Experimental Investigation of Exergy & Energy Analysis of Double Pipe Heat Exchanger using Twisted Tape

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Abstract— Energy saving aspects is very important in the design, construction and operation of industrial heat exchangers. Exergy analysis is the relatively recent method to identify the location of maximum exergy destruction so that necessary action can be taken to increase the performance of the thermal system. Many researchers have attempted to increase the effective contact surface area with fluid to increases the heat transfer rate, and to reduce the entropy generation, entropy generation number. Therefore energy saving aspects is very important in the design, construction and operation of the heat exchangers. For this reason, various active or passive methods have been sought to save energy by increasing the heat transfer coefficients in the cold and warm fluid sides in the heat exchangers. Twisted are best passive techniques in studied in literature. Hot water and cold water are used as working fluids. Here cold water are passed through tube side and hot fluid passing through annulus side. The test runs was done at cold water mass flow rates ranging between 0.034kg/s and 0.102 kg/s and hot water mass flow rate between 0.034kg/s and 0.102 kg/s respectively. The inlet hot water and inlet cold water temperatures are between 400C and 56 °C, and between 27 °C and 32 °C, respectively. The effects with simple twisted tape and without twist insert on both working fluids flowing through the heat exchanger on exergy analysis parameter like effectiveness, entropy generation rate, entropy generation number and exergy loss are discussed and also find the effect of energy analysis parameter like overall heat transfer coefficient, Nusselt number.

Key words: Entropy Generation, Exergy Loss, Double Pipe Heat Exchanger, Second Law, Simple Twisted Tape

I. INTRODUCTION

Basically heat exchangers are classified as Tubular type, Shell and Tube type, Finned Tube type, Compact type heat exchangers according to geometry and Direct type, Recuperator type and Regenerator type according to heat transfer process. Tubular type heat exchangers known as Double Pipe heat exchangers are simple in construction and widely used. Different types of heat exchangers are extensively used in various industries to transfer the heat between cold and hold stream. The key role of the heat exchanger is to transfer heat at maximum rate. The enhancement in heat transfer rate is possible to achieve by two steps viz. (1) to optimize the design of the heat exchanger and (2) to optimize the operational parameters. To optimize the operational parameters play a key role in enhancement of heat transfer rate after the design of heat exchanger. Twisted tape, twisted ducts are most common examples of active method for enhancement of heat transfer rate. Twisted tape inserts are widely used because it increases the heat transfer coefficients considerable with minimum pressure drop. The basic fundamentals of thermodynamics provide the concept of energy, energy transfer, energy balance, entropy balance at equilibrium conditions. The second law of thermodynamics targets energy balance. Exergy is the maximum useful work under the given environmental condition. It depends on the state of the system under consideration and state of environment. Inefficiencies in the process and place of inefficiencies can be very well identified using exergy analysis and thus, an exact place of improvement can be selected for overall improvement. Traditionally, thermodynamic analysis based on first law represents utilization of energy only. It does not provide idea about losses and place of losses. Thus, application of exergy analysis has widely adopted in place of first law analysis. Based on the exergy analysis, various systems can be compared for thermodynamic inefficiencies. The performance of the system can be improved by identifying the area of maximum exergy destruction and modifying the design/parameters to enhance the exergy efficiency. Exergy analysis only suggests the area of maximum exergy destruction which can be modified. But along with exergy analysis, the cost associated with the modification and payback period is also essential. The overall cost of the system increases with increase in the exergetic efficiency. Thus, increase in the economic cost of the system is followed by improvement in performance of the system. Thermo-economic analysis combines thermodynamic and economic analysis which is termed as exergy-economic analysis. Stages involved in exergy-economic analysis are as under.

- To carry out detailed exergy analysis
- To carry out economic analysis
- To carry out exergy costing
- To carry out exergy-economic evaluation of all Sub-systems

Exergy analysis is carried out using Entropy Generation Minimization (EGM) and Exergy Destruction Method (EDM). EGM methods targets to find the design in which the entropy generation is minimum while in EDM, exergy balance is carried out.

