Heat Transfer Enhancement in Double Tube Heat Exchanger with Multiple Tangential Entries Along the Length

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Abstract*- In this work, 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 along the 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 flow model for different values of Reynolds number ranging from 2300 to 5100. For five number of entries are achieved by five nozzle mounted tangential to axis of tube. The results reveals that, enhancement in the value of heat transfer coefficient is about 48 % to 89 % could be accomplished with this kind of swirl generation method compared to heat exchanger without swirl generators. It is seen that maximum enhancement in heat transfer coefficient can be seen 89 % for all five nozzle openings over the plain tube. 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 exchanger, Parallel flow, Heat transfer enhancement, Swirling flow, Tangential entry.

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 concluded 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 SET UP

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 flow for different values of Reynolds number ranging from 2300 to 5100 and for different nozzle openings from single 1-Nozzle opening to all nozzles opening i.e.1-2-3-4-5-Nozzle opening. 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.

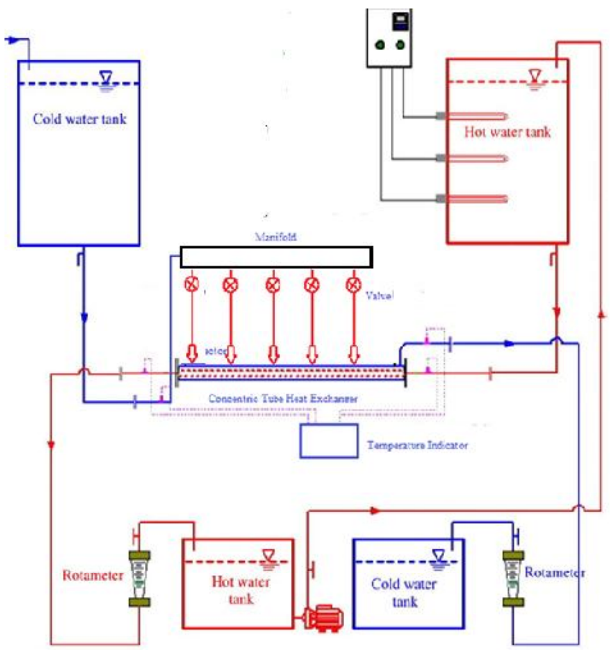

Fig -1: Schematic of Experimental set up

Five nozzles of brass were fitted tangential to the pipe axis which is equidistance along the length of tube. Nozzles are opened one by one from the side of flow of water and the temperatures at the inlet and outlet of cold and hot water is measured.

Fig -2: Photo graph of experimental setup

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:

$$Q_h = m_c C_p (T_{hi} - T_{ho}) \quad (1)$$

Heat transferred to the cold water in the test section

$$Q_c = m_c C_p (T_{co} - T_{ci}) \quad (2)$$

The average heat transfer rate for hot and cold water side

$$Q_{avg} = \frac{Qc + Qh}{2} \quad (3)$$

The overall heat transfer coefficient

$$Uo = \frac{Qavg}{Ao\,\Delta Tlm} \quad (4)$$

Theoretical heat transfer coefficient (h) on Cold water side is estimated using the correlation of Gnielinsky correlation equation [9]

$$Nu = 0.012(Re^{0.87} - 280)Pr^{0.4}\left\{1 + \left(\frac{D}{L}\right)^{\frac{2}{3}}\right\} \quad (5)$$

Reynolds number can be calculation by using

$$Re = \frac{\rho\, V\, Dh}{\mu} \quad (6)$$

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

$$Nu = \frac{h\, D_h}{K} \quad (7)$$

D_h- Hydraulic diameter of Tube = D_o - D_i

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

$$T_{avg} = \frac{Ti + To}{2} \qquad (7)$$

Experimental value of heat transfer coefficient is calculated by plotting Wilson chart [10]. K is the y intercept which is taken from the Wilson chart as shown in Fig.3.

$$\frac{1}{h_{Expt}} = \frac{1}{U} - k \qquad (8)$$

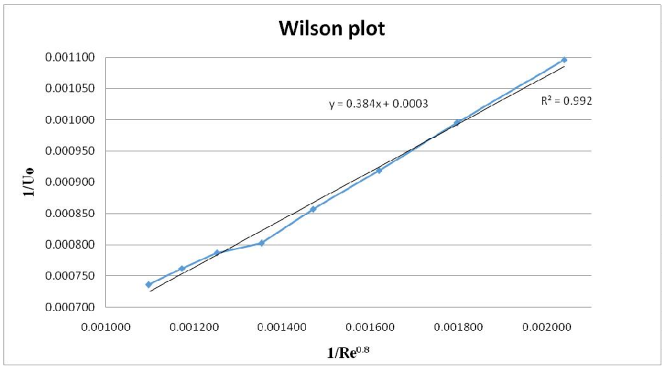

Fig -3: Wilson chart [10]

VI. RESULTS AND DISCUSSION

Experiment was repeated for the different Reynolds number for different nozzle openings. Results obtained for parallel flow model for overall heat transfer coefficient and heat transfer coefficient for cold water side are predicted in following graphs

Fig .4 shows the variation of heat transfer coefficient with Reynolds number for parallel flow model with different nozzle opening. It is observed that experimental value of Heat transfer coefficient (h_{Expt}) increases with increase in Reynolds number (Re). Smallest value of h_{Expt} is 489 W/m2k at lowest value of Re 2300 is observed it reaches to maximum up to 896 W/m2 k for Re value of 5100 for single nozzle opening. As the number of nozzle opening increases value of h_{Expt} also increase with increase in Re. Highest h_{Expt} is seen in all five nozzle openings ranging from 1257 – 2296 W/m^2k.for the 2300 - 5100 range of Re.

