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Heat transfer enhancement in double pipe heat exchanger with swirling flow using tangential entry

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ABSTRACT

In this paper, undertaken a process for improving the efficiency of heat transfer to flowing fluid in double pipe heat exchanger by placing the injectors on the heat exchanger tube. The injectors are designed and mounted to create tangential flow in tube. Experiment was performed for water as working fluid, hot water flowing through inner tube and cold water flowing through annulus space to which swirling motion is imposed. five nozzles having 4.5 mm exit diameter are placed equidistance along the tube of length 1000 mm. inner tube of M.S. having I.D.=16 mm & O.D.=21 mm and outer tube of U-PVC having I.D.=35 mm & O.D.= 42 mm used for experimentation. Experiment was repeated for parallel and counter flow for different values of Reynolds number ranging from 2300 to 5100. The results showed that, the value of Nusselt number increases with increase in value of Reynolds number. 23 % to 75 % enhancement could be accomplished in heat transfer rates with this kind of swirl generation method compared to heat exchanger without swirl generators. It is seen that maximum enhancement can be seen at lower value of Reynolds number. The major mechanisms of heat transfer enhancement observed are 1. Local turbulence is created by pushing the colder fluid near hot wall hence significant mixing of the fluid is carried out. 2. High local turbulence is created due to injection induced swirl promotes mixing of fluid thus heat transfer. 3. Level of turbulence decreases in axial direction along the tube but that turbulence intensity kept same along the tube by placing the nozzles along the tube.

Keywords— Heat Exchangers, Passive method, Swirl Flow, Heat Transfer Enhancement, Tangential Entry

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I. INTRODUCTION

Heat exchangers are widely used in industrial and engineering applications. Enhancing heat transfer are used in many engineering applications such as heat exchanger, air conditioning, chemical reactor and refrigeration systems, hence many techniques have been investigated on enhancement of heat transfer Active and Passive methods have been applied and studied experimentally to enhance heat transfer in heat exchanger. In methods the heat transmission is increased by gaining additional flow energy to fluid where as in passive methods some of flow energy of fluid is utilized. One way for enhancing heat transfer is to improve swirling motion to flowing fluid to increase swirl intensity. There has been a vast literature on these methods available of increasing heat transfer in last decade [1]. Dhir and Chang [2]-[3] studied heat transfer enhancement using tangential injection. Experiments were performed with air as test fluid. They showed that tangential injection an average enhancement of 35 to 40% in heat transfer obtained on constant pumping power. Tangential injection of air through injectors arranged on periphery at entrance section of tube enhances heat transfer due to two major mechanisms maximum axial velocity at wall and high turbulence level in middle of tube improves mixing. Kurtbas et.al [4] used conical injector type swirl generator which is also a prominent technique to improve heat transfer rate which depends on director angle and diameter of the injectors. Ebru karak et.al [5] carried out swirl generation by placing the different arrangement of holes at the entrance section of

the tube. 130% enhancement could be accomplished in heat transfer with this type of swirl generator. Eiamsa-ard et al. [6] studying the heat transfer, friction loss and enhancement efficiency behaviours in a heat exchanger tube equipped with propeller type swirl generators at several pitch ratios. The swirl generator is used to create a decaying swirl in the tube flow. The results indicate that the use of the propeller leads to maximum enhancement efficiency up to 1.2. Jiajun Chen et.al [7] did numerical simulation of tangential injected swirling pipe flow by using CFD result shows that flow pattern was very sensitive to initial swirl intensity. Axisymetry is achieved by higher swirl number. Ebru karak et al. [8] reported that heat transfer rates of swirl generators with holes for the entrance of fluid were investigated by placing them at entrance section of inner pipe of heat exchanger. Various swirl generators having different arrangements of holes were used for water to water heat exchanger. For Reynolds number 8500-17500 heat transfer enhancement is 130% than heat exchanger without swirl element.

