

Major Assignment – 1

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Introduction :-

Through this assignment we are trying to understand how temperature varies along a heat exchanger for Parallel and Counter Flow arrangements by simulating the temperature profiles $Th(x)$ and $Tc(x)$ for the flow arrangements.

We will also some special Cases like Reboiler and Condenser Cases.

Assumptions

We are assuming the following inlet conditions throughout the cases-

Hot fluid inlet temperature, $Th_{in} = 400 \text{ K}$

Cold fluid inlet temperature, $Tc_{in} = 300 \text{ K}$

Heat capacity rates:

$$Ch = 2 \text{ kW/K}$$

$$Cc = 1.5 \text{ kW/K}$$

Overall heat transfer coefficient times area per unit length:

$$UA = 0.5 \text{ kW/K-m}$$

Length of heat exchanger, L = 10 m

Governing Equations :-

For Parallel Flow we have the following equations,

$$\frac{dT_h}{dx} = -\frac{UA'}{C_h}(T_h - T_c)$$
$$\frac{dT_c}{dx} = +\frac{UA'}{C_c}(T_h - T_c)$$

Here, Th(x = 0) = Th_0 = 400 K

Tc(x = 0) = Tc_0 = 300 K

For Counter Flow we have the following equations,

$$\frac{dT_h}{dx} = -\frac{UA'}{C_h}(T_h - T_c)$$
$$\frac{dT_c}{dx} = -\frac{UA'}{C_c}(T_h - T_c)$$

Here, Th(x = 0) = Th_0 = 400 K

Tc(x = L) = Tc_0 = 300 K

MATLAB Code

Following is the complete MATLAB code from solving the equations to plotting the results –

```

%% Simulating the Parallel Flow Temperature profile
Ch = 2;
Cc = 1.5;
UA = 0.5;
L = 10;

```

```

Th0 = 400;
Tc0 = 300;

```

```
% writing the system of ODEs
```

```
TempH = @(X, T)[
    -(UA/Ch)*(T(1) - T(2));
    (UA/Cc)*(T(1) - T(2))
];
```

```
% Solving the system using ODE45
```

```
[X, T_P] = ode45(TempH,[0 L],[Th0 Tc0]);
```

```
% Plotting
```

```
figure(1);
plot(X, T_P(:,1), 'r', 'LineWidth', 2);
hold on;
plot(X, T_P(:,2), 'b', 'LineWidth', 2);
xlabel("Length (m)")
ylabel('Temperature (K)')
legend('Hot Fluid', 'Cold Fluid')
title('Parallel Flow Heat Exchanger')
grid on
```

```
%% Simulating the Counter Flow Temperature profile
```

```
Ch = 2;
Cc = 1.5;
UA = 0.5;
L = 10;
```

```
Th0 = 400;
```

```
TcL = 300; % In counter case Cold fluid inlet is at x = L
```

```
% writing the system of ODEs
```

```
TempC = @(x, T)[
    -(UA/Ch)*(T(1) - T(2));
    -(UA/Cc)*(T(1) - T(2))
];
```

```
% Solving the system using ODE45
```

```
[x, T_C] = ode45(TempC,[0 L],[Th0 TcL]);
```

```
%Plotting
```

```
figure(2);
plot(x, T_C(:,1), 'r', 'LineWidth', 2);
hold on;
plot(x, T_C(:,2), 'b', 'LineWidth', 2);
xlabel("Length (m)")
ylabel('Temperature (K)')
legend('Hot Fluid(->)', 'Cold Fluid(<-)')
title('Counter Flow Heat Exchanger')
grid on
```

```
%% Reboiler Case
```

```
% here Hot fluid temperature remains Constant
x = linspace(0,10,100);
Th_R = 400*ones(size(x));
Tc_R = 300 + 5*x;
```

```
figure(3)
plot(x,Th_R,'r','LineWidth',2)
hold on
plot(x,Tc_R,'b','LineWidth',2)
xlabel('Length (m)')
ylabel('Temperature (K)')
legend('Hot Fluid (Phase Change)', 'Cold Fluid')
title('Reboiler Temperature Profile')
grid on
```