As the numbers of openings are more along the tube length the local turbulence enhances the heat transfer rate. Enhancement in h_{Expt} in each nozzle opening in step is very significant. 36% Enhancement in h_{Expt} for 1-2-Nozzle opening over 1-nozzle opening. 62% Enhancement in h_{Expt} for 1-2-3-Nozzle opening over 1-2 nozzle opening. 12% Enhancement in h_{Expt} for 1-2-3-4-Nozzle opening over 1-2-3 nozzle opening and 5% Enhancement in h_{Expt} for 1-2-3-4-5 Nozzle opening over 1-2-3-4 nozzle opening. Maximum enhancement is seen for three nozzle openings so for parallel flow model minimum three openings are required for better heat transfer enhancement for the 2300 -5100 range of Re.

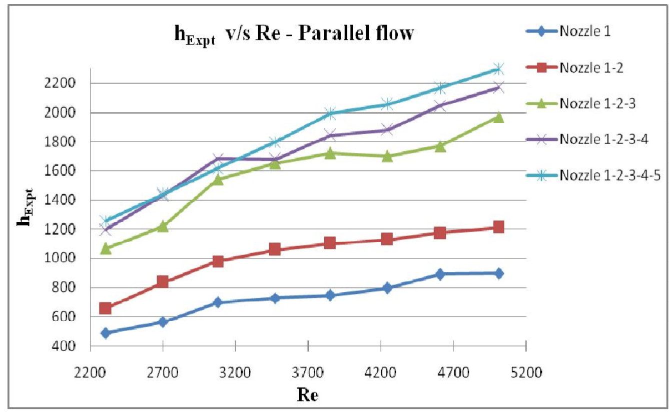

Fig -4: h_{Expt} v/s Re for Tube with tangential entry for different nozzle openings.

Fig. 5 shows the comparison between the plain tube and tube with tangential entry with different nozzle openings. It is seen that h_{Expt} increases with increase in Re for both the tube. For plain tube h_{Expt} value is varies from 670-1218 W/m^2k for range of Re 2300-5100. As compared to tangential entry tube with 1-nozzle and 1-2-nozzles opening plain tube is efficient and gives better results. 25% -34% more h_{Expt} is observed over the 1-nozzle open and 1%-2% more h_{Expt} s observed over 1-2-nozzle openings.

For 1-2-3-nozzles, 1-2-3-4-nozzles and 1-2-3-4-5-nozzle openings value of h_{Expt} dominates over the plain tube value. About 48% - 68%, 63% - 84% and 75% - 89% enhancement in h_{Expt} for 1-2-3-nozzles openings, 1-2-3-4-nozzles and 1-2-3-4-5-nozzle openings over the plain tube is achieved respectively. For parallel flow model consecutive three openings of nozzles are required for the better results.

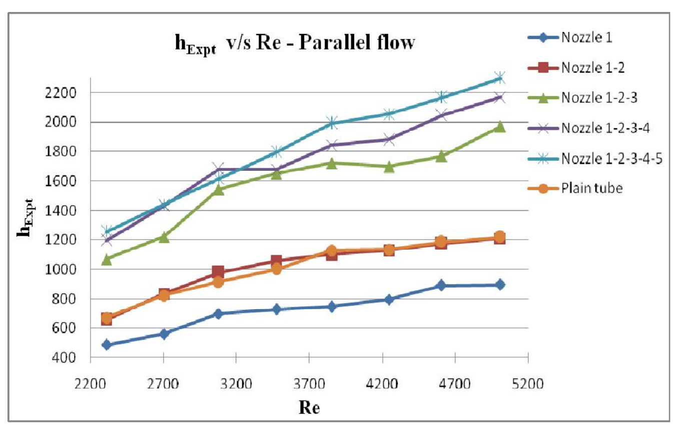

Fig -5: h_{Expt} v/s Re for plain tube and tube with tangential entry with different nozzle openings.

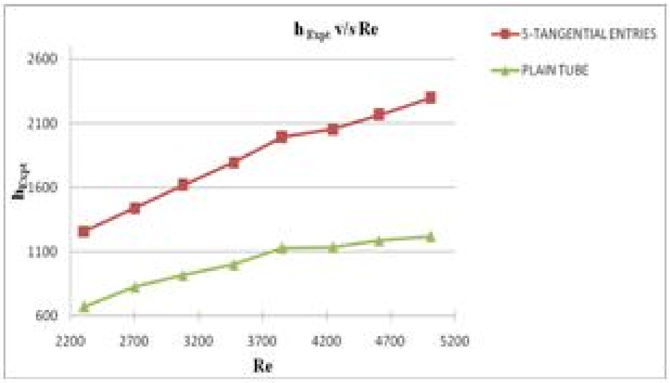

Fig -6: h_{Expt} v/s Re for plain tube and tube with tangential entry with all entries open.

Relation between h_{Expt} and Re for Plain tube and tube with all entries open is shown in fig 6. Heat transfer coefficient enhancement of Tangential entry tube with all five entries open is of 75% to 89% over the plain tube could be accomplished. As the Re increases enhancement in h_{Expt} also increase and reaches to maximum for higher value of Re.

V. CONCLUSIONS

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 experimental Heat transfer coefficient increases with increase in Reynolds number.
2. For parallel flow model 75% to 89% heat transfer enhancement could be accomplished with this type of swirl generator over the plain tube. Highest heat transfer enhancement was seen at higher Reynolds number. So best operating range of Re for this experimentation is 4000-5000.
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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BIOGRAPHIES

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