Performance Evaluation for the Tube in Tube Heat Exchanger by Wire Mesh Technique

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Abstract: This experiment will provide method for increasing tube-in-tube exchanger performance. The tube-in-tube heat exchanger is designed in order to study the process of heat transfer between two fluids through a solid partition. It will be designed for a parallel flow as well as counter-flow arrangement and the logarithmic mean temperature difference (LMTD) method of analysis is adopted. Water will be used as a working fluid for the experiment. The temperatures of the hot and cold water supplied to the equipment. The parameter required to find out the effectiveness of the heat exchanger will be arranged in this setup such as the inlet and outlet temperature of the hot and cold fluid, flow rate of the fluid power consumption etc. The modified wire mesh tube in tube will be replaced for the ordinary tube in tube so the surface area is increased so maximum heat will exchange from hot side to the cold side. This will be proved by calculation of the LMTD, Heat transfer coefficient and temperature difference. Arrangement will be made such that in one set we can achieve the both parallel and counter flow by simply opening and closing of the valve shown in the process of this whole setup. This set up is used for comparing the Logarithmic mean temperature difference, heat transfer coefficient, the effectiveness and the temperature difference for the modified wire mesh heat exchanger & with the ordinary Heat exchanger.

Keywords: LMTD, wire mesh, Heat transfer coefficient, temperature difference, the effectiveness.

I. INTRODUCTION

An A heat exchanger is a device that transfers thermal energy from a high-temperature fluid to a low-temperature liquid with both fluids moving through the device. Examples in practice in which smooth fluids exchange heat are air intercoolers and pre-heaters, condensers and boilers in steam plant, condensers and evaporators in refrigerator units, and a lot of other manufacturing process in which a liquid or gas is requisite to be either cooled or heated.
There are three main types of heat exchangers:
1) The Recuperative type in which the flow exchange heat on either side of a dividing wall.
2) The Regenerative type in which the hot and cold fluids pass alternately during a space containing a matrix of material that provides alternately a sink and a source for heat run.
3) The Evaporative type in which a liquid is cooled evaporative and constantly in the same gap as the coolant.

Recuperative type of heat exchanger, which can further be classified, base on the associate directions of the flow of the hot and cold fluids, into three types:
1) Parallel flow, when both the fluids move in parallel in the same direction.
2) Counter flow, when the fluids move in parallel but in opposite directions.
3) Cross flow, when the directions of flow are equally perpendicular.
Heat exchanger is a special equipment type because when heat exchanger is directly fired by a burning process, it becomes furnace, boiler, heater, tube-still heater and engine. Vice versa, when heat exchanger make a change in phase in one of flowing fluid such as condensation of steam to water, it becomes a chiller, evaporator, sublimator, distillation-column reboiler, still, condenser or cooler-condenser. Heat exchanger may be planned for chemical reactions or energy-generation processes which become an fundamental part of reaction system such as a nuclear reactor, catalytic reactor or polymer. Normally, heat exchanger is used only for the transfer and useful removal or recovery of heat without changed in phase. The fluids on either side of the wall usually liquids but they can be gasses such as steam, air and hydrocarbon vapour or can be liquid metals such as sodium or mercury. In some application, heat exchanger fluids may use fused salts.
Rising heat exchanger performance usually means transferring more duty or operating the exchanger at a closer temperature approach. This can be skilled without a dramatic increase in surface area. This constraint directly translates to increasing the overall heat transfer coefficient, U.
The heat exchanger is a very important device used in many real world applications in which heat must be transferred from one medium to another. In many cases, the two mediums are separated by a solid wall and heat is transfer in between them by the medium with keeps the fluid part, in many heat exchanger problems where seen the lost of heat due

to the insufficient fluid contact with the surface area which transfer the heat, many heat exchanger finds that there length are too short are due to shorter and smaller length laminar flow is formed and this will seen this will create the small film arrangement of the heat flux, so it needs the larger heat surface area, many analyzing are finding the solution to raise the surface are, one of the method has earliest developed is to attach the fin on the tube, bur this method has on large disadvantage that they involve the larger space to attach the fins around the each tube. Formation of the laminar flow on the tube will decrease the heat transfer rate and this problem can only handle but designing some internal deal in tube which will not disturb the flow velocity and also the other parameter such as mechanical and chemical properties. In many industries it is seen that lost of heat will is not only due to the hot side fluid but also in the fluid which carries heat away from the hot fluid, this problem also needs to be handled. Note that a counter flow heat exchanger is more efficient than a parallel flow heat exchanger.

