Heat Transfer Enhancement in Tube Heat Exchanger with Ring Sector Insert

Praveen B [1]
praveenbpillaitt@gmail.com

Venkitaraj K P [2]
kpvraj@gmail.com

Department of Mechanical Engineering,
College of Engineering
Adoor, India

Abstract— **Influence of ring sector insert on heat transfer , friction factor and thermal performance in tube heat exchanger with water as working fluid was investigated. The experiments were conducted in constant heat flux condition and the flow ranging in both laminar and turbulent region. Measure of heat transfer was based on Nusselt number and the pressure drop study was based on friction factor calculation. Effect of variation of pitch of insert was also investigated. The result shows that the average Nusselt number has an increase of 155% to 200% compared to plain tube. There also an increase in pressure drop compared to plain tube. In all with insert shows a better thermal performance factor.**

Index Terms— Ring sector insert, friction factor, Nusselt number **.**

I. INTRODUCTION

Heat exchanger is the apparatus providing heat transfer between two or more fluids, and they can be classified according to the mode of flow of fluid or their construction methods. Heat exchangers with the convective heat transfer of fluid inside the tubes are frequently used in many engineering application. Augmentation heat transfer, in connection with fluid mixing or non mixing, is also involved which most heat exchangers have no contact between the fluids.

At present, the technology of the swirl flow (vortex generator) generators is widely used in various industries. Insertion of swirl flow generators in a tube provides a simple passive technique for enhancing the convective heat transfer by introducing swirl into the bulk flow and by disrupting the boundary layer at the tube surface due to repeated changes in the surface geometry. It has been explained that such inserts induce turbulence and superimposed vortex motion (swirl flow) causing a thinner boundary layer and consequently resulting in a high heat transfer coefficient and Nusselt number due to repeated changes in the insert geometry. Because of low assets and easy setting up, it is widely used, especially in a compact heat exchanger.

In this concept, part of the fluid enters axially while the remainder is injected or directed tangentially at various locations along the tube axis. The radial pressure gradient results in thinning of the thermal boundary layer with an accompanying improvement in heat transfer. The swirl flow induces the turbulence near the tube wall and increases the residence time of the fluid flow in the tube. The higher turbulence intensity of the fluid close to the tube wall associated with the twisted tape is responsible for an excellent fluid mixing and an efficient redevelopment of the thermal/hydrodynamic boundary layer which consequently results in the improvement of convective heat transfer. In fact, swirl induces both desirable heat transfer enhancement and undesirable increase of shear stress and pressure drag in a tube. The latter escorts with the reduction of thermal performance factor which restricts the industrial applications of the twisted tape. Many previous research works signify that the heat transfer enhancing performances of swirl flow generators strongly depend on their geometries. The proper design of swirl flow generators provides an increase of heat transfer rate with a reasonable pressure drop ,resulting in effecting energy saving.

Most of the swirl flows were created by insertion of helical screw tapes[1],helical twisted tape[2][11][12],twin and triple twisted tape[3][4],short length twisted tapes[5],loose fit twisted tapes[6],serrated twisted tapes[7],delta winglet twisted tapes[8],broken twisted tapes[9],spiky twisted tapes[10] etc in the tube. Such inserts, when inserted into tubes, tend to promote turbulence as well as to intensity mixing of the hot fluid and cold fluid. Thin in turn improves the heat transfer process.

The objective of the current work is to study the use of ring sector as VGs for heat transfer enhancement in tubes. The use of VGs for heat transfer enhancement in rectangular channel is popular, but very few literature is available on use of VGs in circular tube. Here our attempt is to get high heat transfer enhancement with less pressure drop penalty. For this purpose specially designed insert assembly was used and results are obtained for different Reynolds number.

II. EXPERIMENTAL SETUP

A. *Schematic of experimental set up*

An experimental test facility is constructed to measure the heat transfer coefficient in smooth tube & tube fitted with ring sector. The sketch of test facility is as shown in figure.(1) and photograph of experimental set up is as shown in figure. (2)

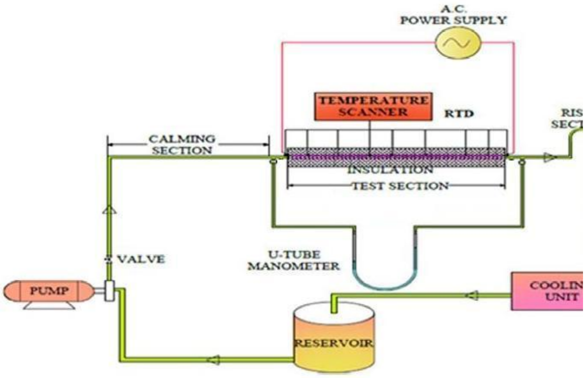

Figure 1. Schematic diagram of experimental set up.

