# trocador

September 8, 2021

[65]:
```
from CoolProp.CoolProp import PropsSI
import numpy as np
import matplotlib.pyplot as plt
```

[66]:
```
"############### Parâmetros fixos ##############"

"############### chute inicial de temp. ##############"

T_f_ent_1 = 28 + 273.15
T_f_sai_chut_1 =  700 + 273.15
T_f_sai_chut_5 = (T_f_sai_chut_1 - T_f_ent_1)/2 + T_f_ent_1

T_q_ent_2 = 665 + 273.15
T_q_sai_chut_2 =  50 + 273.15
T_q_sai_chut_4 = (T_q_sai_chut_2 - T_q_ent_2)/3 + T_q_ent_2
T_q_sai_chut_5 = 2*(T_q_sai_chut_2 - T_q_ent_2)/3 + T_q_ent_2

"############### chute inicial de comprimentos. ##############"

L_chut_5 = 0.6

L = 2

L_chut_4 = L/3

L_chut_5 = L*2/3


"############### parametros do trocador ##############"

L = 2
D = 76e-3
n_tubos = 19
P_T = 15e-3
B_chi = L / 8
d_i = 10e-3
d_e = d_i + 1e-3
```

```python
A_i = np.pi * d_i
A_e = np.pi * d_e
P_e_m = np.pi * d_e
A_i_t = (np.pi * d_i**2)/4
A_c_t = np.pi * D**2/4
k_aco = 401

"############### parâmetros de entrada dos flúidos ##############"

m_dot_f_eval = np.linspace(0.00005,0.0002,num=100)
m_dot_q = 0.0016
P_q = 101325
P_f = 101325

parameters_2 = {'q' : [],
                'D_P' : [],
                'epsilon' : [],
                'Re_D_i' : [],
                'h_i' : [],
                'T_q_sai' : [],
                'T_f_sai' : [],
                'L' : []}


parameters_4 = {'q' : [],
                'D_P' : [],
                'epsilon' : [],
                'Re_D_i' : [],
                'h_i' : [],
                'T_q_sai' : [],
                'T_f_sai' : [],
                'L' : []}


parameters_5 = {'q' : [],
                'D_P' : [],
                'epsilon' : [],
                'Re_D_i' : [],
                'h_i' : [],
                'T_q_sai' : [],
                'T_f_sai' : [],
                'L' : []}


parameters_6 = {'q' : [],
                'D_P' : [],
                'epsilon' : [],
```

```
                'Re_D_i' : [],
                'h_i' : [],
                'T_q_sai' : [],
                'T_f_sai' : [],
                'L' : []}
```

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############### Volumes de Controle II ##############

for m_dot_f in m_dot_f_eval:

    while True:

        A_c = np.pi * d_e * L


        #"parametros do fluido frio"

        T_med_f_1 = (T_f_ent_1 +T_f_sai_chut_1) / 2
        c_p_f_1 = PropsSI('CPMASS','P',P_f,'T',T_med_f_1,'water')
        I_f_ent_1 = PropsSI('H','P',P_f,'T',T_f_ent_1,'water')
        I_f_sai_1 = PropsSI('H','P',P_f,'T',T_med_f_1,'water')
        mu_f_1 = PropsSI('viscosity','P',P_f,'T',T_med_f_1,'water')
        Pr_f_1 = PropsSI('Prandtl','P',P_f,'T',T_med_f_1,'water')
        k_f_1 = PropsSI('conductivity','P',P_f,'T',T_med_f_1,'water')
        rho_f_1 = PropsSI('D','P',P_f,'T',T_med_f_1,'water')

        # parametros do fluido quente

        T_med_q_2 = (T_q_ent_2 + T_q_sai_chut_2)/2
        c_p_q_2 = PropsSI('CPMASS','P',P_q,'T',T_med_q_2,'air')
        mu_q_2 = PropsSI('viscosity','P',P_q,'T',T_med_q_2,'air')
        Pr_q_2 = PropsSI('Prandtl','P',P_q,'T',T_med_q_2,'air')
        k_q_2 = PropsSI('conductivity','P',P_q,'T',T_med_q_2,'air')
        rho_q_2 = PropsSI('D','P',P_q,'T',T_med_q_2,'air')

        # Balanço de massas e energias

        q_2 = m_dot_f * (I_f_sai_1 - I_f_ent_1)

        # calculo da efetividade

        c_q_2 = m_dot_q * c_p_q_2

        c_min_2 = c_q_2

        c_r_2 = 0
```

```
        q_max_2 = c_min_2 * (T_q_ent_2 - T_f_ent_1)

        epsilon_2 = q_2 / q_max_2

        T_q_sai_2 = T_q_ent_2 - q_max_2 * epsilon_2/(m_dot_q * c_p_q_2)

        if epsilon_2 >= 1:
            print(m_dot_f)
            break


        NUT_5 = -np.log(1-epsilon_2)


        # Estudo do escoamento externo

        D_e_kern = (4*((P_T**2 * 3**(1/2))/4 - (np.pi * d_e**2)/8))/(np.pi *␣
↪d_e/2)

        C_kern = P_T - d_e

        A_c = (D * C_kern * B_chi)/P_T

        # Numero de Reynolds

        Re_c = (m_dot_q * D_e_kern)/(A_c * mu_q_2)

        # Coeficiente convectivo

        h_e = (0.36 * k_q_2)/D_e_kern * Re_c**0.55 * Pr_q_2**(1/3)

        # Fator de atrito

        if Re_c >= 2300:

            f = 0.0375

        else:
            f = Re_c/64

        # queda de pressão

        D_P_2 = n_tubos*f*(m_dot_q/A_c)*(7)*D_e_kern/(2*rho_q_2*D)