1.1 Objective

1) To design and construct a Mesh in concentric- tube heat exchanger in which two tubes are concentrically arranged and either of the fluids (hot or cold) flows through the tube and the other through the annulus.
2) To carry out test on the Mesh in concentric- tube heat exchanger and obtain values which will be compared to the ordinary heat exchanger.
3) Observing the temperature difference for ordinary heat exchanger.

II. LITERATURE REVIEW

As per the paper prepared by Hiroshi IWAI, Soushi KAWAKAMI, Kenjiro SUZUKI, Junichi TSUJII, Tetsuo ABIKO, they worked on the Performance of Wire Springs as Extended Heat Transfer Surface for Compact Heat Exchangers. Use of thin metal wire structures as a new type of extended heat transfer surface is proposed. As one of the most basic shapes of such wire structures, heat transfer performance of spring shaped fins is experimentally investigated under relatively low Reynolds number conditions. The averaged heat transfer coefficient is evaluated by a single-blow method while the pressure drop is measured at a steady state flow condition. The effects of the geometric parameters such as the wire diameter, the spring pitch and the pitch ratio were systematically examined and the obtained data were compared with that of a conventional offset fin, which is commercially available. It was found that the geometric parameters of the spring fins and the arrangement of spring fins in the test section affect their heat transfer performance. Some types of spring fins showed better heat transfer performance than a conventional offset fin, when they are evaluated in terms of the total heat transfer at a constant pumping power [9].
Prabhakar Ray, Dr. Pradeep Kumar Jhinge works on the review paper of Heat Transfer Rate Enhancements by Wire Coil Inserts in the Tube. This paper reviews experimental works taken by researchers, on this technique wire coil insert in tubes to enhance the thermal efficiency in heat exchangers and useful to designers implementing passive augmentation techniques in heat exchange. The authors found that variously developed wire coil inserts are popular researched and used to strengthen the heat transfer efficiency for heat exchangers[11].
Folaranmi Joshua, in his paper, he in print the design and construction of a concentric tube heat exchanger. The concentric tube heat exchanger was purposeful in order to study the process of heat move between two fluids through a solid divider. It was planned for a counter-flow deal and the logarithmic mean temperature difference (LMTD) method of analysis was adopted. Water was used as fluid for the experiment. The temperatures of the hot and cold water complete to the equipment were 87o and 27oC, respectively and the outlet temperature of the water after the experiment was 73oC for hot and 37oC for cold water. The outcome of the experiment was tabulate and a graph of the mean temperatures was drawn. The heat exchanger was 73.4% efficient and has an overall coefficient of heat transfer of 711W/m2K and 48oC Log Mean Temperature Difference. The research takes into account different types of heat exchangers [8].
In the paper of V.Natarajan, They alert on the investigational cram of the recital characteristics of tube-in-tube dense heat exchangers. Experiments are conducted in the compact heat exchangers with R-134a and liquefied petroleum gas. The use of diminutive metal wire mesh as an extended heat transfer surface is proposed. The effectiveness of the heat exchangers was calculated using the experiment data and it was found that the effectiveness of heat exchanger-1 is above 75 and heat exchanger-2 is above 84% for R-134a.The effectiveness of heat exchanger-1 is about 60% and heat exchanger-2 is about 81% for liquefied petroleum gas. In this paper, details about the new tube-in-tube type dense heat exchanger, experimental setup, results and conclusions are discussed [1].
As per paper existing by S. Pradeep Narayanan, G. Venkatarathnam, they presented the Performance of a counter flow heat exchanger with heat loss through the wall at the cold end. The presentation of high effectiveness heat exchangers used in cryogenic systems is strongly prohibited by irreversibilities such as longitudinal heat conduction and heat leak from ambient. In all heat exchanger analyses, it is unspoken that no heat is lost through the heat exchanger walls. In the case of small J-T refrigerators such as micro miniature refrigerators, the heat exchanger cold end is almost directly associated to the evaporator, which may outcome in a large amount of heat loss through the heat exchanger wall at the cold end. The rate of heat loss through the wall at the cold end is also powerfully needy on the longitudinal thermal resistance of the wall. In this paper, we present the connection between the efficiency of a heat exchanger losing heat at

