MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
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DEPARTMENT OF MECHANICAL AND INDUSTRIAL ENGINEERING

Mechanical Lab II (MME 3272)

VI Semester Mechanical Engineering, Section: D

MINI PROJECT

GROUP -3

PARALLEL FLOW RADIAL PIN FIN HEAT EXCHANGER

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GROUP DETAILS

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INTRODUCTION

In power generating and manufacturing plants working fluids are used for a wide range of operations. These operations are carried out in different environments and at different temperatures, thus the fluid must be at specified temperature required for its intended use in the process. This is done through the means of Heat Exchanger which is a heat transfer device that exchanges heat between two or more process/working fluids. (Bahman Zohuri, in Physics of Cryogenics, 2018)

In thermal engineering applications, both the fluids are in motion and the main mode of heat transfer is convection. Some examples are automobile radiators, air conditioner, condenser coil in the refrigerator, solar water heater, chemical industries, domestic boilers, milk chillers , oil coolers in a heat engine, (Sachin Thorat,in Thermal engineering ,p.1)

In engineering Heat exchangers play an important role of transferring heat between two different flow streams and temperatures. There are various designs of heat exchangers based on size, direction of fluid flows & construction.

(P.S. Arshi Banu, D. N. S. Ramesh Lohith, M. Praveen Kalyan, Dilip Sai Vempati, B. Hemanth Sai)

1.a Heat Exchanger

Heat exchangers are industrial devices that are used to transfer Thermal energy from one fluid to another fluid. The fluids are separated by a solid wall with high thermal conductivity to prevent mixing. (Nick Connor, Thermal Engineering.org, p.1)

The process of heat transfer in a heat exchanger involves convection between the fluids and thermal conduction through the insulating wall separating the working fluids.

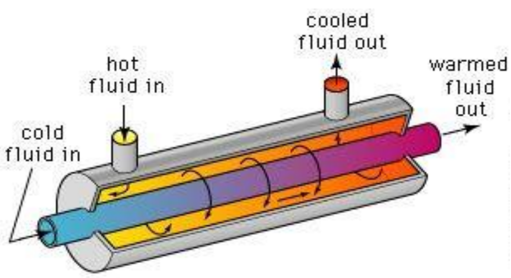
In the analysis of heat exchangers, it is often convenient to work with an overall heat transfer coefficient, known as a U-factor. It is defined by an expression analogous to Newton's law of cooling.

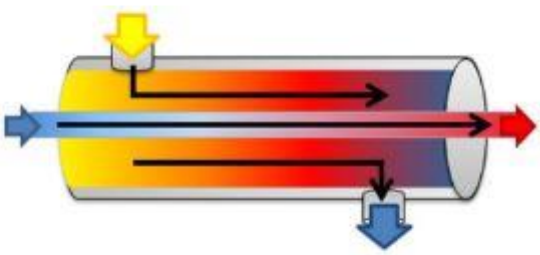
The temperature driving force for heat transfer in heat exchangers is determined using (LMTD) The logarithmic mean temperature difference is used.

Classification of heat exchanger:

Based on flow arrangement:

- Parallel-flow heat exchanger: In a parallel-flow arrangement, the hot and cold fluids enter the heat exchanger at the same end they flow in the same direction and leave at the same end.





- <u>Counter-flow heat exchanger:</u> In a counter flow arrangement, the fluids enter the heat exchanger at opposite ends they flow in opposite directions and leave at opposite ends.

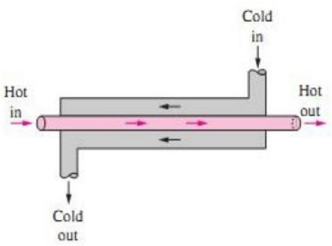
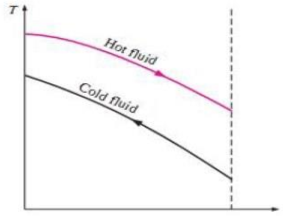


Fig b(i)



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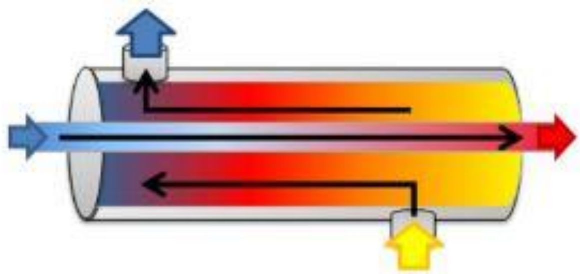
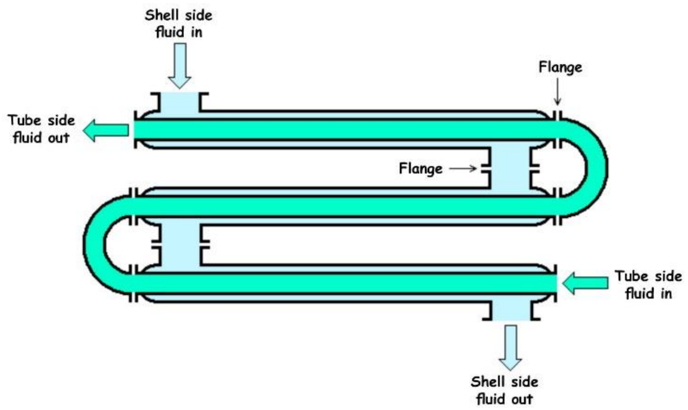


Based on construction:

<u>Double pipe heat exchangers:</u>

In double pipe heat exchangers fluid flows inside the inner pipe/tube and the working fluid flows through the outer tube this fluid covers the inner tube. They are inexpensive for both design and routine maintenance & service making them a good choice for small scale industries.