        #"############## parametros do loop ##############"

        error_q_2 = ((T_q_sai_chut_2 - T_q_sai_2)**2)**0.5
```

```
        T_q_sai_chut_2 = (T_q_sai_chut_2 + T_q_sai_2)/2


        if error_q_2 < (T_q_sai_2 * 0.01):
            break

    parameters_2['q'].append(q_2)
    parameters_2['D_P'].append(D_P_2)
    parameters_2['epsilon'].append(epsilon_2)
    parameters_2['Re_D_i'].append(Re_c)
    parameters_2['h_i'].append(h_e)
    parameters_2['T_q_sai'].append(T_q_sai_2)
    parameters_2['L'].append(L)
```

[68]:

```
############### Volume de Controle IV ##############

for m_dot_f in m_dot_f_eval:

    while True:

        A_i_4 = A_i *L_chut_4


        #"parametros do fluido frio"

        T_f_ent_4 = T_f_ent_1
        T_f_sai_4 = 373.15
        T_med_f_4 = (T_f_ent_4 +T_f_sai_4) / 2
        c_p_f_4 = PropsSI('CPMASS','P',P_f,'T',T_med_f_4,'water')
        I_f_ent_4 = PropsSI('H','P',P_f,'T',T_f_ent_1,'water')
        I_f_sai_4 = PropsSI('H','P',P_f,'T',T_f_sai_4,'water')
        mu_f_4 = PropsSI('viscosity','P',P_f,'T',T_med_f_4,'water')
        Pr_f_4 = PropsSI('Prandtl','P',P_f,'T',T_med_f_4,'water')
        k_f_4 = PropsSI('conductivity','P',P_f,'T',T_med_f_4,'water')
        rho_f_4 = PropsSI('D','P',P_f,'T',T_med_f_4,'water')


        #"parametros do fluido quente"

        T_q_ent_4 = T_q_ent_2
        T_med_q_4 = (T_q_ent_4 + T_q_sai_chut_4)/2
        c_p_q_4 = PropsSI('CPMASS','P',P_q,'T',T_med_q_4,'air')

        #"Balanço de massas e energias"
```

```python
        T_q_sai_4 = T_q_ent_4 - m_dot_f * c_p_f_4*(T_f_sai_4-T_f_ent_4)/
↪(m_dot_q * c_p_q_4)

        q_4 = m_dot_f * c_p_f_4 * (T_f_sai_4 - T_f_ent_4)

        #"calculo da efetividade"

        c_q_4 = m_dot_q * c_p_q_4
        c_f_4 = m_dot_f * c_p_f_4

        if c_q_4<c_f_4 :
            c_min_4 = c_q_4
            c_max_4 = c_f_4

        else:
            c_min_4 = c_f_4
            c_max_4 = c_q_4

        c_r_4 = c_min_4/c_max_4

        q_max_4 = c_min_4 * (T_q_ent_4 - T_f_ent_4)

        epsilon_4 = q_4 / q_max_4

        if epsilon_4 >= 1:
            print(m_dot_f)
            break

        E_c_4 = ((2/epsilon_4) - (1 + c_r_4))/((1 + c_r_4**2)**(1/2))

        NUT_4 = -(1 + c_r_4**2)**(-1/2) * np.log((E_c_4 - 1)/(E_c_4 + 1))

        #NUT_4 = (c_r_4-1)**(-1) * np.log((epsilon_4 - 1)/(epsilon_4*c_r_4 - 1))

        "Numero de Reynolds"

        Re_D_i_4 = (m_dot_f*d_i)/(A_i_t*mu_f_4)


        "numero de Nusselt"

        if Re_D_i_4 >= 2300:

            f_f = 0.0375

            Nu_D_4 = ((f_f/8)*(Re_D_i_4-1e3)*Pr_f_4)/(1 + 12.7 * (f_f/8)**0.5 *␣
↪(Pr_f_4**(2/3)-1))
```

```
elif Re_D_i_4 >= 10000 and Pr_f_4 >= 0.6 and Pr_f_4 <= 160:

    Nu_D_4 = 0.023 * Re_D_i_4**(4/5) * Pr_f_4 * 0.4

else:

    Nu_D_4 = 4.36


"coeficiente de convecção interna"

h_i_4 = (Nu_D_4*k_f_4)/(d_i)


"coeficientes globais"

R_d_i_4 = 0.0002
R_d_e = 0.0009

U_i_4 = (1/ h_i_4 + R_d_i_4 + d_i * n_tubos * (np.log(d_e/d_i))/
        (2 * k_aco ) + (d_i * R_d_e)/d_e + d_i * 1/(d_e * h_e))**(-1)


"encontrando comprimento do volume de controle"

L_4 = (NUT_4 * c_f_4)/( U_i_4 * A_i_4)


"Queda de pressão"

f_4 = Re_D_i_4/64

vm_4_f = m_dot_f/(rho_f_4*A_i_t)

D_P_4 = rho_f_4 * vm_4_f**2 * L_4 * n_tubos/(2*d_i)


