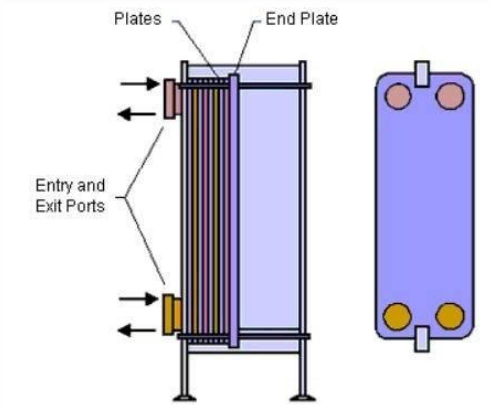
1. Title – Performance assessment of heat exchanger using MATLAB.

2. Objective –

- **To write a MATLAB programme to calculate the overall heat transfer coefficient.**
- **Analyse the plots and data to make statement about heat exchanger's performance.**

3. Introduction –

Heat transfer is a device used to transfer heat between two or more fluids and between solid and fluid. The fluids may be separated by solid wall to prevent mixing or they ay be direct contact. Heat exchangers are widely used in space heating, refrigerator, air conditioning, power station, chemical plants, petroleum refineries and sewage treatment. The classic example of a heat exchanger is found in an internal combustion engine in which a fluid circulates around engine case and cools it.



Heat exchangers can be classified in many ways like flow arrangement, heat transfer arrangement, construction geometry, heat transfer mechanism etc. according to flow arrangement it is divided into three categories –

In parallel flow heat exchangers, the two fluids enter the exchanger at the same end and travel in parallel to one another to another side.

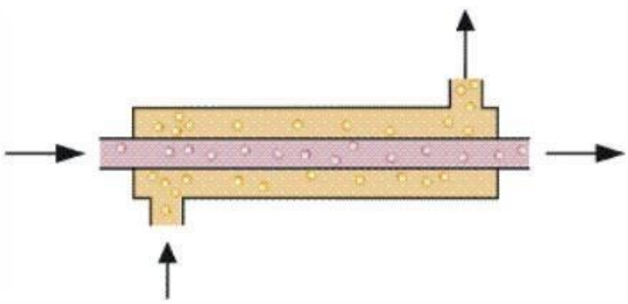


Figure 2. Cocurrent flow.

In counter flow heat exchanger, fluids enter from opposite end and run towards each other. It is the most efficient heat exchanger.

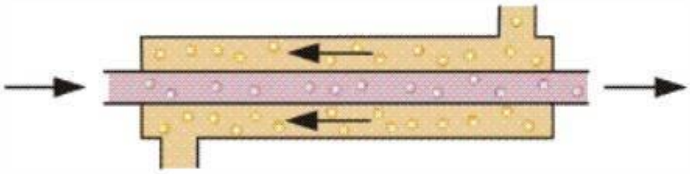


Figure 1. Countercurrent flow.

In cross flow heat exchanger, the fluid travel perpendicular to each other.

