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"EXPERIMENTAL ANALYSIS OF HEAT TRANSFER AUGMENTATION IN A COUNTER FLOW HEAT EXCHANGER"

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ABSTRACT

The present work focuses on experimental and computational investigation of the augmentation of laminar flow heat transfer in a horizontal counter flow heat exchanger by means of twist tape insert with water as working fluid. The improvement of the performance of heat exchanger with water as the working fluid becomes particularly important due to the thermal resistance offered by water in general. In order to compensate for heat transfer property of water, the surface area density of heat exchanger can be increased. In addition, a promising technique for augmentation of heat transfer in the use of twist tape inserts with different twist tape ratio. The twist tape generate vortex between the flow. Twist tape facilitate the exchange of more heat near the wall with the fluid in the core and hence, the boundary layer is disturbed. It result heat transfer gradient at the surface which leads to the augmentation in heat transfer.

Twist tape insert with twist ratio 5.1 and twist ratio 2.6 with the width of 6mm and thickness 1mm fabricated and use for the augmentation of heat transfer in heat exchanger. The horizontal tube was subjected to constant mass flow rate and constant input cold and hot supply of water.The work include the determination of friction factor, heat transfer coefficient, overall heat transfer coefficient in the experimental setup for smooth tube and twist tape ratio Aw=5.1 and Bw=2.6.

The result is also compare with the computational method. CFD technique is employed to perform optimization analysis of mesh insert. The horizontal pipe along with mesh insert was modeled in ANSYS Fluent. CFD analysis was performed for smooth tube and for different twist inert.

For twist tape it was observed that the heat transfer coefficient vary from 1.4 to 2.8 times the smooth tube and the friction factor increased by 1.8 to 6.3 times the smooth tube. It was also observed that with increases in Reynolds number, the heat transfer coefficient increases where as the friction factor decreases. The result of computational investigation observed that the heat transfer coefficient vary from 1.9 to 3.9 times the smooth tube and the friction factor increased by 2.4 to 7.8 times the smooth tube. Computational investigation is the true for our experimental investigation and this validate the all result experimental result.

Keywords:- *Circular tube,Heat transfer Augmentation,laminar and turbulent flow, Heat Transfer Coefficient, Friction factor.*

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I. INTRODUCTION

A heat exchanger is a complex device that provides the transfer of thermal energy between two or more fluids, which are at different temperatures and thermally Contact with each other. Heat exchangers are used either individually or as components of a large thermal system, wide variety of commercial, industrial and household applications, e.g. power generation, refrigeration, ventilating and air-conditioning systems, process manufacturing, aerospace industries, electronic chip cooling as well as in environmental engineering. The improvements in the performance of the heat Exchanger have attracted many researchers for a long time as they are of great technical, economical and not the least, ecological importance.

"Heat transfer Augmentation" means Increase in heat exchanger's performance with the help of augmentation techniques, this can lead to more economical design of heat exchanger that can also help to make energy, material and cost savings related to a heat exchange process. for the augmentation of heat transfer in tube. The subject of heat transfer growth in heat exchanger is of serious interest in the design of effective and economical heat exchanger Bergles et al., identified about 14 augmentation techniques used for the heat exchangers. These augmentation techniques can be classified into passive, active and compound techniques. Passive techniques do not require any type of external power for the heat transfer augmentation such as coating of Surface, rough surface, extended surface, displaced insert, swirl flow device, surface flow device, surface tension, additives for liquid, and additives for gases. Whereas, the active techniques need some power externally, such as electric or acoustic fields, surface vibration, mechanical aid, fluid vibration, injection, suction, jet impingement, etc., and compound technique are the combination of this two method.

II. CIRCULAR TUBES FITTED WITH INSERT IN LAMINAR FLOW

This paper involving recent research work on heat transfer growth in circular tube. many studies were conducted previously to analyze heat transfer growth in circular tube with laminar flow.