"############### parametros do loop ##############"

error_q_4 = ((T_q_sai_chut_4 - T_q_sai_4)**2)**0.5

T_q_sai_chut_4 = (T_q_sai_chut_4 + T_q_sai_4)/2


if error_q_4 < (T_q_sai_4 * 0.01):
    break
```

```
    parameters_4['q'].append(q_4)
    parameters_4['D_P'].append(D_P_4)
    parameters_4['epsilon'].append(epsilon_4)
    parameters_4['Re_D_i'].append(Re_D_i_4)
    parameters_4['h_i'].append(h_i_4)
    parameters_4['T_q_sai'].append(T_q_sai_4)
    parameters_4['T_f_sai'].append(T_f_sai_4)
    parameters_4['L'].append(L_4)
```

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############### Volume de Controle V ##############

for m_dot_f,T_q_sai_4,h_i_4 in␣
 ↪zip(m_dot_f_eval,parameters_4['T_q_sai'],parameters_4['h_i']):


    while True:

        A_i_5 = A_i * L_chut_5
        A_e_5 = A_e * L_chut_5

        "parametros do fluido frio"

        T_f_ent_5 = 373.15
        T_f_sai_5 = 373.15
        I_f_ent_5 = PropsSI('H','Q',0,'T',T_f_ent_5,'water')
        I_f_sai_5 = PropsSI('H','Q',1,'T',T_f_sai_5,'water')

        mu_f_a = PropsSI('viscosity','Q',0,'T',T_f_ent_5,'water')
        Pr_f_a = PropsSI('Prandtl','Q',0,'T',T_f_ent_5,'water')
        k_f_a = PropsSI('conductivity','Q',0,'T',T_f_ent_5,'water')
        c_p_f_a = PropsSI('CPMASS','Q',0,'T',T_f_ent_5,'water')
        I_f_a = PropsSI('H','Q',0,'T',T_f_ent_5,'water')
        rho_f_a = PropsSI('D','Q',0,'T',T_f_ent_5,'water')

        mu_f_v = PropsSI('viscosity','Q',1,'T',T_f_ent_5,'water')
        Pr_f_v = PropsSI('Prandtl','Q',1,'T',T_f_ent_5,'water')
        k_f_v = PropsSI('conductivity','Q',1,'T',T_f_ent_5,'water')
        c_p_f_v = PropsSI('CPMASS','Q',1,'T',T_f_ent_5,'water')
        I_f_v = PropsSI('H','Q',1,'T',T_f_ent_5,'water')
        rho_f_v = PropsSI('D','Q',0,'T',T_f_ent_5,'water')

        "parametros do fluido quente"

        T_q_ent_5 = T_q_sai_4
        T_med_q_5 = (T_q_ent_5 + T_q_sai_chut_5)/2
        c_p_q_5 = PropsSI('CPMASS','P',P_q,'T',T_med_q_5,'air')
```

```
"parametros adicionais"

mu_f_s_v = PropsSI('viscosity','Q',0,'T',647.096,'water')


"Balanço de massas e energias"

q_5 = m_dot_f * (I_f_sai_5 - I_f_ent_5)

"calculo da efetividade"

c_q_5 = m_dot_q * c_p_q_5

c_min_5 = c_q_5

c_r_5 = 0

q_max_5 = c_min_5 * (T_q_ent_5 - T_f_ent_5)

epsilon_5 = q_5 / q_max_5

T_q_sai_5 = T_q_ent_5 - q_max_5 * epsilon_5/(m_dot_q * c_p_q_5)

if epsilon_5 >= 1:
    print(m_dot_f)
    break

NUT_5 = -np.log(1-epsilon_5)


"Numero de Reynolds"

Re_D_i_5_v = (m_dot_f*d_i)/(A_i_t*mu_f_v)

Re_D_i_5_a = (m_dot_f*d_i)/(A_i_t*mu_f_a)



"Calculo do coeficiente convectivo"

q_s_flux = q_5/(A_i_5)

x = np.linspace(0,L_chut_5,num=100)

X_eval = (q_s_flux * np.pi * d_i * x)/(m_dot_f*(I_f_v-I_f_a))
```

```
        G_s_f = 1

        Fr = ((m_dot_f/A_i_t)**2 / rho_f_a)/(10*d_i)

        if Fr >= 0.04:
            f_Fr =1

        else:
            f_Fr = 2.63*Fr**0.3


        "coeficiente de convecção interna"

        h_mf = h_i_4

        aux = []

        for X in X_eval:


            if (X > 0) and (X <= 0.8):

                aux.append((1.136*(rho_f_a/rho_f_v)**0.45 * X**0.72 * (1-X)**0.08 * f_Fr +
                667*(q_s_flux/((m_dot_f/A_i_t)*(I_f_v-I_f_a)))**0.7 * (1-X)**0.8 * G_s_f))

            else:

                r = 0.6683*((rho_f_a/rho_f_v)**0.1) * X**0.16 * (1-X)**0.64 * f_Fr + 1058*((q_s_flux/((m_dot_f/A_i_t)*(I_f_v-I_f_a)))**0.7) * (1-X)**0.8 * G_s_f

                if np.isnan(r) == True:
                    aux.append(0)

                else:
                    aux.append(r)


        h_i_5 = np.mean(aux) * h_mf


        "coeficientes globais"

        R_d_i_5 = 0.0002
```

```
        U_e_5 = (d_e/(d_i*h_i_5) + R_d_i_5 * d_e /d_i + d_e * n_tubos * (np.
↪log(d_e/d_i))/(2 * k_aco ) +
                R_d_e + 1/h_e)**(-1)


        "encontrando comprimento do volume de controle"

        L_5 = (NUT_5 * c_q_5)/(U_e_5 * A_e_5)


        "Queda de pressão"

        f_5 = Re_D_i_5_v/64

        vm_5_f = m_dot_f/(rho_f_v*A_i_t)

        D_P_5 = rho_f_v * vm_5_f**2 * L_5 * n_tubos/(2*d_i)

        "############### parametros do loop ##############"


        error_L_5 = ((L_chut_5 - L_5)**2)**0.5

        L_chut_5 = (L_chut_5 + L_5)/2

        if error_L_5 < (L_5 * 0.01):
            break

    parameters_5['q'].append(q_5)
    parameters_5['D_P'].append(D_P_5)
    parameters_5['epsilon'].append(epsilon_5)
    parameters_5['Re_D_i'].append(Re_D_i_5_v)
    parameters_5['h_i'].append(h_i_5)
    parameters_5['T_q_sai'].append(T_q_sai_5)
    parameters_5['T_f_sai'].append(T_f_sai_5)
    parameters_5['L'].append(L_5)
```

```
/home/thiago/yes/envs/tf/lib/python3.7/site-packages/ipykernel_launcher.py:111:
RuntimeWarning: invalid value encountered in double_scalars
```