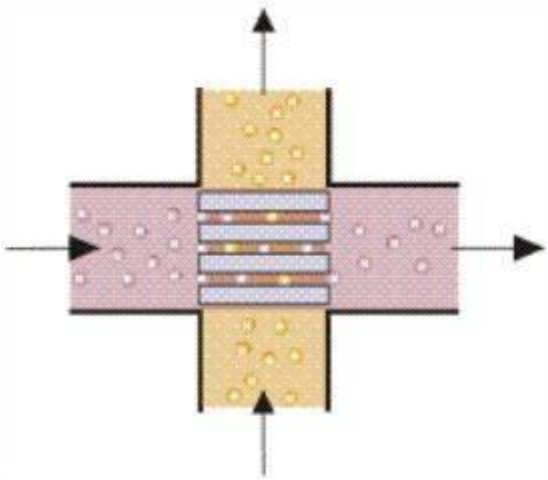
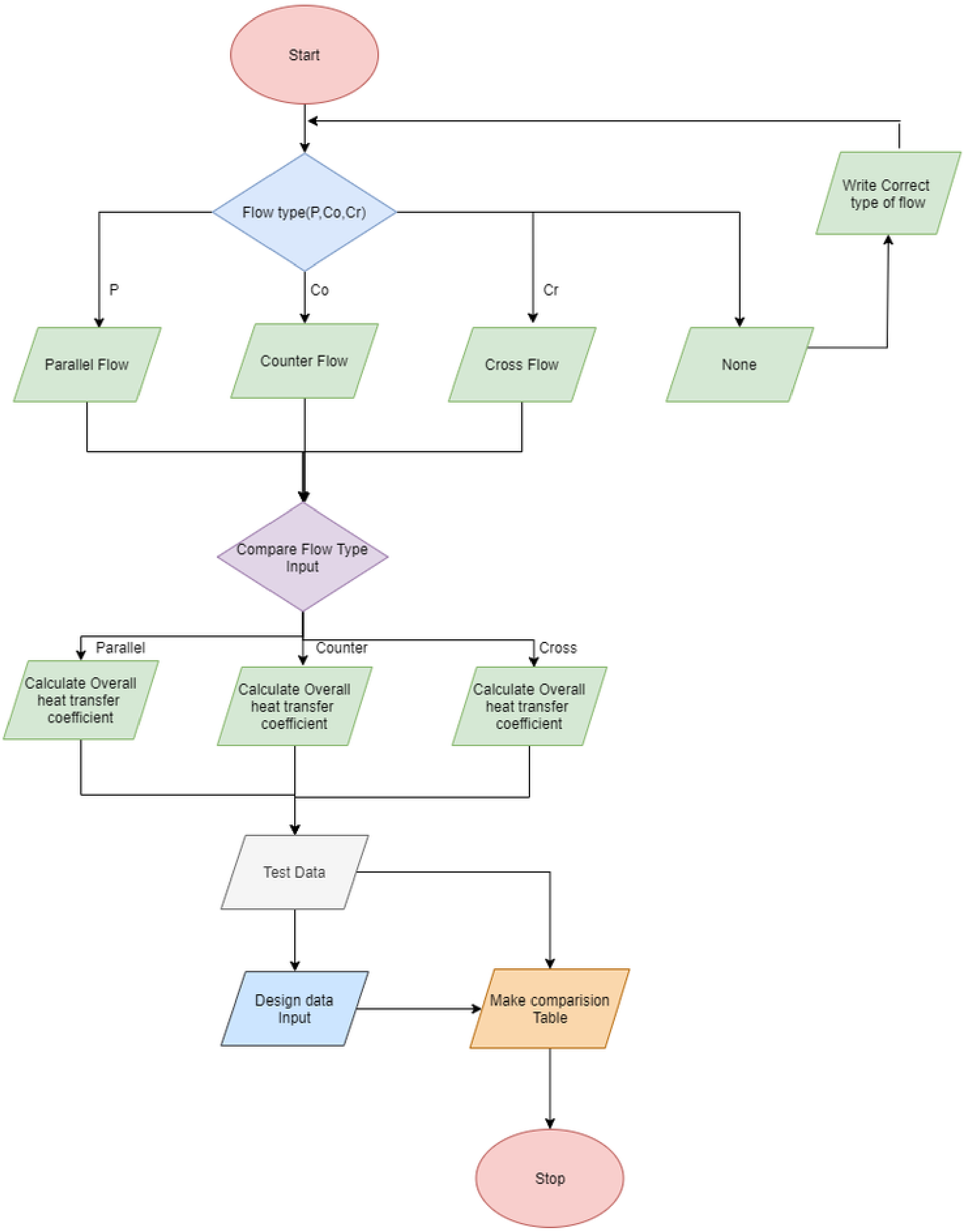


Figure 3. Crossflow.

4.Methodology –

In this project we are going to assess the performance of the heat exchanger. for it, first, we need to study thoroughly about heat exchanger. After it we going to make a flow chart which contains the logic behind the code. Then we will write code in MATLAB and analyse the output parameters. After it we can tell about heat exchanger's performance, whether it needs to be cleaned or is it performing well or not.



5.Description –

Heat exchanger are made to deliver heat or to take heat from a system, so for great performance they need to be checked periodically, because their performance deteriorates with the time due to fouling and scaling. In this project we are going to build a MATLAB program, which will be installed in a system consist of sensors and display to

check parameters and one can easily make statement about the performance by just looking at parameters and plots.

