embreagem_study

August 16, 2022

1 Importando variáveis

```
[ ]: import numpy as np
     import matplotlib.pyplot as plt
     from scipy.interpolate import interp1d
     import pandas as pd
```

2 Anotações

- no maximo duas vezes o pinãho
- 4 molas ou mais
- 1 mm para soltar

3 Embreagem

```
[ ]: # constantes embragem

     Pot = 7.5e3
     w = 900 / 60 * 2 * np.pi
     torque_proj = Pot / w
     f = 0.45
     p_max = 2070e3
     b = 3e-3
     rho_emb = 7070
     r_pinhao = 75
     torque_proj
```

```
[ ]: 79.57747154594767
```

```
[ ]: r_o_eval = np.linspace(10, r_pinhao, num=14, dtype=int )
     r_i_list = []
     r_o_list = []
     N_list = []
```

```
P_list = []
F_emb_list = []
torque_list = []
Perim_list = []

for r_o_mm in r_o_eval:

    r_o = r_o_mm *1e-3

    # calculo de embreagem

    N = 2

    r_i = r_o * (1/3) ** 0.5

    torque = np.pi * p_max * f * r_i * (r_o**2 - r_i**2) * N

    while True:

        torque = np.pi * p_max * f * r_i * (r_o**2 - r_i**2) * N

        if (N > 14) or (torque > torque_proj):
            break

        N += 2


    if torque < torque_proj:
        torque_list.append(0)

    else:
        torque_list.append(torque)

    F_emb = 2 * np.pi * p_max * r_i * (r_o - r_i)

    P = (np.pi * r_o ** 2 - np.pi * r_i ** 2) * b * rho_emb * (N * 2 - 1)

    r_i_list.append(r_i)
    r_o_list.append(r_o)
    N_list.append(N)
    P_list.append(P)
    F_emb_list.append(F_emb)
    Perim_list.append(2*np.pi*((r_o-r_i)/2 + r_i))

df_emb = pd.DataFrame(
    np.vstack((
        r_i_list,
```

```
        r_o_list,
        N_list,
        P_list,
        F_emb_list,
        torque_list,
        Perim_list,
        )).T,
        columns=["r_i", "r_o", "N","P","F","torque","Perim"]
)

df_emb = df_emb.drop(df_emb[df_emb.torque == 0].index.values)

df_emb
```

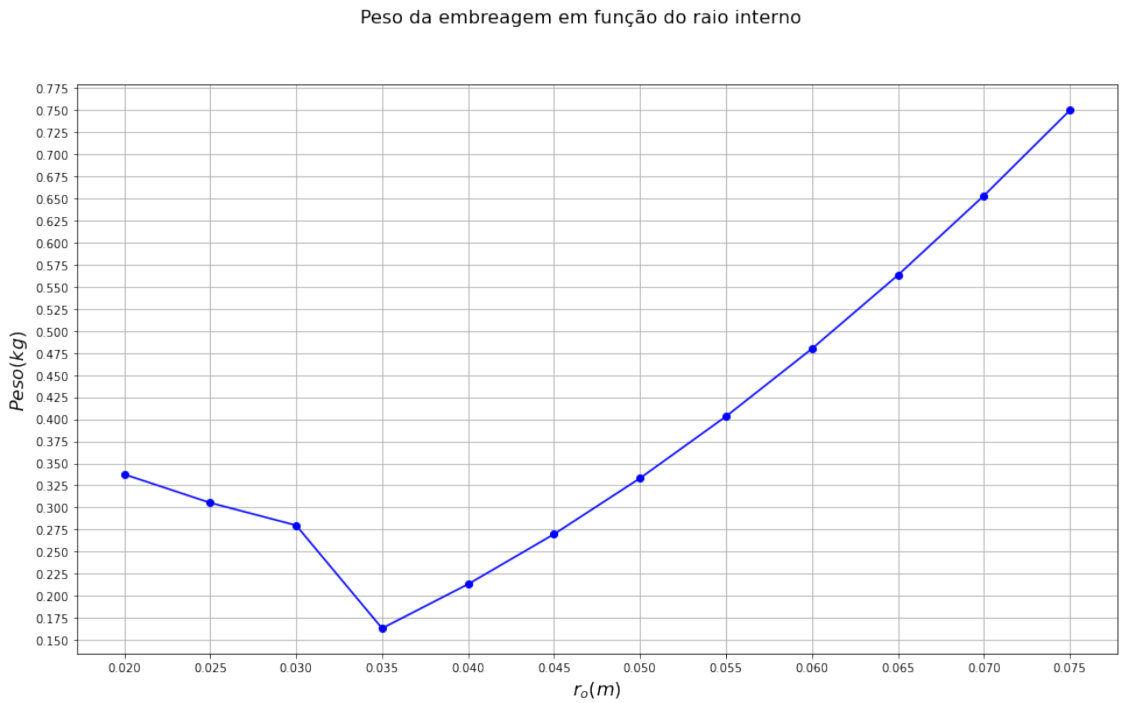
[ ]:

	r_i	r_o	N	P	F	torque	Perim
2	0.011547	0.020	10.0	0.337608	1269.492602	90.109552	0.099108
3	0.014434	0.025	6.0	0.305402	1983.582191	105.597132	0.123885
4	0.017321	0.030	4.0	0.279859	2856.358355	121.647896	0.148662
5	0.020207	0.035	2.0	0.163251	3887.821095	96.586176	0.173439
6	0.023094	0.040	2.0	0.213226	5077.970410	144.175284	0.198216
7	0.025981	0.045	2.0	0.269864	6426.806300	205.280824	0.222993
8	0.028868	0.050	2.0	0.333166	7934.328765	281.592351	0.247770
9	0.031754	0.055	2.0	0.403131	9600.537806	374.799420	0.272547
10	0.034641	0.060	2.0	0.479759	11425.433422	486.591583	0.297324
11	0.037528	0.065	2.0	0.563050	13409.015613	618.658396	0.322100
12	0.040415	0.070	2.0	0.653005	15551.284379	772.689412	0.346877
13	0.043301	0.075	2.0	0.749623	17852.239721	950.374186	0.371654

[ ]:

```
fig = plt.figure(figsize=[16, 9])
fig.suptitle('Peso da embreagem em função do raio interno', fontsize=16)

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

# Plotando 2D

ax.plot(df_emb.r_o,
    df_emb.P,
    'o',
    df_emb.r_o,
    df_emb.P,
    '-',
    color='b',
)

ax.locator_params(axis='y', nbins=30)
ax.locator_params(axis='x', nbins=20)
ax.set_ylabel('$Peso (kg)$', fontsize=16)
```

```
ax.set_xlabel('$r_o (m)$', fontsize=16)
ax.grid()

plt.show()
```



4 Mola

```
[ ]: # constantes
Su = 1250e6
Su_lim = 0.80
Su_vida_inf = 0.62
Sy_lim = 0.65
delta_p = 1e-3
G = 79e9
E = 207e9
rho = 7700
```

```
[ ]: n_molas_list = np.linspace(8,4,num=5,dtype=int)

# plotagem diagrama de goodman

fig = plt.figure(figsize=[16, 25])
```

```python
for i,n_molas in enumerate(n_molas_list):

    F_min = 1 / n_molas

    F_max = F_min * 1.2

    Fs = 1.1 * F_max

    linha_sobrecarga_1 = np.array(
        ([0,Su_vida_inf],
        [Su_lim,Su_lim])
    )

    linha_sobrecarga_2 = np.array(
        ([0,Sy_lim],
        [Su_lim,Sy_lim])
    )

    linha_carga = np.array(
        ([0,0],
        [Su_lim*(F_min/F_max),Su_lim])
    )


    # Plotando 2D

    ax = fig.add_subplot(3, 2, (i+1) )

    ax.set_title('Diagrama de Goodman p/ {} molas'.format(i+1), fontsize=16)

    ax.plot(linha_sobrecarga_1[:,0], linha_sobrecarga_1[:,1], 'r', linewidth=2)
    ax.plot(linha_sobrecarga_2[:,0], linha_sobrecarga_2[:,1], 'r', linewidth=2)
    ax.plot(linha_carga[:,0], linha_carga[:,1], 'b', linewidth=2)

    ax.set_xlim(0)
    ax.set_ylim(0)
    ax.locator_params(axis='y', nbins=20)
    ax.grid()

plt.show()
```