Shell and tube heat exchangers:

In shell and tube heat exchanger, several small diameter pipes are fitted between two tube plates through which the primary fluid flows. The secondary fluid flows through the shell and the tube bundle placed inside the shell over the surface of the tubes.

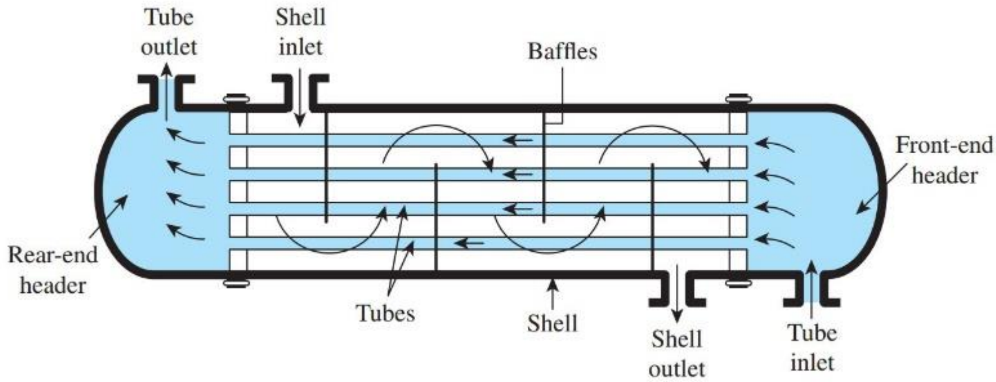
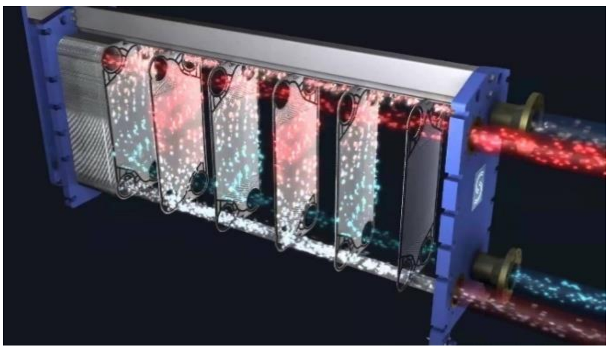
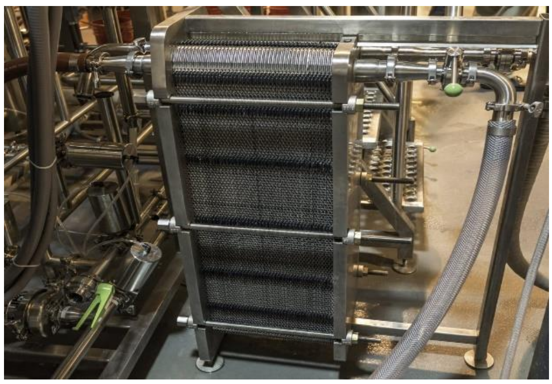


Plate heat exchangers:

A plate heat exchanger uses metal plates to achieve heat transfer between two working fluids. These heat exchangers are used for air, gas & conditions of low velocity fluid flow. .(Maurice Stewart, Oran T. Lewis, in Heat Exchanger Equipment Field Manual, 2013)





1.b Fins

Extended surfaces which are designed to increase the heat transfer rate for a fixed surface temperature of a heated surface or body or system where the heat must be continuously dissipated to the surrounding environment to maintain the system in a steady-state condition.

Fins can be used to increase Convective Heat transfer between a surface and the fluid surrounding. Fins increase the effective area of a surface thereby increasing the convective heat transfer rate.

Methods of increasing Heat transfer rate:

By increasing the Convection heat transfer coefficient: This can be achieved by installing a pump or fan to blow air over the surface

By increasing the surface: This is achieved by attaching fins /extended surfaces to the surface (Romina Ronquillo,thomasnet.com, pp 1-3)

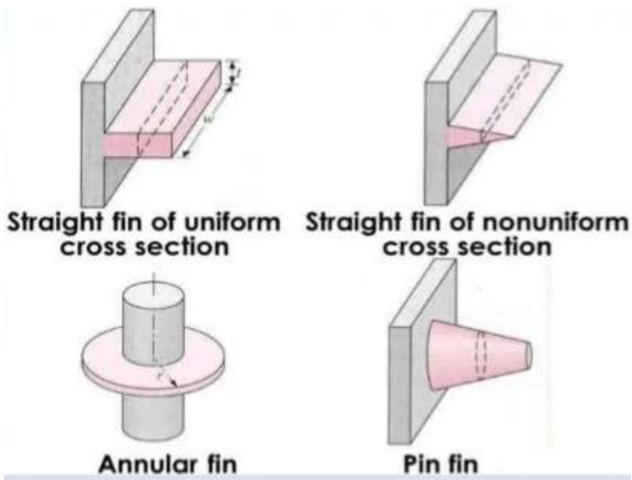
Types of Fins:

Various types of fins are as follows:

A) Pin fin

B) Longitudinal fin

C) Radial fin



Materials used in manufacturing fins:

Fins are usually made of Aluminum, copper & copper alloys, steel.

