EXPERIMEANTAL ANALYSIS OF DOUBLE PIPE HEAT EXCHANGER WITH STAINLESS STEEL TUBE WITH AND WITHOUT FINS

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ABSTRACT

In this paper, experiments were performed to investigate the performance of double pipe heat exchanger with stainless steel tube with and without fins of rectangular cross section having 80mm and 160mm pitch differences. Also the flow arrangement is both parallel and counter in nature. The experimental setup consists of two concentric tubes with outer annulus of G.I tube and inner annulus of stainless steel tube. Hot water is flowing across the inner tube and cold water is flowing across the outer tube, thus the heat is transferred from the inner annulus to the outer annulus. Firstly we conducted the experiment without fins and recorded the parameter for plane heat exchanger and then with fins of 160mm and 80mm pitch difference. The observations and calculations are determined on the basis of the thermal performance of the double pipe heat exchanger.

The overall experiment is conducted under steady state condition where mass flow rate of cold water is controlled by the manometer and mass flow rate of hot water is same on both side of the outer tube. The result so obtained after number of experiments states that the effectiveness increases with decrease in the pitch difference and in the case of counter flow, effectiveness is higher than in case of parallel flow.

Keywords: Double pipe heat exchanger, effectiveness, heat transfer rate, overall heat transfer coefficient, parallel flow arrangement, counter flow arrangement.

NOMENCLATURE

T_{hi}	Hot water inlet temperature
T_{ho}	Hot water outlet temperature
T_{ci}	Cold water inlet temperature
T_{co}	Cold water outlet temperature
D_p	Diameter of tube
D_o	Diameter of orifice meter
A_p	Area of tube
A_o	Area of orifice meter
H_m	Head of mercury column
H_w	Head of water column
ρ	Density of mercury
C_{dis}	Coefficient of discharge
Q	Discharge of orifice meter
m_{cw}	Mass flow rate of cold water

m_{hw} Mass flow rate of hot water

V Volume of bucket

t Time taken to fill the bucket

ΔT_m LMTD

€ Effectiveness

Ů Overall heat transfer coefficient

INTRODUCTION

Heat exchanger is a device used to transfer heat from one medium to other medium either by direct contact or by indirect contact. Heat exchanger is widely used in industrial purpose and is present in our refrigerator and air conditioning unit. The transfer of heat occurs in three modes: conduction, convection and radiation. The industries where it is generally used are chemical, power plants, nuclear reactors, heavy industries, etc.

In this paper, experiments were conducted to analysis the effect of fins on the effectiveness and overall heat transfer coefficient of the double pipe heat exchanger. The fins of rectangular configurations were attached on the outer surface of the tubes which causes a separate and reattach flow. A number of experiments are carried out using aluminum tube material and rectangular fins configuration, but this paper is investigating the performance of stainless steel tube material with and without fins of rectangular configurations.

EXPERIMENTAL SETUP

The above setup is used to determine the heat transfer. The setup consist of two concentric tube with outer annulus of G.I with 50.8mm diameter and 2430.5mm length and inner annulus of stainless steel tube of 16.67mm diameter and 2438.4mm length. The hot water is flowing across the inner tube and cold water is flowing across the outer tube such that heat transfer takes place from inner to outer annulus of the heat exchanger and flow considered is parallel and counter. A digital temperature indicator is used to record the temperature which is connected to the tubes through thermocouple wires at the inlet and outlet of both the tubes. The hot water coming from the geyser is circulated across the inner annulus with the help of pump. The mass flow rate of hot water is same whereas the mass flow rate of cold water is varied with the help of U- shaped manometer attached at the inlet and outlet of the orifice meter attached at the inlet of the inner tube. Firstly we conducted the experiment with plane stainless steel tube as inner annulus and recorded the performance parameter. We repeated the same procedure to obtain the performance parameter of stainless steel tube with fins of two pitch differences.

