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Enhancement of Heat Transfer Using Conical Ring Inserts In Tube

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Abstract :- The development of high performance heat exchanger has gaining importance in various engineering application such as in air conditioning, ship, thermal power plant, automotive and space vehicle, heat sink, for electronics and so on. To reduce the cost and size of heat exchanger which may lead to considerable saving in material cost. These techniques are broadly classified into three categories: Active, Passive and compound technique. Passive heat transfer augmentation method can play an important role in design of heat exchanger. The most commonly used passive heat transfer augmentation tools are twisted tape, wire coil, ribs, baffles, conical ring and helical coil etc. This paper presents detailed analysis of passive heat transfer augmentation technique using conical ring.

Keywords :- - Conical Ring , Heat Transfer Augmentation.

I. INTRODUCTION

Heat transfer is a discipline of thermal engineering that concerns the generation, use, conversion and exchange of thermal energy and heat between physical systems. There are several engineering and industrial applications of Heat Exchangers. Accurate analysis of heat transfer rate and pressure drop estimations makes the design procedure of heat exchanger complicated one. Making the equipment compact and achieving high heat transfer rate are main obstacles in designing heat exchanger. Techniques that are used to enhance convective heat transfer by reducing the thermal resistance in a heat exchanger are referred to as the Heat Transfer Augmentation which leads to reduce the cost and size of the heat exchanger. Heat transfer augmentation technology has been developed and widely used employed to heat exchanger application such as automotive industries, chemical industries, refrigeration etc. These are several heat transfer augmentation techniques developed and are used in area as like thermal power plant, refrigerators, automobiles, ships, process industries, electronics devices, air conditioning equipments etc.

These techniques are listed as:

1. Active techniques.

2. Passive techniques.

3. Compound techniques.

Out of these, passive method of heat transfer enhancement is more effective as it doesn’t need external power and the simple insert manufacturing process are now available also these techniques can be retrofitted to existing units. Passive heat transfer augmentation method can play an important role in design of heat transfer. The passive techniques includes used for rough surfaces, treated surfaces, extended surfaces, coiled tube, displayed enhancement devices, swirl flow devices and additives for gases and liquid. Bergles [1] presented a comprehensive survey on heat transfer enhancement by various techniques. S.S. Giri [2] in his paper studied various methods of heat transfer enhancement adopting various types of tube inserts. P.Promvonge [3] studied in this paper the heat transfer in circular tube with conical ring insets. In this experiment three different ratios ring to tube diameter where used for the conical rings . the rings where placed with three different arrangements

(divergent conical ring, referred to as DR array, converging conical ring, CR array and converging-diverging conical ring referred CDR array) for Reynolds number in a range 6000-26000 it was used as cold air at ambient condition. Yakut [4] studied the effect of conical ring tabulators on the pressure drop , flow induced vibrations and turbulent heat transfer and also investigated the thermal performances of heat transfer promoters in relation with their heat transfer enhancement efficiency for unchanged pumping power. Alberto Garcia et al [5] their aim was to study the heat transfer rate and frictional characteristics of the helical wire coil insets in transient flow at different prandtl number.D G khumbar [6] concentrated on the effect of conical shape and conical shape coiled wire spring with various pitches on friction and heat transfer characteristics of air flow in tube as shown in fig (a) and fig (b) Shivlingaswamy B.P. [7] In this paper the effect of circular ring tabulator on three heat transfer and fluid friction characteristics in a heat exchanger tube. This can be done by insertion of conical ring tabulators with various shape containing 3 different diameter and 2 different pitch ratios. M.A. Rashid Sarkar [8] focused on experimental as well as numerical investigation in a horizontal circular tube by the effect of conical ring insert on turbulent flow heat transfer. Pramod S. Purandare [9] in this paper the heat transfer and pressure drop synthesis of conical coil heat exchanger with different diameters, fluid flow rates and cone angle. Different coils of cone angle are manufactured with same average coil diameter and tube length by various tube diameters by using hot and cold water with flow rate of 10 to 100 lph and 30 to 90 lph. The temperature and pressure are calculated across the heat exchanger at various mass flow rate of hot and cold water. The various features like transfer coefficient, friction factor, Nussle number are calculated by using temperature, mass flow rate, and pressure drop across heat exchanger. Durum [10] experimentally investigated the effect on heat transfer rate by placing in a heat exchanger tube and cutting conical tabulators using four different types of tabulators and different conical angles.