Diagrama de Goodman p/ 1 molas

Diagrama de Goodman p/ 2 molas

Diagrama de Goodman p/ 3 molas

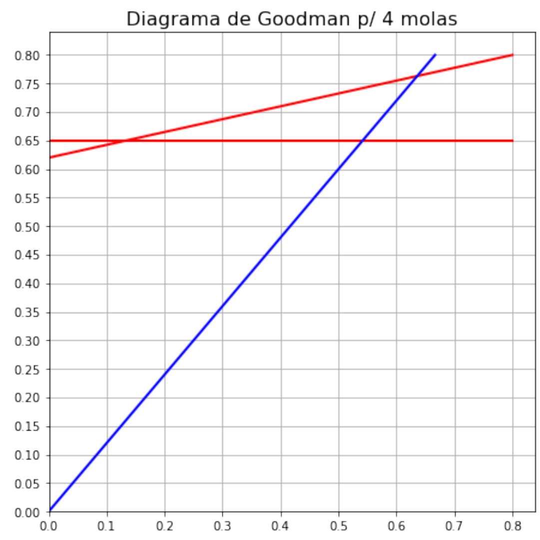


Diagrama de Goodman p/ 4 molas

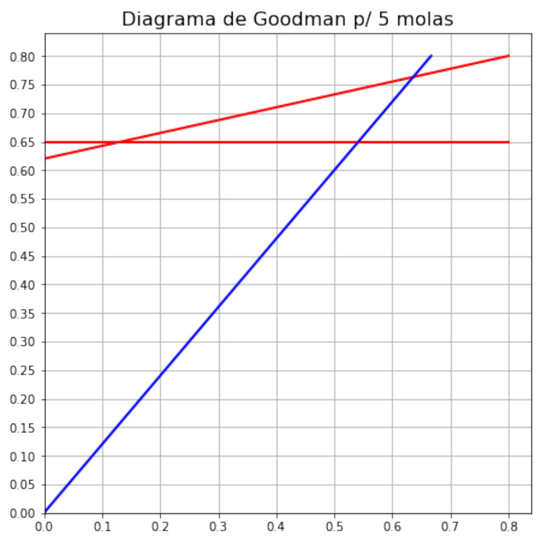


Diagrama de Goodman p/ 5 molas

[ ]:
```
# encontrando tensão limite

tensao_max_teorico = 0.65 * Su

f_seguranca = 0.1

f_mola_solida = 0.1

tensao_max = tensao_max_teorico/(1+f_seguranca)/(1+f_mola_solida)

print('{:.2e} MPa'.format(tensao_max/1e6))
```

```
6.71e+02 MPa
```

[ ]:
```
# estabelecendo um diãmetro alvo

C_t = 5

Kw = (4*C_t - 1)/(4*C_t - 4) + 0.615/C_t

d_alvo = (8*F_max*C_t*Kw/(np.pi*tensao_max))**0.5

print('{:.2e} mm'.format(d_alvo*1e3))
```

```
8.63e-02 mm
```

[ ]:
```
## converge C

def C_converge(C_t,d,tau,F_max,verbose=False):

    k = 0


    while True:

        k += 1

        Ks = (4*C_t - 1)/(4*C_t - 4) + 0.675/C_t

        C_p = tau*np.pi*d**2/(8*F_max*Ks)

        error = ((C_p-C_t)**2)**0.5

        C_t = (C_p+C_t)/2

```

```
        if verbose:
            print("C_t",C_t)
            print("C_p",C_p)
            print("error",error)
            print('*'*12)

        if error <= C_t*0.1:
            return C_t


        if k >= 200:
            return 0
```