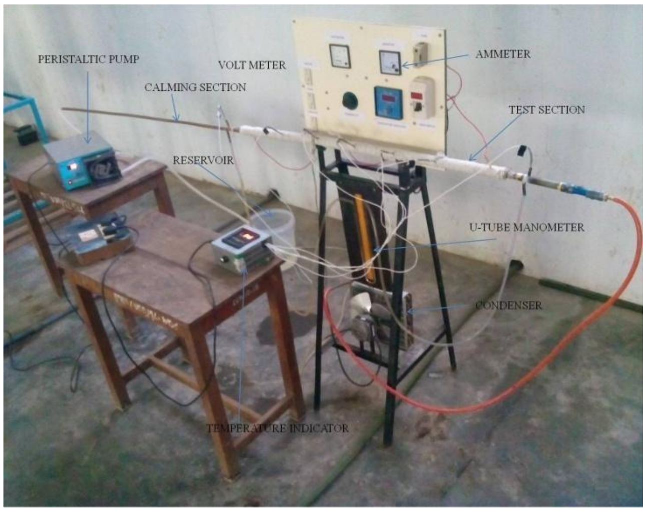

Figure 2. Photograph of Experimental Setup.

The experimental set up consists of a test section, calming section, pump, cooling unit, and a fluid reservoir. Both the calming section and test sections are made of straight copper tube with the dimension 1000 mm long, 10 mm ID and 12 mm OD. The test section tube is wound with ceramic beads coated electrical SWG Nichrome heating wire . Over the electrical winding a thick insulation is provided using glass wool to minimize heat loss. The terminals of the Nicrom wire are attached to an auto-transformer, by which heat flux can be varied by varying the voltage. Five calibrated RTD PT 100 type temperature sensors of are placed in the thermo wells mounted on the test section at axial positions in mm of 170, 350, 510, 680, 850, and from the inlet of the test section to measure the outside wall temperatures. The entry and exit temperatures of the fluid are measured by using two calibrated RTD PT 100 type temperature sensors immersed in the mixing chambers provided at the inlet and exit. A differential U-tube manometer is fitted across the test section to measure the pressure drop.

B. Technical Details of Insert.

The insert using for this work is a ring sector insert for heat transfer enhancement in pipe flow. The typical inserts were fabricated with central rod. The projections of ring sectors were attached to the central rod while the ring sectors were just touching the circular wall. The ring sector has been designed to confirm to the circular geometry of test section. They are made up of 1 mm thick MS sheets. They are attached on 3 mm stainless steel rod at a specified axial location. Different inserts were prepares by varying the axial distance between two adjacent projections.

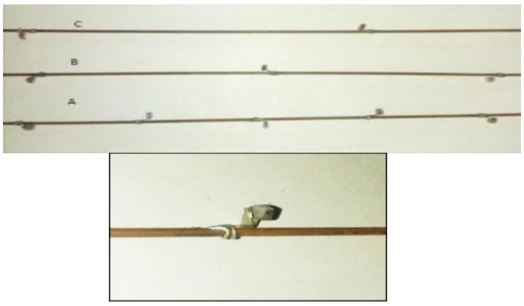

Figure 3. Photogrph of Insert.

III. Data Reduction

Heat carried by the water can calculated by the equation

$$Q = m\ Cp\ (T_{out} - T_{in}) \quad (1)$$

Where m is the mass flow rate,Cp is the specific heat capacity of water, $(T_{out} - T_{in})$ is the temperature difference between inlet and outlet.

Mean convective heat transfer coefficient h can be find by

$$h = \frac{q}{T_w - T_f} \quad (2)$$

where q is the heat flux,Tw-the average wall temperature and Tf- average fluid temperature.