The special feature of this experiment is to use fins on the outer surface of the tube of rectangular configurations. The use of fins gives many advantages which include perfect separation of fluid around the annulus, high effectiveness, no moving parts, high reliability, etc. The fins provides the zigzag motion to the cold water at the outer annulus resulting in high heat transfer and increase in effectiveness as more surface is exposed to flowing water.

SPECIFICATIONS

Digital temperature indicator: K-Type sensor, 0-400 range, 230V- AC Voltage.

Geyser: 1litre capacity, 3000 watt power and 230V-AC Voltage.

Centrifugal pump: Mini super model, 100 watt input, 500mm head and 230V Voltage/50Hz.

Specification of fins:

Shape	Rectangular
Base	5mm
Height	10mm
Thickness	1.5mm

CALCULATION

1. $Q = C_{dis}*[(A_pA_o\sqrt{2gH}_w)/(A_p\text{-}A_o)^{1/2}]$

2. $m_{cw} = \rho*Q$

3. $Q_{act} = m_{cw}*C_{pcw}*(T_{co}\text{-}T_{ci})$

4. $Q_{max} = m_{cw}*C_{pcw}*(T_{hi}\text{-}T_{ho})$

5. $€ = Q_{act}/Q_{max}$

6. $\mathring{U} = Q_{act}/(A*\Delta T_m)$

OBSERVATION

1. Experimental data of plane stainless steel tube in parallel flow arrangement:-

S.No.	Manometer reading H_m= (L-R) cm		m_{hw} Kg/sec	m_{cw} Kg/sec	T_{hi} °C	T_{ho} °C	T_{ci} °C	T_{co} °C	ΔT_m °C	€	Ů W/m^2
	Left	Right									
1	7.5	5	0.253	0.091	50	48	28	33	18.28	0.227	546.188
2	8.5	4	0.253	0.122	48	47	28	32	17.38	0.190	616.137
3	9.5	3	0.253	0.147	47	45	28	31	16.37	0.158	591.149
4	10.5	2	0.253	0.168	46	44	28	30	15.92	0.111	436.130
5	11.5	1	0.253	0.187	43	41	28	29	13.44	0.067	305.316

Q_{act} = 0.091*4.2*(33-28) = 1.911 KW

Q_{max} = 0.091*4.2*(50-28) = 8.4084 KW

€ = 1.911/8.4084= 0.227

Ů= (1.911*1000)/(0.1914*18.28)= 546.188W/m^2

2. Experimental data of stainless steel tube with fins of 160mm pitch difference in parallel flow arrangement:-

S.No.	Manometer reading H_m= (L-R) cm		m_{hw} Kg/sec	m_{cw} Kg/sec	T_{hi} °C	T_{ho} °C	T_{ci} °C	T_{co} °C	ΔT_m °C	€	Ů W/m^2
	Left	Right									
1	7.5	5	0.253	0.091	50	47	28	35	16.50	0.318	847.154
2	8.5	4	0.253	0.122	47	45	28	33	15.23	0.263	878.895
3	9.5	3	0.253	0.147	46	43	28	31	14.80	0.167	542.658

4	10.5	2	0.253	0.168	44	41	28	30	13.34	0.125	483.614
5	11.5	1	0.253	0.187	40	27	28	29	9.86	0.085	416.171

Q_{act} = 0.091*4.2*(35-28) = 2.6754 KW

Q_{max} = 0.091*4.2*(50-28) = 8.4084 KW

€ = 2.6754/8.4084= 0.318

Ů= (2.6754*1000)/(0.1914*16.50)= 847.154W/m^2

3. Experimental data of stainless steel tube with fins of 80mm pitch difference in parallel flow arrangement:-

S.No.	Manometer reading H_m= (L-R) cm		m_{hw} Kg/sec	m_{cw} Kg/sec	T_{hi} °C	T_{ho} °C	T_{ci} °C	T_{co} °C	ΔT_m °C	€	Ů W/m^2
	Left	Right									
1	7.5	5	0.253	0.091	50	46	28	36	15.22	0.364	1049.60
2	8.5	4	0.253	0.122	47	43	28	34	13.38	0.316	1200.50
3	9.5	3	0.253	0.147	45	41	28	33	11.94	0.294	1350.80
4	10.5	2	0.253	0.168	42	38	28	32	9.44	0.286	1562.08
5	11.5	1	0.253	0.187	40	37	28	30	9.28	0.167	884.36

