Major Assignment – 2

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Introduction :-

The objective of this assignment is to simulate the performance of a double–pipe heat exchanger using the ε–NTU method and to study how effectiveness and outlet temperatures vary with flow arrangement and operating parameters.

Given data

Hot fluid inlet temperature: Th_in = 120 C

Cold fluid inlet temperature: Tc_in = 30 C

Hot-side heat capacity rate: Ch = 4.5 kW/K

Cold-side heat capacity rate: Cc = 3.0 kW/K

Overall heat transfer coefficient: U = 300 W/m^2 K

Heat transfer area: A = 6 m^2

Calculation :-

Formulas used :

- Use $C_{\min} = \min(\dot{C}_h, \dot{C}_c)$
- NTU is defined as:

$$\mathrm{NTU} = \frac{UA}{C_{\min}}$$

- Effectiveness relations:

$$\varepsilon_{\text{parallel}} = \frac{1 - \exp[-\mathrm{NTU}(1 + C_r)]}{1 + C_r}$$

$$\varepsilon_{\text{counter}} = \frac{1 - \exp[-\mathrm{NTU}(1 - C_r)]}{1 - C_r \exp[-\mathrm{NTU}(1 - C_r)]}$$

i) Min heat capacity = 3.0

ii) Max heat capacity = 4.5

iii) Number of transfer units (NTU) = 0.40

iv) Parallel Flow Effectiveness = 0.292

v) Counter Flow Effectiveness = 0.300

vi) Parallel Flow: Th_out = 102.48 C, Tc_out = 56.28 C

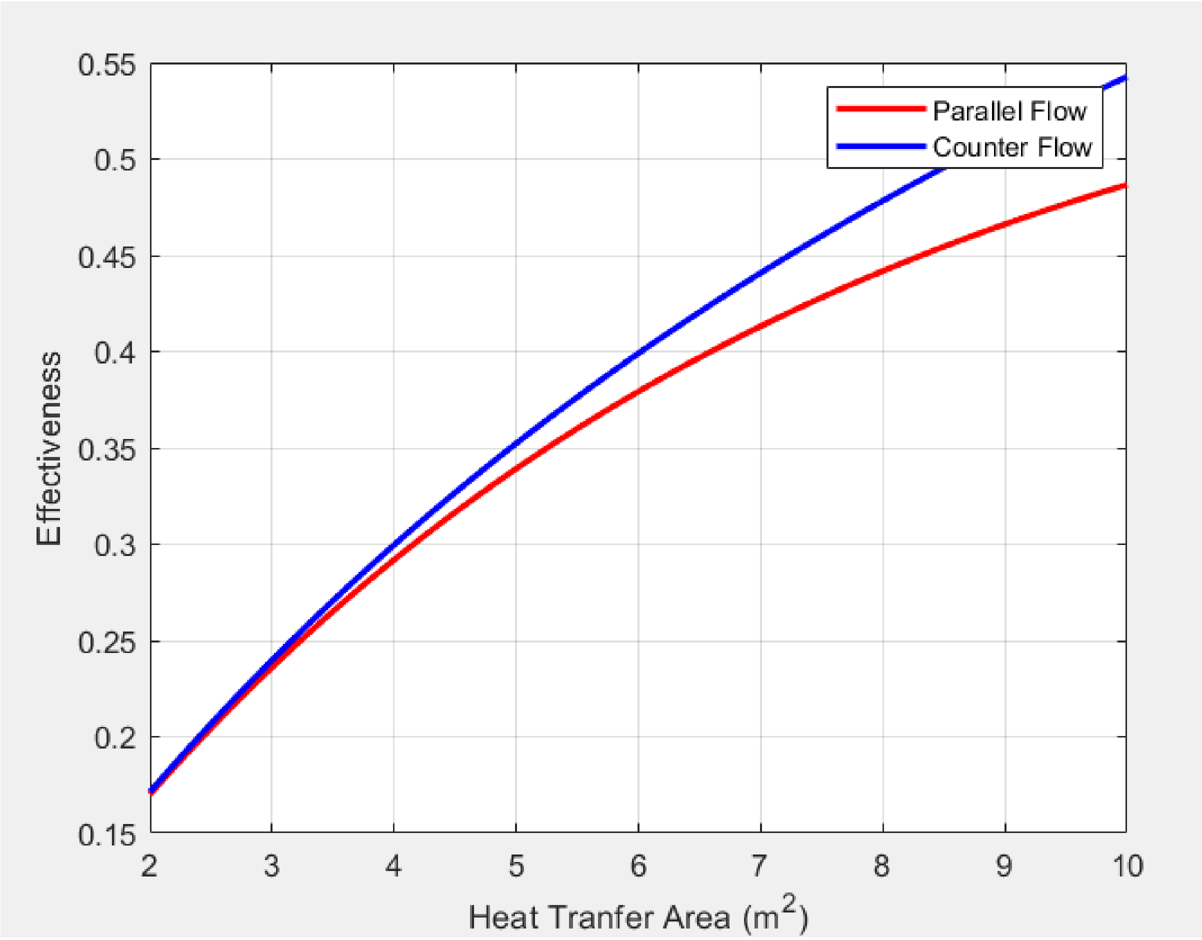
vii) Counter Flow: Th_out = 102.02 C, Tc_out = 56.97 C

