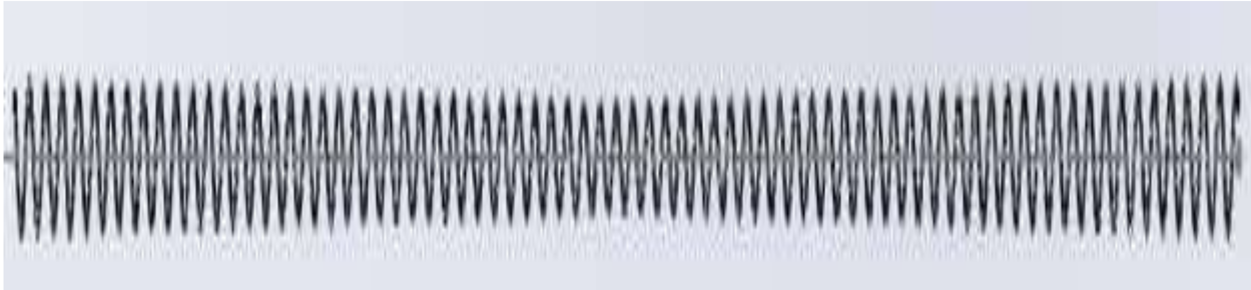


Figure 4.3: CAD Model of Divergent Convergent Turbulator

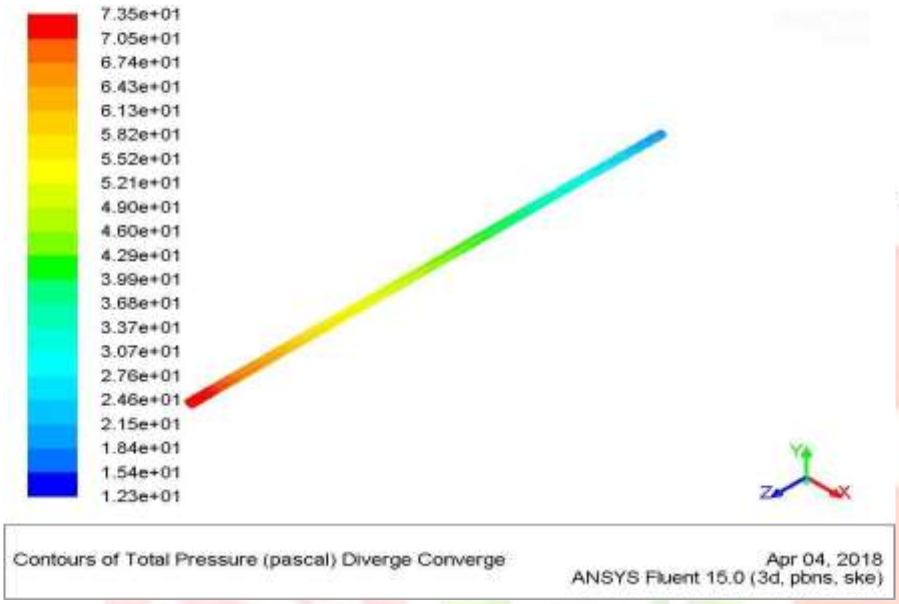


Figure 4.4: Pressure Contour

Max pressure = 73.5 Pascal Min pressure = 21.5 Pascal

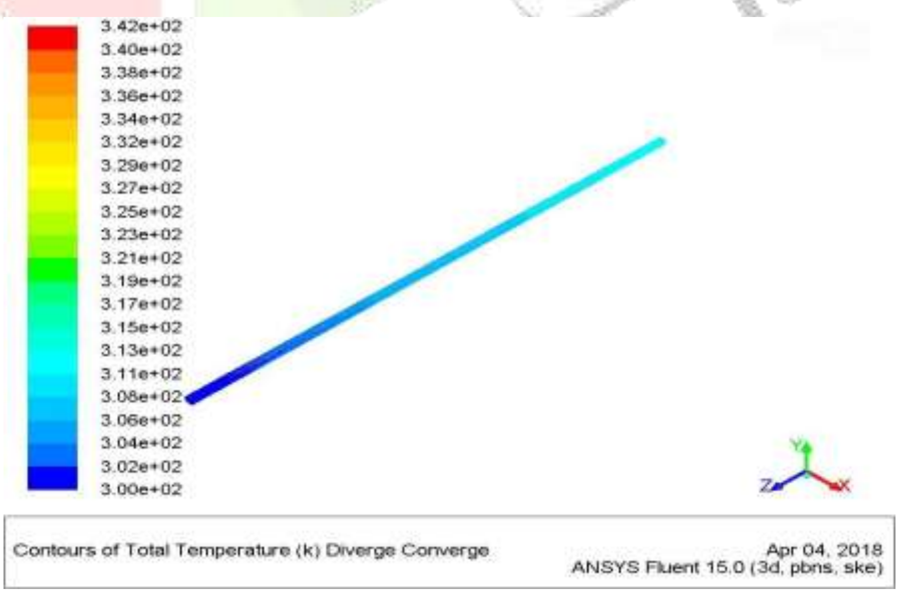