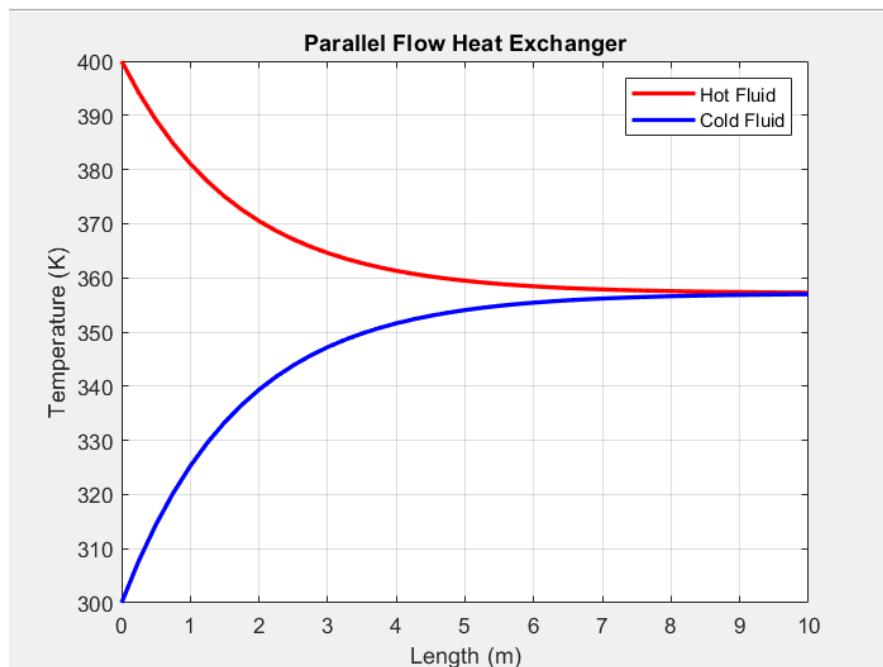
```
%% Condenser Case
```

```
% here Cold fluid temperature remains Constant
x = linspace(0,10,100);
Tc_C = 320*ones(size(x));
Th_C = 400 - 6*x;
```

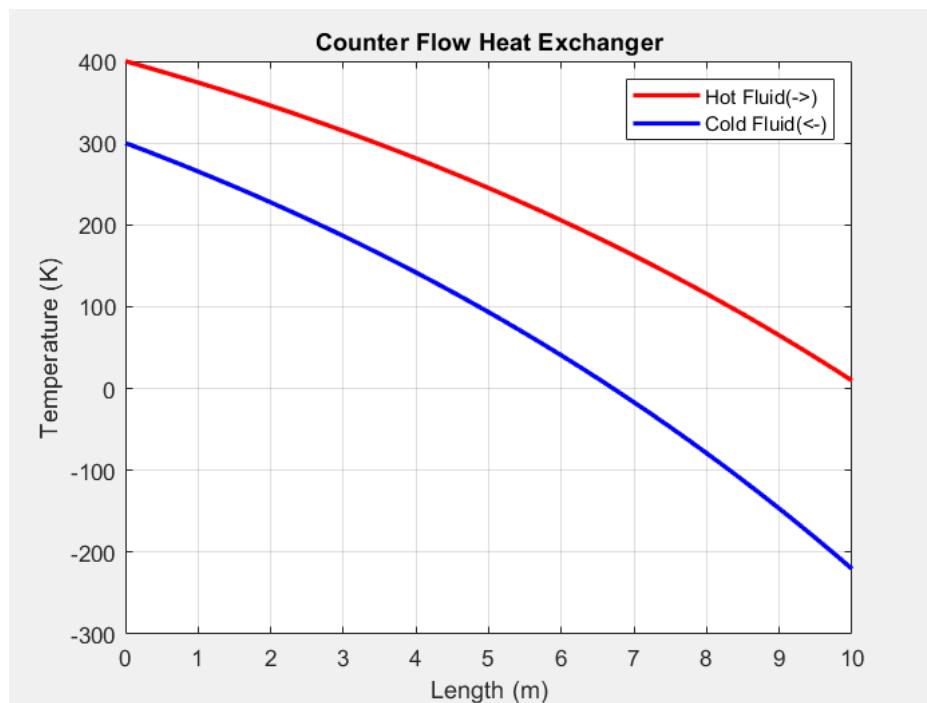
```
figure(4)
plot(x,Th_C,'r','LineWidth',2)
hold on
plot(x,Tc_C,'b','LineWidth',2)
xlabel('Length (m)')
ylabel('Temperature (K)')
legend('Hot Fluid', 'Cold Fluid (Phase Change)')
title('Condenser Temperature Profile')
grid on
```

Plots

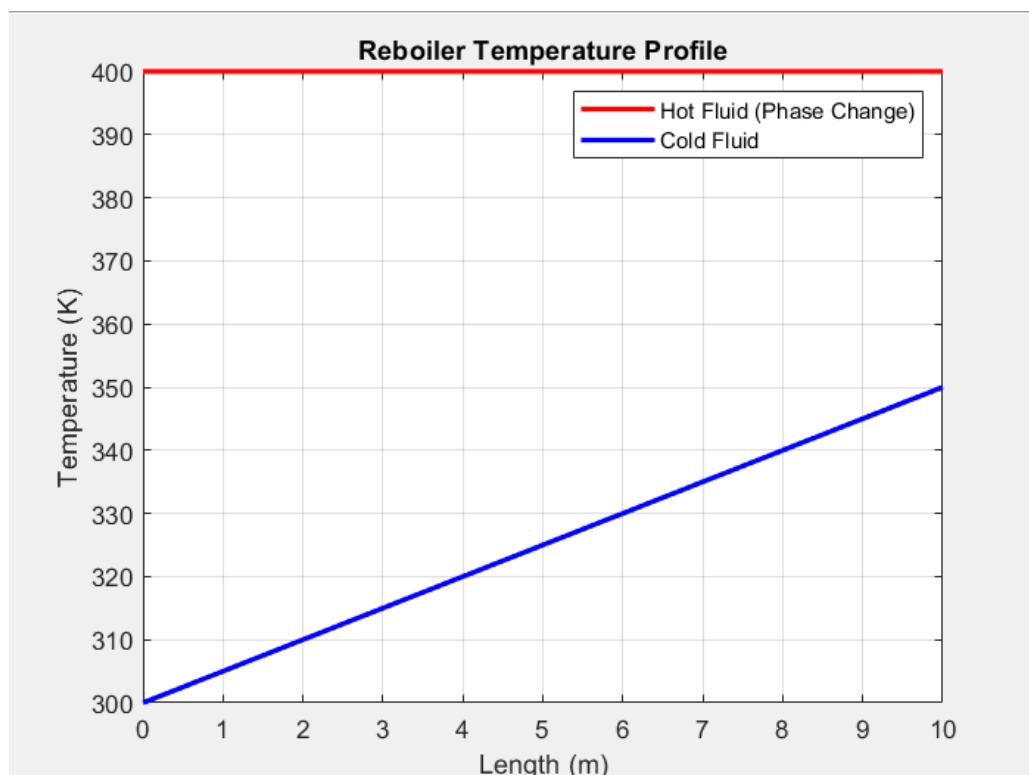
Temperature profile for Parallel Flow :-