[ ]:
```
from curses.ascii import LF


d_mm_list = np.linspace(1,10,num=10,dtype=float)

C_list = []
D_list = []
Nt_list = []
Lf_D_list = []
delta_Lf_list = []
V_list = []
P_list = []
fn_list = []
d_list = []
N_list = []
Diam_list = []
k_list = []
R_ex_list = []
r_o_list = []
L_min_list = []

for F_emb, r_i_emb, r_o_emb in zip(df_emb.F, df_emb.r_i, df_emb.r_o):
    for n_molas in n_molas_list:
        for i,d_mm in enumerate(d_mm_list):

            F_min = F_emb / n_molas

            F_max = F_min * 1.2

            Fs = 1.1 * F_max

            d = d_mm*1e-3

            k = (F_max-F_min)/delta_p
```

```
C = C_converge(C_t,d,tensao_max,F_max)

D = C * d

N = d * G/(8 * C**3 * k)

N_t = N + 2

Ls = N_t * d

delta_s = Fs/k

L_f = Ls + delta_s

Lf_D = L_f/D

delta_Lf = delta_s/L_f

V = (np.pi * d **2 / 4) * 2 * np.pi * D/2

P += V * rho * n_molas

fn = 353e3*d/(N*D**2) * 60

Diam = D + d

if Diam > (r_o_emb - r_i_emb):
    Diam_list.append(0)

else:
    Diam_list.append(Diam)

Perim = n_molas * Diam

R = Perim /(2 * np.pi)

R_ex = R + ((d + D)/2)


if R_ex > r_o_emb:
    R_ex_list.append(0)

else:
    R_ex_list.append(R_ex)

C_list.append(C)
```

```
            D_list.append(D)
            Nt_list.append(N_t)
            Lf_D_list.append(Lf_D)
            delta_Lf_list.append(delta_Lf)
            V_list.append(V)
            P_list.append(P)
            fn_list.append(fn)
            d_list.append(d)
            N_list.append(n_molas)
            k_list.append(k)
            r_o_list.append(r_o_emb)
            L_min_list.append(L_f)

df = pd.DataFrame(np.vstack((
        d_list,
        C_list,
        N_list,
        Diam_list,
        R_ex_list,
        r_o_list,
        k_list,
        L_min_list,
        D_list,
        Nt_list,
        Lf_D_list,
        delta_Lf_list,
        P_list,
        fn_list,
    )).T,columns=[
            'd',
            'C',
            'n_molas',
            'Diam',
            'R_ex',
            'r_o_emb',
            'k',
            'L_carr',
            'D',
            'Nt',
            'Lf_D',
            'delta/Lf',
            'P',
            'fn',
        ], dtype=float)

df = df.drop(df[df.C == 0].index.values)
df = df.drop(df[df.R_ex == 0].index.values)
```

```
df = df.drop(df[df.Diam == 0].index.values)
df = df.drop(df[df.Lf_D > 7].index.values)

df
```

```
/tmp/ipykernel_9712/3680420355.py:40: RuntimeWarning: divide by zero encountered
in double_scalars
  N = d * G/(8 * C**3 * k)
/tmp/ipykernel_9712/3680420355.py:58: RuntimeWarning: invalid value encountered
in double_scalars
  fn = 353e3*d/(N*D**2) * 60
```

[ ]:

	d	C	n_molas	Diam	R_ex	r_o_emb	k
223	0.004	2.598977	6.0	0.014396	0.020945	0.040	169265.680319
253	0.004	2.816269	8.0	0.015265	0.027069	0.045	160670.157490
284	0.005	2.716010	5.0	0.018580	0.024076	0.045	257072.251984
324	0.005	2.598977	6.0	0.017995	0.026181	0.050	264477.625498
345	0.006	2.326437	4.0	0.019959	0.022685	0.050	396716.438247
354	0.005	3.113119	8.0	0.020566	0.036468	0.055	240013.445139
385	0.006	2.465072	5.0	0.020790	0.026940	0.055	384021.512223
425	0.006	2.598977	6.0	0.021594	0.031418	0.060	380847.780717
455	0.006	3.243078	8.0	0.025458	0.045144	0.065	335225.390319
465	0.006	2.475285	7.0	0.020852	0.033656	0.065	383114.731793
486	0.007	2.354786	5.0	0.023484	0.030429	0.065	536360.624510
505	0.006	2.412148	8.0	0.020473	0.036303	0.070	388782.109482
526	0.007	2.598977	6.0	0.025193	0.036654	0.070	518376.145976
556	0.007	3.339850	8.0	0.030379	0.053869	0.075	446305.993028
566	0.007	2.665194	7.0	0.025656	0.041412	0.075	510063.992032
587	0.008	2.274370	5.0	0.026195	0.033943	0.075	714089.588845
598	0.009	2.326437	4.0	0.029938	0.034028	0.075	892611.986056