Figure 4.5: Temperature Contour

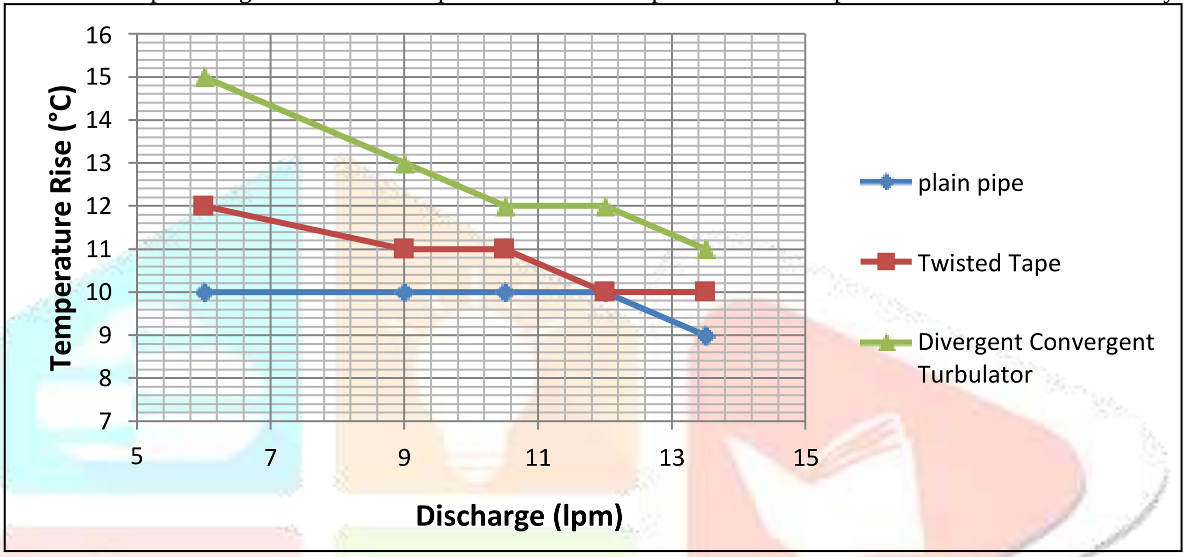
Maximum Temperature = 312°K Minimum Temperature = 300°K

V. RESULTS:

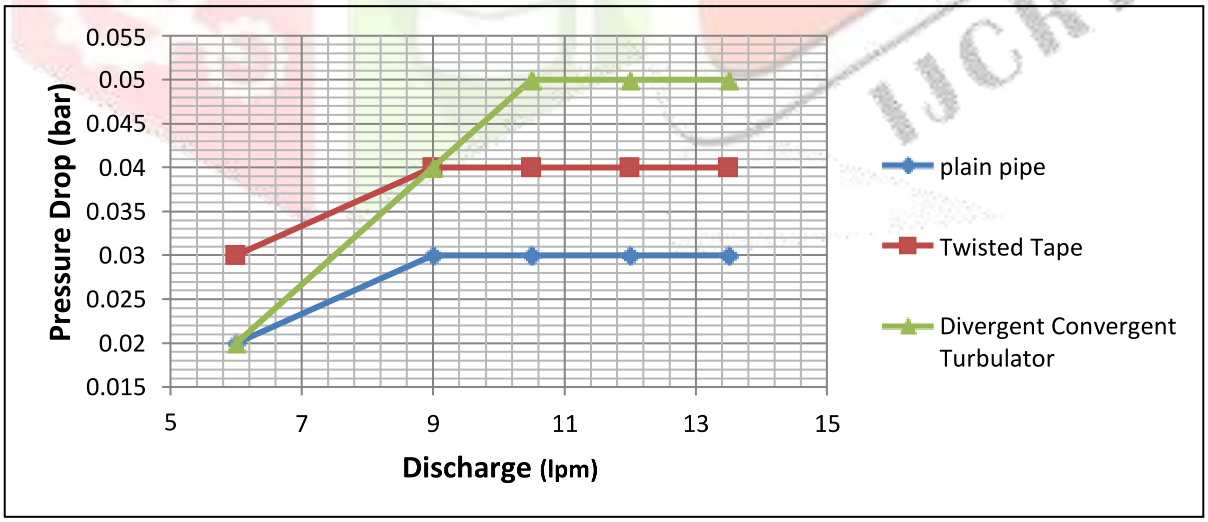
Results involve in this research is for Analysis, Experimentation along with validation.