M. Yilmaz et al. [1], in 2001, have studied double pipe heat exchanger based on second-law based analysis and evaluated the effect of entropy, exergy, entropy generation minimization and entropy generation number. Ebru Kavak Akpinar and Yasar Bicer [2] in 2004 have studied the effect on heat transfer rates, friction factor and exergy loss of various swirl generators having circular holes at different number and diameter on double pipe heat exchanger. They have experimentally observed that Heat Transfer rates increase with decrease in diameter and with increase in number of holes on the swirl generators. They have also found increase in the dimensionless exergy loss and NTU with the increase in number of holes number and the decrease in diameter of hole. Paisarn Naphon [3],in 2006, worked on experimental analysis of second law analysis on the heat transfer and flow of a horizontal concentric tube heat exchanger using hot water and cold water as working fluids. They have checked the effects of the inlet conditions of both working fluids (water) flowing through the heat exchanger on exergy loss, heat transfer characteristic and entropy generation. Paisarn Naphon [4], in 2010, has investigated experimentally and theoretically on the entropy generation, exergy loss of a horizontal concentric micro-fin tube heat exchanger with a central finite difference method. Hakan Karakaya and Aydin Durmus [5], in 2012, have found the effect on heat transfer, pressure loss and exergy analysis for the conditions with and without tabulators. Parth P. Parekh and Chavda N. K. [6], in 2014, have carried out experimental and exergy analysis

Based on second law analysis of a double-pipe heat exchanger for parallel flow arrangement. Very few papers have appeared on exergy analyses of concentric heat exchanger with swirl generator [2, 3].

Shyy W. C. et al. [7], in 2007, have experimentally double pipe heat exchanger with a broken twisted tape with different twist ratio and their effect of heat transfer coefficients, mean fanning friction factors and thermal performance. Anil Singh Yadav [8], in 2009, has studied the heat transfer and pressure drop characteristics of double pipe heat exchanger with twisted tape experimentally. The found that heat transfer rate and heat transfer coefficient increases than plain heat exchanger. Bhardwaj et al. [9], in 2009, have experimentally determined pressure drop and heat transfer characteristics of flow of water in copper tube with twisted tape insert. They have found that the direction of twist (clockwise and anticlockwise) effect the thermo-hydraulic characteristics.

S. Eiamsa-ard et al. [10], in 2010, have studied experimentally double pipe heat exchanger with aluminium delta winglet twisted tape having different twist ratio and depth of wing cut ratio and water as the working fluid. They found that Nusselt number and mean friction factor in the tube with the delta-winglet twisted tape increase with decreasing twisted ratio and increasing depth of wing cut ratio (DR). S. Naga Sarada1 et al. [11] in 2010, have carried out experiments on double pipe heat exchanger with varying width twisted tapes having different twist ratios (3, 4 and 5), (26-full width, 22, 18, 14 and 10 mm) and pitches (82.5, 110, and 137.5 mm). They have found enhancement of heat transfer with twisted tape inserts as compared to plain tube varies from 36 to 48% for full width (26mm) and 33 to 39% for reduced width (22 mm) inserts. P. Murugesan et al. [12], in 2011, have carried out experimental investigation on the double pipe heat exchanger with plain twisted tapes and U–cut twisted tapes with different twist ratio. They have found that U–cut twisted tapes can be used to reduce the size of heat exchanger.

A. García et al. [13], in 2012, have analysed the thermal hydraulic behaviour of three types of enhancement technique based on artificial roughness like corrugated tubes, dimpled tubes and wire coils. They investigated heat transfer and pressure drop in laminar, transition and turbulent regimes. They were found that the shape of the artificial roughness exerts a greater effect on the pressure drop characteristics than on the heat transfer augmentation. Veeresh fuskele et al. [14], in 2012, have investigated the double pipe heat exchanger with twisted tape wire mesh of twist ratio 5.0 and 7.0. They have predicted that the heat transfer coefficient and friction factor increases with the decrease in twisted twist ratio compared with smooth tube experimentally.