II. EXPERIMENTAL SETUP

Experimental set up used to study is shown in Fig.1. Five nozzles having 4.5 mm exit diameter are placed equidistance along the tube of length 1000 mm. inner tube of M.S. having I.D.=16 mm & O.D.=21 mm and outer tube of U-PVC having I.D.=35 mm & O.D.= 42 mm used for experimentation. Experiment was repeated for parallel and counter flow for different values of Reynolds number ranging from 2300 to 5100. In this and experiment hot water was passed through inner tube of mild steel, while cold water was passing through annulus space. Hot water was achieved by auxiliary heater as well as heater provided to the setup. The mass flow rate of cold water and hot water was varied from 300 LPH to 600 LPH in step of 50 LPH simultaneously and temperature of inlet and outlet of hot and cold water were recorded. also the experiment was repeated for varying flow rate of cold water from 300 Lpm to 650 LPH in step of 50 LPH keeping flow rate of hot water constant i.e. 300 LPH and temperature were recorded. Temperatures of cold water and hot water inlet and outlet were measured with the help of PT-100 thermocouples.

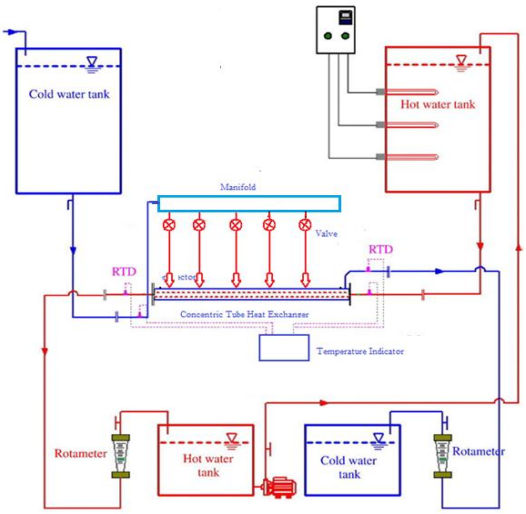

Fig.1 Schematic of Experimental set up

III.DATA REDUCTION

For fluid flows in a concentric tube heat exchanger, the heat transfer rate from the hot water in the inner tube can be expressed as:

$$Q_h = mc\ Cp(Thi - Tho)$$

Heat transferred to the cold water in the test section

$$Q_C = mh\ Cp(Tci - Tco)$$

The average heat transfer rate for hot and cold water side

$$Q_{avg} = \frac{Qc+Qh}{2}$$

The overall heat transfer coefficient

$$Uo = \frac{Qavg}{Ao\ \Delta Tlm}$$

Cold water side heat transfer coefficient (h) is estimated using the correlation of Gnielinsky correlation equation:

$$Nu = 0.012(Re^{0.87} - 280)Pr^{0.4}\left\{1 + \left(\frac{D}{L}\right)^{\frac{2}{3}}\right\}$$

Reynolds number can be calculation by using

$$Re = \frac{\rho\ V\ Dh}{\mu}$$

Heat transfer coefficient on cold water side (h) can be calculated by

$$Nu = \frac{h\ D_h}{K}$$

D_h- Hydraulic diameter of Tube = D_o - D_i

Thermo physical Properties of water are selected at mean water temperature,

$$T_{avg} = \frac{Ti+To}{2}$$

Experimental value of heat transfer coefficient is calculated by plotting Wilson chart. K is the y intercept which is taken fron the Wilson chart as shown in Fig.2.

$$\frac{1}{h} = \frac{1}{U0} - k$$

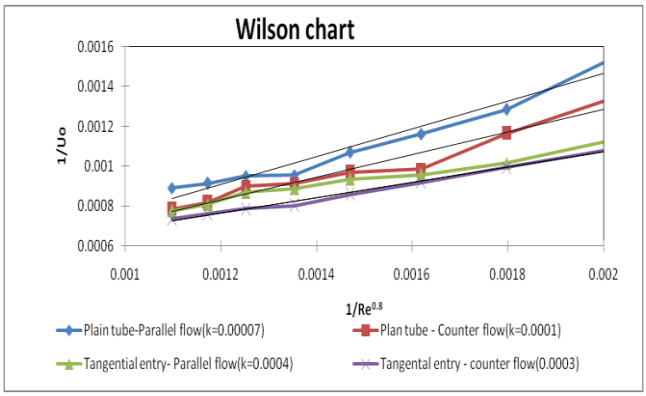

Fig.2 Wilson chart

IV. RESULT & DISCUSSION

The results obtained from experimental investigation of Plain tube and tubes with tangential entry are as follows.