Q_{act} = 0.091*4.2*(36-28) = 3.0576 KW

Q_{max} = 0.091*4.2*(50-28) = 8.4084 KW

€ = 3.0576/8.4084= 0.364

Ů= (3.0576*1000)/(0.1914*15.22)= 1049.60W/m^2

4. Experimental data of plane stainless steel tube in counter flow arrangement:-

S.No.	Manometer reading H_m= (L-R) cm		m_{hw} Kg/sec	m_{cw} Kg/sec	T_{hi} °C	T_{ho} °C	T_{ci} °C	T_{co} °C	ΔT_m °C	€	Ů W/m^2
	Left	Right									
1	7.5	5	0.253	0.091	50	48	28	34	17.70	0.273	679.90
2	8.5	4	0.253	0.122	48	46	28	33	16.25	0.250	823.73
3	9.5	3	0.253	0.147	46	44	28	32	14.80	0.222	871.81
4	10.5	2	0.253	0.168	44	40	28	30	12.76	0.125	574.38
5	11.5	1	0.253	0.187	42	38	28	29	11.88	0.071	345.41

Q_{act} = 0.091*4.2*(34-28) = 2.2932 KW

Q_{max} = 0.091*4.2*(50-28) = 8.4084 KW

€ = (2.2932*1000)/(0.1914*17.70)= 679.90W/m^2

5. Experimental data of stainless steel tube with fins of 160mm pitch difference in counter flow arrangement:-

S.No.	Manometer reading H_m= (L-R) cm		m_{hw} Kg/sec	m_{cw} Kg/sec	T_{hi} °C	T_{ho} °C	T_{ci} °C	T_{co} °C	ΔT_m °C	€	Ů W/m^2
	Left	Right									

1	7.5	5	0.253	0.091	50	46	28	36	15.22	0.364	1049.60
2	8.5	4	0.253	0.122	47	45	28	34	14.64	0.316	1097.18
3	9.5	3	0.253	0.147	46	43	28	32	14.21	0.222	908.00
4	10.5	2	0.253	0.168	44	39	28	31	11.54	0.187	958.37
5	11.5	1	0.253	0.187	40	38	28	30	9.86	0.167	832.32

Q_{act} = 0.091*4.2*(36-28) = 3.0576 KW

Q_{max} = 0.091*4.2*(50-28) = 8.4084 KW

€ = 3.0576/8.4084= 0.364

Ů= (3.0576*1000)/(0.1914*15.87)= 1049.60W/m^2

6. Experimental data of stainless steel tube with fins of 80mm pitch difference in counter flow arrangement:-

S.No.	Manometer reading H_m= (L-R) cm		m_{hw} Kg/sec	m_{cw} Kg/sec	T_{hi} °C	T_{ho} °C	T_{ci} °C	T_{co} °C	ΔT_m °C	€	Ů W/m^2
	Left	Right									
1	7.5	5	0.253	0.091	50	46	28	38	15.22	0.454	1049.60
2	8.5	4	0.253	0.122	47	44	28	35	13.38	0.368	1200.50
3	9.5	3	0.253	0.147	45	43	28	34	11.94	0.353	1350.80
4	10.5	2	0.253	0.168	42	39	28	34	9.44	0.286	1562.08
5	11.5	1	0.253	0.187	40	37	28	31	9.28	0.250	884.36