[70]:
```
############### Volume de Controle VI ##############

for m_dot_f,T_q_sai_5,T_q_sai_2,L_4,L_5 in␣
↪zip(m_dot_f_eval,parameters_5['T_q_sai'],parameters_2['T_q_sai'],parameters_4['L'],paramete
↪

    while True:
```

```
L_6 = L - (L_4 + L_5)

A_i_6 = A_i * L_6

"parametros do fluido frio"

T_f_ent_6 = 373.15
T_med_f_6 = (T_f_ent_6 + T_f_sai_chut_1) / 2
c_p_f_6 = PropsSI('CPMASS','P',P_f,'T',T_med_f_6,'water')
I_f_ent_6 = PropsSI('H','P',P_f,'T',T_f_ent_6,'water')
I_f_sai_6 = PropsSI('H','P',P_f,'T',T_f_sai_chut_1,'water')
mu_f_6 = PropsSI('viscosity','P',P_f,'T',T_med_f_6,'water')
Pr_f_6 = PropsSI('Prandtl','P',P_f,'T',T_med_f_6,'water')
k_f_6 = PropsSI('conductivity','P',P_f,'T',T_med_f_6,'water')


"parametros do fluido quente"

T_q_ent_6 = T_q_sai_5
T_med_q_6 = (T_q_ent_6 + T_q_sai_2)/2
c_p_q_6 = PropsSI('CPMASS','P',P_q,'T',T_med_q_6,'air')


"parametros adicionais"

mu_f_s_6 = PropsSI('viscosity','P',P_f,'T',T_med_f_6,'water')


"Balanço de massas e energias"

q_6 = m_dot_q * c_p_q_6 * (T_q_ent_6 - T_q_sai_2)

"calculo da efetividade"

c_q_6 = m_dot_q * c_p_q_6
c_f_6 = m_dot_f * c_p_f_6

if (c_q_6<c_f_6) :
    c_min_6 = c_q_6
    c_max_6 = c_f_6

else:
    c_min_6 = c_f_6
    c_max_6 = c_q_6
```

```
    c_r_6 = c_min_6/c_max_6

    q_max_6 = c_min_6 * (T_q_ent_6 - T_f_ent_6)

    epsilon_6 = q_6 / q_max_6

    T_f_sai_6 = T_f_ent_6 + q_max_6 * epsilon_6/(m_dot_f * c_p_f_6)


    #NUT_6 = (c_r_6 - 1)*np.log((epsilon_6-1)/(epsilon_6*c_r_4-1))

    e_c_6 = (2/epsilon_6 - 1 + c_r_6)/(1 + c_r_6**2)**(1/2)

    NUT_6 = -(1 + c_r_6**2)**(-1/2) * np.log((e_c_6 - 1)/(e_c_6 + 1))

    "Numero de Reynolds"

    Re_D_i_6 = (m_dot_f*d_i)/(A_i_t*mu_f_6)

    "numero de Nusselt"

    if Re_D_i_6 >= 2300:

        f_f = 0.0375

        Nu_D_6 = ((f_f/8)*(Re_D_i_6-1e3)*Pr_f_6)/(1 + 12.7 * (f_f/8)**0.5 *␣
↪(Pr_f_6**(2/3)-1))

    elif Re_D_i_6 >= 10000 and Pr_f_6 >= 0.6 and Pr_f_6 <= 160:

        Nu_D_6 = 0.023 * Re_D_i_6**(4/5) * Pr_f_6 * 0.4

    else:

        Nu_D_6 = 4.36

    "coeficiente de convecção interna"

    h_i_6 = (Nu_D_6*k_f_6)/(d_i)

    "coeficientes globais"

    R_d_i_6 = 0.0002

    U_i_6 = (1/h_i_6 + R_d_i_6 + d_i * n_tubos * (np.log(d_e/d_i))/(2 *␣
↪k_aco) +
            (d_i/d_e) * R_d_e + d_i/(d_e * h_e))**(-1)
```

```
        "Queda de pressão"

        f_6 = Re_D_i_6/64

        vm_6_f = m_dot_f/(rho_f_v*A_i_t)

        D_P_6 = rho_f_v * vm_6_f**2 * L_6 * n_tubos/(2*d_i)


        "############### parametros do loop ##############"

        error_f_6 = ((T_f_sai_chut_1 - T_f_sai_6)**2)**0.5

        T_f_sai_chut_1 = (T_f_sai_chut_1 + T_f_sai_6)/2

        if (error_f_6 < (T_f_sai_6 * 0.01)):
            break


    parameters_6['q'].append(q_6)
    parameters_6['D_P'].append(D_P_6)
    parameters_6['epsilon'].append(epsilon_6)
    parameters_6['Re_D_i'].append(Re_D_i_6)
    parameters_6['h_i'].append(h_i_6)
    parameters_2['T_f_sai'].append(T_f_sai_6)
    parameters_6['T_q_sai'].append(T_q_sai_2)
    parameters_6['T_f_sai'].append(T_f_sai_6)
    parameters_6['L'].append(L_6)
```