Take a situation, where we are working as heat exchanger engineer in a plant which consists thirty heat exchangers. Our work is to assess performance of all installed heat exchanger, periodically. The task would be difficult task because sensing data with sensors manually and then work on that data to calculate overall heat transfer and other parameter is a complex process.so through this we are providing a solution which assess performance with not time, we need to just feed the data.

Performance terms and definition –

1. Heat duty(Q) – it the amount of heat transferred from hot fluid to cold fluid per unit time.

$Q=m\cdot cp\cdot \Delta tQ=m\cdot cp\cdot \Delta t$

2. Effectiveness(e) – it is the ratio of actual heat transfer to maximum heat transfer.

$e=QQmaxe=QQmax$

3. Overall heat transfer coefficient(U) – it is a measure of overall ability of a series of barriers to heat transfer.

$U=QU\cdot A\cdot TlmtdU=QU\cdot A\cdot Tlmtd$

4. Capacity ratio(C) – it is the ratio of minimum to maximum heat transfer capacity rate.

$C=CminCmaxC=CminCmax$

5. LMTD – logarithmic mean temperature difference is a logarithmic average of the temperature difference between the hot and cold stream at each end of heat exchanger.

$LMTD=\Delta T1–\Delta T2ln(\Delta T1\Delta T2)LMTD=\Delta T1–\Delta T2ln(\Delta T1\Delta T2)$

6.Fouling factor – Fouling is the accumulation of unwanted material on solid surfaces. Fouling factor quantifies the effect of fouling in the reduced heat transfer efficiency.

MATLAB code –

```
close all

clear all

clc


%design data

th_d1 = 146;                    % Hot fluid inlet temperature

th_d2 = 101;                    % Hot fluid outlet temperature

tc_d1 = 25;                     % Cold fluid inlet temperature

tc_d2 = 50;                     % Cold fluid outlet temperature

U = 1.178;                      % Overall heat transfer coefficient
```

```
% Ask for flow type
fprintf('Give the input variables n')
fprintf('Flow type n P - Parallel flow n Co - Counter flow n Cr - Cross flow n ')
flow_type = input('Tell the type of flow(P/Co/Cr)  ','s');
if strcmp(flow_type,'P')
elseif strcmp(flow_type,'Co')
elseif strcmp(flow_type,'Cr')
else
   fprintf('Write correct type of flow')
   return
end

% User input of required parameters
mh = str2num(input('Flow rate of hot fluid(Kg/h)  ','s'));
mc = str2num(input('Flow rate of cold fluid(Kg/h)  ','s'));
th1 = str2num(input('Inlet temperature of hot fluid(C)  ','s'));
th2 = str2num(input('Outlet temperature of hot fluid(C)  ','s'));
tc1 = str2num(input('Inlet temperature of cold fluid(C)  ','s'));
tc2 = str2num(input('Outlet temperature of cold fluid(C)  ','s'));
ph1 = str2num(input('Inlet pressure of hot fluid(bar)  ','s'));
ph2 = str2num(input('Outlet pressure of hot fluid(bar)  ','s'));
pc1 = str2num(input('Inlet pressure of cold fluid(bar)  ','s'));
pc2 = str2num(input('Outlet pressure of cold fluid(bar)  ','s'));
a = str2num(input('Heat transfer area(m^2)  ','s'));
l = str2num(input('Length of heat exchanger(m)  ','s'));
cp_c = str2num(input('Hot fluid specific heat capacity(KJ/Kg.K)  ','s'));
cp_h = str2num(input('Cold fluid Specific heat capacity(KJ/Kg.K)  ','s'));

% Compare for heat duty
l = linspace(0,l,2);
```

```
Q_h = mh*cp_c*(th1 - th2)/3600;
Q_c = mc*cp_c*(tc2 - tc1)/3600;
if Q_h > Q_c
   q_o = Q_h;
else
   q_o = Q_c;
end
dp_h = ph1 - ph2;                    % hot fluid pressure difference at inlet and outlet
dp_c = pc1 - pc2;                    % cold fluid pressure difference at inlet and outlet
dt_h = th1 - th2;                    % hot fluid temperature difference at inlet and outlet
dt_c = tc2 - tc1;                    % cold fluid temperature difference at inlet and outlet
cr = dt_h/dt_c;
e = dt_c/(th1 - tc1);

% compare string which is earlier taken, to decide flow type
if strcmp(flow_type,'P')
   fprintf('   Parallel flow')
   LMTD_a = ((th1 - tc1)-(th2 - tc2))/log(((th1 - tc1)/(th2 - tc2)));
   U_calc = q_o/(a*LMTD_a);

   % plot temperature values
   hold on
   plot(l,[th1 th2],'Color','r','Linewidth',2)
   plot(l,[th_d1 th_d2],':','Color','g','Linewidth',2)
   plot(l,[tc1 tc2],'Color','b','Linewidth',2)
   plot(l,[tc_d1 tc_d2],':','Color','m','Linewidth',2)
   ylabel('temperature')
   xlabel('length')
   new = copyobj(gca,gcf)
   set(new,'YAxisLocation','right')
elseif strcmp(flow_type,'Co')
```

```
  fprintf('   Counter flow')
  LMTD_a = ((th1 - tc2)-(th2 - tc1))/log(((th1 - tc2)/(th2 - tc1)));
  U_calc = q_o/(a*LMTD_a);

  % plot temperature values
  hold on
  plot(l,[th1 th2],'Color','r','Linewidth',2)
  plot(l,[th_d1 th_d2],':','Color','g','Linewidth',2)
  plot(l,[tc2 tc1],'Color','b','Linewidth',2)
  plot(l,[tc_d2 tc_d1],':','Color','m','Linewidth',2)
  ylabel('temperature')
  xlabel('length')
  new = copyobj(gca,gcf)
  set(new,'YAxisLocation','right')

elseif strcmp(flow_type,'Cr')
  fprintf('   Cross flow')
  c_f = 0.977;
  LMTD_a = (((th1 - tc2)-(th2 - tc1))/log((th1 - tc2)/(th2 - tc1)))*c_f;
  U_calc = q_o/(a*LMTD_a);
end

% take input of design parameter
Parameter =
{'heat_duty';'hot_side_pressure_drop';'cold_side_pressure_drop';'Temperature_range_hot_
fluid';'Temperature_range_cold_fluid';'Capacity_ratio';'Effectiveness';'Corrected
LMTD';'Heat_transfer_coefficient'};
Design_Data = [25623;1.34;0.95;45;25;0.556;0.375;82.2;1.178];
% make array of test data
Test_Data = [q_o;dp_h;dp_c;dt_h;dt_c;cr;e;LMTD_a;U_calc];
% make comparison table
table(Parameter,Design_Data,Test_Data)
```