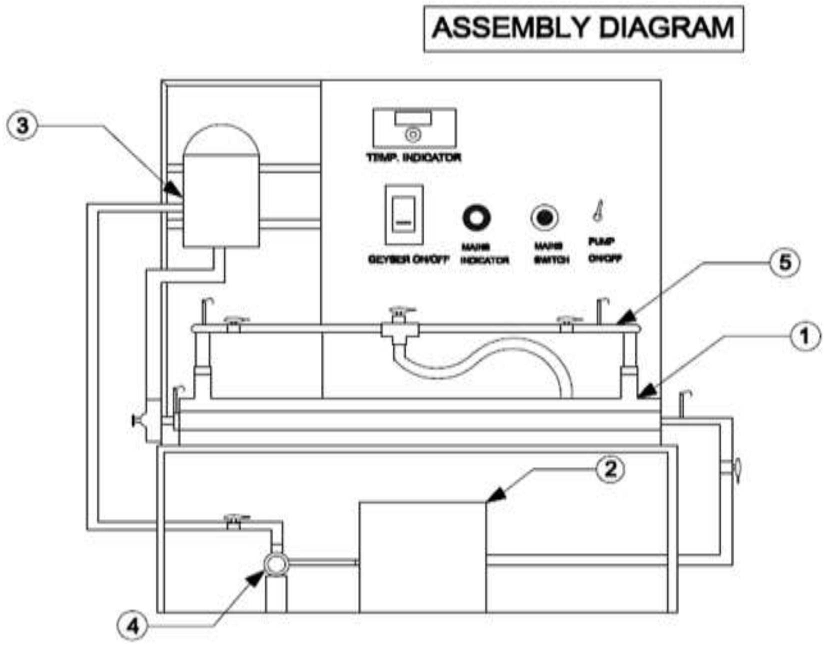
the cold end and other resistances such as number of move units (NTU), longitudinal thermal resistance etc. The performance of such heat exchangers under different operating conditions is also discussed [4].
As per paper offered by Prabhat Gupta, M.D. Atrey, they presented Performance evaluation of counter flow heat exchangers considering the effect of heat in leak and longitudinal conduction for low-temperature applications. In this paper, Counter flow heat exchangers are frequently used in cryogenic systems because of their high effectiveness. In addition to operating and design parameters, the thermal performance of these heat exchangers is strongly governed by various losses such as longitudinal conduction through wall, heat in leak from nearby, flow maldistribution, etc. Design based on predictable procedure, which

normally does not take these losses into deliberation, could be misleading and actual performance could be quite dissimilar than the predictions. In this, the numerical model urbanized earlier is extensive to take into consideration the effect of heat in escape and the predictions are compared with the experimental outcome. The study is further extended to understand quantitative effect of heat in escape and axial conduction parameters on degradation of heat exchanger performance for 300-80 K and 80-20 K temperature range [2].

III. METHODOLOGY

3.1Method

The parameter required to find out the effectiveness of the heat exchanger is arranged in this setup such as the inlet and outlet temperature of the hot and cold fluid, flow rate of the fluid, power consumption etc. The modified tube in tube is replaced for the ordinary tube in tube so the surface area is increased so maximum heat will exchange from hot side to the cold side this will be proved by calculation of the LMTD, Heat transfer coefficient and temperature difference.
As shown in fig. 1 Inner tube used in this set up is made of the copper so the maximum heat is transfer to the outer fluid and outer pipe is made of the MS which is the insulated by the insulation to reduce the heat losses.



PART LIST		
SR.NO	PART DESCRIPTION	QTY
1	HEAT EXCHANGER	1
2	SUMP TANK	1
3	HOT WATER GENERATOR	1
4	SUPPLY PUMP	1
5	PIPPING	1

Fig. 1 General setup for modified tube heat exchanger

2.2 Required components
Base stand, Heat exchanger, Sump tank, Geyser, Multipoint Temperature Indicator, K-type pencil thermocouples, Centrifugal pump, Pipes & valves.

2.3 fabrication of Concentric Tube type heat exchanger

it is consist of concentric tube type heat exchanger having inner tube length 1800 mm & the inner tube having diameter 6.4 mm and outer tube of diameter 12.5 mm. Heat exchanger is a device in which the exchange of energy between two fluids at different temperatures takes place.

The copper tubes were cut according to the required length. The cutting operation is done by means of a tube cutter. Then the inner tube is placed inside the outer tube is kept within by using copper plates using the brazing process. Before brazing the outer tube is drilled to locate the inlet and outlet tubes. Then these inlet and outlet tubes are also brazed.