[71]:
```
################ Análise geral ###############

parameters = parameters_4.keys()

zones = [
    parameters_2,
    parameters_4,
    parameters_5,
    parameters_6
]

z_names =[
    'Escoamento no casco',
    'Água líquida',
    'Escoamento bifásico',
    'Vapor super-aquecido'
```

```
]

colors = [
    'r',
    'b',
    'y',
    'g'
]

styles = [
    '-',
    '--',
    '-.',
    ':'
]

names = [
    'Taxa de transferência de calor',
    'Queda de Pressão',
    'Efetividade',
    'Número de Reynolds',
    'Coeficiente de transferência convectiva',
    'Temperatura de saída do fluido quente',
    'Temperatura de saída do fluido frio',
    'Comprimento da zona'
]

symbols = [
    '$q$',
    '$\Delta P$',
    '$\epsilon$',
    '$Re_D$',
    '$h_i$',
    '$T_{q,sai}$',
    '$T_{f,sai}$',
    '$L$'
]

for parameter, name , symbol in zip(parameters,names,symbols):

    fig = plt.figure(figsize=[16,9])

    fig.suptitle((name + ' em função de $\dot{m}_f$'), fontsize=16)

    ax = fig.add_subplot(1, 1, 1)

    ax.set_xlabel('$\dot{m}_f$',fontsize=16)
```

```
    ax.set_ylabel(symbol,fontsize=16)


    for zone,z_name,color,style in zip(zones,z_names,colors,styles):

        ax.plot(m_dot_f_eval,zone[parameter],color,␣
↪linewidth=2,linestyle=style,label = z_name)

        if name == 'Queda de Pressão':
            plt.yscale("log")

        elif name == 'Número de Reynolds':
            plt.yscale("log")

        elif name == 'Temperatura de saída do fluido frio':
            plt.yscale("log")

        elif name == 'Coeficiente de transferência convectiva':
            plt.yscale("log")

    if name == 'Queda de Pressão':

        tot = [p1+p2+p3 for p1,p2,p3 in zip(parameters_4[parameter],
                                            parameters_5[parameter],
                                            parameters_6[parameter])]

        ax.plot(m_dot_f_eval,tot,'k', linewidth=2,linestyle='-',label = 'Queda␣
↪total de pressão')

    ax.grid()

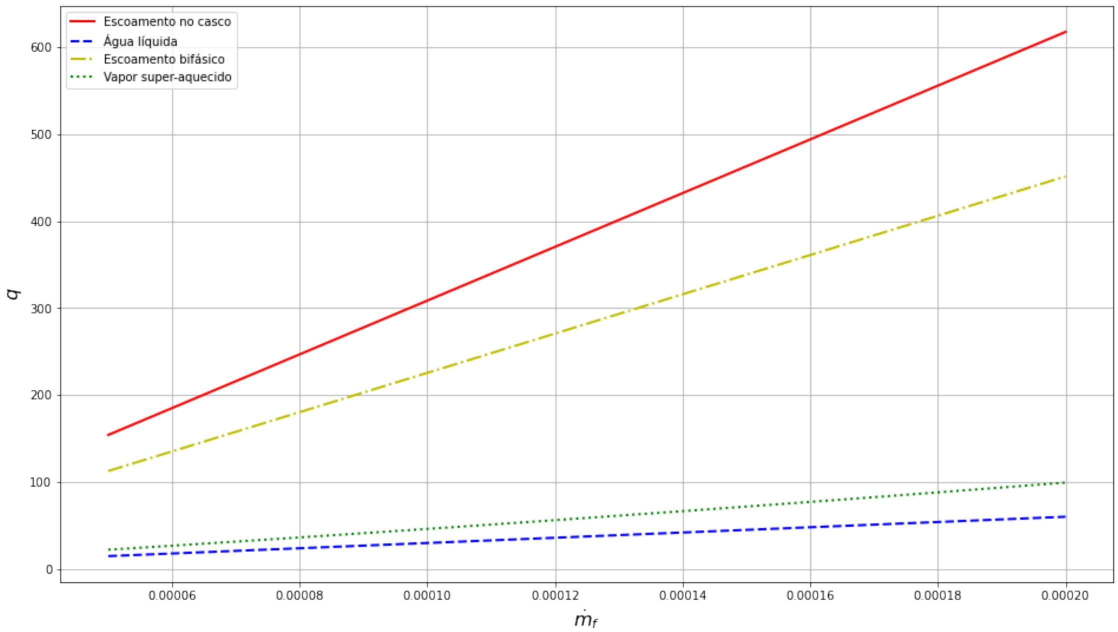
    ax.legend()

    plt.show()

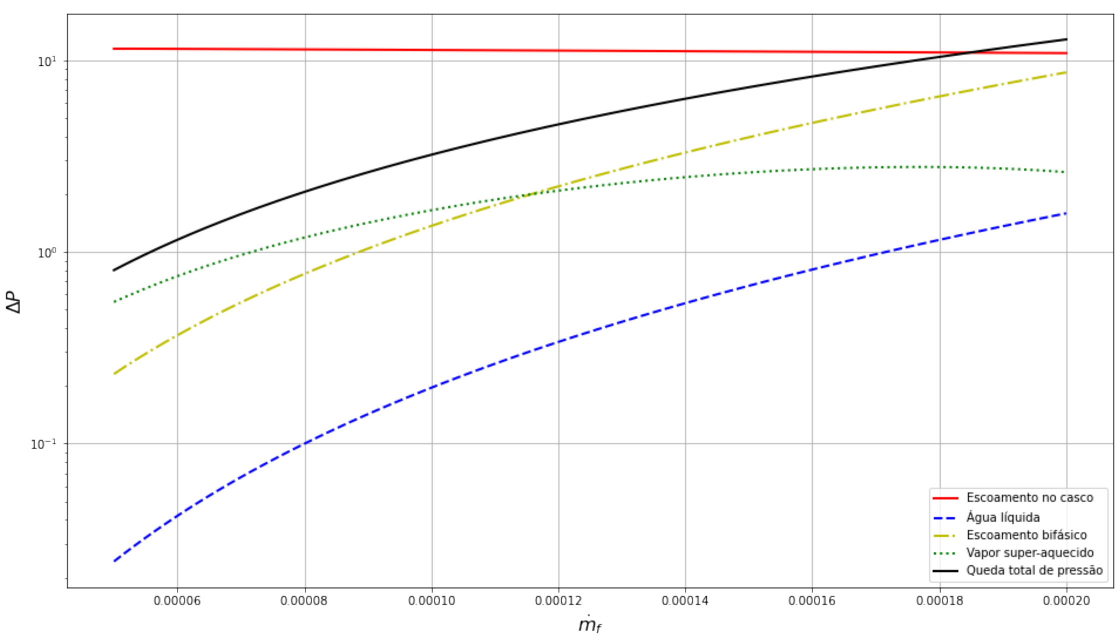
    fig.savefig('plots/' + name + '.png', bbox_inches='tight')

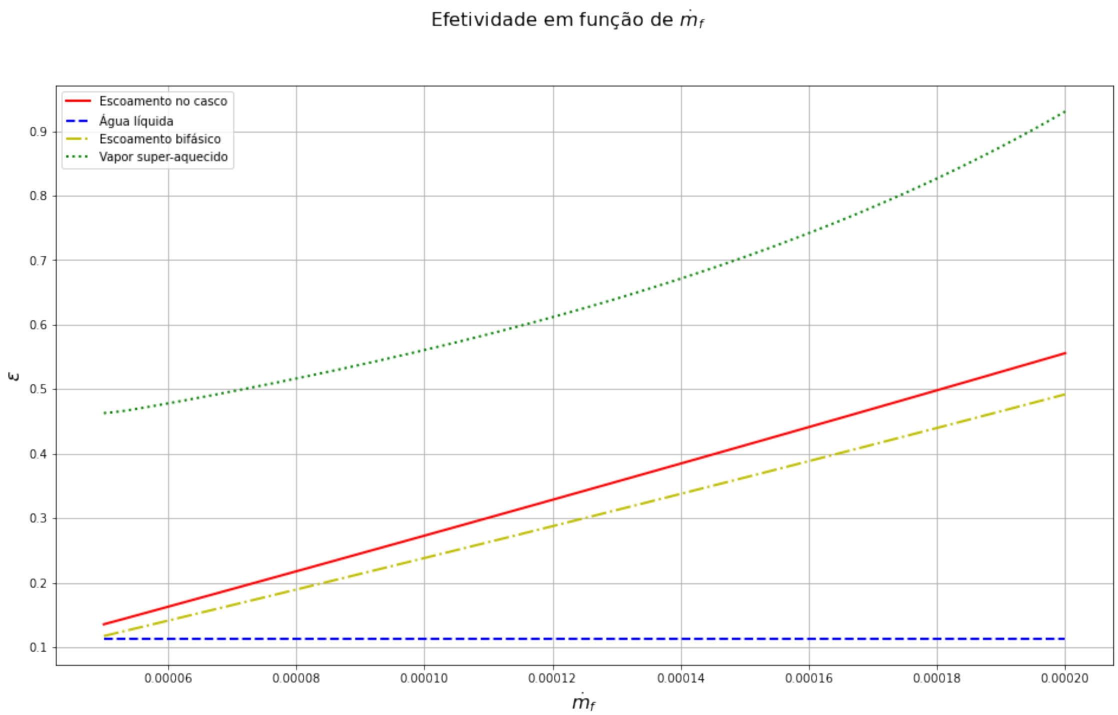
    del fig
    del ax
    plt.close()
```

