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Heat Exchanger Matlab simulation

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```
% This code is to analyze our spiral-tube-in-shell heat exchanger

% Assumptions made:
%   This heat exchanger will be modeled like a single tube in shell heat
%   exchanger.
%   - Fluid property values for water were determined using lookup tables,
%     and the water temperature at the inlet.
%   - The metal material values were determined from the textbook.
%   - The flow profile through the baffles were considered as two
%     concentric annuli, and considered in the hydraulic diameter calc.
%   - The effects of a partially cross- and partially
%     counter-flow system are considered negligible.
%   - Assume constant, circular cross section (neglecting pipe defomation
%     durning bending)
%   - Assume wall thickness of pipe is negligible
%   - Note that Re number calcualted before inputting constants
%     - Assume in hot water, the flow is turbulent (high Re)and
%       immediately tripped by the weld residue on the reducing fitting
%     - Assume in cold water, the flow is laminar due to slower velocity,
%       without being substantially tripped by the baffles.
%     - Assume .03 absolute roughness of both the smooth copper and
%       plastic, and find friction factor from Re num and Moody diagram
%   - Assume equations 8.62, 8.57 and table 11.3 equation 11.30a apply
%   - Assume efficency is 1.0 (as in lecture)
%   - Most of the pressure drop will be pipe friction losses, drops across
%     connectors are proportional to v^2 with emprically determined
%     coefficients

clear;
```

User Input Values - Accurately Handles temperatures 0-50C

```
T_hot_in = input("Input the hot water temp(C): "); % C
T_cold_in = input("Input the cold water temp(C): "); % C
```

```
Error using input
```

```
Cannot call INPUT from EVALC.

Error in HX_sim (line 37)
T_hot_in = input("Input the hot water temp(C): "); % C
```

Physical Parameters

Heat Exchanger tubing Params

```
length_hot = (10*12)/39.37;      % meters (from 10 ft of tubing)
length_cold = 28/39.37;          % meters (from 28 inches of box)
hyd_dia_hot = (3/8)/39.37;       % meters (from 3/8" pipe)

% Tightly wrapped tube baffle
outer_radius1_cold = 1.77/39.37;  % meters (from 1.75")
inner_radius1_cold = 1.75/39.37;  % meters (from 1.25")
% Tightly pressed shell baffle
outer_radius2_cold = 1.50/39.37;  % meters (from 1.75")
inner_radius2_cold = 1.48/39.37;  % meters (from 1.25")
% Combined Hydraulic diameter
hyd_dia_cold = 2*(outer_radius1_cold +outer_radius2_cold - inner_radius1_cold
 - inner_radius2_cold); % hydralic diameter of annulus

%physical dimensions and cost
hx_mass=2.165;  %kg
hx_cost=96.51+7.50; %$USD
hx_vol=0.009291; %m^3

k_copper = 390;                 % W/mk (thermal conductivity from text)

% Total Area of HT (m^2)
A_ht_tot = pi()*hyd_dia_hot*length_hot;
```

Fluid Params

```
% Fluid parameters (source University of Waterloo)
tempC = [0 1 4 10 15 20 25 30 35 40 45 50]; % Note: assume 0 == .1
rho = [1001 1001 1000 1000 999 998 997 995 994 992 990 988];
mu =
 [.00169 .00165 .0015 .00127 .00111 .00098 .00087 .00078 .0007 .00064 .00058 .00053];
Pr = [12.199 11.822 10.675 8.803 7.5788 6.5870 5.776 5.108 4.552 4.086 3.693
 3.358];
k = [.570 .572 .578 .588 .597 .605 .612 .619 .626 .632 .638 .644];
C_p = [4116 4113 4104 4090 4082 4076 4073 4070 4069 4067 4067 4066];


% Hot fluid params
v_dot_hot = 2/1000/60;                     % m^3/s (2 L/min)
C_p_hot = interp1(tempC, C_p, T_hot_in);   % J/Kg*K
Pr_hot = interp1(tempC, Pr, T_hot_in);     % Hot Pr number
k_hot = interp1(tempC, k, T_hot_in);       % Hot thermal cond. W/mK
rho_hot = interp1(tempC, rho, T_hot_in);   % Hot density kg/m^3
mu_hot = interp1(tempC, mu, T_hot_in);     % Hot viscosity kg/ms
```

```
f_hot = .025;                                         % from Moody diagram

% Cold fluid params
v_dot_cold = 2/1000/60;                                % m^3/s (2 L/min)
C_p_cold = interp1(tempC, C_p, T_cold_in);             % J/Kg*K
Pr_cold = interp1(tempC, Pr, T_cold_in);               % Cold Pr number
k_cold = interp1(tempC, k, T_cold_in);                 % Cold thermal cond. W/mK
rho_cold = interp1(tempC, rho, T_cold_in);             % Cold density kg/m^3
mu_cold = interp1(tempC, mu, T_cold_in);               % Cold viscosity kg/ms
f_cold = .125;                                          % from Moody diagram