Heat Transfer from Extended Surface

As per Newton's law of cooling , the rate of heat transfer from a surface at a temperature Ts to the surrounding medium at T infinity is given by

$$\dot{Q}_{\text{conv}} = hA_s(T_s - T_\infty)$$

Where,

Ts and T_∞ are fixed.

H = convection heat transfer coefficient

As = heat transfer surface area.

Fin efficiency

The ratio of heat transfer from the actual fin to that of an imaginary fin of the same geometry and same conditions but with infinite conductivity.

Where $\eta<1$

$$\eta = \frac{Q_{fin}}{hA_{total\ area}(T_b - T_\infty)}$$

Fin effectiveness

Fin effectiveness is the ratio of heat transfer from the fin to the heat transfer without fin .

$$\epsilon = \frac{Q_{fin}}{hA_{fin\ base}(T_b - T_\infty)}$$

Advantages Of Fins:

Fins are the most effective way of increasing heat transfer from a hot body in conditions which do not allow the use of large heat dissipators this method utilizes a very small form factor to achieve improved heat transfer rates.

Disadvantages Of Fins:

Fins add additional weight of the unit. they must be machined on or attached which increases the manufacturing costs. They are also difficult to transport and are prone to bending or shearing if not maintained properly.

Application Of Fins:

1. Reciprocating air compressors
2. Electric transformers
3. Condenser tubes used in refrigeration.
4. Air-cooled I.C. engines

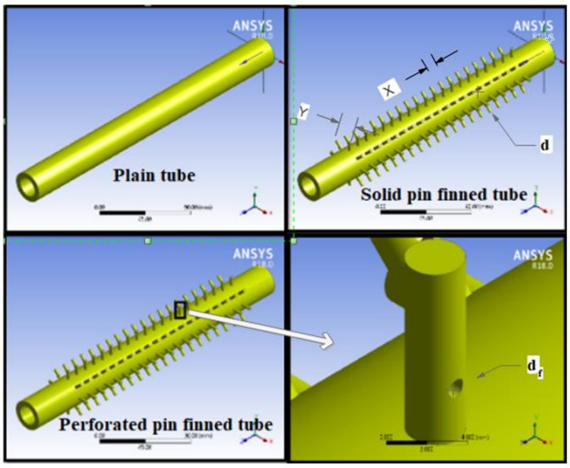
1.c Radial pin fin heat exchanger

Radial pin fin heat exchangers have the inner tubes lined with fins on the surface of tubes in a radial pattern.

Radial pin fins are manufactured by welding a stud or rod to the base of the tube by Electrical Resistance welding process.

This type of Finned Tubes is used in in high pressure and high temperature applications. The mechanical bond is very strong and hence finds application in places where extreme mechanical load, stress is expected during the process or cleaning etc.

They are used in heat exchangers and in air coolers which are used in petrochemical refineries, chemical industries , power plants and steel plants etc.



1.d Working principle.

Heat exchangers operate under fundamental principle of the Zeroth law , First law, and Second Law of Thermodynamics which describe and dictate the transference/exchange of heat from one fluid to another.

According to the Zeroth Law of Thermodynamics- Thermodynamic systems that are in thermal equilibrium have the same temperature. If two systems are individually in thermal equilibrium with a third system, then the two former systems must be in equilibrium with each other; thus, all three systems are of the same temperature. This law expresses thermal equilibrium as a transitive property & also defines the concept of temperature and establishes it as a measurable property of thermodynamic systems.

According to the Second Law of Thermodynamics –

Entropy (S) is an additional property of thermodynamic systems and describes the natural and invariable tendency of a closed thermodynamic system to increase in entropy over time.

$$\Delta S = \frac{\Delta Q}{T}$$

where ΔS =change in entropy

ΔQ = change in the heat added to the system

T = absolute temperature:

As established by the Second Law, entropy can only increase, never decrease.

As the entropy increases to the highest value achievable for said system, the system reaches a state of equilibrium where entropy can no longer increase nor decrease, as that action would violate the Second Law.

In a Parallel flow heat exchanger the working fluids move in parallel direction the fluids enter from the same end of the heat exchanger .This configuration allows for the greatest thermal uniformity across the walls of the heat exchanger.

The experiment is done in a parallel flow configuration in which the direction of flow of both ethe hot and cold fluids are in the same direction.

The hot water which is sent through the tube undergoes heat reduction as heat transfer takes place between the two fluids separated by a metal boundary, this is further amplified by using radial pin fins along the pipe which increases surface area hence increase in heat transfer can be observed the cold-water temperature increases due to heat absorption.