S. D. Patil et. al.[15], in 2012, have investigated the heat transfer and friction factor characteristics of double pipe heat exchanger fitted with straight delta winglet made of aluminium strip with thickness of 2.01 mm and the length of 1500 mm. They found that the heat transfer coefficient increases with decrease in the twist ratio (y/w). Bodius Salam et al. [16], in 2013, carried out experimental investigation on a circular tube fitted with stainless steel rectangular-cut twisted tape insert of 5.25 twist ratio. M. M. K. Bhuiya et al. [17], in 2013, have studied experimentally double pipe heat exchanger with mild steel twisted tape inserts having different twist ration and pitches. They have found that the Nusselt number, friction factor and thermal enhancement efficiency increases with decreasing twist ratio. They have also found that the heat transfer rate and friction factor were 60 to 240% and 91 to 286% higher than those of the plain tube values.

Maughal Ahmed Ali Baig et al. [18] in 2013 have worked on the concentric tube heat exchanger with twisted tapes. M. M. K. Bhuiya et al. [19] in 2013 have studied brass double pipe heat exchanger with mild steel perforated twisted tapes having different twist ratio. They have found that perforated twisted tape offers a higher heat transfer rate, friction factor and thermal performance factor compared to that of the plain tube. Snehal S. Pachegaonkar et al. [20] in 2014 have analysed heat transfer and pressure drop characteristics of double pipe heat exchanger with annular twisted tape insert having different twist ratio. A.V. Gawandare1 et al. [21] in 2014, experimentally investigated the double pipe heat exchanger with different square jagged twisted tapes. Experimental work have been carried out with copper twisted tape width 12 mm, 3 mm thickness, 100 mm length and twist ratio 5.2, 4.2 and 3.2.

It is therefore the purpose of this work to study the effect of a number of different swirl generators on the heat transfer, friction factor, effectiveness, entropy generation rate and dimensionless exergy loss. Swirl generators in this work have got different properties from the works at the literature. The twisted tape is best passive technique for heat transfer enhancement given in literature with different parameter effect like twist ratio, pitch variation, and angle etc. effect on heat enhancement. [7-20].

Twist ratio and twisted angle is crucial role in heat transfer were given literature. So that New modified twisted tape with inside tube side flow. However, in the case of hot water flowing in an annulus and cold water through the tube side, heat transfer enhancement on the inside wall is important. The heat transfer from hot water to cold water through the tube is influenced by three components, namely: the thermal convection resistance of

The condensing hot water on the inside of the outer tube (1/hoAo), the conduction resistance of the tube wall (ln (ro/ri)/ (2πkL) and the convection resistance (1/hiAi) of the Water in the tube side. The tube wall is thin and has a high thermal conductivity (k) as it is generally manufactured from copper or stainless steel. The result is that the wall's Thermal resistance is negligibly small in comparison with the two convection resistance terms. The heat transfer coefficient of condensing water (ho) is usually relatively large in comparison with the convection coefficient (hi) of the water in the tube side. Therefore, the thermal resistance is the highest on the tube side of the wall and that is the reason why heat transfer enhancement on the inside wall of the outer tube can make an important contribution to deliver higher hot-water temperatures. [20]

II. Experimental Set-Up and Procedure

A. Experimental Set Up

The schematic diagram of the experimental set up is shown in Fig 1. The test section was made from 1600 mm of copper tube (16 mm ID and 19 mm OD), of which 1500 mm was considered to be the test section. A stainless steel twisted tape was made by twisting 1.75 mm thickness, 15.75 mm width (w) straight strip. Tape pitch (y) of 89 mm was made which gave twist ratio (y/w) 5.65 and modified twisted tape made hole in twisted tape 2 mm and distance between two hole(c) = 10 mm, distance between two

B. Experimental Method

Fig.1.shows the experimental setup. It counter flows double pipe heat exchanger. Insulation of glass wool was provided on the outer side of outer pipe to reduce the heat loss. The tank contains fluid (water) which is heated with the help of attached heater with hot water tank. The hot fluid from the hot water tank was going to the annulus side inlet through rotameter. Pump was providing between hot water tank and rotameter. Outlet of hot fluid is collected in hot water tank. Another fluid (cold water) passing to inlet of inner pipe in counter direction through rotameter. And outlet of cold water was drainage. Temperature of both pipes at the inlet as well as the outlet is measured with the

Help of thermocouple. Rotameter at inlet of both pipe measure flow rates. Pressure of fluid in inner pipe can be measured with the help of manometer.