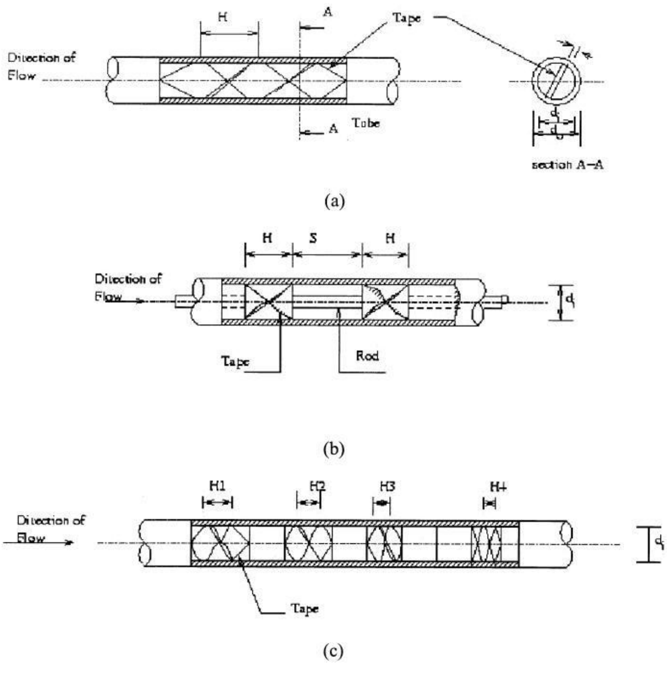

Fig:-1 (a) full-length twisted tape, (b) regularly spaced twisted tape and (c) smoothly varying (gradually decreasing) pitch full-length twisted tape

[1]Sheeba et al., investigated the thermal performance of thermosyphon solar water heater system fitted with helical twisted tape of various twist ratios. conclusions made from the results that heat transfer enhancement in twisted tape collector is higher than the plain tube collector with minimum twist ratio and gradually decreases with increase in twist ratio in laminar flow [2] Eiasma Ard et al., investigated the behavior of heat transfer and friction loss in circular tube

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and they found that apart from the friction factor, heat transfer rate can be substantially improved by using both the wavy surfaced wall and the helical tape insert. [3] P Selvaraj et al., used water and ethylene glycol mixture 90:10 (by weight) flow through the circular tube because ethylene glycol prevents corrosion and acts as antefreezing agent. They investigate that the maximum heat transfer enhancement is obtained up to 36% for circular Tube in laminar flow with grooved inserts as compare to simple tube with turbulent flow. [4] Veysel Ozceyhan et al., investigate the heat transfer enhancement in a tube with the circular cross sectional ring, uniform heat flux was applied to the external surface of the tube and their findings as follows:

The variation of Nusselt number, friction factor and overall enhancement ratios for the tube with rings were presented and the best overall enhancement of 18% was achieved.

[5]P.K. Nagarajana et al., used 300 mm right-left helical twist with 100 mm spacer of different twist ratio on their investigation and found that Nusselt number for the tube fitted with 300 mm right-left helical twist is higher than that for plain tube for a given Reynolds number attributing to heat transfer enhancement due to swirl flow inside of tube. [6] J P Meyer and J. A Olivier investigated the heat transfer and pressure drop characterizes for enhanced tube with helical coil insert. There investigation covered the laminar, transitional and turbulent flow regimes. They found the better heat transfer in the laminar flow as compare to turbulent in heat transfer tube.[7] Timothy et al., performed an experimental study of a double pipe helical heat exchanger used coil tape insert with laminar flow of fluid. They found that increase in Nusselt number significantly in the entrance region and heat transfer rates were higher in counter flow configuration as compared to parallel flow. [8] M E Ali investigates that average heat transfer coefficient increases as number of coil turns decrease for a fixed diameter ratio in laminar flow. [9]Veeresh Uskele and R M Sarviya experimentally studied the heat transfer and friction factor characteristics of double pipe and plane tube heat exchanger. They found that heat transfer coefficient and friction factor increase with the decrease in twist ratio compared to plain tube in laminar flow. [10] P. Sivashanmugam and S.Suresh studied the laminar heat transfer and friction factor characteristics in a circular tube fitted with full length helical screw tapes with different twist ratios under constant heat flux conditions,They reported significant improvement of the heat transfer rate for using the tape inserts and found that there is not much change in the magnitude of heat transfer coefficient to vary twist ratio sets. [11] Ujhidy et al., have studied and proposed Dean Number. Dean Number is a measure of the magnitude of the secondary flow, which is useful for the future investigation of heat transfer growth in circular tubes contained twist tape in laminar flow. [12]Suresh Kumar et al. investigated the thermohydraulic performance of twisted tape inserts in a large hydraulic diameter annulus and found that thermohydraulic performance in laminar flow with a twisted tape is better than the wire coil for the same helix angle and Thickness ratio.