II. TECHNICAL DETAILED FOR CONICAL RING INSERTS

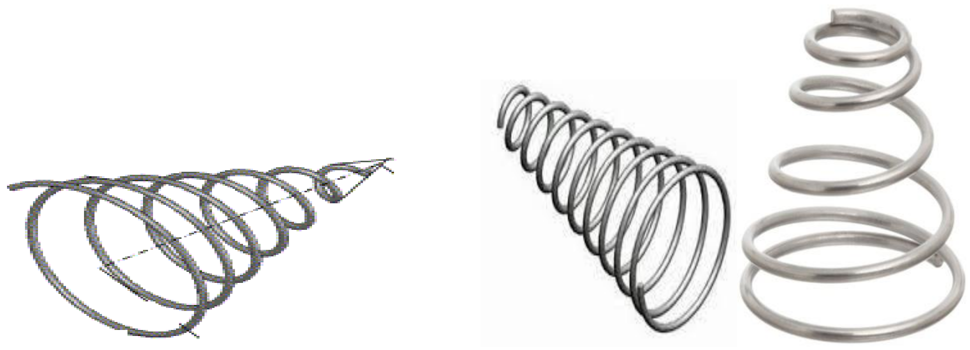

Fig 1 : conical insert

As aluminum material ribs can be easily bend in desired angle and shape also these are light in weight and easily available, these are used for experimental set-up. Five conical spring inserts are manufactured are equal length and equal diameter are used for experiment purpose. also experimental purpose with four conical spring inserts and different arrangement and its performance is also compared.

Maximum diameter (D) = 22.22mm
Diameter of wire (d)=3mm
Material = Aluminum
Length of spring =100mm

III. EXPERIMENTAL SET-UP

Conical spring inserts are made from aluminum where as copper due to its easy availability and easy manufacturing used to manufactured tube. Fig shows the experimental setup from front side. water is used as a working fluid .the length of tube is 1 m with 1mm thickness and diameter of tube is 22.22mm.the material which is used for uniform heat flux wire coil heater is nicrome wire .to prevent the heat leakage at external surface due to convection and radiation glass wool insulation is coated. at different place of heating surface five thermocouple is used and one thermocouple at inlet and one thermocouple at outlet for measuring the bulk temperature. Centrifugal type of pump is used. for measuring the flow rate rotameter is used range of 0-25 lpm. With the help of valve flow rate of Water is controlled and by measuring the pressure manometer is used. Experimental setup consists of following components:

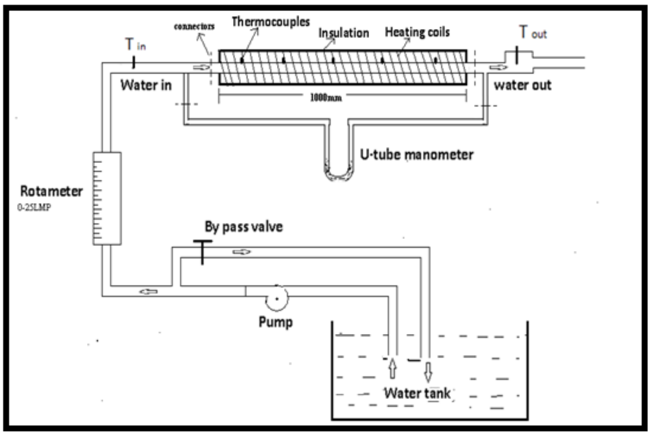

Fig 2: Front View of Experimental Setup.