Experiments were performed with various inlet temperatures and flow rates of hot water entering the test section. In the experiments, the cold water flow rate was increased in small increments while the hot water flow rate is constant, inlet cold water and hot water temperatures were kept constant. The inlet hot and cold water temperatures were adjusted to achieve the desired level by using electric heaters controlled by temperature controllers. Before any data were recorded, the system was allowed to approach the steady state. The flow rates of the water are Controlled by adjusting the valve and measured by two calibrated flow meters with a range of 0.034- 0.102 kg/s.

The average value of heat transfer rate is obtained by the supplied heat by hot water and the absorbed heat by cold water. The uncertainties of measurements data and the relevant parameters obtained from the data reduction process are calculated. The uncertainty and accuracy of the measurements are given in Table 2. The maximum uncertainties of the relevant parameters in the data calculation are based on Coleman and Steel method [25]. Readings are being taken for following types of inserts and noted in the observation table with 1. Without any insert (plain tube) 2. Simple Twisted tape inserts 3.Modified twisted tape insert .Before starting the experimental study on entropy generation method in heat exchanger using inserts, standardization of the experimental setup is done by obtaining energy loss results for different twisted insert comparing them with the standard equations available

III. Analysis

A. Energy Analysis

Hot water and cold water are used as working fluids and take Hot water is outer fluid and cold water is inner fluid here.

Heat transferred by Hot water to cold Water

$$Q_h = m_h * Cp_h * (T_{hi} - T_{ho}) \quad (1)$$

Heat Gained by Cold water to Hot Water

$$Q_c = m_c * C_{pc} * (T_{co} - T_{ci}) \quad (2)$$

Average Heat Transfer Coefficient

$$Q_{avg} = \frac{Q_c + Q_h}{2} \quad (3)$$

Overall heat transfer co-efficient in tube side

$$U_i = \frac{Q_{avg}}{A_i * \Delta T_m} \quad (4)$$

Heat transfer film coefficient tube side

$$h_i = \frac{N_{ui} * K}{d_i} \quad (5)$$

Heat transfer film coefficient shell side

$$h_o = \frac{N_{uo} * K}{D_i - d_o} \quad (6)$$

The overall heat transfer coefficient U (by neglecting thermal resistances of copper tube wall), can be calculated from

$$U_{th} = \frac{1}{\frac{1}{h_i} + \frac{r_i}{r_o} * \frac{1}{h_o} + \frac{r_i}{k_o} \ln\left(\frac{r_o}{r_i}\right)} \quad (7)$$

B. Exergy Analysis

Exergy is the maximum amount of work obtained theoretically at the end of a reversible process in which equilibrium with the environment is attained. According to this definition, the reference environment conditions must be known to calculate exergy. Temperature of the reference environment in this work varied between 20o C with 22 ◦C (ambiance temperature). A heat exchanger is characterized by two types of losses: Temperature difference and frictional pressure drop in the pipe. These losses refer to irreversibility quantity, and some methods have been devised for minimizing these losses [3, 4]. However, in this study, the exergy analysis does not include friction (or pressure drop) irreversibility's and based only heat transfer irreversibility's.

$$S'_{gen} = (mc_p)_h \ln \frac{(T_{h,out})}{(T_{h,in})} + (mc_p)_c \ln \frac{(T_{c,out})}{(T_{c,in})} \quad (8)$$

Where $T_{h,out}$ is the outlet hot-side temperature, $T_{h,in}$ is the inlet hot side Temperature, $T_{c,out}$ is the outlet cold-side temperature, $T_{c,in}$ is the inlet cold-side temperature.