Fig. 3 and Fig. 4 shows the variation in overall heat transfer coefficient with Reynolds numbers which reveals that for parallel and counter flow model value of Uo is higher for tube with tangential entry and it increases with Re.

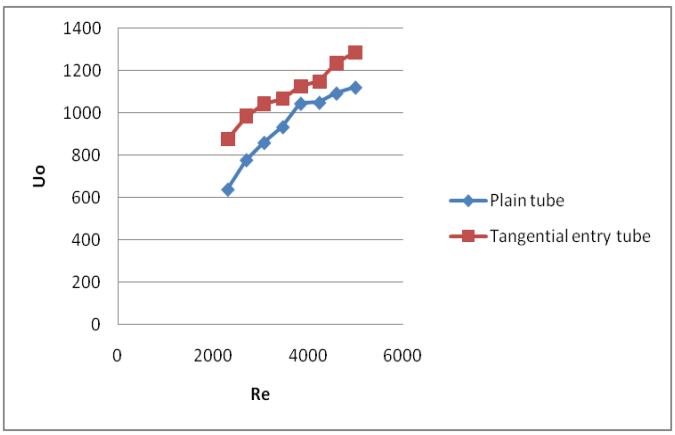

Fig.3 The relation between overall heat transfer coefficient and Reynolds number for Parallel flow

Comparison between Plain tube and tube with tangential entry is shown in Fig. 5. Highest values of Uo obtain in tube with tangential entry for counter flow model. For all the cases the value of Uo increases with Re.

Fig. 6 shows the relation between Nusselt number and Reynolds numbers for parallel flow model. Nu increases with increase in Re for Plain tube as well as for tube with tangential entry. The Nu for tube with tangential entry is 20 % to 70 % than that of plain tube. Maximum enhancement in Nu can be seen at lower value of Re. So for parallel flows model the best operating regime of Re is 2300 to 3000.

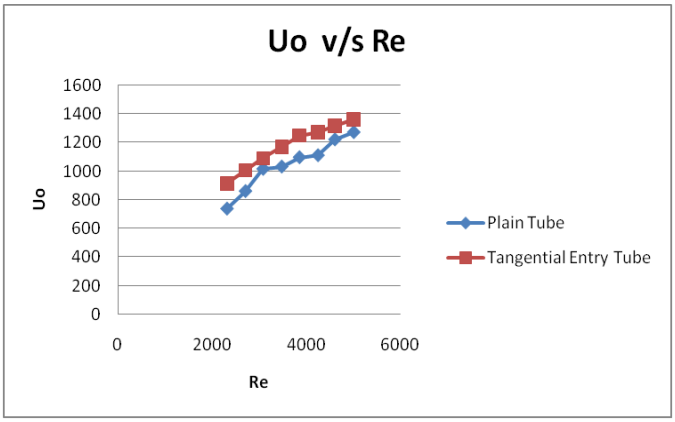

Fig.4 The relation between overall heat transfer coefficient and Reynolds number for counter flow

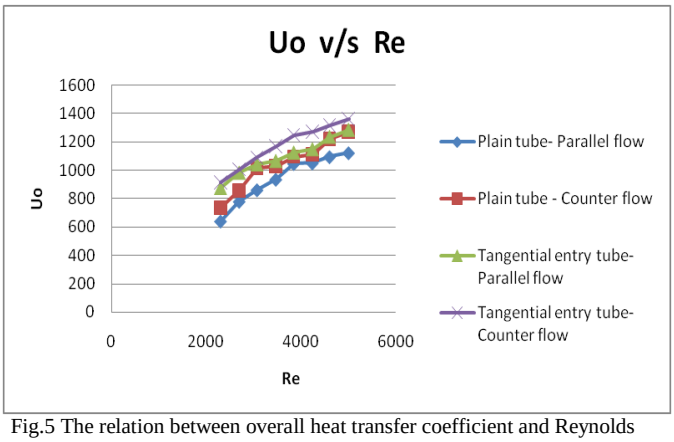

Fig.5 The relation between overall heat transfer coefficient and Reynolds number for Plain tube and Tube with tangential entry.