1) Pump 2) rotameter 3) thermocouple 4) U- tube manometer 5) Control valve
6) Digital temperature indicator 7) Ammeter and voltmeter.

1) Pump: pump is adapted to water flow inside the tube. Pump carries the water at such a high pressure to pass the water through the tube.2800 RPM, 0.5 H.P pump is used in this project.

2) Rotameter: an instrument employed to measure the mass flow rate of water is known as rotameter .the rotameter with the range of 0-25 LPM is used in this experiment set-up.

3) Thermocouple: the mass flow rate of water is regulated used in control valve. It is located in path of water and is having the handle with graduation in degrees. The mass flow rate of water can be increased or decreased by varying the regulator and various readings can be noted down accordingly.

4) U-tube manometer: an instrument employed to measure the pressure drop across the duct is called U-tube manometer.

5) Control-valve: the mass flow rate of water is regulated used in control valve. It is located in path of water and is having the handle with graduation in degrees. The mass flow rate of water can be increased or decreased by varying the regulator and varies readings can be noted down accordingly.

6) Digital temperature indicator : an instrument is used to get reading from different places of duct is called digital temperature indicator.

7) Ammeter and Voltmeter : instrument is used to measure the current and voltage are called as ammeter and voltmeter.

IV. EXPERIMENTAL PROCEDURE

After complete the fabrication of experimental set-up,by using the tap water fill the water tank and then start the pump .an ammeter and voltmeter set the current and voltage range which gives the uniform heat flux to the tube 40°c to 41°c at wall temperature. after set the working fluid flow rate at 41 lpm,61 lpm,81 lpm,101 lpm,121 lpm.foe steady state the set-up would be run continually. Take the temperature reading at inlet and outlet of tube after obtaining the steady state without using any inserts called as smooth tube. By using digital temperature indicator take the reading of tube surface wall temperature. Take the reading of pressure drop by using U-tube manometer. Repeat the experimental procedure by changing the valve of the inlet working fluid at different flow rate, till the steady state obtain. After obtaining the steady state in smooth tube repeat the experimental procedure for conical spring inserts. in the conical spring was inserted and its end were adjusted so that it remain fixed and pipe is not chocked. And then compare the test sectioned with smooth tube.

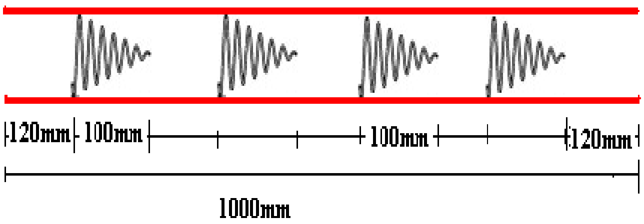

Fig 3: conical convergent spring insert in tube

At equal distance four conical springs are inserted in tube and these are contact with heated tube surface. Figure shows the systematic arrangement of conical spring used in a tube for investigation.

V. CALCULATION

The experiment was conducted with smooth tube and different heat transfer characteristics were calculated and then the same is done for conical spring insert tube. The valve can be control the water supply and heat transfer characteristics can be calculated by providing various mass flow rates.

Table 1: Observation and calculation for smooth tube (without using any insert)

Sr. No.	Flow rate of water lpm	Tube surface temp					Water inlet	Water outlet	Mano meter reading
		T1	T2	T3	T4	T5	Tin	Tout	
1	4	40.9	41.6	39.7	41.7	40.8	31.8	32.9	0.6
2	6	40.9	41.5	39.8	41.6	40.9	31.8	32.7	0.8
3	8	41	41.7	39.7	41.7	41	31.8	32.6	1
4	10	40.9	41.5	39.7	41.5	41	31.8	32.5	1.2
5	12	40.9	41.5	39.7	41.6	40.8	31.8	32.4	1.3