Here we was taken the two case

Case A. The hot-side capacity rate, (m Cp) h, is lower than that of the cold fluid, (m Cp) c. Therefore, the minimum capacity rate, (mCp) min, is replaced by the capacity rate of the hot fluid. The heat exchanger effectiveness, (ε), can be given:-

$$C_h < C_c$$

Where $C_h=m_hC_{ph}$, $C_c=m_cC_{pc}$ and, $C_{min}= m_cC_{pc}$, $C_{max}=m_hC_{ph}$

1) *Effectiveness*

$$\varepsilon = \frac{(mc_p)_c\,(T_{c,out}-T_{c,in})}{(mc_p)_{min}(T_{h,in}-T_{c,in})} = \frac{(T_{h,in}-T_{h,out})}{(T_{h,in}-T_{c,in})} \quad (9)$$

2) *Entropy generation rate*

$$S'_{gen}=C_{min}\ln[1+\varepsilon(T_R-1)]+C_{max}\ln[1-\varepsilon C_r(1-\frac{1}{T_R})] \quad (10)$$

Where

$$C_r=\frac{C_{min}}{C_{max}} \text{ and } T_R=T_h/T_c$$

3) *Entropy Generation Number*

$$N'_s=\ln[1-\varepsilon(1-\frac{1}{T_R})]+\frac{1}{C_r}\ln[1+\varepsilon C_r(T_R-1)] \quad (11)$$

4) *Exergy loss*

$$I'=T_oS'_{gen} \quad (12)$$

Case B. The capacity rate of the hot fluid, $(mC_p)_h$, is higher than that of the cold fluid, $(mC_p)c$. Therefore, the minimum capacity rate, (mCp) min, is replaced by the capacity rate of the cold water. The heat exchanger effectiveness is obtained from

$$C_h < C_c$$

Where $C_h=m_hC_{ph}$, $C_c=mcC_{pc}$ and, $C_{min}= m_cC_{pc}$, $C_{max}=m_hC_{ph}$

5) *Effectiveness*

$$\varepsilon = \frac{(T_{c,out}-T_{c,in})}{(T_{h,in}-T_{c,in})} \quad (13)$$

6) *Entropy generation rate*

$$S'_{gen}=C_{min}\ln[1+\varepsilon(T_R-1)]+C_{max}\ln[1-\varepsilon C_r(1-\frac{1}{T_R})] \quad (14)$$

7) *Entropy Generation Number*

$$N'_s=\ln[1+\varepsilon(T_R-1)]+\frac{1}{C_r}\ln[1-\varepsilon C_r(1-\frac{1}{T_R})] \quad (15)$$

8) *Exergy loss*

$$I'=T_oS'_{gen} \quad (16)$$

C. *Friction factor and pressure drop coefficient*

The experimental pressure drops in the inner test pipe of concentric heat exchanger were measured for air side conditions and were arranged in non-dimensional form by using the following equation:

$$f = \frac{\Delta p}{\left(\frac{L}{D}\right)*\left(\frac{\rho v^2}{2}\right)} \quad (17)$$

Pressure drop coefficient

$$CP = \frac{\Delta p}{\left(\frac{1}{2\rho v^2}\right)} \quad (18)$$

IV. RESULTS AND DISCUSSION

With the values obtained from the experimental data in inner pipe, the changes in the Nusselt numbers with the Reynolds numbers were drawn for various simple twisted tape and modified twisted tape as shown in Fig. 2. The experiments were performed for counter flow arrangement, and results were compared to those obtained from the empty tube. From observation table result indicated that Reynolds number range between 3500-12,000.Relevant tube-side and shell-side heat transfer coefficients are needed. The correlation proposed by Gnielinski [2] to predict shell-side and tube side heat transfer coefficient is as follows and Dittus–Boelter correlation Nu = 0.2274 Re 0.8 Pr 0.4 (describes non-swirling flow in the smooth-tube) [2] is as below

$$N_u = \frac{(f/2)*(Re-1000)*Pr}{1+12.7*\left(\frac{f}{2}\right)^{0.5}*\left((Pr)^{\frac{2}{3}}-1\right)} \quad (19)$$