III. CIRCULAR TUBES FITTED INSERT IN TURBULENT FLOW

Investigation of heat transfer augmentation insert used in turbulent flow circular tubes discussed in this section. Heat transfer augmentation insert in turbulent flow is effective up to certain Reynolds number. More Reynolds number blocks the flow passage and increases the pressure drop

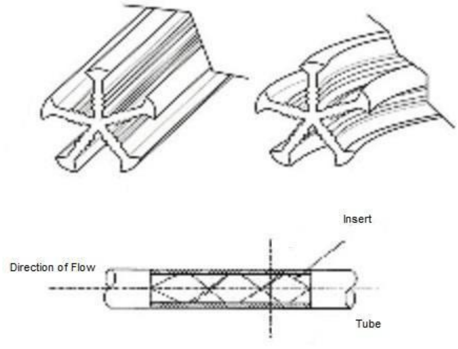

Fig:-2 Turbulent flow generator in circular tube on

[13] W. Noothong et al., studied influences of insert in a concentric double pipe heat exchanger. The turbulent flow was introduced by using twisted tape in the flow direction with different twist tape ratio; result shows that's twist ratio increases heat transfer rate as compare to plain tube in turbulent flow. [14]M.A.K. Chowdhuri et al., used special geometry inside of tube with turbulent flow. The test section is electrically heated and air is allowed to flow as the working fluid through the tube by means of blowers. Same experiment is carried out to determine heat transfer through

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the same tube without any insert. Comparing the results obtained from these two different sets of experiments and found that heat transfer through tubes can be enhanced by using inserts inside the tube up to 9.8 times than tube without insert with turbulent flow in circular tube. [15] P. Sivashanmugam and S. Suresh investigated heat transfer and friction factor characteristics of circular tubes fitted with full length helical screw element of different twist ratio with heat flux under turbulent flow conditions, they investigate that maximum performance of the helical twist insert was achieved as compare to twisted tape insert in turbulent flow. [16] P. Murugesan et al. reported experimental investigations of heat transfer and friction factor for turbulent flow in a tube fitted with trapezoidal cut twisted tape. There observation says that that heat transfer coefficient and friction factor increases with the decreases in twist ratio. The trapezoidal cut twisted tape with twist ratios increases the heat transfer rate 41.8 % higher than plain tubes. [17] P.Coronel and K.P. Sandeep conducted experiments in helical heat exchangers with coils of two different curvature ratios, straight tubular heat exchangers at various flow rates and for different end point temperatures. The inside and outside convective heat transfer coefficients were determined based on overall heat transfer coefficient and a correlation to compute the inside convective heat transfer coefficient as a function of Reynolds number. [18]M. Mridha and K P D Nigam investigated turbulent forced convection in a new device of coiled flow inverter and found 4-13% enhancement in heat transfer as compared to straight helical coil while relative pressure drop was found to be 2-9%. Further, gain in heat transfer in coiled flow inverter for turbulent flow condition as compared to straight tube for same flow rate and boundary condition was 35-45% while increase in pressure drop found 29-30%. [19] Smith Eiamsa-ard et al., presented an experimental study on the mean Nusselt number friction factor efficiency in a round tube with short-length twisted tape insert under uniform wall heat flux boundary conditions. In the experiments, measured data are taken at Reynolds numbers in a turbulent region with air as the test fluid. The experimental result indicates that the short-length tapes perform lower heat transfer and friction factor values than the full-length tape around 14%, 9.5% and 6.7%; and 21%, 15.3% and 10.5% respectively. [20] Sharma et al., Conducted experiments to evaluate heat transfer coefficient and friction factor for turbulent flow in a tube with twisted tape inserts in the transition range of flow with AI203 nanofluid are conducted. The results showed considerable enhancement of convective heat transfer with Al203 nanofluids compared to flow with water. [21] C Thianpong et al., investigated experimentally heat transfer and friction characteristics for water, ethylene glycol, and ISO VG46 turbine oil flowing inside four tubes with three-dimensional internal extended surfaces and segmented twisted-tape inserts. Investigation shows that tube with three-dimensional internal extended surfaces and twisted-tape inserts; enhance the convective heat transfer for the turbulent tube side flow of highly viscous fluid.