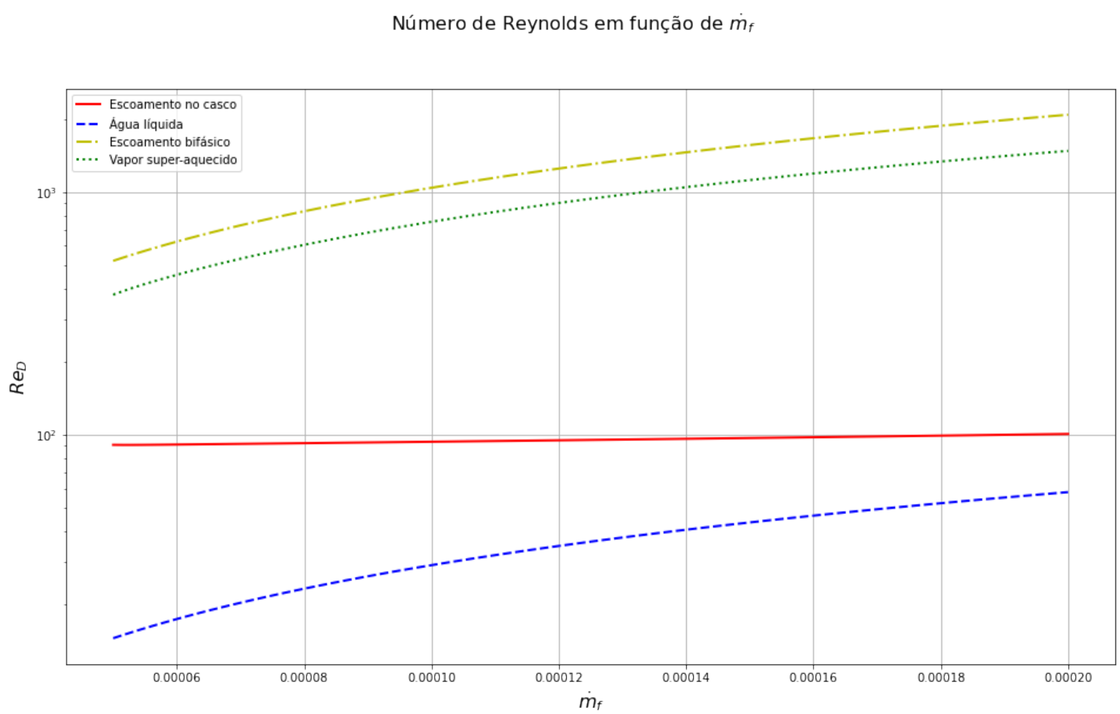
Taxa de transferência de calor em função de $\dot{m}_f$