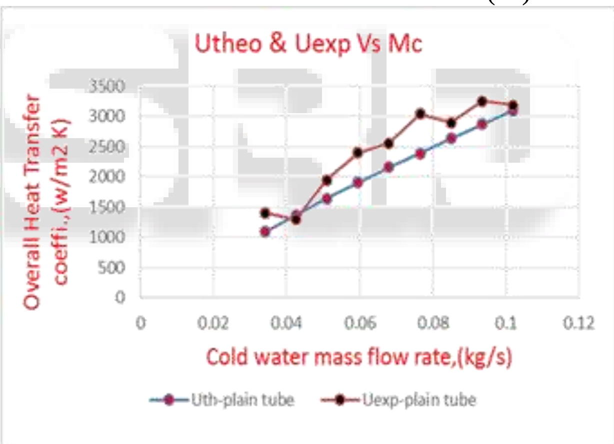

Fig. 3: Variation of overall heat transfer coefficient with cold water mass flow rate for constant hot water mass flow rate for plain tube, simple twisted tape, modified twisted tape

In Fig.3 the U results for Plain Tube, with simple twisted Tape Insert and with modified twisted tape along with the corresponding performance evaluation criteria Re for each of the readings. As depicted in fig.3, U was increased with twisted tape insert as compared to the plain tube results, and there is increase in U, when modified twist insert. At higher mass flow rate of working fluid from the test section difference in U between Plain tube, with twisted tape and modified twist insert was increased. From fig 3 we observe that the U was increased from 521 to 3900 and Re was increased from 3500 to 12000. Maximum value of U can be predicted by modified twist insert in the test section. It directly increases the heat transfer rate.

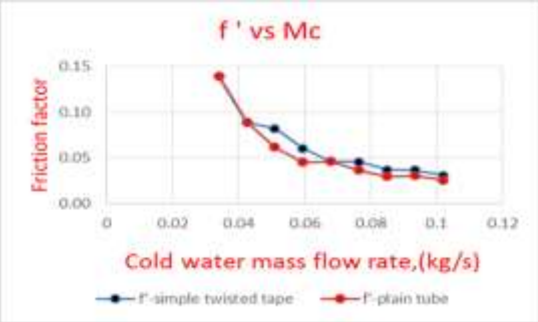

Fig. 4 Variation of friction factor with cold water mass flow rate for constant hot water mass flow rate for plain tube, simple twisted tape, modified twisted tape

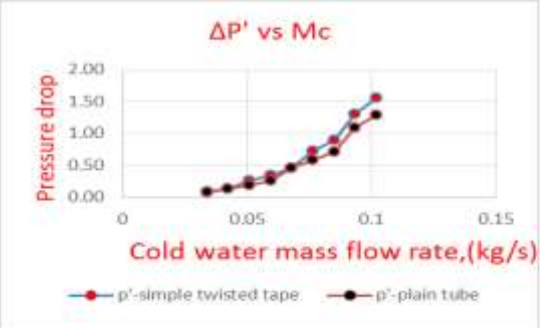

Fig. 5.Variation of pressure drop coefficient with cold water mass flow rate for constant hot water mass flow rate for plain tube, simple twisted tape, modified twisted tape