	L_carr	D	Nt	Lf_D	delta/Lf	P
223	0.067772	0.010396	15.292937	6.519080	0.097386	1549.822570
253	0.058625	0.011265	13.006258	5.204141	0.112580	1561.976609
284	0.064532	0.013580	11.586445	4.751987	0.102274	1580.730338
324	0.069772	0.012995	12.634350	5.369170	0.094594	1596.908040
345	0.089768	0.013959	13.861362	6.431021	0.073523	1602.749125
354	0.050692	0.015566	8.818432	3.256680	0.130198	1604.191528
385	0.080401	0.014790	12.300158	5.436011	0.082089	1616.117122
425	0.071772	0.015594	10.861958	4.602564	0.091958	1626.520505
455	0.049691	0.019458	7.181785	2.553681	0.132822	1631.165060
465	0.079784	0.014852	12.197263	5.372012	0.082724	1634.636247
486	0.089691	0.016484	11.870148	5.441260	0.073586	1639.048206
505	0.083751	0.014473	12.858511	5.786756	0.078805	1640.956202
526	0.073772	0.018193	9.595964	4.054988	0.089465	1646.011330
556	0.049702	0.023379	6.157396	2.125920	0.132792	1649.030605
566	0.070710	0.018656	9.158530	3.790113	0.093339	1651.400494

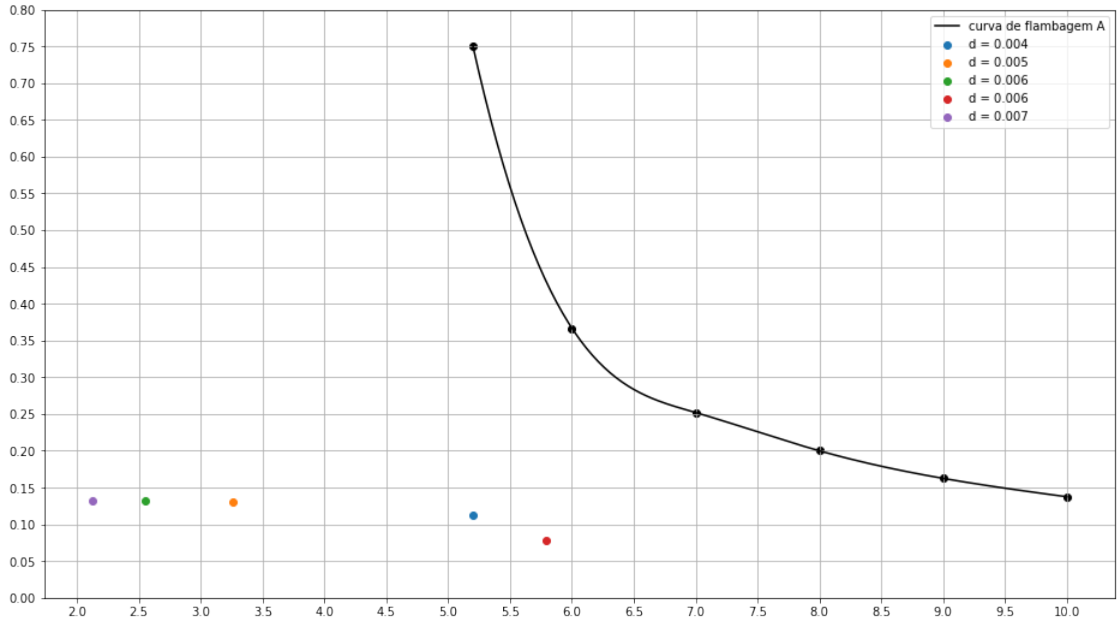
```
587  0.097828  0.018195  11.403527  5.376665  0.067465  1654.364503
598  0.095768  0.020938   9.907574  4.573908  0.068916  1655.201041

               fn
223  5.897123e+07
253  6.065661e+07
284  5.990119e+07
324  5.897123e+07
345  5.498671e+07
354  6.410326e+07
385  5.639902e+07
425  5.897123e+07
455  6.477100e+07
465  5.649897e+07
486  5.528422e+07
505  5.587230e+07
526  5.897123e+07
556  6.524579e+07
566  5.950402e+07
587  5.442805e+07
598  5.498671e+07
```