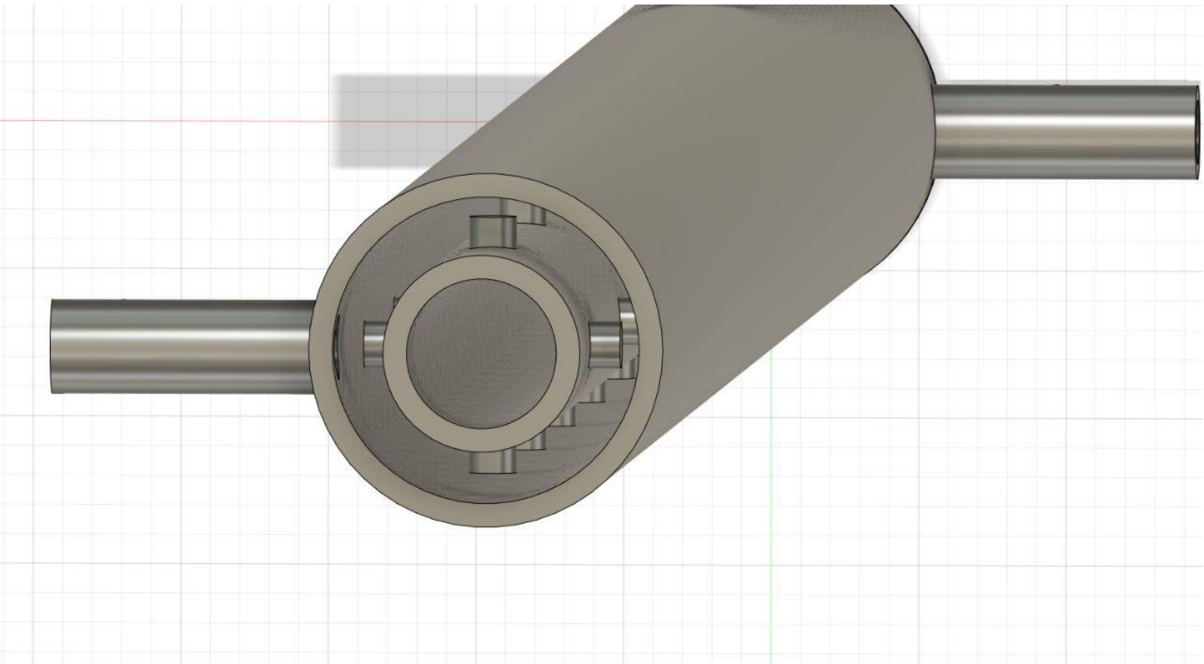
Through the experiment we must observe and record the change in heat transfer in the case of heat exchanger with radial pin fins and without pin fin.