Bulk mean temp T_b = (Tin +Tout)/2	**Average wall temp (tw) (T1+T2+T3+T4+T5) / 5**
32.35	40.94
32.25	40.94
32.2	41.02
32.15	40.92
32.1	40.9

Table 2: Observation table for conical convergent spring

SN	Flow rate of water lpm	Tube surface temp					Water inlet	Water outlet	Manometer reading
		T1	T2	T3	T4	T5	Tin	Tout	
1	4	41	41.6	39.8	40.9	41.2	31.2	32.9	8.1
2	6	40.9	41.5	39.8	41.8	41	31.2	31.7	15.7
3	8	41	41.6	39.8	41.8	41	31.2	32.5	21.4
4	10	41	41.5	39.8	41.8	41	31.2	32.4	29.7
5	12	40.9	41.5	39.8	41.8	41	31.2	32.3	35.9

Bulk mean temp T_{b} = (Tin +Tout)/2	**Average wall temp (tw) (T1+T2+T3+T4+T5) / 5**
32.05	40.9
31.95	41
31.85	41.04
31.8	41.02
31.75	41

Sample calculation for smooth tube:

For reading 2,

1) Constant heat flux :
   I= 2.7Amp, V= 35 V, q= VI
   q= 35×2.7
   = 94.5 Watt.
2) Properties at mean bulk temperature :
   $T_{mean}= (T_{in}+T_{out})/2$
   =(31.8+32.7)/2
   =32.25°C

(From heat transfer data book – C.P. kothandraman And subramanyan)

Density ϱ = 997 $kg/m^{3.}$
Absolute viscosity μ= 7.942× 10^4 N-S/m^2
Specific heat of water cp =4178 J/kg-k
Thermal conductivity of water k= 0.616 W/m-k
Diameter of tube = 0.02222 m

3) $A= \frac{\pi}{4}\times (0.02222)^2$ Area of tube (A)
   $= 3.88 \times 10^{-4}\, m^2$
4) Velocity of water flow (V)
   Flow rate = 6lpm
   Flow rate = ϱ ×A×V
   $6.67\times10^{-5}= 997\times3.88\times10^{-4}\times V$
   V=0.258 m/s
5) Mass flow rate (m)
   m = ϱAV
   $= 997\times3.88\times10^{-4}\times 0.258$
   = 0.099kg/sec

6) Heat transfer coefficient (h)

$Q = m \times cp \times (T_{b2}-T_{b1})$

$= h\times A_s \times (T_w-(T_{b1}+T_{b2})/2)$

Where ,

Q= heat transfer rate

h= heat transfer coefficient w/m^2-k

$A_{s=}$ heat transfer area m^2=0.064 $m^{2.}$

T_{in} = water temperature at inlet ○C'

T_{out}= water temperature at outlet ○C

T_w = average tube surface temp

$= (T1+T2+T3+T4+T5) / 5 = 40.94^oC$

$Q = h \times cp \times (T_{b2}-T_{b1})$

$= 0.099 \times 417 \times (32.7-31.8)$

= 37.15 W.

$Q=h\times A_s \times (T_w-(T_{in}+T_{out})/2)$

$37.15 = h\times 0.064\times (40.94-(31.8+32.7)/2)$

h= 66.79 w/m^2-k.

7) Reynold number (R_e)

$R_e= (\varrho \times D \times V)/\mu$

$= (997 \times 0.02222 \times 0.258)/7.942 \times 10^{-4}$

= 7196.62.

8) Nusselt number (N_u)

$(N_u) = h \times D / k$

$= 44.51 \times 0.02222/0.616$

= 2.40

9) Pressure drop(Δp) = $\varrho\times g\times$ h(mano reading)

$=997\times 9.81\times 0.8/1000$

$=7.82 N/m^2$

10) Friction factor (f) = $\Delta p\times 2\times D/L_t\times \varrho\times v^2$

$= 7.82\times 2\times 0.02222/1\times 997\times 0.258$

= 0.067.

