ESD Homework 2

March 6, 2022

[2]:
```
import sympy as sp
from msu_esd import cross_flow_unmixed, log_mean_temp_difference
```

Contents

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1 Problem 1

1.1 Given

Water enters a counterflow, double-pipe heat exchanger at a rate of 70 $\frac{kg}{min}$ and is heated from 15°C to 60°C by an oil with a specific heat of 1.9 $\frac{kJ}{kg\,K}$. The oil enters at 116°C and leaves at 27°C. The overall heat transfer coefficient is 300 $\frac{W}{m^2\,K}$

1.2 Find

a. What heat transfer area is required?
b. What area is required if all conditions remain the same except that a shell and tube heat exchanger is used, with the water making one shell pass and the oil making two tube passes?
c. What exit water temperature would result if, for the exchanger of part (a), the water flow rate were decreased to 50 $\frac{kg}{min}$

1.3 Solution

The specific heat of water will be taken at the average temperature of the water entrance and exit ($C_p = 4.18\,\frac{kJ}{kg\,K}$)

1.3.1 Part A

The oil is the hot fluid and the water is the cold fluid. The condition is unmixed because the fluids never meet.

[3]:
```
# Declare constants as given
mc_ = 70
Cp_c_, Cp_h_ = 4.18, 1.9
Tc_in_, Tc_out_ = 15, 60
Th_in_, Th_out_ = 116, 27
U_ = 300

Cc, Ch, Th_out, Th_in, Tc_out, Tc_in = sp.symbols(r'C_c C_h T_{h\,out} 
↪T_{h\,in} T_{c\,out} T_{c\,in}')

# Solving for Ch
eq = sp.Eq(Cc*(Tc_out - Tc_in), Ch*(Th_in - Th_out))
eq
```

[3]:

$$C_c\left(-T_{c,in} + T_{c,out}\right) = C_h\left(T_{h,in} - T_{h,out}\right)$$

[4]:
```
Ch_solved = sp.solve(eq, Ch)[0]
Ch_solved
```

[4]:

$$\frac{C_c\left(-T_{c,in} + T_{c,out}\right)}{T_{h,in} - T_{h,out}}$$

[5]:
```
# Solving for Cc
Cc_ = mc_*Cp_c_
Cc_  # kJ per (min deg C)
```

[5]: 292.59999999999997

[6]:
```
Ch_ = Cc_*(Tc_out_ - Tc_in_)/(Th_in_ - Th_out_)
Ch_  # kJ per (min deg C)
```

[6]: 147.94382022471908

[7]:
```
C_min_ = min([Ch_, Cc_])
C_min_  # kJ per (min deg C)
```

[7]: 147.94382022471908

[8]:
```
# Get actual q
q_act_ = Cc_*(Tc_out_ - Tc_in_)
q_act_  # kJ per min
```

[8]: 13166.999999999998

[9]:
```
# Get q max
q_max_ = C_min_*(Th_in_ - Tc_in_)
q_max_  # kJ per min
```

[9]: 14942.325842696626

[10]:
```
# Effectiveness
epsilon_ = q_act_/q_max_
epsilon_
```

[10]: 0.8811881188118813

[11]:
```
# C
C_ = C_min_/Cc_
C_
```

[11]: 0.5056179775280899

[12]:
```
# Find the ntu value
ntu_ = cross_flow_unmixed(epsilon_, C_)
ntu_
```

[12]: 4.180545804015178

The NTU relationship is,

$NTU = \frac{UA}{C_{min}} \rightarrow A = NTU\frac{C_{min}}{U}$

[13]:
```
# Finding the area (unit manipulation added)
A_ = ntu_*C_min_/U_*1000/60
A_  # m^2
```

[13]: 34.36032871502362

1.3.2 LMTD Method

[14]:
```
T_ = log_mean_temp_difference(Th_in_, Th_out_, Tc_in_, Tc_out_)
q_act_/(U_*T_)*1000/60
```

[14]: 25.60989880574635