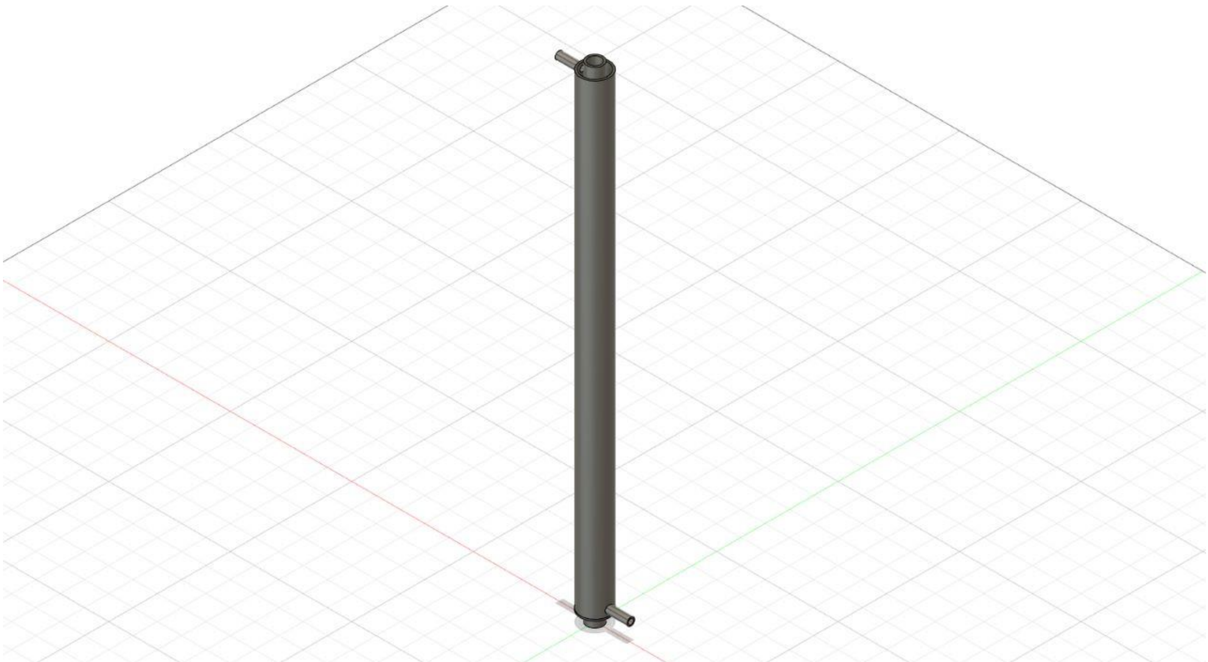
1.e Applications of Heat exchanger

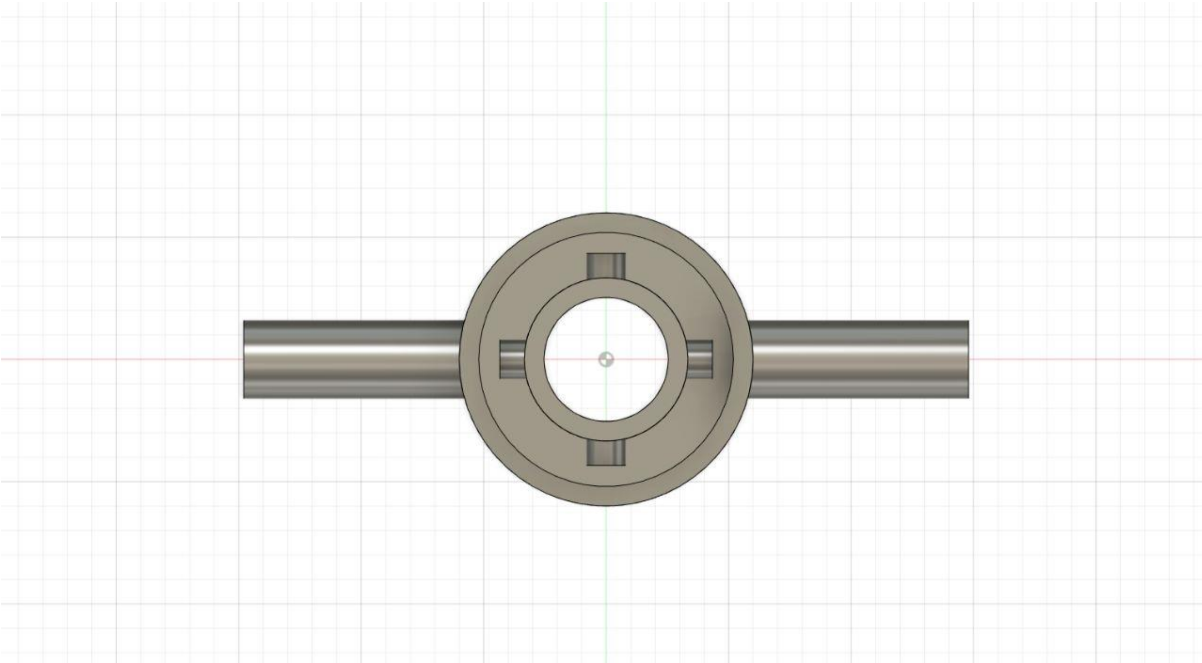
- Heat exchangers for Chemical process
- Heat exchangers for cryogenic processes
- Heat exchangers used in deep sea applications
- Power generation facilities
- Refrigeration facilities
- Chemical and petrochemical processing
- Petroleum and crude oil refineries
- Food processing industries
- Pasteurization plants
- Aerospace applications
- Orbital Satellites

DESIGN

2.a CAD Design







SETUP OF HEAT EXCHANGER

3.a Aim of project

To design a parallel flow heat exchanger of 1 meter length by using radial pin fins on the hot water pipe. Compare The effectiveness of such a heat exchanger with that of heat exchanger without radial Pin fin.

3.a Components used.

Serial Number	Component Name	Quantity
1	Inner pipe	2
2	Outer pipe	2
3	Solid stainless-steel rod (fins)	1
4	Pipe	4
5	Billets for closure	2
6	m-seal, adhesives, tapes	5
7	Geyser	1
8	Rotameter	2
9	Thermocouples & Digital Display	4

SPECIFICATIONS

Component	Material	Diameter(in)	Length(m)
Inner tube	Mild steel	1	1
Function: The inner tube carries hot water Through the heat exchanger and fins are attached to this tube to increase its Heat transfer to the cold water surrounding it.			

Component	Material	Diameter(in)	Length(m)
Outer tube	Mild steel	2	1
Function: The Outer tube has a larger diameter, and the inner tube is placed within the outer tube. Cold water is passed through this tube as it surrounds the inner tube and creates a water jacket around it .			

Component	Material	Diameter(mm)	Length(mm)
Fins	Stainless steel	8	5
Function: Fins are attached to the inner pipe through the process of welding. These increase the heat transfer due to increased surface area.			

Component	Material	Diameter(in)	Length(m)
Pipes	PVC	1	2
Function: The pipe is used to route hot water from the geyser to the inner tube of heat exchanger. It is also used to route cold water through the heat exchanger.			

Component	Material
Billets	steel
Function: Used to close the ends of the outer pipe to create a watertight closure.	

Component
M- seal, Adhesives, Tape
Function: used to seal and make connections airtight, To secure other components.

Component
M- seal, Adhesives, Tape
Function: used to seal and make connections airtight, To secure other components.

Component
Electric geyser
Function: heats up the water which is then made to flow through the heat exchanger. Thermocouples & Digital Display

Component
Thermocouple & Display
Function: A total of four thermocouples are used to measure hot water inlet and exit temperature, cold water temperature at inlet and exit

3.b Processes used in construction.

Turning and facing operations: These are material removal operations which are achieved through a lathe machine. Turning operation creates a clean external surface on the external pipe. facing operations creates a clean flat face on either ends of the pipe.

Welding: Welding is process by which 2 metals are permanently joined together through the application of heat. This process is used to join the fins to the pipe carrying heated fluid in the heat exchanger. It is used to weld the inlet and exit ports of the cold water entering the heat exchanger and to make an airtight seal at the ends of the heat exchanger using billets and m-seal.

Grinding: It is a material removal process which is used to smooth out rough edges at the ends of each pipe.

Cutting: This is a material removal process used to cut fins of equal sizes from the same stock (solid stainless-steel pipe)

Drilling: It is process of material removal which creates holes. This is used to make inlet and exit holes for water on the heat exchanger.

IMAGES OF SETUP

PROCEDURE

5.a Conduction of experiment

1. Connect the equipment to the power supply.

2. Put on the geyser. Adjust the flow rate of hot water side say 600 ml/minute.

3. Start the flow on cold water through the annulus and run the parallel flow Pin-fin heat exchanger unit.

4. Keep the flow rates the same till the steady state conditions are reached.

5. Note down the temperatures on hot and cold-water sides.

6. Measure the flow rates.

7. Repeat the same steps for heat exchanger without fins and note down the readings.

5.b Caution to be exercised.

