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DEVELOPMENT OF A PRACTICAL MODEL TO FIND OUT EFFECTIVENESS OF HEAT EXCHANGER AND ITS COMPARISON WITH STANDARD VALUES

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Abstract: *Exchange of heat from hot body to cold body or hot fluid to cold fluid will takes place by means of heat exchanging device. The device in which heat is transferred from hot fluid to cold fluid with maximum rate, minimum investment and less running cost is generally known as heat exchanger. The exchange of heat in heat exchanger may be in the form of sensible heat or latent heat or else it may be both latent and sensible heat. Usually the heat transfer in heat exchanger involves convection of fluids on each side and conduction through the wall that separates the two fluids. This paper focused on the development of a practical model with locally available materials to reduce the equipment cost and conducting experiment on it and studying its effectiveness for different flows like parallel flow, counter flow, crossed flow in the developed model, when hot and cold fluids flows through it. In heat exchanger when fluids are flowing hot fluid loses its temperature and cold fluid gain the temperature which is equivalent to fall of temperature by the hot fluid. This exchange heat relates with the length of heat exchanger. Readings recorded based on experiment and results are compared by different methods.*

Key words: *LMTD, NTU, Effeteness, Parallel flow and counter flow*

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1. INTRODUCTION

Developing a practical Model to find out effectiveness of heat exchanger and it comparison involves three stages one is developing a practical model with locally available material , that involves purchasing suitable raw material and fabrication in to the shape and the second stage is conducting Experimentation on developed model for parallel flow and counter flow at different flow rates of hot and cold fluids and recording it readings and third stage involves calculation part for both parallel and counter flow to find out effectiveness by different methods like LMTD method, NTU method and comparison with heat transfer datebook values

2. CLASSIFICATION OF HEAT EXCHANGERS:

2.1. Based on the nature of heat exchange process

a) Direct contact type- here heat transfer takes place by direct mixing of hot and cold fluids

b) Indirect contact heat exchangers-Here the two fluids are separated through a metallic wall. Ex. regenerator, recuperators etc.

2.2. Based on the relative direction of fluid flow

a) Parallel flow heat exchanger- here both hot and cold fluid flow in the same direction

b) Counter flow heat exchanger – here hot and cold fluids flow in opposite direction

c) cross flow heat exchangers-here the two fluids cross one another

Examples of heat exchangers are

i. condensers and boilers in steam plant

ii. Intercoolers and pre heaters

iii. Automobile radiators

iv. Regenerators

3.0 EXPERIMENTAL SETUP

The apparatus consists of concentric tube of the heat exchangers. The hot fluid namely hot water is obtained from the Geyser (heater capacity 3 KW) and it flows through the inner tube. The cold fluid i.e. cold water can be admitted at any one of the ends enabling the heat exchanger to run as a parallel flow or as a counter flow exchanger. Measuring jar used for measure flow rate of cold and hot water. This can be adjusted by operating the different valves provided. Temperature of the fluid can be measured using thermocouples with digital display indicator. The outer tube is provided with insulation to minimize the heat loss to the surrounding.

Specifications:

Specimen material : copper tube

Size of the specimen : ϕ 19 mm X 1650 mm long

Outer shell material : G.I Tube

Size of outer shell : ϕ 38 mm

Geyser capacity : 1 lit, 3 KW

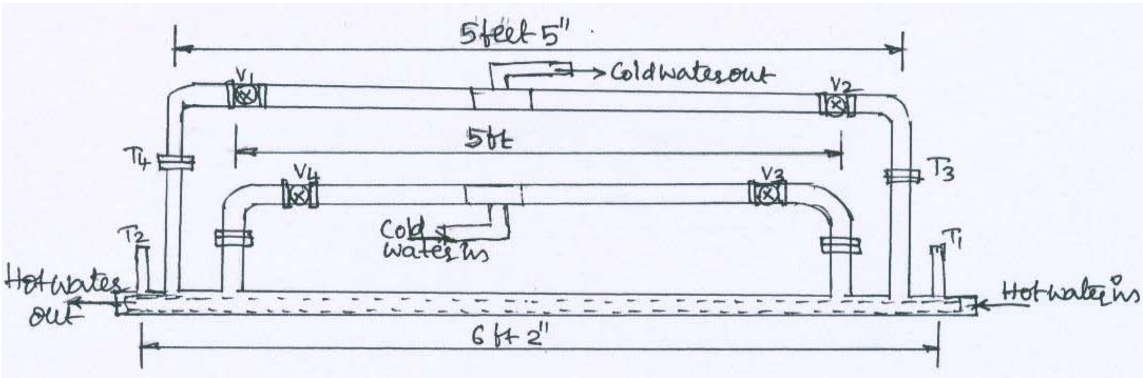

Fig: 1 Experimental set up block diagram

For parallel flow

T_1= hot water inlet temperature in ^{0}C

T_2=hot water outlet temperature in ^{0}C

T_3= t_1=cold water in let temperature ^{0}C

T_4 = t_2 = cold water outlet temperature ^{0}C

For counter flow

T_1= hot water inlet temperature in ^{0}C

T_2=hot water outlet temperature in ^{0}C

T_3= t_2=cold water outlet temperature ^{0}C

T_4 = t_1 = cold water inlet temperature ^{0}C

With the above water flow arrangement the practical developed model is shown in below figure