The Nusselt number (Nu) with inserts is calculated in terms of heat transfer coefficient, diameter of tube (D) and thermal conductivity (k) as

$$N_u = \frac{hD}{k} \text{Nu} \quad (3)$$

The pressure drop(Δp) measured across the test section under isothermal condition is used to determine the friction factor (f) using the following relation

$$f = \frac{\Delta pD}{\frac{1}{2}\rho V^2 L} \quad (4)$$

The thermal performance ratio is defined as the ratio of Nusselt number for tube with insert to that of the plain tube at the same level of pumping power.

$$\eta = \frac{N_{ur} / N_{upt}}{(f_r / f_{pt})^{0.33}} \quad (5)$$

The experiment has been performed for different Reynolds number and pitches.

IV. RESULTS AND DISCUSSIONS

The objective of the present work were to study the convective heat transfer in pipe flow and effect of ring sector vortex generator. For that the experiment is conducted for plain tube with different Reynolds number flow. From the result the Nusselt number is increasing by increasing the Reynolds number because for more turbulent in high Reynolds number flow and hence the heat trance rate become more. And as a result the wall temperature is decreasing as Reynolds number increase. In order to study the effect or ring sector insert the experiment is conducted by inserting the ring sector inset of different pitches. It is observed that the Nusselt number is increasing when vortex generator in placed inside the tube because the insert generates more turbulence in flow.

The results are obtained in plain tube and inserts with different pitches. The result of this study is presented in term of Nusselt number,friction factor and thermal performance factor as function of influencing parameter of ring sector

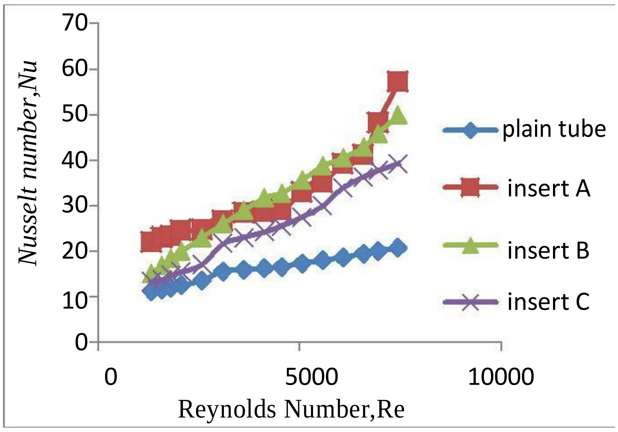

Figure.4 .Variaton of Nusselt number for three inserts

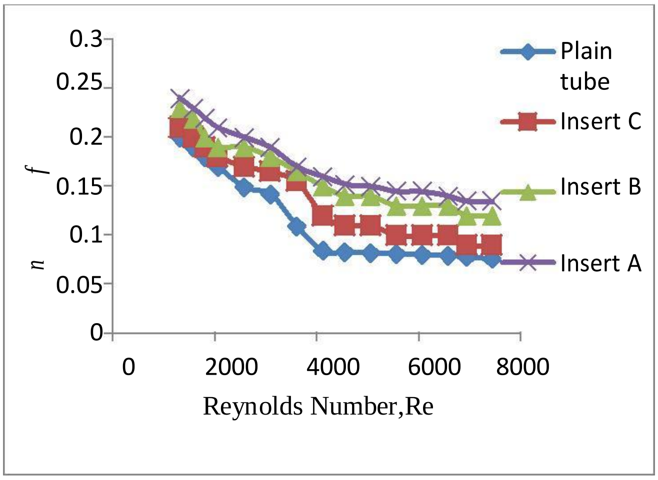

Figure.5.Varition of friction factor for three inserts

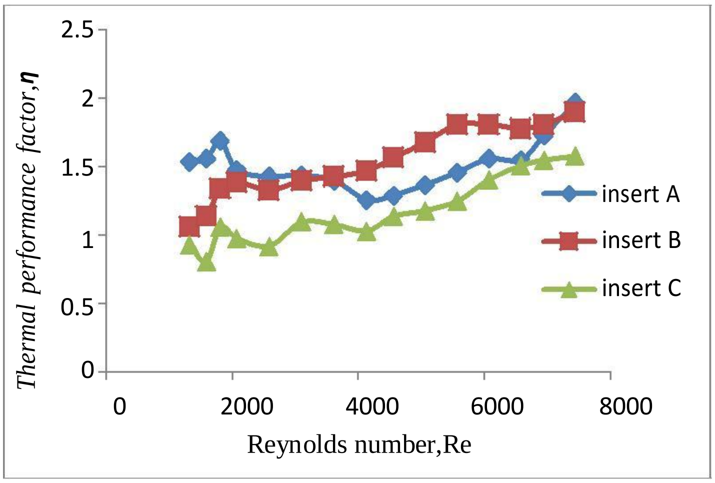

Figure.6.Thermal performance factor of three inserts

From the result it is evident that the Nusselt number is increasing when insert is placed inside the tube. Along that to observe the effect of variation of pitch ,three different pitched inserts are placed. The variation in Nusselt number with insert is shown in Fig.4. The result shows increase in friction factor than in plain tube .This is due the presence of an obstruction to the flow when inserts are placed. The variation in friction factor shown in fig 5.