VI. RESULT AND DISCUSSION

the experiment were carried out on the smooth tube without using any inserts and the different heat transfer characteristics were calculated. And then the same is done using conical spring inserts. The experiment is dividing in two cases.

Cases I: Experiment on test tube without using any inserts.

Cases II: Experiment on test tube with conical convergent spring inserts (number of inserts 4).

In this experiment following parameters are calculated:-

1) Mass flow rate for 2 cases
2) Heat transfer coefficient
3) Nusselt number for 2cases
4) Reynolds number for 2 cases
5) Pressure drop for 2 cases

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6) Frictional factor.

Based on above calculations following are plotted for interpretation of performance.

1) Heat transfer coefficient vsReynold number
2) Nusselt number vs Reynolds number
3) Frictional factor vs Reynolds number
4) Friction factor vs mass flow rate.
5)

Table 3: Calculation table for smooth tube

Sr.no	velocity	Mass flow rate	Reynold number	Heat transfer coefficient	Nusselt number	Friction factor
1	0.172	0.066	4798	55.06	1.98	0.0088
2	0.258	0.099	7195	66.79	2.40	0.0067
3	0.345	0.133	9623	87.14	3.14	0.0036
4	0.428	0.165	11938	85.80	3.09	0.0026
5	0.515	0.199	14365	87.98	3.17	0.0021

Table 4: Calculation for conical spring inserts

Sr.no	Velocity (m/s)	Mass flow rate	Reynold number	Heat transfer coefficient	Nusselt number	Friction factor
1	0.172	0.066	4798	82.61	2.71	0.074
2	0.258	0.099	7195	106.91	3.51	0.064
3	0.345	0.133	9623	122.59	4.02	0.049
4	0.428	0.165	11938	139.93	4.59	0.044
5	0.515	0.199	14365	154.19	5.06	0.038

Table 5: Comparison between heat transfer and pressure drop

Sr. No	Smooth tube		Convergent spring inserts	
	Pressure- drop	Heat transfer coefficient	Pressure drop	Heat transfer coefficient
1	5.86	55.06	79.22	82.61
2	7.82	66.79	159.55	106.91
3	9.78	87.14	209.30	122.59
4	11.73	85.80	290.48	139.93
5	12.71	87.98	351.12	154.19

VII. GRAPH

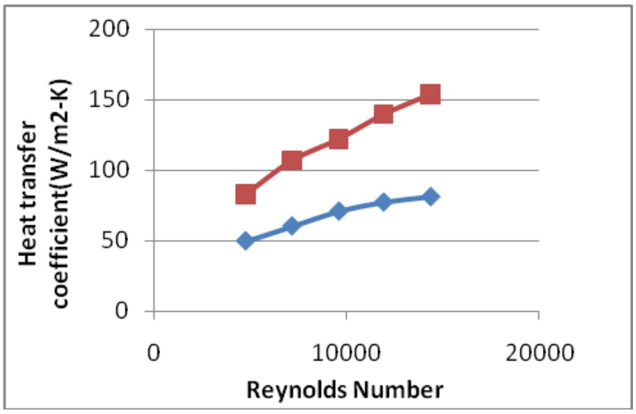

Fig 4:Heat transfer coefficient vs Reynolds number

From above graph it is observed that Reynold number is increased with increased the Heat transfer coefficient.the water flows more turbulence when reynols number increased. From graph it is observed less heat transfer coefficient than conical spring inserts in tube when using without any inserts. Conical spring inserts create more turbulence in tube which increased heat transfer coefficient. as compared to smooth tube conical inserts gives maximum heat transfer coefficient.