% Derived hot water values
A_cs_hot = pi()*(hyd_dia_hot/2)^2;                   % Cross section of copper tube
m_dot_hot = v_dot_hot*rho_hot;                       % Hot water mass flow rate
C_hot = m_dot_hot*C_p_hot;                           % Hot water heat capacity
v_hot = v_dot_hot/A_cs_hot;                          % Veocity of hot water
Re_hot = v_hot*rho_hot*hyd_dia_hot/mu_hot;           % Re number of hot water
Nu_hot = (f_hot/8)*(Re_hot-1000)*Pr_hot/
(1+12.7*(f_hot/8)^1/2*(Pr_hot^(2/3)-1)); % Internal turb flow- Text eqn 8.62
Nu_hot_avg = Nu_hot; % assume most of flow is fully developed See eqn 8.63
h_hot = Nu_hot_avg*k_hot/hyd_dia_hot;                % heat transfer coeff of hot water


% Derived cold water values
A_cs_cold = pi()*(outer_radius1_cold^2-
inner_radius1_cold^2+outer_radius2_cold^2-inner_radius2_cold^2); % Cross
 section of space between baffles
m_dot_cold = v_dot_cold*rho_cold;                        % Cold water mass flow rate
C_cold = m_dot_cold*C_p_cold;                            % Cold water heat capacity
v_cold = v_dot_cold/A_cs_cold;                           % Cold water velocity
Re_cold = v_cold*rho_cold*hyd_dia_cold/mu_cold; % Re number of cold water
Nu_cold_avg = 3.66 + (.068*Re_cold*Pr_cold*hyd_dia_cold/length_cold)/
(1+.04*(Re_cold*Pr_cold*hyd_dia_cold/length_cold)^(2/3));% Internal laminar
 flow - Text eqn 8.57
h_cold = Nu_cold_avg*k_cold/hyd_dia_cold;                % heat transfer coeff of cold
 water
```

Heat transfer derivations

```
eff = 1;                               % Assumption  based on that made in
 lecture
C_min = min(C_hot, C_cold);            % Minimum heat capacity
C_max = max(C_hot, C_cold);            % Maximum heat capacity
C_r = C_min/C_max;                     % Ratio of min to max
q_max = C_min*(T_hot_in-T_cold_in); % Maximum possible heat transfer

U = 1./(1/h_hot+1/h_cold);             % Overall heat transfer coefficient
NTU = U*A_ht_tot/C_min;                % Number of Thermal Units

% Table 11.3 eqn 11.30a
e = 2*(1+C_r+(1+C_r^2)*(1+exp(-NTU*(1+C_r^2)^(1/2)))/(1-exp(-
NTU*(1+C_r^2)^(1/2))))^(-1);
```

```
% Heat transfer
q_hot = e*q_max;
q_cold = q_hot*eff;

% Resulting temperatures
T_cold_out = T_cold_in+q_cold/C_cold;
T_hot_out = T_hot_in-q_hot/C_hot;

% Fitting equivalent length
fittings_eqiv_len_hot = 2*150*v_hot^2/(2*9.8);  % 2x reduction fittings
fittings_eqiv_len_cold = 2*5*v_hot^2/(2*9.8);  % transition to/from plastic
 bag

% Pressure drop in kPa
delt_P_hot = f_hot*(1/2*rho_hot*v_hot^2)*(length_hot+fittings_eqiv_len_hot)/
hyd_dia_hot/1000;
delt_P_cold = f_cold*(1/2*rho_cold*v_cold^2)*(length_cold
+fittings_eqiv_len_cold)/hyd_dia_cold/1000;

%Figures of Merit
f1=q_hot;   %W
f2=q_hot/hx_vol;    %W/m^3
f3=q_hot/hx_mass;   %W/kg
f4=q_hot/max(delt_P_cold,delt_P_hot);   %W/kPa
f5=q_hot/hx_cost;   %W/$USD
```

Display calcualted values

```
disp(" ");
disp("Hot Water Outlet Temp: " + T_hot_out + " C");
disp("Cold Water Outlet Temp: " + T_cold_out + " C");
disp("Hot Water Pressure Drop: " + delt_P_hot + " kPa");
disp("Cold Water Pressure Drop: " + delt_P_cold + " kPa");
disp("Heat Rate Out of Hot Water: " + q_hot/1000 + " kW");
disp("Heat Rate Out of Cold Water: " + q_cold/1000 + " kW");
disp("Thermal Efficiency: " + q_cold/q_hot);
disp("Overall Heat Transfer Coefficient: " + U + " W/m^2.K");
disp("Heat Exchanger Effeciveness: " + e);
disp("NTU: " + NTU);
disp(" ");
disp("Figure of Merit 1: " + f1 + " W");
disp("Figure of Merit 2: " + f2 + " W/m^3");
disp("Figure of Merit 3: " + f3 + " W/kg");
disp("Figure of Merit 4: " + f4 + " W/kPa");
disp("Figure of Merit 5: " + f5 + " W/$USD");
disp(" ");
```

Published with MATLAB® R2022b