[ ]:

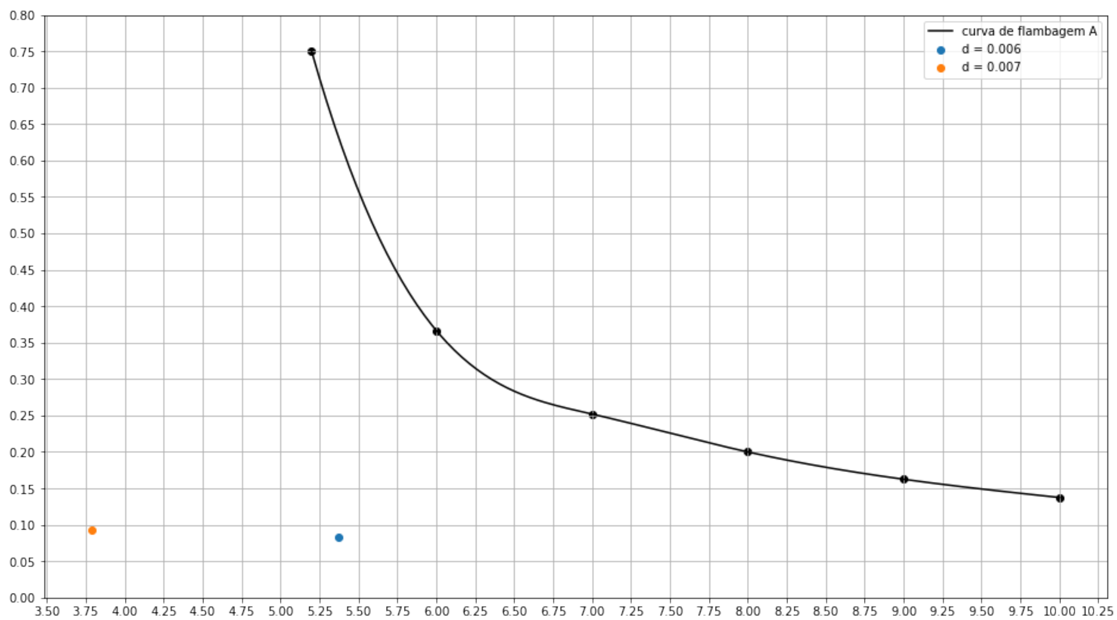
```python
# Análise de flambagem

for n_molas in n_molas_list:
    fig = plt.figure(figsize=[16, 9])
    fig.suptitle('Análise de flambagem para {:d} molas'.format(n_molas),␣
 ↪fontsize=16)

    flambagem_seed = np.array((
        [5.2,0.75],
        [10,0.1375],
        [9,0.1625],
        [6,0.3667],
        [8,0.2],
        [7,0.252]
    ))


    f2 = interp1d(
        flambagem_seed[:,0],
        flambagem_seed[:,1],
        kind='cubic'
    )

    flambagem_eval = np.linspace(
        min(flambagem_seed[:,0]),
```

```
        max(flambagem_seed[:,0]),
        num=200
    )
    curva_A = f2(flambagem_eval)   # use interpolation function returned by␣
↪`interp1d`


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


    ax.plot(
        flambagem_eval,
        curva_A,
        '-',
        color='k',
        label='curva de flambagem A'
    )

    ax.scatter(
        flambagem_seed[:,0],
        flambagem_seed[:,1],
        color='k', )

    df_selected = df.loc[df.n_molas == n_molas]

    for Lf_D, delta_Lf, d in zip(df_selected.Lf_D, df_selected['delta/Lf'],␣
↪df_selected.d,):

        ax.scatter(
            Lf_D,
            delta_Lf,
            label="d = {:.3f}".format(d))

    ax.set_ylim(0,0.8)
    ax.locator_params(axis='y', nbins=30)
    ax.locator_params(axis='x', nbins=30)
    ax.grid()
    ax.legend()

    plt.show()
```