Fig.2 practically developed model of heat exchanger for parallel and counter flow

3.1 EXPERIMENTAL PROCEDURE:

1. First switch on the unit panel
2. Start the flow of cold water through the annulus and run the exchanger as parallel flow or counter flow
3. Switch ON the Geyser provided on the panel and allow to flow through the inner tube by regulating valve.
4. Adjust the flow rate of hot water and cold water by using rotameters and valves.
5. Keep the flow rate same till steady state conditions are reached.
6. Note down the temperatures of hot and cold water sides. Also note the flow rate.
7. Repeat the experiment for different flow rates and for different temperatures. The same method is followed for counter flow also.

3.2. Experimental readings of Parallel flow arrangement

Sno	Hot water flow rate m_h, kg/s	Cold water flow rate mc kg/s	Temp.of hot water ^{0}C		Temp.of cold water ^{0}C	
			Inlet T1	Out let T2	Inlet t1	Outlet t2
1	0.0227	0.0416	47.2	42.6	25.8	29.4
	(250ml/11 s)	(500ml/12s)				

3.2.1. Heat transfer for hot water

Qh = mh Cph(T1-T2) watts

mh=mass flow rate of hot water kg/sec

Cph =specific heat of hot water = 4186.8 J kg-k

Qh = 0.0227 x4186.8(47.2-42.6) = 437.185 watts

3.2.2. Heat transfer for cold water

Qc = mc Cpc(t1-t2) watts

mc=mass flow rate of cold water kg/sec

Cpc =specific heat of cold water = 4186.8 J kg-k

Qc = 0.0416 x 4186.8(29.4 -25.8) =627.015 watts

3.2.3. $Q=\frac{Qh+Qc}{2}$ **watts**

$Q=\frac{437.18+627.0}{2}$ =532.09 watts

3.2.4. LMTD = $\frac{\theta 1-\theta 2}{\ln\left(\frac{\theta 1}{\theta 2}\right)}$

Where θ1=T1- t1 = 47.2 – 25.8=21.4 for parallel flow heat exchanger

θ2= T2- t2 =42.6 – 29.4 =13.2

LMTD = $\frac{21.4-13.2}{\ln\left(\frac{21.4}{13.2}\right)} = 16.971$

4. OVERALL HEAT TRANSFER COEFFICIENT

Overall heat transfer coefficient is calculated based on outside surface area of inner tube which is as follows.

Uo = $\frac{Q}{Ao\ X\ LMTD}$ W/m^2-k

Where Ao= π do L

Do = outer diameter of the tube = 0.019 m

L= length of the tube = 1.65 m

Ao= π X 0.019X 1.65 m = 0.0985m^2

Uo = $\frac{532.09}{0.0985\ X\ 16.977}$ =318.191 W/m^2-k

5.0 TO FIND EFFECTIVENESS (ε)

5.1 By using LMTD method

Find Ch =heat capacity rate of hot fluid

Heat carrying capacity of hot fluid   Ch= mh Cph

Heat carrying capacity   Ch= 0.0227 X 4186.8 =95.040   (Min)

Find Cc =heat capacity rate of cold fluid

Heat carrying capacity of cold fluid   Cc= mc Cpc

Heat carrying capacity of cold fluid   Cc= 0.0416 X 4186.8 =174.170   (Max)

mh and mc are mass flow rate of hot and cold fluids

Cph and Cpc are specific heat of hot and cold fluids J/kg-k

$C=\frac{Cmin}{Cmax} = \frac{95.040}{174.170} = 0.5456$

If Ch < Cc then effectiveness $\varepsilon = \frac{T1-T2}{T1-t1}$ (hot fluid is min so this is applicable)

$\varepsilon = \frac{47.2-42.6}{47.2-25.8} = 0.214$

If Cc< Ch then effectiveness $\varepsilon = \frac{t2-t1}{T1-t1}$

This is applicable for both parallel and counter flow heat exchangers

5.2 By using NTU method

i) NTU = $\frac{\boldsymbol{Uo\ Ao}}{\boldsymbol{Cmin}}$

Note:

If Ch < Cc then Ch = Cmin (hot fluid is minimum) and Cc = Cmax(cold fluid is maximum)

If Cc< Ch then Cc = Cmin (cold fluid is minimum) and Ch = Cmax (hot fluid is maximum)

Where Ch= mh Cph

and Cc= mc Cpc

NTU = $\frac{\mathbf{318.191\ X\ 0.0985}}{\mathbf{95.040}}$ =0.329

ii) Effectiveness of parallel flow heat exchanger

$$\varepsilon = \frac{1-exp[-N(1+C]}{1+C}$$

$$\varepsilon = \frac{1-exp[-0.329(1+0.545]}{1+0.545}$$

ε =0.29

Note: effectiveness can also obtained by using chart from HMT data Book

Select NTU on X-axis and corresponding curve of C=Cmin /Cmax and read ε value on Y-axis, similarly for counter flow