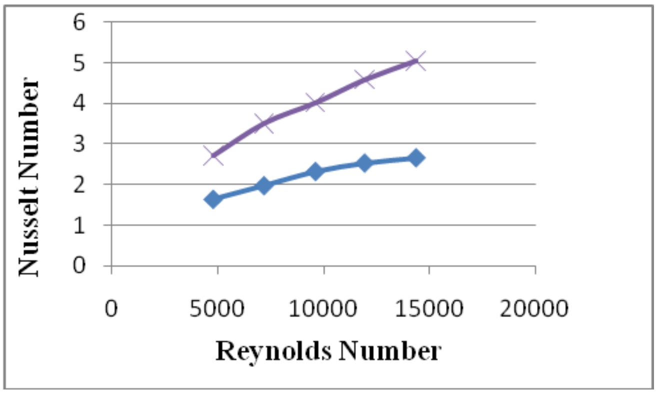

Fig 5: Nusselt number vs Reynolds number

From graph it is observed that when nusselt number is increased the Reynolds number is also increasd.and and when Reynolds number increased water flow more turbulence and due to which heat transfer rate will be increased. Heat transfer coefficient is directly proportional to the nusselt number i.e incresed with nusselt number heat transfer coefficient also incresed.minimum nusselt number is obtained in smooth tube without using any inserts and maximum nusselt number is obtained with using conical spring inserts.

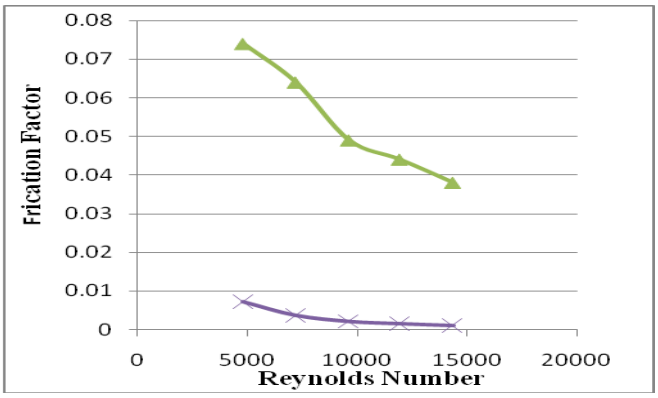

Fig 6: Friction factor vs Reynlods Number

From graph it is observed that friction factor is decresed when the Reynolds number is incresed because friction factor is inversely proportional to the velocity.hence velocity is incersed i.e Reynold number is also increased and frictiom factor will decresed.in conical spring inserts friction factor is more and due to these pressure drop is maximum in tube. From graph it is observed that less friction factor is obtained in smooth tube.

VIII. CONCLUSION

Experimental investigation hane been carried out in the circular tube to study the effect of conical spring inserts on heat transfer enhancement, friction factor. From graph following conclusion are made.

The heat transfer in tube with conical spring inserts is found to be more as compared to smooth tube i.e,without using any inserts.the increase in heat transfer coefficients of water 77.88% higher for conical spring inserts, over when number of inserts are use in tube.the increase in heat transfer occurs because more turbulances are generated within the tube by using diffferents shaped of inserts as compaerd to without using inserts.

As the reynolds number increse the friction factor will be reduced.as the reynold number increase ,velocity is also increses and the friction factor is inversely proportional to the velocity and hence it decreses.in smooth tube less friction factor is obtained as compaerd to conical spring inserts. In conical spring more friction factor is obtained,in tube when number of inserts is used more than 4,then it gives more heat tranfer coefficient.anda lso in tube pressure drop increses and due to this maximum friction factor is obtained.
Percentage increse in average values of heat transfer coefficient of inserts as compaerd to smooth tube without using any inserts is given as:

Table 6: Comparison of heat transfer enhancement for all case

Sr. no	Arrangement	Avg. heat transfer coefficient	Increase % of heat transfer coefficient
1	Without using any inserts	76.55	-------
2	Conical spring inserts	121.166	77.88

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