From observation the *f* and Δp' results for Plain Tube, With Twisted Tape Insert and modified twist insert along with the corresponding performance evaluation criteria Mc for each of the readings. As depicted in fig.4, *f* was increased with twisted tape insert .As compared to the plain tube results, and there is increase in *f*, when Modified twist insert. At higher mass flow rate of working fluid from the test section difference in *f* between Plain tube, with twisted tape and Modified twist insert was decreased. From fig 4. We observe that the *f* was increased from 0.03 to 0.17 and Mc was increased from 0.034 to .102 kg/s. Minimum value of *f* can be predicted by the plain in the test section. As also represented in fig.5. ΔP' was increased with twisted tape insert as compared to the plain tube results, and there is increase in Δp', when Modified twist insert. At higher mass flow rate of working fluid from the test section difference in Δp' between Plain tube, with twisted tape and Modified twist insert was increase. From fig 4.35 we observe that the Δp' was increased from 0.09 to 2.59 and Mc was increased from 0.034 to .102 kg/s. Minimum value of Δp' can be predicted by the plain in the test section

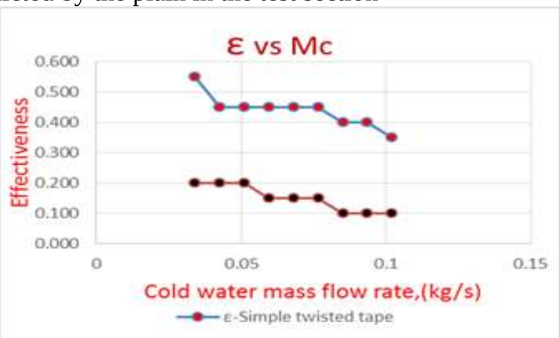

Fig. 6: Variation of Effectiveness with cold water mass flow rate for constant hot water mass flow rate for plain tube, simple twisted tape, modified twisted tape

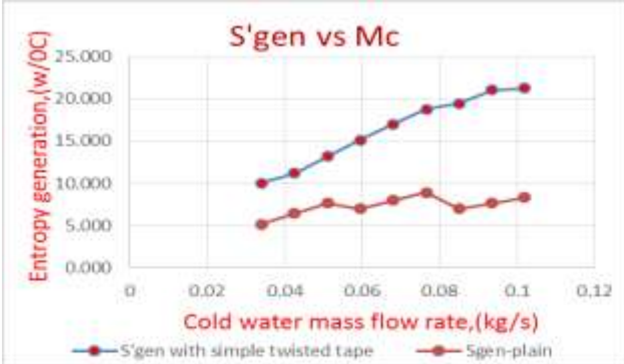

Fig. 7: Variation of Entropy generation rate with cold water mass flow rate for constant hot water mass flow rate for plain tube, simple twisted tape, modified twisted tape

gives the ε, S'gen, N's and I' results for Plain Tube, With Twisted Tape Insert and modified twist insert along with the corresponding performance evaluation criteria Mc for each of the readings. As depicted in Fig.4.37 and Fig.4.39 S'gen and I' was increased with twisted tape insert as compared to the plain tube results, and there is increase in S'gen and I', when Modified twist insert. At higher mass flow rate of working fluid from the test section difference in S'gen and I' between Plain tube, with twisted tape and Modified twist insert was increased

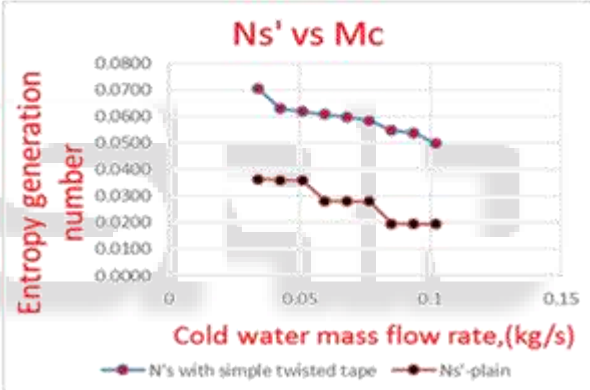

Fig. 8: Variation of Entropy generation number with cold water mass flow rate for constant hot water mass flow rate for plain tube, simple twisted tape, modified twisted tape

From fig 7. we observe that the S'gen was increased from 5.16 to 23 and Mc was increased from 0.034 to .102 kg/s. Minimum value S'gen of can be predicted by the plain in the test section. Similarly From fig 4.39 we observe that the I' was increased from 1586 to 6919 and Mc was increased from 0.034 to .102 kg/s. Minimum value I' of can be predicted by the plain in the test section

As represented in Fig.6 and Fig.8 ε and N's was increased with twisted tape insert as compared to the plain tube results, and there is increase in ε and N's, when Modified twist insert. At higher mass flow rate of working fluid from the test section difference in ε and N's between Plain tubes, with twisted tape and Modified twist insert was decrease continuous. From fig 6 we observe that the ε was increased from 0.10 to 0.60 and Mc was increased from 0.034 to .102 kg/s. Minimum value of ε can be predicted by the plain in the test section.