5.1 EXPERIMENTAL RESULTS:

The following results were obtained experimentally for different mass flow rates. The first graph shows variation of temperature rise for different mass flow rates for the entire three cases i.e. plain pipe, Twisted Tape and Divergent Convergent Turbulator and second graph shows pressure drop for all three cases for various mass flow rate. The experimentally plotted graphs show us that for Divergent Convergent Turbulator Temperature rise is maximum at the expense of higher pressure drop. Also, out of the two turbulator Divergent Convergent Turbulator provide good result for temperature rise as compare to twisted tape turbulator for same boundary condition.



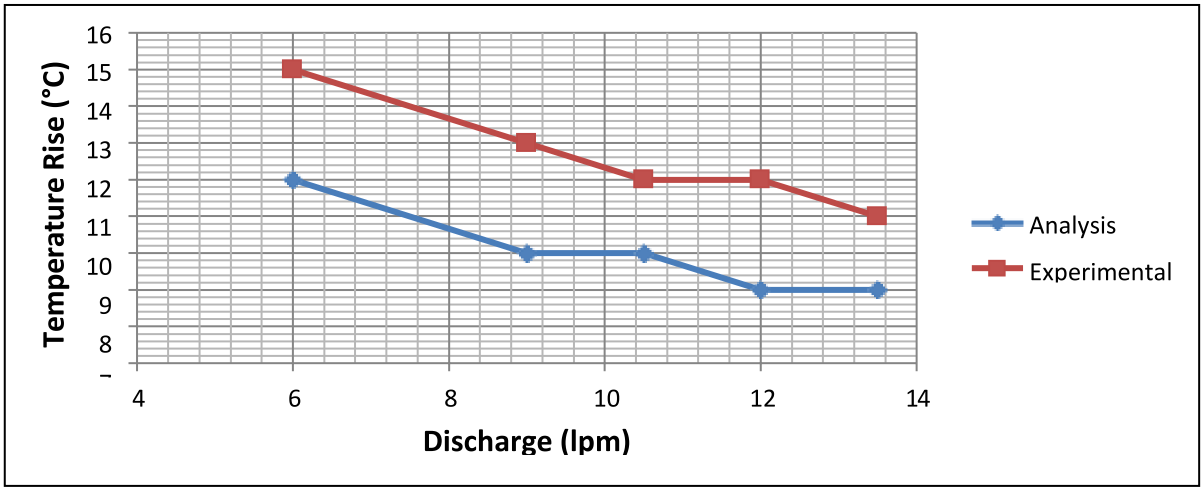
Graph 5.1: Graph of Temperature Rise vs Discharge



Graph 5.2: Graph for Pressure drop vs Discharge

5.2 CFD ANALYSIS:

CFD ANALYSIS was done on Divergent Convergent Turbulator for same boundary conditions as in for Experimentation. The results of the analysis are as follow:



Graph 5.3: Graph for Validation

The validation from above graph leads to deviation of Analysis result from Experimental result by 4.25%.

VI. CONCLUSION:

Numerical and Experimental study of HTC and pressure drop in pipe using turbulator model has been done. In Experimental study the apparatus was set up to measure temperature rise and pressure drop maintaining constant heat flux on pipe.

- Diverging Converging configuration is more effective than the Twisted Tape Turbulator to get high HTC with optimum Pressure Drop in less mass flow rate.
- HTC is increase by 33 % in Divergent Convergent Turbulator with respect to Twisted Tape Turbulator.
- Validation of Ansys and experimental results show an error of 4.25 %.
- Pressure drop in Divergent Convergent Turbulator is 25% more as compared to Twisted Tape Turbulator.

VII. REFERANCES:

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