Q_{act} = 0.091*4.2*(38-28) = 3.822 KW

Q_{max} = 0.091*4.2*(50-28) = 8.4084 KW

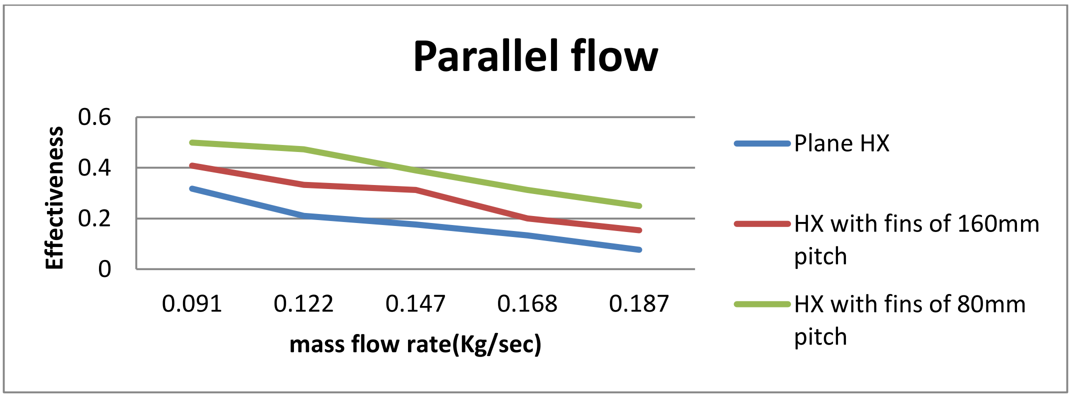
€ = 3.822/8.4084= 0.454

Ů= (3.822*1000)/(0.1914*15.22)= 1049.60W/m^2

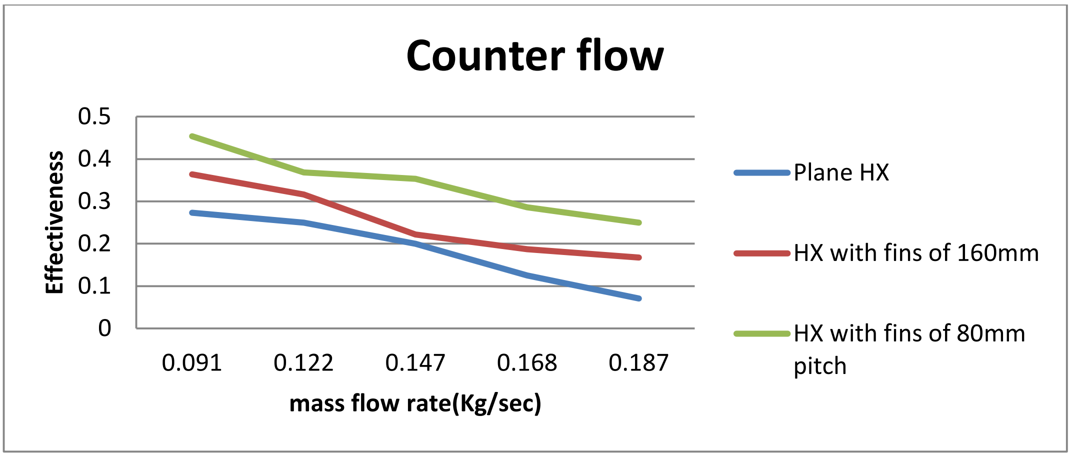
RESULTS AND DISCUSSION

In order to describe the experiment, graphs are plotted between different parameters obtained from number of observations. The graph based on different parameters is shown below at different mass flow rate of cold water.

a. Variation of effectiveness with mass flow rate of cold water of stainless steel tube in parallel flow



b. Variation of effectiveness with mass flow rate of cold water of stainless steel tube in counter flow



CONCLUSION

This paper states that when there is decrease in the pitch difference, the effectiveness and overall heat transfer coefficient of heat exchanger increases.. The counter flow arrangement gives better result than parallel flow arrangement. It is also seen that at minimum mass flow rate of cold water at 0.091Kg/sec, effectiveness, overall heat transfer coefficient and heat transfer rate is maximum.

The insulation on the outer annulus plays a vital importance in the performance of the heat exchanger. Here in many observations it can be noted that heat loss by hot water is higher than the cold water which states that insulation is not enough to resist the losses.

Thus it can be concluded that heat exchanger with fins gives better performance than heat exchanger without fins under the same conditions and parameters, improving the applications of heat exchangers in every field of industries.

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