- Keep out of hot surface that may cause skin burn.
- Ensure hot water pipes are well secured before operation.
- Make sure that the water outlet pipes are placed in the appropriate drainage.
- Do not operate switches with wet hands.

OBSERVATION TABLE

Parallel flow radial pin fin heat exchanger										
SL. NO.	HOT WATER FLOW RATE $(m^3)/s$			COLD WATER FLOW RATE$m^3)/s$			Cold Water Temperature $(°c)$		Hot water Temperature $(°c)$	
	Vol. of water	Time taken	Vol.flow rate Q_{wh}	Vol. of water	Time taken	Vol.flow rate Q_{wc}	Inlet	Outlet	Inlet	Outlet
	V_{wh}	t	V_w/t	V_{wc}	t	V_w/t	T_{ci}	T_{co}	T_{hi}	T_{ho}
	cm^3	s	m^3/s	cm^3	s	m^3/s	$°c$			
1			$40*10^{-6}$			$78*10^{-6}$	30	35	50	40

Parallel flow heat exchanger without fin										
SL. NO.	HOT WATER FLOW RATE $(m^3)/s$			COLD WATER FLOW RATE$m^3)/s$			Cold Water Temperature $(°c)$		Hot water Temperature $(°c)$	
	Vol. of water	Time taken	Vol.flow rate Q_{wh}	Vol. of water	Time taken	Vol.flow rate Q_{wc}	Inlet	Outlet	Inlet	Outlet
	V_{wh}	t	V_w/t	V_{wc}	t	V_w/t	T_{ci}	T_{co}	T_{hi}	T_{ho}
	cm^3	s	m^3/s	cm^3	s	m^3/s	$°c$			
1			$40*10^{-6}$			$78*10^{-6}$	30	34	50	45

CALCULATIONS

Fin Effectiveness of Parallel flow radial pin fin Heat exchanger: -

1.Heat transfer from hot water: $Q_h = \dot{m}_h c_{ph} \Delta T$ W

Where,

mh = Mass flow rate of hot water = ρQwh, kg/s

Qwh = Volumetric flow rate of hot water, m3/s

ρ = Density of water at mean temperature ([Thi+Tho]/2),kg/m3

Cph = Specific heat of hot water ~ 4187J/kgK

$$Q_h = \dot{m}_h c_{ph}(T_{hi} - T_{ho}) \text{ W}$$

$$=0.048*4187*(50-40)$$

$$Q_h = \underline{\underline{2009.76\text{W}}}$$

2. Heat gained by cold water: $Q_c = \dot{m}_c c_{pc} \Delta T$ W

Where,

mc= Mass flow rate of cold water = ρQwc, kg/s

Qwc = Volumetric flow rate of cold water, m3/s

ρ = Density of water at mean temperature ([Tco+Tci]/2), kg/m3

Cpc = Specific heat of cold water = 4187J/kgK

$$Q_c = \dot{m}_c c_{pc}(T_{hi} - T_{ho}) \text{ W}$$

$$Q_c=0.078*4187*(35-30) = \underline{\underline{1632.93 \text{ W}}}$$

$$Q_c = 1632.93 \text{ W}$$

3. Mean heat transfer between hot and cold water:

$Q = \frac{Q_h + Q_c}{2}$ W $= \frac{1632.93+2009.76}{2}$

Q=1821.345W

4. Logarithmic mean temperature difference, $(\Delta T)_{LMTD}$

$$(\Delta T)_{LMTD} = \frac{\theta_2 - \theta_1}{ln\frac{\theta_2}{\theta_1}} {}^\circ C$$

Where, $\theta_1 = T_{hi} - T_{ci}$ = 50-30 = 20

$\theta_2 = T_{ho} - T_{c0}$ = 40-35 = 5

$$(\Delta T)_{LMTD} = \frac{20-5}{ln\frac{20}{5}}$$

$(\Delta T)_{LMTD}$=$10.82^\circ C$

5. Overall heat transfer coefficient based on outside surface area of inner tube,

$U_\circ = \frac{Q}{A_\circ * (\Delta T)_{LMTD}}$ W/m^2K

Where, $A_\circ = \pi d_\circ l + SA\ m^2$

Number of fins = 40

Pitch = 100mm

Diameter of fins = 8mm

Length = 5mm

Surface area= π*d*l = π*8*$(5 * 10^{-6})$

$= \underline{1.25*10^{-4} m^2}$

$A_\circ = \pi d_\circ l + surface\ area * n$

$= \pi*33.14*(1*10^{-3}) + (1.256 * 10^{-4})*40$

$A_\circ = \underline{0.1099 m^2}$

Therefore, we have:

$U_\circ = \frac{1821.345}{0.1099*10.82}$ $\underline{U_\circ = 1531.677\ W/m^2K}$

6. Effectiveness (ΔT) $\in = \frac{T_{hi}-T_{ho}}{T_{hi}-T_{ci}}$ if $C_h < C_C$

$\in = \frac{T_{co}-T_{ci}}{T_{hi}-T_{ci}}$ if $C_c < C_h$

Where,

Ch = Heat capacity of hot water

Cc = Heat capacity of cold water

$$C_h = \dot{m}_h * C_{ph} = 0.048 * 4187 = 200.9$$

$$C_c = \dot{m}_c * C_{pc} = 0.078 * 4187 = 326.58$$

We have, $C_c > C_h$

Therefore,

$$\in = \frac{T_{hi} - T_{ho}}{T_{hi} - T_{ci}} = \frac{q}{q_{max}}$$

$$\in = \frac{50 - 40}{50 - 30} = \underline{\underline{0.5 = 50\%}}$$

7. Effectiveness (NTU), NTU = $\frac{U_\circ * A_\circ}{C_{min}}$

Note: if Ch<Cc then Ch= C min. & Cc= Cmax.