From result it is evident that the insert the projections are closely arranged insert have more increase in Nusselt number than the other two. And the insert B has better increase in Nusselt number than the insert C. This is due the effect of more vortexes creation for inserts. It can be understood from those figure that the friction factor is more for insert-A than the other two insert and for insert-B has more than insert-C. This is due the fact that, as the pitch increase the obstruction to the flow is also increasing and hence friction factor.

The effect of ring sector insert is studied using the evaluation of thermal performance factor. The value of thermal performance factor must be greater than unity for a net gain in system. The Fig.6 shows the variation of thermal performance factor of three inserts. It can be under stood that the values are greater than unity .This indicate that the proposed insert are feasible in terms of energy saving in both laminar and turbulent flows.

V. CONCLUSIONS

The following conclusion are derived from the detailed analysis presented in the result and Discussions

1. Experimental study on convective heat transfer in straight circular plain tube shows that the Nusselt number increases with increase in Reynolds number and hence more heat removing from the tube wall.

2. From the comparison of heat transfer with ring sector insert-A and plain tube ,it has an enhancement of 200% in average Nusselt number.

3. The shows that by using ring sector insert –B ,there is an increase of average Nusselt number about 194% than in plain tube.

4. With ring sector insert –C ,the result shows an increase in average Nusselt number in the range of 155% compared with plain tube flow.

5. From the comparison of thermal performance factor, insert- B shows better performance.

ACKNOWLEDGMENT

The authors wish thank to TEQIP PHASE-II organized by world bank for its financial support to this work.

REFERENCES

[1] S. Suresh , K.P. Venkitaraj, P. Selvakumar Comparative study on thermal performance of helical screw tape inserts in laminar flow using Al2O3/water and CuO/water nanofluids, Elsevier Superlattices and Microstructures 49 (2011) 608–622

[2] S. Jaisankar, T.K. Radhakrishnan, K.N. Sheeba, Studies on heat transfer and friction factor characteristics of thermosyphon solar water heating system with helical twisted tapes, Energy 34 (2009) 1054–1064.

[3] S.W. Chang, K.W. Yu, M.H. Lu, Heat transfers in tubes fitted with single, twin and triple twisted tapes, Experimental Heat Transfer 18 (2005) 279–294.

[5] S. Eiamsa-ard, C. Thianpong, P. Eiamsa-ard, Turbulent heat transfer enhancement by counter/co-swirling flow in a tube fitted with twin twisted tapes, Experimental Thermal and Fluid Science 34 (2010) 53–62.

[6] S. Eiamsa-ard, C. Thianpong, P. Eiamsa-ard, P. Promvonge, Convective heat transfer in a circular tube with short-length twisted tape insert, International Communications in Heat and Mass Transfer 36 (2009) 365–371.

[7] S. Eiamsa-ard, K. Wongcharee, S. Sripattanapipat, 3-D Numerical simulation of swirling flow and convective heat transfer in a circular tube induced by means of loose-fit twisted tapes, International Communications in Heat and Mass Transfer 36 (2009) 947–955

[8] S.W. Chang, Y.J. Jan, J.S. Liou, Turbulent heat transfer and pressure drop in tube fitted with serrated twisted-tape, International Journal Thermal Science 46 (2007) 506–518.

[9] S. Eiamsa-ard, K. Wongcharee, P. Eiamsa-ard, C. Thianpong, Heat transfer enhancement in a tube using delta-winglet twisted tape inserts, Applied Thermal Engineering 30 (2010) 310–318.

[10] S.W. Chang, T.L. Yang, J.S. Liou, Heat transfer and pressure drop in tube with broken twisted tape insert, Experimental Thermal and Fluid Science 32 (2007) 489–501.

[11] S. Jaisankar, T.K. Radhakrishnan, K.N. Sheeba, Experimental studies on heat transfer and friction factor characteristics of forced circulation solar water heater system fitted with helical twisted tapes, Solar Energy 83 (2009) 1943–1952.