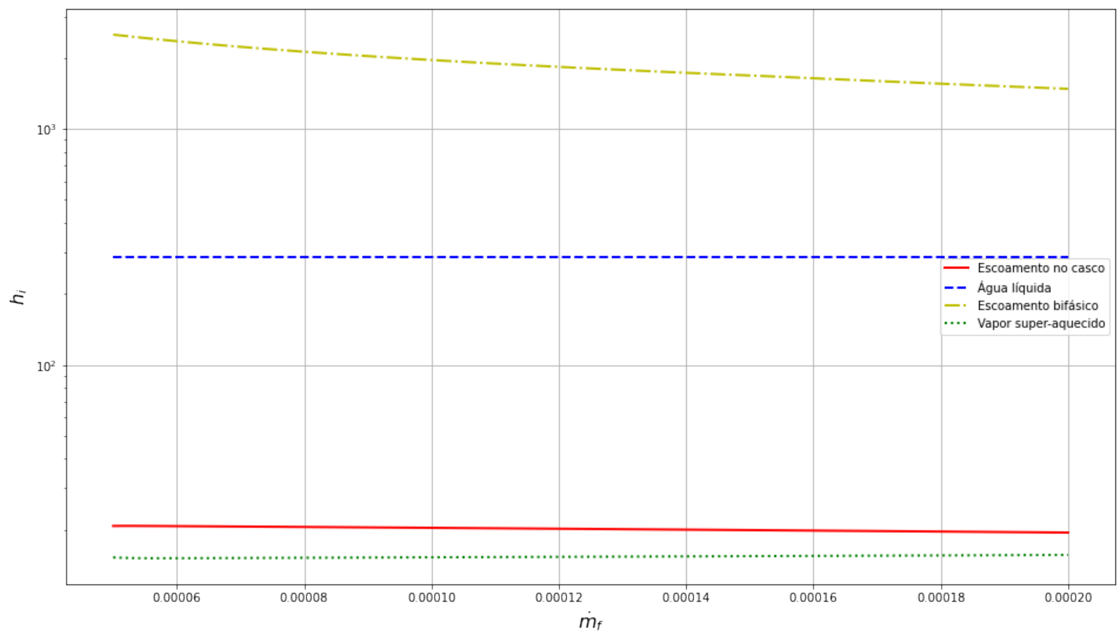

Queda de Pressão em função de $\dot{m}_f$



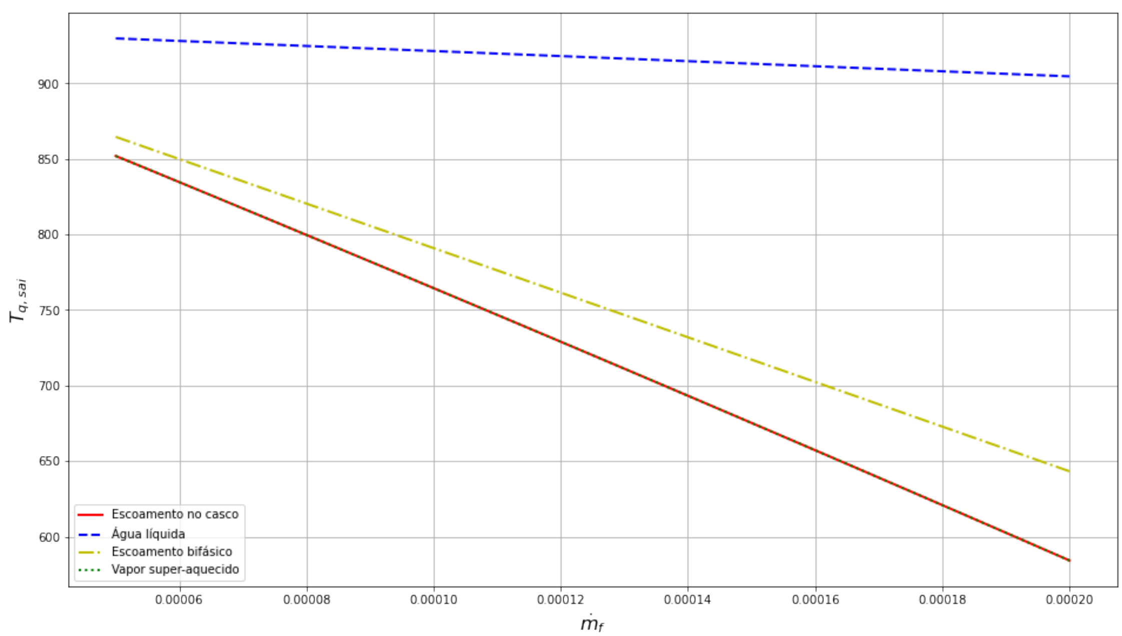

Efetividade em função de $\dot{m}_f$
Escoamento no casco
Água líquida
Escoamento bifásico
Vapor super-aquecido
$\varepsilon$
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0.00006
0.00008
0.00010
0.00012
0.00014
0.00016
0.00018
0.00020
$\dot{m}_f$