Copper meshes are placed in the form of small discs in between the tubes and the copper wire is wound like a coil which is inserted in the inner tube.

The copper wire mesh has the following specifications:

1) Wire diameter – 0.4mm
2) Thickness of wire mesh – 1mm

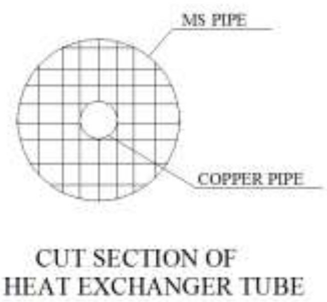


Fig. 2 Wire mesh

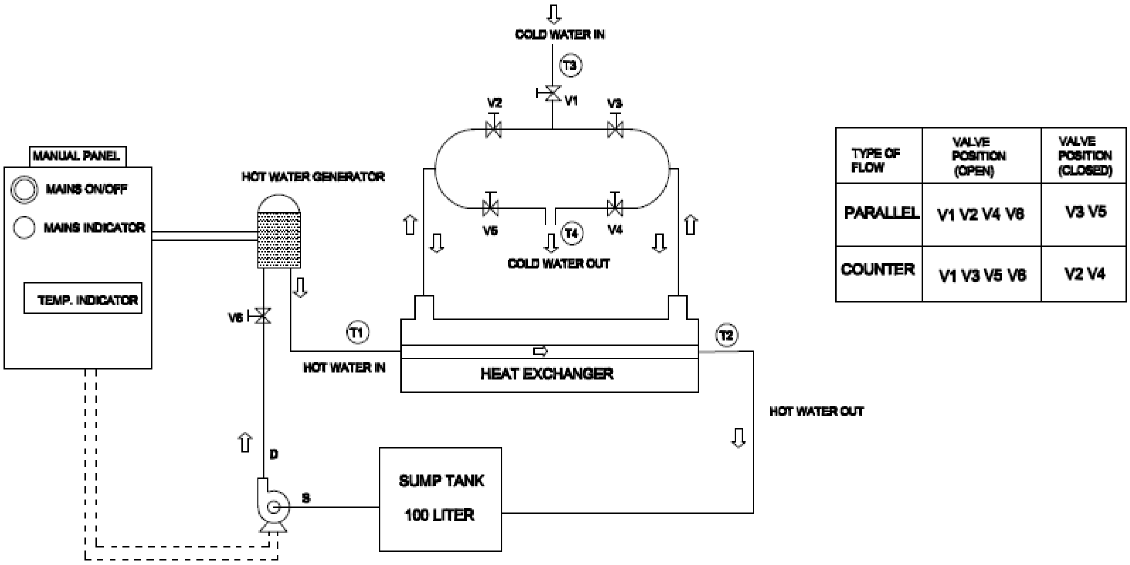


Fig. 3 General setup parallel & counter flow for modified heat exchanger

3.4 Experimental procedure

The experimental procedure shows in fig.3 which carries tests for both ordinary heat exchanger and modified wire mesh heat exchanger.

It consists of a concentric tube type of heat exchanger. This heat exchanger consist of a tube is housed in shell. A pipe & valve arrangement is provided to select the direction of cold water. A water heater is provided to supply hot water at specified temperature continuously. K-type thermocouples are fitted at the inlets & outlets of both fluids to measure the temperature.

Arrangement is made such that in one set we can achieve the both parallel and counter flow by simply opening and closing of the valve shown in the process and information diagram of this whole setup.

The mass flow rates for hot water and cold water are as follows:

Table 1 Mass flow rates

Sr. No.	m_h	m_c
	(kg/sec)	(kg/sec)
1	0.005	0.01
2	0.0048	0.012
3	0.0048	0.011
4	0.0047	0.0105
5	0.0048	0.0107

3.5 Experimental Temperatures in system

For parallel flow system:

T1= temperature of hot water at inlet
T2= temperature of hot water at outlet
T3= temperature of cold water at inlet
T4= temperature of cold water at outlet

For counter flow system:
T1= temperature of hot water at inlet
T2= temperature of hot water at outlet
T3= temperature of cold water at outlet
T4= temperature of cold water at inlet

IV. CALCULATION PROCEDURE

1) LMTD (θ_m)

$$(\theta_m)_{Parallel\ flow} = \frac{(T_1 - T_3) - (T_2 - T_4)}{\ln\left\{\frac{(T_1 - T_3)}{(T_2 - T_4)}\right\}}$$

Where,

T_1 - Hot Water In.
T_2 - Hot Water Out.
T_3 - Cold Water In.
T_4 - Cold Water Out

$$(\theta_m)_{Counter\ flow} = \frac{(T_1 - T_4) - (T_2 - T_3)}{\ln\left\{\frac{(T_1 - T_4)}{(T_2 - T_3)}\right\}}$$

Where,
T_1 - Hot Water In.
T_2 - Hot Water Out.
T_3 - Cold Water Out.
T_4 - Cold Water In.