Code explanation –

1. **Start with close all, clear all and clc command.**
2. **Now define inlet and outlet temperature of hot fluid and cold fluid, which will be used for comparison, later.**
3. **Use fprintf() command to display some lines which ask for type of flow.**
4. **Apply if-else statement, which will decide correct letter to indicate flow type.**
5. **Now use input() command to take feed parameter in and use str2num() to convert user input into numeric from character.**
6. **Apply if-else statement to find for which we need to find heat duty.**
7. **Define some variable, which calculates pressure drop and temperature range for hot fluid and cold fluid.**
8. **Now use if-else statement structure to find values of parameter like LMTD and heat transfer coefficient according to type of flow. Use plot command to show temperature variation.**
9. **Now define two variables, first one will contain parameter name and second one will contain values of parameters respective first variable.**
10. **Now use table () command and pass variables which contains values of actual parameters and designed parameters. Table is easy to visualize.**

Result –

Hand calculation –

1. Heat duty(Hot fluid) = mh·cph·Δt3600mh·cph·Δt3600

=719800·2.847·(145−102)3600=719800·2.847·(145-102)3600

=24477.4KW=24477.4KW

Heat duty(Cold fluid) = mc·cpc·dt3600mc·cpc·dt3600

=881150·4.187·(49−25.5)3600=881150·4.187·(49-25.5)3600

=24083.4KW=24083.4KW

2. Hot fluid pressure drop = Phi–PhoPhi–Pho

=4.1−2.8=4.1-2.8

=1.3=1.3bar

Cold fluid pressure drop = Pci–PcoPci–Pco

=6.2−5.1=6.2-5.1

=1.1=1.1bar

3. Temperature range(Hot fluid) ΔTh=Thi−ThoΔTh=Thi-Tho

=145−102=145-102

=43C=43C

Temperature range(Cold Fluid) ΔTc=Tci−TcoΔTc=Tci-Tco

=49−25.5=49-25.5

=23.5C=23.5C

4. Capacity ratio Cr=ΔThΔTcCr=ΔThΔTc

=4323.5=4323.5

=1.83=1.83

5. Effectiveness e=qqmaxe=qqmax

=23.5119.5=23.5119.5

=0.20=0.20

6. LMTD

a. Counter Flow

LMTD=(th1−tc2)−(th2−tc1)log(th1−tc2th2−tc1)LMTD=(th1-tc2)-(th2-tc1)log(th1-tc2th2-tc1)