if Cc<Ch then Cc= C min. & Ch= Cmax

we have $C_c > C_h$

therefore, Ch= C min. & Cc= Cmax

$$C_{min} = C_h = 200.97$$

NTU = $\frac{1531.677 * 0.1099}{200.97} = \underline{\underline{0.837}}$

a) Effectiveness of Parallel Flow heat Exchanger:

$$\in = \frac{1 - e^{-NTU(1+(C_{min}|C_{max}))}}{1 + (C_{min}|C_{max})}$$

$C_r = (C_{min}|C_{max}) = \frac{200.97}{326.5} = \underline{\underline{0.6155}}$

Therefore,

$$\in = \frac{1-e^{-0.837(1+0.6155)}}{1+0.6155} = 0.458$$

$$\in_{with\ fins} = \underline{\underline{0.458 = 45.8\%}}$$

Fin Effectiveness of Parallel flow Heat exchanger without fins: -

1.Heat transfer from hot water: $Q_h = \dot{m}_h c_{ph} \Delta T$ W

Where,

$\dot{m}_h$= Mass flow rate of hot water = ρQwh, kg/s

Qwh = Volumetric flow rate of hot water, m3/s

ρ = Density of water at mean temperature ([Thi+Tho]/2),kg/m3

c_{ph} = Specific heat of hot water ~ 4187J/kgK

$$Q_h = \dot{m}_h c_{ph} (T_{hi} - T_{ho}) \text{ W}$$

=0.048*4187*(50-45)

Q_h=1004.88W

2. Heat gained by cold water: $Q_c = \dot{m}_c c_{pc} \Delta T$ W

Where,

$\dot{m}_c$= Mass flow rate of cold water = ρQwc, kg/s

Qwc = Volumetric flow rate of cold water, m3/s

ρ = Density of water at mean temperature ([Tco+Tci]/2), kg/m3

c_{pc} = Specific heat of cold water = 4187J/kgK

$$Q_c = \dot{m}_h c_{pc} (T_{hi} - T_{ho}) \text{ W}$$

=0.078*4187*(34-30) =1306.344 W

Q_c=1306.344 W

3. Mean heat transfer between hot and cold water:

$Q = \frac{Q_h + Q_c}{2}$ W $= \frac{1004.88+1306.344}{2}$

Q=1155.612W

4. Logarithmic mean temperature difference, $(\Delta T)_{LMTD}$

$$(\Delta T)_{LMTD} = \frac{\theta_2 - \theta_1}{ln\frac{\theta_2}{\theta_1}} {}^\circ C$$

Where, $\theta_1 = T_{hi} - T_{ci}$ = 50-30 = 20

$\theta_2 = T_{ho} - T_{c0}$ = 45-34 = 11

$$(\Delta T)_{LMTD} = \frac{20 - 11}{ln\frac{20}{11}}$$

$$(\Delta T)_{LMTD} = 15.05^\circ C$$

5. Overall heat transfer coefficient based on outside surface area of inner tube,

$U_\circ = \frac{Q}{A_\circ * (\Delta T)_{LMTD}}$ W/m^2K

Where, $A_{\circ} = \pi d_{\circ} l m^2$

$= \pi * 33.14 * (1*10^{-3})$

$A_{\circ} = \underline{\underline{104.92 * 10^{-3} m^2}}$

Therefore, we have:

$U_{\circ} = \frac{1155.612}{(104.92*10^{-3})*15.05}$ $\underline{\underline{U_{\circ} = 731.98\ \mathrm{W/m^2K}}}$

6. Effectiveness (ΔT) $\in = \frac{T_{hi}-T_{ho}}{T_{hi}-T_{ci}}$ if $C_h < C_C$

$\in = \frac{T_{co}-T_{ci}}{T_{hi}-T_{ci}}$ if $C_c < C_h$

Where,

Ch = Heat capacity of hot water

Cc = Heat capacity of cold water

$$C_h = \dot{m}_h * C_{ph} = 0.048 * 4187 = 200.9$$

$$C_c = \dot{m}_c * C_{pc} = 0.078 * 4187 = 326.58$$

We have, $C_c > C_h$

Therefore,

$$\in = \frac{T_{hi}-T_{ho}}{T_{hi}-T_{ci}} = \frac{q}{q_{max}}$$

$\in = \frac{50-45}{50-30} = \underline{\underline{0.25 = 25\%}}$

7. Effectiveness (NTU), NTU = $\frac{U_{\circ} * A_{\circ}}{C_{min}}$

Note: if Ch<Cc then Ch= C min. & Cc= Cmax.