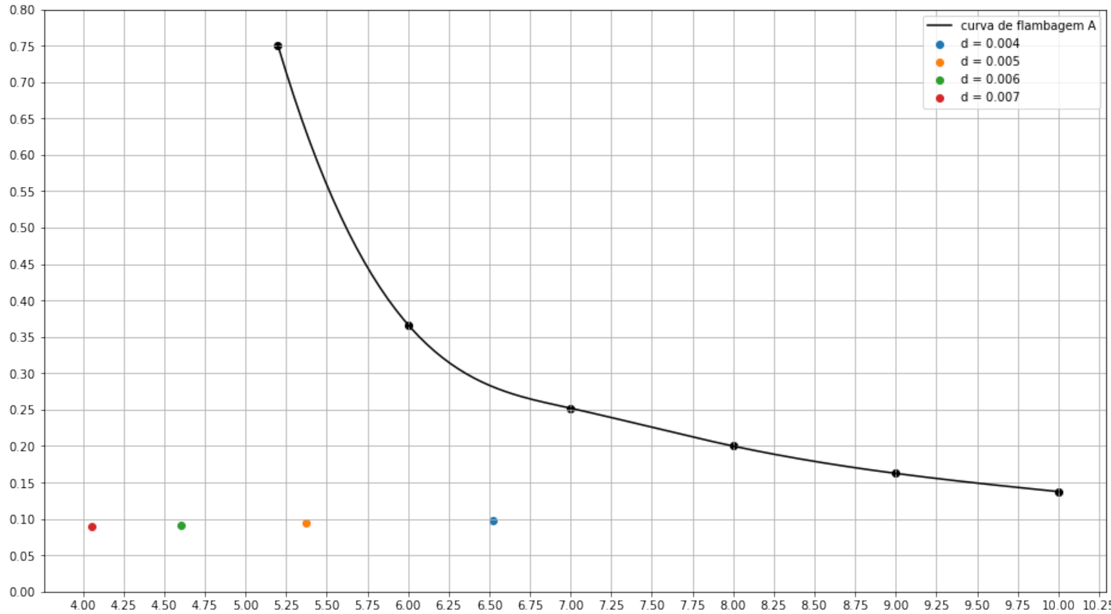
Análise de flambagem para 8 molas



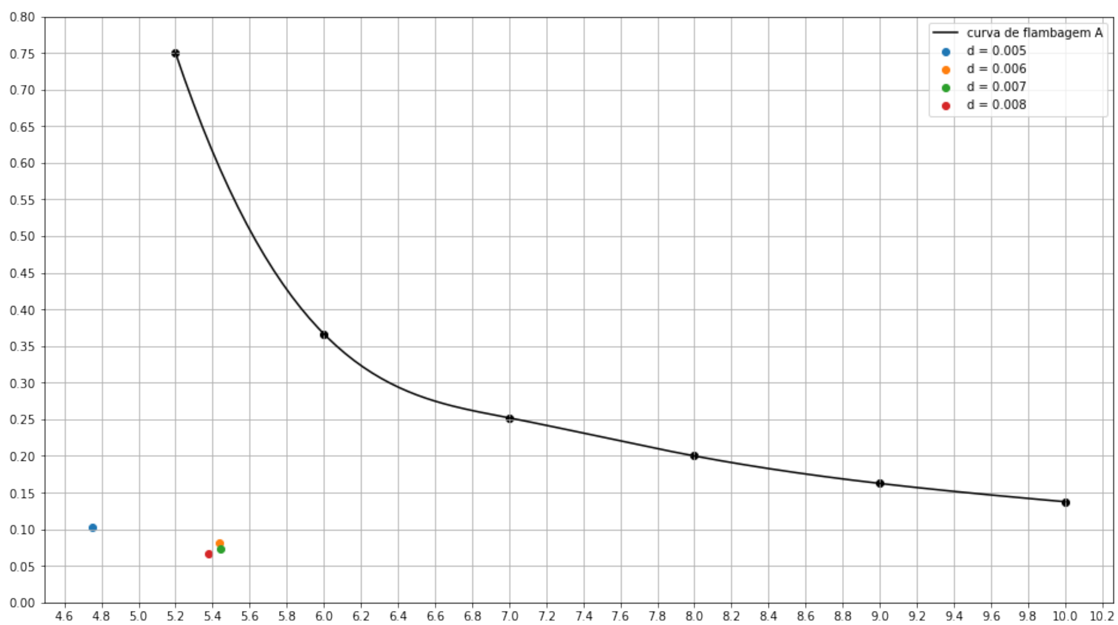
Análise de flambagem para 7 molas