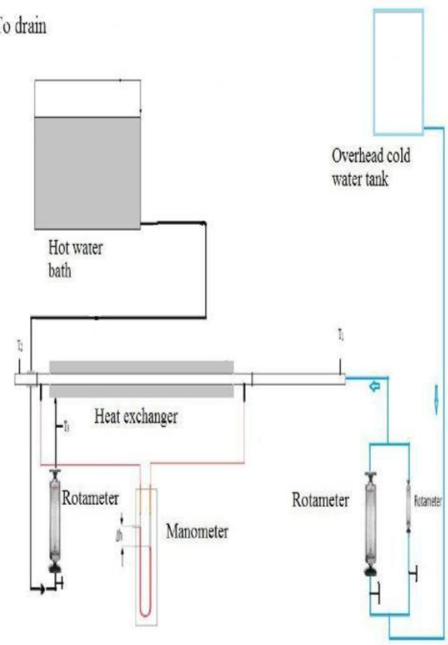

Fig.3 Experimental Set up

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Fig.4 Twist Tap Insert

IV. Friction Factor Results

Friction factor (Exp. & CFD) vs Reynolds number for smooth tube:

The variation of experimental and computational friction factor with Reynolds number for smooth tube. It is seen that, as the Reynolds number increases friction factor decreases.
Limitations of experimental setup where in we were unable to measure lower pressure drop of Rotameter. As the pressure drop values were very small for low Reynolds number so we couldn't Measure low pressure drop with high accuracy. Higher Reynolds number gives the better result in experimental as well computational methods for smooth tube.

Experimental Friction factor vs Reynolds number for twist tube with twist ratio 5.1 and 2.6

Shows the variation of experimental friction factor (f_{exp}) with Reynolds number for smooth tube and twist tape with twist ratio 5.1 and 2.6. It is seen that, as the twist ratio decreases a higher degree of swirl is created inside the tube which leads to higher pressure drop and hence higher friction factor. Twist tape 2.6 performs higher friction factors than twist tape with ratio 5.1 and smooth tube. Order of friction factor is:

f_{exp}, twist 2.6 > f_{exp}, twist 5.1 > f_{exp}, smooth

Twist tape yield higher pressure drop those in the tube as the tube fitted with twist tape. This is because of additional disturbance increases the tangential contact between secondary flow and the wall surface of the tube.

Friction factor (Exp & CFD) vs Reynolds number for twist tape with twist ratio 5.1 and 2.6

It is seen that, CFD result shows the grater result as compare to experimental , due to the limitation of experimental setup and standard consideration of the computational working.
As the Reynolds Number increases result of friction decrease, Higher Reynolds number produce swirl inside of tube wall.The value of Experimental friction factor is close to the CFD result. Large deviation is shown by the twist ratios at lower Reynolds number.

Friction factor ratio (Exp / CFD) vs Reynolds number for smooth tube, twist tape with twist ratio 5.1 and 2.6

In order to compare friction factor ratio of experimental and computational result of smooth tube and twist ratio 5.1, 2.6 with the variation of Reynolds number.
Experimental and CFD friction Factor ratio (fexp/fCFD) VS Reynolds number for smooth tube, indicates that the twist ratio 2.6 observed better result than the 5.1 because twist tape 2.6 generate more secondary flow then twist tape 5.1.

V. Conclusion

Computational and Experimental investigation of twist tape inserts to augmentation heat transfer of a horizontal counter flow heat exchanger tube, inside diameter 10 mm with water as a working fluid. The effect of parameters such as twist ratio, pressure drop inside the tube, Reynolds number, friction factor, heat transfer coefficient and overall heat enhancement are studied.

The findings:

1. The Reynolds number and friction values for the tube with twist tape insert are noticeably higher than that of smooth tube.

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2. Twist tape gives the greater heat transfer result, because of high degree of turbulence generated by the twist tape which reduce resistance near the wall to promote better heat transfer as compared to other heat transfer augmentation device used in heat exchanger for heat transfer growth.

3. In the case of twist tape insert the friction factor varied from 1.002 to 1.59 times as compared to smooth tube .

4 The pressure drop result indicates that the friction factor depends primarily on Reynolds number as swirl flow increases the friction factor somewhat decreases at higher Reynolds number.

5. Friction factor increasing with a decreasing as the twist ratio

Order, for their friction factor ratio is.

Twist 2.6 ,(fexp / fCFD) > Twist 5.1 , (fexp / fCFD) > Smooth (fexp / fCFD)

6. The heat transfer process in experimental setup enhances by using twist tape inserts . The type of twisted tape indicate the increasing amount of enhancement efficiency

Order, for their overall heat transfer coefficient ratio is: Twist 2.6 , (Ui,exp/Ui,CFD) > Twist 5.1 , (Ui,exp / Ui,CFD)

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