if Cc<Ch then Cc= C min. & Ch= Cmax

we have $C_c > C_h$

therefore, Ch= C min. & Cc= Cmax

$$C_{min} = C_h = 200.97$$

NTU = $\frac{731.98 * 0.1049}{200.97}$ = <u>0.382</u>

<u>a)</u> Effectiveness of Parallel Flow heat Exchanger:

$$\epsilon = \frac{1 - e^{-NTU(1+(C_{min}|C_{max}))}}{1 + (C_{min}|C_{max})}$$

$C_r = (C_{min}|C_{max}) = \frac{200.97}{326.5}$ = <u>0.6155</u>

<u>Therefore,</u>

$$\epsilon = \frac{1-e^{-0.382(1+0.6155)}}{1+0.6155} = 0.285$$

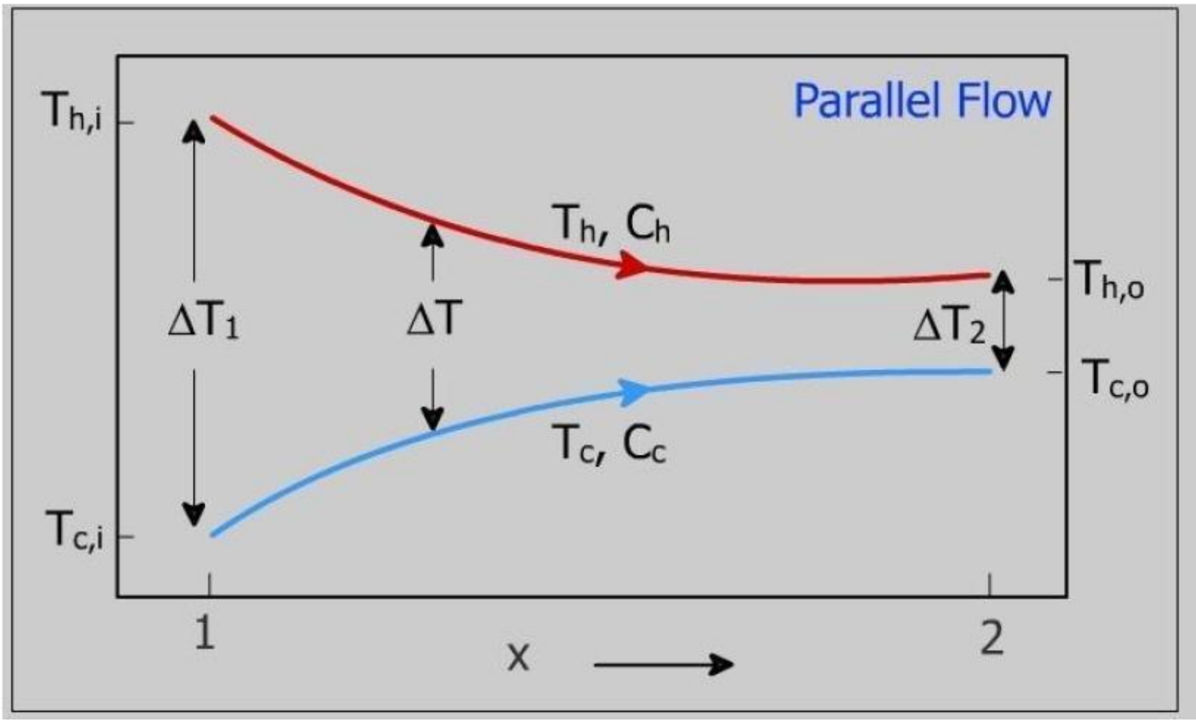
$\epsilon_{without\ fins}$=<u>0.285 =28.5%</u>

Effectiveness due to fins: $= \frac{\epsilon_{with\ fins} - \epsilon_{without\ fins}}{\epsilon_{without\ fins}}$

$= \frac{0.458-0.285}{0.285}$ = 0.607*100%

Effectiveness due to fins = 60.7%

LMTD graph for parallel flow heat exchanger:



In a parallel flow exchanger, a large temperature difference between inlet temperatures of hot and cold fluid exists at the inlet side, which may include high thermal stresses in the exchanger wall at inlet flow arrangement is not used for applications requiring high temperature effective (Gut et al., 2004 & Bhutta et al., 2007).

RESULT

Given below are the parameters obtained from the experiment of Radial pin fin heat exchanger and heat exchanger without fins: -

SL.NO	Parameter		Heat exchanger with fins	Heat exchanger without fins
1	Overall heat transfer coefficient	$U_{\circ}$(W/m²K)	1531.677	731.98
2	Logarithmic mean temperature difference	$(\Delta T)_{LMTD}$ $(^{\circ}C)$	10.82	15.05
3	Effectiveness	ΔT (%)	50	25
		NTU (%)	83.7	38.2
		∈(%)	45.8	28.5
4	Effectiveness due to fins	60.7%		

Discussion / inference:

Through the results we can observe that a heat exchanger without radial pin fins will have a lower heat transfer rate and thus lower effectiveness as compared to a heat exchanger with radial pin fins. The effectiveness of a radial pin fin heat exchanger will depend on various factors such as size and arrangement of the fins, Thermal properties of fluid and heat transfer co-efficient.

$\in=0.458 > \in = 0.285$

Q_h=2009.76W >1004.88W

$Q_c = 1632.93$ W >1306.344 W

The Logarithmic Mean temperature difference of the finned heat exchanger is lower at $10.82^{\circ}C$ it is higher at the heat exchanger without fins at$15.5^{\circ}C$.

CONCLUSION

In this Mini project we have successfully Designed, fabricated & operated a radial pin fin heat exchanger which is capable of transferring heat better than a finless Heat exchanger. The designed Heat exchanger is also more effective at dissipating heat compared to that of a finless heat exchanger. In conclusion, the addition of radial pin fins to a parallel flow heat exchanger can significantly improve its heat transfer rate and effectiveness, making it a useful design feature for many useful applications.

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