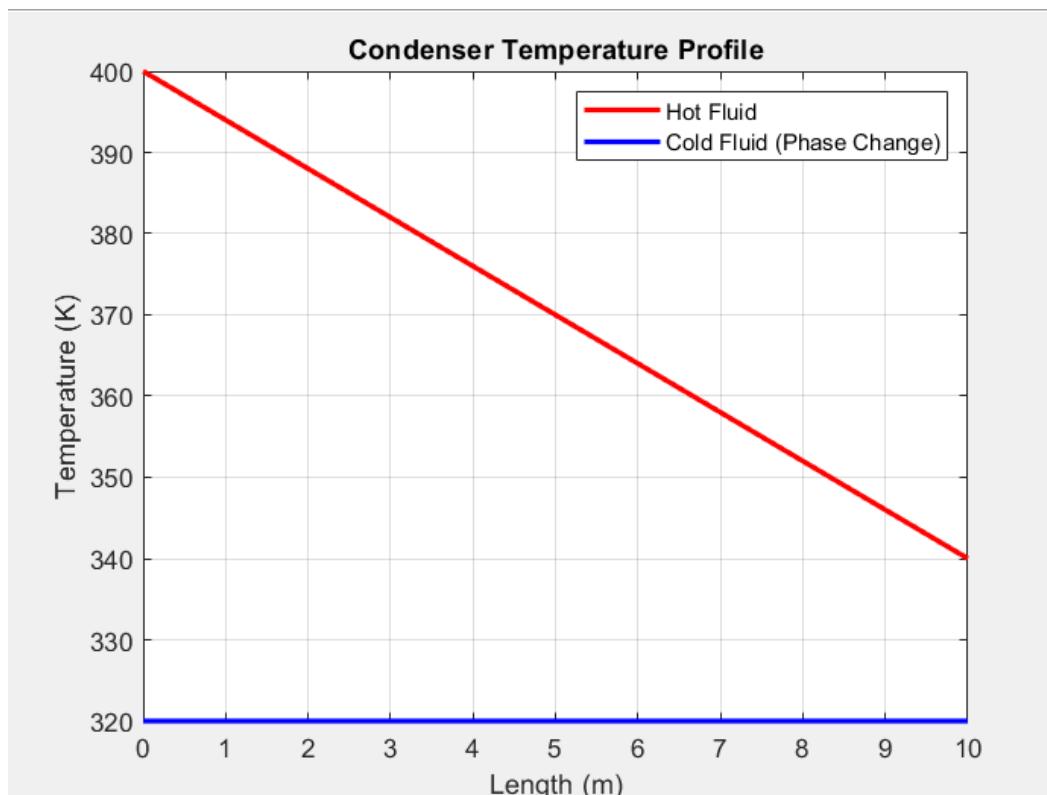
Temperature profile for Counter Flow :-



Temperature Profile for Reboiler Case :-



Temperature Profile for Condenser Case :-



DISCUSSION

- The counter-flow configuration yields a higher cold-fluid outlet temperature. In parallel flow, the cold fluid can never be heated above the temperature at which the hot fluid exits. In counter-flow, the cold fluid exits near the point where the hot fluid enters, allowing it to reach much higher temperatures.
- In counter-flow, the driving force ($\Delta_T = T_h - T_c$) is better maintained along the length. In parallel flow, Δ_T is massive at the inlet but vanishes quickly. In counter-flow, because the fluids flow in opposite directions, the newly cold fluid get in contact with the coolest hot fluid, and the hottest cold fluid get in contact with the hottest hot fluid, keeping Δ_T relatively uniform.
- During phase change, the fluid temperature remains constant as heat transfer occurs through latent heat rather than sensible heat which eliminates the exponential temperature variation.
- Since one fluid remains at a constant temperature, the temperature difference varies linearly, making the logarithmic mean temperature difference reduce to a simpler arithmetic form.