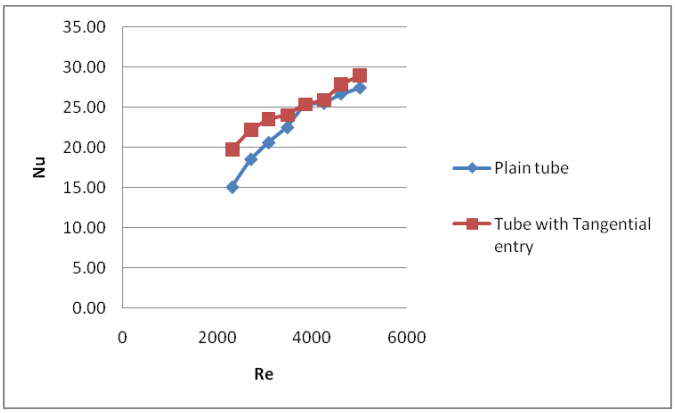

Fig.6 Variation Nusselt number with Reynolds number in Parallel flow.

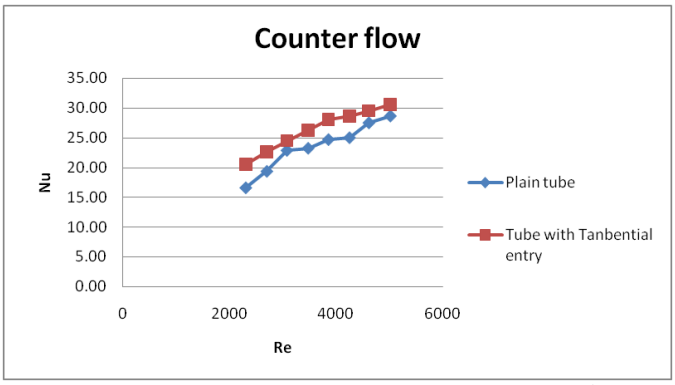

Fig.7 Variation Nusselt number with Reynolds number in Parallel flow

Fig. 7 shows the relation between Nu and Re for counter flow model. Nusselt number is more for the tube with tangential entry and is increases with increase in Reynolds number. It is seen that 23 % to 75 % increase in Nusselt number for the tube with tangential entry over the plain tube. The maximum enhancement in Nu can be seen at lower value of the Re. so the best operating regime of Re for counter flow model is 2300 to 3800. Fig. 8 shows the comparison of plain tube and Tube with tangential entry. Where more heat transfer enhancement carried out in tube with tangential entry in counter flow model.

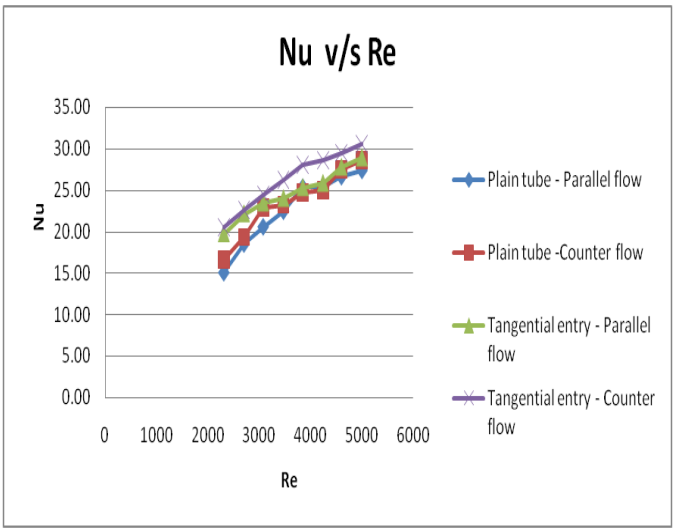

Fig.8 Comparison of Nu as function of Re for Plain tube and tube with tangential entry

V.CONCLUSION

Experimental investigation of tangential injectors used as a heat transfer enhancement device has been carried out. The results summarised as follows

1. For both Plain tube and Tube with tangential entry on cold water side Nusselt number increases with increase in Reynolds number.
2. For parallel flow model 20% to 70% and for counter flow model 23% to 75% heat transfer enhancement could be accomplished with this type of swirl generator over the plain tube. But, highest heat transfer enhancement was seen at lower value of Reynolds number. So best operating range of Re for this experimentation is 2300 to 4000.
3. Heat transfer enhancement carried out by local turbulence created by injection induced swirl which promotes significant mixing of fluid and local turbulence intensity remains constant along the length of tube due to multiple injectors placed along the tube.

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