Número de Reynolds em função de $\dot{m}_f$
Escoamento no casco
Água líquida
Escoamento bifásico
Vapor super-aquecido
$Re_D$
$10^3$
$10^2$
0.00006
0.00008
0.00010
0.00012
0.00014
0.00016
0.00018
0.00020
$\dot{m}_f$

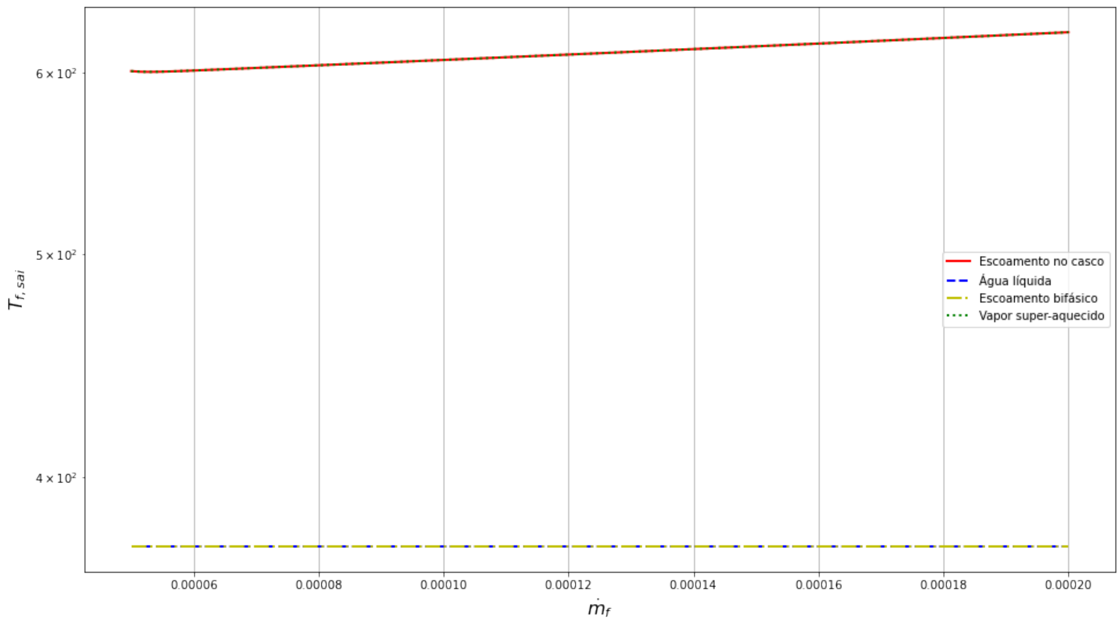
Coeficiente de transferência convectiva em função de $\dot{m}_f$



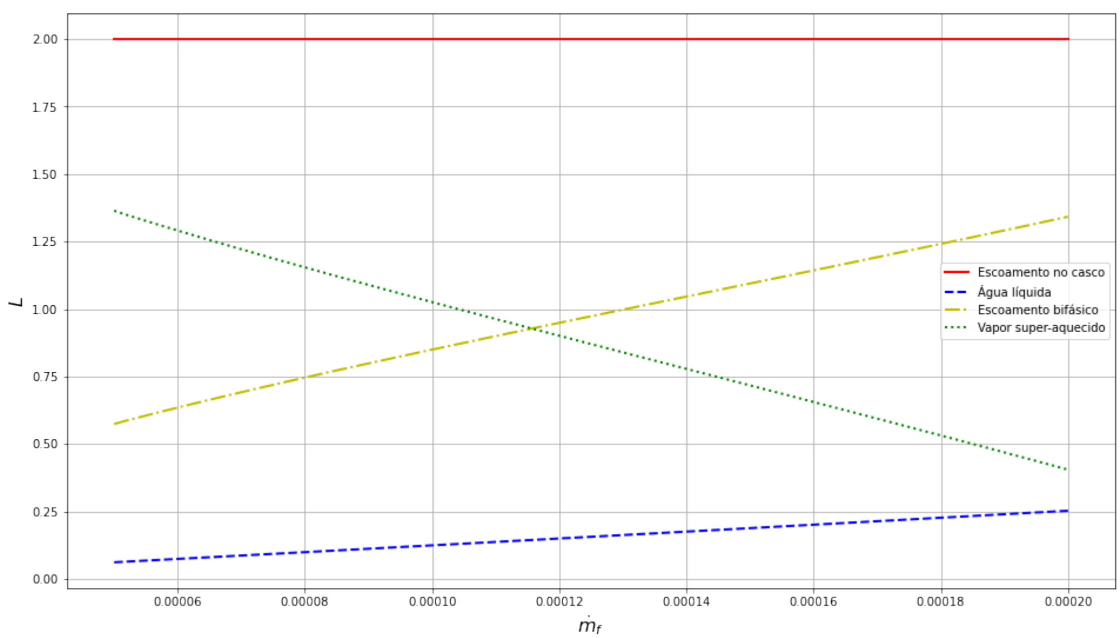

Temperatura de saída do fluido quente em função de $\dot{m}_f$



Temperatura de saída do fluido frio em função de $\dot{m}_f$




Comprimento da zona em função de $\dot{m}_f$




```
[ ]:
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[ ]:

```

```