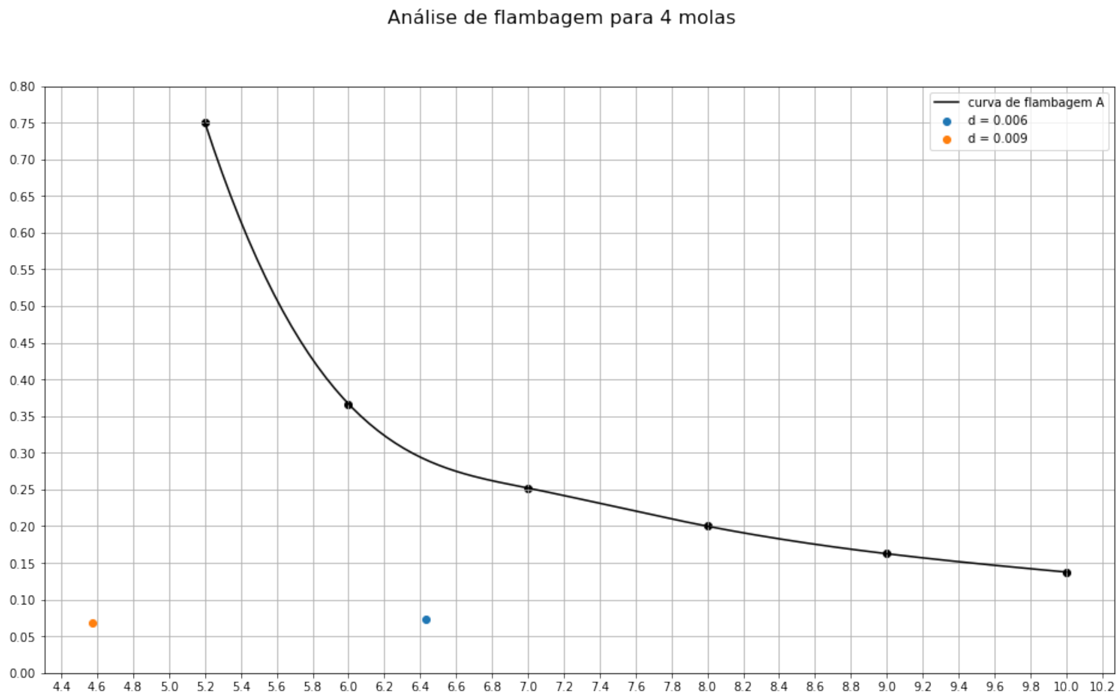


Análise de flambagem para 6 molas



Análise de flambagem para 5 molas




Análise de flambagem para 4 molas
curva de flambagem A
d = 0.006
d = 0.009