From fig.8 we observe that the N's was increased from 0.036 to 0.053 and Mc was increased from 0.034 to .102 kg/s. Minimum value of ε can be predicted by the plain in the test section.

From the above results, it has been observed that, if the mass flow rate of the water in inner pipe was increased than Reynolds Number, heat transfer coefficient U Nu and Δp' has been increased and friction factor was decreased. The maximum value of the Nu, heat transfer coefficient U and friction factor has been observed in Modified twisted insert counter flow heat exchanger.

It has been also observed that, if the mass flow rate of the water in inner pipe was increased than effectiveness and entropy generation number has been decreased and Entropy generation rate and exergy loss was increased. The maximum value of the ε, N's, S'gen and exergy loss has been observed in Modified twisted insert counter flow heat exchanger. But here observed that effectiveness is higher at lower cold water mass flow rate and exergy loss is minimum at lower cold water mass flow rate.

V. CONCLUSIONS

The present study discovered the effect of different twisted tape insert on the heat transfer, friction factor and pressure drop, effectiveness, entropy generation, entropy generation number, exergy loss obtained by experiment. Important findings from the study may be summarized as follows:

1) We observe that Nu and U was increase with respect to increase in cold water mass flow rate and friction factor was decreased with respect to cold water mass flow rate. Maximum Nu and U has been observed in the experiments by Modified twisted tape.

   The highest enhancement was seen to occur in modified twisted tape and overall heat transfer coefficient increased up to 252% by the modified twisted tape.
2) Friction factor was increased with twisted tape insert as compared to the plain tube results. At higher mass flow rate of working fluid from the test section difference in *f* between Plain tube, with twisted tape and Modified twist insert was decreased. We observe that maximum friction factor found in modified twisted tape. The friction factor was negligible increased up to 21% in modified twisted tape.
3) Pressure drop coefficient was increased with twisted tape insert as compared to the plain tube results, and there is increase in Δp', when Modified twist insert. We observe that the Δp' was negligible increased up to 33% in modified twisted tape.
4) The effectiveness decreased with increase cold water mass flow rate used in the experiments. When minimum cold water mass flow rate was maximum effectiveness found in any insert. The highest enhancement was seen to occur in modified twisted tape and The effectiveness values of heat exchanger which used modified twisted tape insert was obtained up to 200 % compared to a heat exchanger with the empty tube and simple twisted tape insert was obtained 175% compared to a heat exchanger with the empty tube.
5) Entropy generation rate and exergy loss was increased with twisted tape insert as compared to the plain tube results, we observe that the S'gen was increased up to 100% compared to a heat exchanger with the empty tube and simple twisted tape insert was obtained 93.97% compared to a heat exchanger with the empty tube. Minimum value S'gen of can be predicted by the plain in the test section.
6) Similarly, we observe that the exergy loss was increased up to 99.93% compared to a heat exchanger with the empty tube and simple twisted tape insert was obtained 93.69% compared to a heat exchanger with the empty tube. Minimum value S'gen of can be predicted by the plain in the test section.
7) It has been also observed that, if the mass flow rate of the water in inner pipe was increased than effectiveness and entropy generation number has been decreased and Entropy generation rate and exergy loss was increased. The maximum value of the ε, N's, S'gen and exergy loss has been observed in Modified twisted insert counter flow heat exchanger. But here observed that effectiveness is higher at lower cold water mass flow rate and exergy loss is minimum at lower cold water mass flow rate.

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