MATLAB Code

```
% Given data
Th_in = 120;
Tc_in = 30;
Ch = 4.5;
Cc = 3.0;
U = 0.3;
A = 6;

% Calculating Heat capacity rates
Cmin = min(Ch, Cc);
Cmax = max(Ch, Cc);
Cr = Cmin / Cmax;

% Number of Transfer Units (NTU) calculation
NTU = U * A / Cmax;

% Effectiveness using epsilon-NTU relation
eps_parallel = (1 - exp(-NTU*(1 + Cr))) / (1 + Cr);
eps_counter = (1 - exp(-NTU*(1 - Cr))) / (1 - Cr*exp(-NTU*(1 - Cr)));

% Heat transfer rate
Q_parallel = eps_parallel*Cmin*(Th_in - Tc_in);
Q_counter = eps_counter*Cmin*(Th_in - Tc_in);

% Outlet temparatures
Th_out_p = Th_in - Q_parallel / Ch;
Tc_out_p = Tc_in + Q_parallel / Cc;

Th_out_c = Th_in - Q_counter / Ch;
Tc_out_c = Tc_in + Q_counter / Cc;
```

```
% Displaying the results:-
fprintf('min heat capacity: %.3f\n', Cmin);
fprintf('max heat capacity: %.3f\n', Cmax);
fprintf('Number of transfer units(NTU): %.3f\n', NTU);

fprintf('Parallel Flow Effectiveness: %.3f\n', eps_parallel);
fprintf('Counter Flow Effectiveness: %.3f\n\n', eps_counter);

fprintf('Parallel Flow: Th_out = %.2f C, Tc_out = %.2f C\n', Th_out_p, Tc_out_p);
fprintf('Counter Flow: Th_out = %.2f C, Tc_out = %.2f C\n', Th_out_c, Tc_out_c);

%% Plot: epsilon vs Area(A)
A = linspace(2,10,50);
NTU = (U .*A)/Cmin;

eps_p = (1 - exp(-NTU .* (1 + Cr))) ./ (1 + Cr);
eps_c = (1 - exp(-NTU .* (1 - Cr))) ./ (1 - Cr .* exp(-NTU .* (1 - Cr)));

figure;
plot(A, eps_p, 'r', 'LineWidth', 2);
hold on;
plot(A, eps_c, 'b', 'LineWidth', 2);
xlabel('Heat Tranfer Area (m^2)');
ylabel('Effectiveness');
legend('Parallel Flow', 'Counter Flow');
grid on;
```

Plots of effectiveness versus area



Discussion:

- Counter-flow heat exchangers maintain a larger and more uniform temperature difference between the hot and cold fluids along the entire length, allowing more heat transfer compared to parallel flow.
- As NTU increases, the heat transfer area becomes large and the temperature difference driving heat transfer decreases, causing effectiveness to approach a maximum limit and increase more slowly.