=96−76.5log(9676.5)=96-76.5log(9676.5)

=85.9C=85.9C

b. Parallel Flow

LMTD=(th1−tc1)−(th2−tc2)log(th1−tc1th2−tc2)LMTD=(th1-tc1)-(th2-tc2)log(th1-tc1th2-tc2)

=119.5−53log(119.553)=119.5-53log(119.553)

=82.2C=82.2C

c.Cross Flow

LMTD = LMTD of counter flow* correction factor

=85.9·0.977=85.9·0.977

=83.9=83.9

7. Overall heat transfer coefficient U=QA·LMTDU=QA·LMTD

a. Counter Flow

=24477.4264.55·85.9=24477.4264.55·85.9

=1.1072KWm2.C=1.1072KWm2.C

b. Parallel Flow

=24477.4264.55·82.2=24477.4264.55·82.2

=1.1210KWm2.C=1.1210KWm2.C

c. Cross flow

=24477.4264.55·83.9=24477.4264.55·83.9

=1.104KWm2.C=1.104KWm2.C

Calculation and plots obtained by code –

Our MATLAB programme has successfully calculated required parameters, we can see in the table. Now one can think what is the need of pressure drop and other which has no role in the calculation of overall heat transfer coefficient, but these are kept for record purpose, which might be useful to assess the need of replacement of heat exchanger. We got overall heat transfer value 1.1312 which is lower than designed one 1.178, so heat transfer needs to be cleaned here, otherwise its performance will further reduce. The drop of overall heat transfer coefficient is most likely due to frosting.

Parallel Flow

Parameter	Design_Data	Test_Data
{'heat_duty' }	25623	24477
{'hot_side_pressure_drop' }	1.34	1.3
{'cold_side_pressure_drop' }	0.95	1.1
{'Temperature_range_hot_fluid' }	45	43
{'Temperature_range_cold_fluid'}	25	23.5
{'Capacity_ratio' }	0.556	1.8298
{'Effectiveness' }	0.375	0.19665
{'Corrected LMTD' }	82.2	81.793
{'Heat_transfer_coefficient' }	1.178	1.1312

Counter Flow

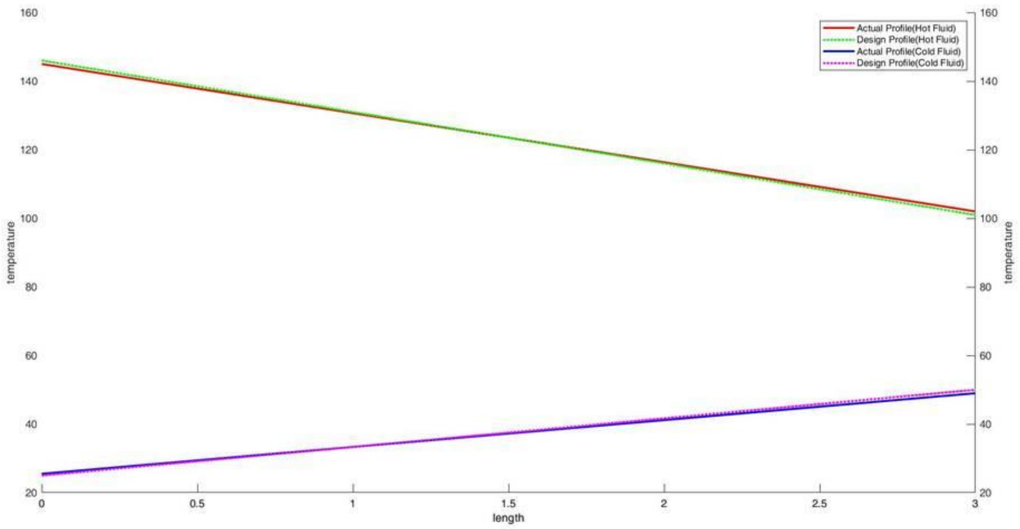
Parameter	Design_Data	Test_Data
{'heat_duty' }	25623	24477
{'hot_side_pressure_drop' }	1.34	1.3
{'cold_side_pressure_drop' }	0.95	1.1
{'Temperature_range_hot_fluid' }	45	43
{'Temperature_range_cold_fluid'}	25	23.5
{'Capacity_ratio' }	0.556	1.8298
{'Effectiveness' }	0.375	0.19665
{'Corrected LMTD' }	82.2	85.881
{'Heat_transfer_coefficient' }	1.178	1.0774