6. EXPERIMENTAL READINGS FOR COUNTER FLOW ARRANGEMENTS

Sno	Hot water flow rate m_h, kg/s	Cold water flow rate mc kg/s	Temp.of hot water ^{0}C		Temp.of cold water ^{0}C	
			Inlet T1	Out let T2	Inlet t1	Outlet t2
1	0.0227	0.0357	43.2	40.1	26.6	30.2
	(250 ml/11s)	(250ml/7s)				

6.1. Heat transfer for hot water

Qh = mh Cph(T1-T2) watts

mh=mass flow rate of hot water kg/sec

Cph =specific heat of hot water = 4186.8 J kg-k

Qh = 0.0227 x4186.8(43.2 – 40.1) = 294.625 watts

6.2. Heat transfer for cold water

Qc = mc Cpc(t1-t2) watts

mc=mass flow rate of cold water kg/sec

Cpc =specific heat of cold water = 4186.8 J kg-k

Qc = 0.0357 x 4186.8(30.2 -26.6) =538.087 watts

6.3. $Q=\frac{Qh+Qc}{2}$ **watts**

. $Q=\frac{294.625+538.087}{2}$ =416.356 watts

6.4. LMTD = $\frac{\theta 1-\theta 2}{\ln\left(\frac{\theta 1}{\theta 2}\right)}$

Where θ1=T1- t2 = 43.2 – 30.2=13 for counter flow heat exchanger

θ2= T2- t1 =42.6 – 26.6=13.5

LMTD = $\frac{13-13.5}{\ln\left(\frac{13}{13.5}\right)}$ = 13.24

7. OVERALL HEAT TRANSFER COEFFICIENT

Overall heat transfer coefficient is calculated based on outside surface area of inner tube

Uo = $\frac{Q}{Ao \ X \ LMTD}$ W/m^2-k

Where Ao= π do L

Do = outer diameter of the tube = 0.019 m

L= length of the tube = 1.65 m

Ao= π X 0.019 X 1.65 m = 0.0985 m^2

Uo = $\frac{416.356}{0.0985 X \ 13.24}$ =319.257W/m^2-k

8.0 TO FIND EFFECTIVENESS (ε)

8.1 By using LMTD method

Find Ch =heat capacity rate of hot fluid

Heat carrying capacity of hot fluid Ch= mh Cph

Heat carrying capacity Ch= 0.0227 X 4186.8 =95.040 (Min)

Find Cc =heat capacity rate of cold fluid

Heat carrying capacity of cold fluid Cc= mc Cpc

Heat carrying capacity of cold fluid Cc= 0.035 X 4186.8 =149.468 (Max)

mh and mc are mass flow rate of hot and cold fluids

Cph and Cpc are specific heat of hot and cold fluids J/kg-k

C=$\frac{Cmin}{Cmax}$ = $\frac{95.040}{149.468}$ = 0.6356

If Ch < Cc then effectiveness ε =$\frac{T1-T2}{T1-t1}$ (hot fluid is min so this is applicable)

ε =$\frac{43.2-40.1}{43.2-26.6}$ = 0.19

If Cc< Ch then effectiveness ε =$\frac{t2-t1}{T1-t1}$

This is applicable for both parallel and counter flow heat exchangers

8.2 By using NTU method

i)NTU = $\frac{Uo \ Ao}{Cmin}$

Note:

If Ch < Cc then Ch = Cmin (hot fluid is minimum) and Cc = Cmax(cold fluid is maximum)

If Cc< Ch then Cc = Cmin (cold fluid is minimum) and Ch = Cmax (hot fluid is maximum)

Where Ch= ṁh Cph

and Cc= ṁc Cpc

NTU = $\frac{\mathbf{319.257X\ 0.0985}}{\mathbf{95.040}}$ =0.33

ii) Effectiveness of counter flow heat exchanger

$$\boldsymbol{\varepsilon} = \frac{1-exp[-N(1-C)]}{1-C\ exp[-N(1-C)]}$$

$$\boldsymbol{\varepsilon} = \frac{1-exp[-0.33(1-0.635)]}{1-0.635\ exp[-0.33(1-0.635)]}$$

ε =0.26

Note: effectiveness can also obtained **by using chart** from HMT data Book

Select NTU on X-axis and corresponding curve of C=Cmin /Cmax and read ε value on Y-axis

Similarly for counter flow

9.0 COMPARISON OF EFFECTIVENESS BY DIFFERENT METHODS

9.1 For parallel flow arrangement:

i) By LMTD method: ε=0.214

ii) By NTU method : ε=0.29

iiI) By using chart : ε=0.28

9.2 Comparison for counter flow arrangement:

i) By LMTD method : ε=0.19

ii) By NTU method :ε=0.26

iiI) By using chart : ε=0.22

10. CONCLUSION

The experimental data calculated and analyzed for parallel flow arrangement and counter flow arrangement by both methods of logarithmic mean temperature difference and NTU method and it was compared for both parallel and counter flow measurement and also the comparison is made for the both flows with the charts available in heat transfer data book and found the results obtained are almost giving the same effectiveness (matching) and hence the model developed is giving satisfactory results

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