2) Heat Transfer Coefficients

$Q_{\text{Parallel flow}} = (m\ C_p)_{hot}\ (T_1 - T_2) = (m\ C_p)_{cold}\ (T_4 - T_3)$
$Q_{\text{Counter flow}} = (m\ C_p)_{hot}\ (T_1 - T_2) = (m\ C_p)_{cold}\ (T_3 - T_4)$

Where,
m - Mass of hot water
C_p - specific heat of hot water (2000 J/Kg K)
C_p - specific heat of cold water (4178 J/Kg K)

$Q = U\ A\ \theta_m$
Where,
Q = total heat required.
U = Heat transfer coefficient.
θ_m = log mean temperature difference.
A = Heat transfer area = ΠDL

3) Determination of Heat Exchanger Effectiveness

$$\text{Effectiveness} = \frac{(m\,C_p\,\Delta T)_{\text{hot or cold}}}{(mC_p)_{small}\ (T_1 - T_4)}$$

4) Capacity ratio (C)

$$C = \frac{(mC_p)_{min}}{(mC_p)_{max}}$$

V. RESULT AND DISCUSSION

I had design and construct a Mesh in concentric- tube heat exchanger in which two tubes are concentrically arranged and either of the fluids (hot or cold) flows through the tube and the other through the annulus. I had also made an ordinary tube in tube heat exchanger for which temperature readings for hot water and cold water taken.

4.1 Results for parallel flow

Firstly, in this project the parallel flow is made by simply opening and closing of the valve. The different temperature readings at different interval of time have taken as given below.

Table 2 Temperature readings

Sr. No.	Cold Water		Hot water	
	T_{ci}	T_{co}	T_{Hi}	T_{Ho}
1	28	34	90	61
2	28	35	89	60
3	28	36	90	58
4	28	36	91	57
5	28	37	90	55

For the above given temperature, the calculations for the LMTD, overall heat transfer coefficient, capacity ratio and effectiveness are given below.

Table 3 Result table for parallel flow

Sr. No.	LMTD (θm)	Overall Heat Transfer Coefficient (U)	Capacity Ratio	Effectiveness
	° C	W/m2 ° K	C	ε
1	42.1	161.71	0.189	0.47
2	40.35	189.08	0.200	0.48
3	38.6	217.80	0.190	0.52
4	38.23	226.78	0.192	0.54
5	35.57	248.92	0.178	0.56

4.2 Results for counter flow

The counter flow is made by simply opening and closing of the valve. The different temperature readings at different interval of time have taken as given below.

Table 4 Temperature readings

Sr. No.	Cold Water		Hot water	
	T_{ci}	T_{co}	T_{Hi}	T_{Ho}
1	28	36	90	53
2	28	38	89	51
3	28	35	90	49
4	28	38	88	50
5	28	39	92	52

For the above given temperature, the calculations for the LMTD, overall heat transfer coefficient, capacity ratio and effectiveness are given below.

Table 5 Result table for counter flow

Sr. No.	LMTD (θm)	Overall Heat Transfer Coefficient (U)	Capacity Ratio	Effectiveness
	° C	W/m2 ° K	C	ε
1	37.65	198.89	0.215	0.60
2	35.16	209.98	0.159	0.62
3	35.31	225.57	0.178	0.66
4	34.11	211.96	0.182	0.63
5	36.61	212.31	0.178	0.63

VI. CONCLUSIONS

By this project work, it design and construct a Mesh in concentric- tube heat exchanger in which two tubes are concentrically arranged and either of the fluids (hot or cold) flows through the tube and the other through the annulus. It also made an ordinary tube in tube heat exchanger for which temperature readings for hot water and cold water for parallel and counter flow had taken. Also, it calculate the different parameters like the LMTD, overall heat transfer coefficient, capacity ratio and effectiveness for both parallel flow and counter flow. From the results, it is observed that the overall heat transfer coefficient and effectiveness is increased for counter flow. For the future scope, the mesh technique will be used to carry the test on parallel as well as counter flow.

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