Cross Flow

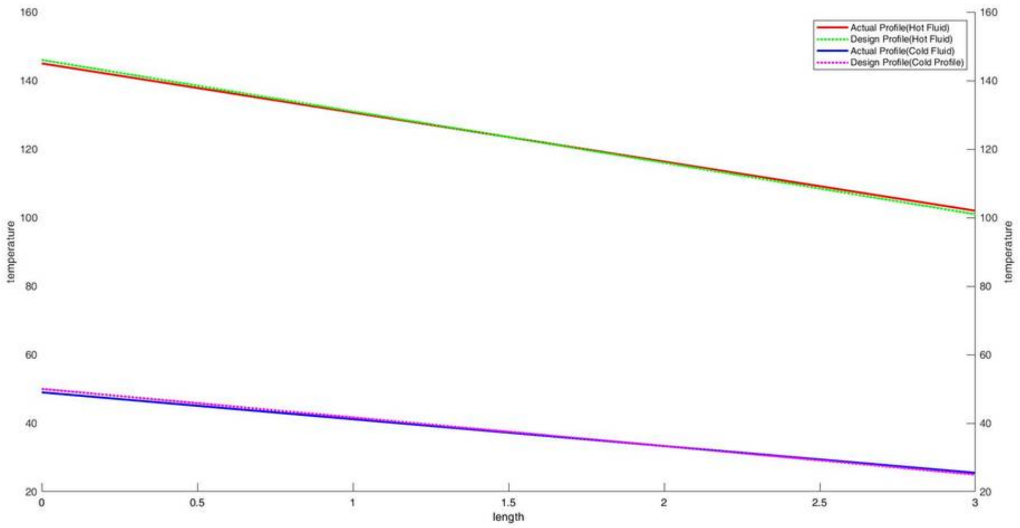
Parameter	Design_Data	Test_Data
{'heat_duty' }	25623	24477
{'hot_side_pressure_drop' }	1.34	1.3
{'cold_side_pressure_drop' }	0.95	1.1
{'Temperature_range_hot_fluid' }	45	43
{'Temperature_range_cold_fluid'}	25	23.5
{'Capacity_ratio' }	0.556	1.8298
{'Effectiveness' }	0.375	0.19665
{'Corrected LMTD' }	82.2	83.906
{'Heat_transfer_coefficient' }	1.178	1.1027

The following figure is showing the variation of actual profile verses design profile for both hot fluid and cold fluid in terms of temperature.

Parallel Flow-



Counter Flow –



6.Scope of the project-

MATLAB stands for matrix laboratory, is a programming language which combines computation, visualization and programming in a single environment. MATLAB is used in different areas like mathematics, research and in education. Mechanical engineer needs MATLAB for scrutiny of problems in control system, mechanical vibration, mechanics and many more. This project scrutinizes heat exchangers. It is a little effort towards the automation. MATLAB program of this program assess the performance of heat exchanger by calculating overall heat transfer coefficient. It asks for some input values and tells whether heat exchanger is needs to be cleaned or not, but we may thick, why there is program to assess heat exchanger, we can check it manually. It is easy to take parameters of few heat exchanger and assess them, but what if you have a unit of thirty heat exchanger. The more the heat exchangers the more the clumsy process, so this program plays a vital role in these types of situations. The program can be implemented with a hardware system which has required sensors to take reading of parameters and has displays. The program will calculate and displays the assessment report.

7.Conclusion –

it's been a fantastic journey through the course and project. We have successfully written the code and made statement about the performance of heat exchanger by analysing the data and plots. The code can be implemented on hardware to assess heat exchanger in no time. Similar code can be written for other system also, which would save time and cost.