project1

October 29, 2022

[1]:
```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
from matplotlib import pyplot as plt
```

1 Data

[2]:
```
N_design   = 18000      #RPM
D1_model   = 0.5        #meter
T_a_model  = 30+273.15  #kelvin
P_a_model  = 100        #kPa
gama_air   = 1.4
R_air      = 287        #j/kg-k
gama_argon = 1.66
R_argon    = 208        #j/kg-k
```

[3]:
```
Data = np.array(pd.read_excel("Data.xlsx", engine='openpyxl'))
```

[4]:
```
cols1 = pd.MultiIndex.from_product([
    [u'40%', u'60%', u'80%', u'100%', u'110%'],
    [u'Mass flow rate[kg/s]', u'Efficiency'],
])
```

[5]:
```
Efficiency_model = pd.DataFrame(Data[0:7], index=range(1,8), columns=cols1)
```

[6]:
```
cols2 = pd.MultiIndex.from_product([
    [u'40%', u'60%', u'80%', u'100%', u'110%'],
    [u'Mass flow rate[kg/s]', u'Pressure ratio'],
])
```

[7]:
```
PR_model = pd.DataFrame(Data[16:23], index=range(1,8), columns=cols2)
```

2 Part 1

2.1 Conditions

[8]:

```
T_a     = 15+273.15    #kelvin
P_a     = 101          #kPa
T01_m   = T_a_model
P01_m   = P_a_model
R_m     = R_air
gama_m  = gama_air
D1_p    = D1_model
P01_p   = P_a
T01_p   = T_a
gama_p  = gama_air
R_p     = R_air
N_m     = np.array([40, 60, 80, 100, 110])
```

[9]:

```
def data_generator(Efficiency_model, PR_model, gama_p, gama_m, P01_p, T01_p,␣
 ↪P01_m, T01_m, R_p, R_m, D1_p, D1_model, N_m ):

    Cp_m = gama_m*R_m/(gama_m-1)
    Cp_p = gama_p*R_p/(gama_p-1)
    gama_ratio = gama_p/gama_m
    P0_ratio = P01_p/P01_m
    T0_ratio = T01_p/T01_m
    R_ratio = R_p/R_m
    A_ratio = (D1_p/D1_model)**2
    D_ratio = (D1_p/D1_model)
    N_correction = ((gama_ratio*R_ratio*T0_ratio)**0.5)*D_ratio
    dh0_correction = gama_ratio*R_ratio*T0_ratio
    m_dot_correction = (gama_ratio)*(P0_ratio)*(A_ratio)\
                  /((gama_ratio*R_ratio*T0_ratio)**0.5)

    N_p = N_m*N_correction
    Counter = [0, 0, 1, 1, 2, 2, 3, 3, 4, 4]
    counter = 0

    for column, S in PR_model.items():
        s = np.array(S)
        new_column = (f'{N_p[Counter[counter]]:.4}%',column[1])

        if str(column[1])=='Mass flow rate[kg/s]':

            if counter == 0:
                PR_prototype = pd.DataFrame(s*m_dot_correction,␣
 ↪index=range(1,8),\
                                            columns=pd.MultiIndex.from_product([
                    [new_column[0]],[column[1]]
                ]))

            else:
                PR_prototype[new_column] = s*m_dot_correction

        else:
            dh0s_m = Cp_m*T01_m*(s**((gama_m-1)/gama_m)-1)
            dh0s_p = dh0_correction*dh0s_m
            PR_prototype[new_column] = (dh0s_p/(Cp_p*T01_p)+1)**(gama_p/
 ↪(gama_p-1))

        counter += 1

    counter = 0

    for column, S in Efficiency_model.items():
        s = np.array(S)
        new_column = (f'{N_p[Counter[counter]]:.4}%',column[1])

        if str(column[1])=='Mass flow rate[kg/s]':

            if counter == 0:
                Efficiency_prototype = pd.DataFrame(s*m_dot_correction,␣
 ↪index=range(1,8),\
                                            columns=pd.MultiIndex.from_product([
                    [new_column[0]],[column[1]]
                ]))

            else:
                Efficiency_prototype[new_column] = s*m_dot_correction

        else:
            Efficiency_prototype[new_column] = s

        counter += 1

    return Efficiency_prototype ,PR_prototype
```

[10]:

```
Efficiency_prototype1 ,PR_prototype1 = data_generator(
    Efficiency_model, PR_model, gama_p, gama_m, P01_p, T01_p, P01_m, T01_m,␣
 ↪R_p, R_m, D1_p, D1_model, N_m
)
```

[11]:

```
Efficiency_prototype1
```

```
[11]:                 39.0%                               58.5%                \
       Mass flow rate[kg/s] Efficiency Mass flow rate[kg/s] Efficiency
     1             5.847390   0.766144             6.851115   0.799060
     2             6.178895   0.777900             7.237872   0.813636
     3             6.491984   0.778840             7.578586   0.815987
     4             6.759030   0.761912             7.882466   0.802351
     5             6.952408   0.722884             8.121886   0.766614
     6             7.090536   0.665047             8.260014   0.706426
     7             7.127370   0.641536             8.306056   0.667868

                      78.0%                               97.49%               \
       Mass flow rate[kg/s] Efficiency Mass flow rate[kg/s] Efficiency
     1             7.919300   0.814107             9.042735   0.808934
     2             8.352099   0.832445             9.475534   0.827273
     3             8.738855   0.841379             9.871499   0.841379
     4             9.088778   0.831034            10.193796   0.847962
     5             9.337407   0.797649            10.470051   0.834796
     6             9.512368   0.738871            10.626595   0.779781
     7             9.576828   0.682915            10.672638   0.713950

                     107.2%
       Mass flow rate[kg/s] Efficiency
     1            10.479259   0.794828
     2            10.700263   0.807994
     3            10.884433   0.815047
     4            11.040977   0.818339
     5            11.160687   0.815987
     6            11.243564   0.789655
     7            11.261981   0.742163
```

```
[12]: PR_prototype1
```

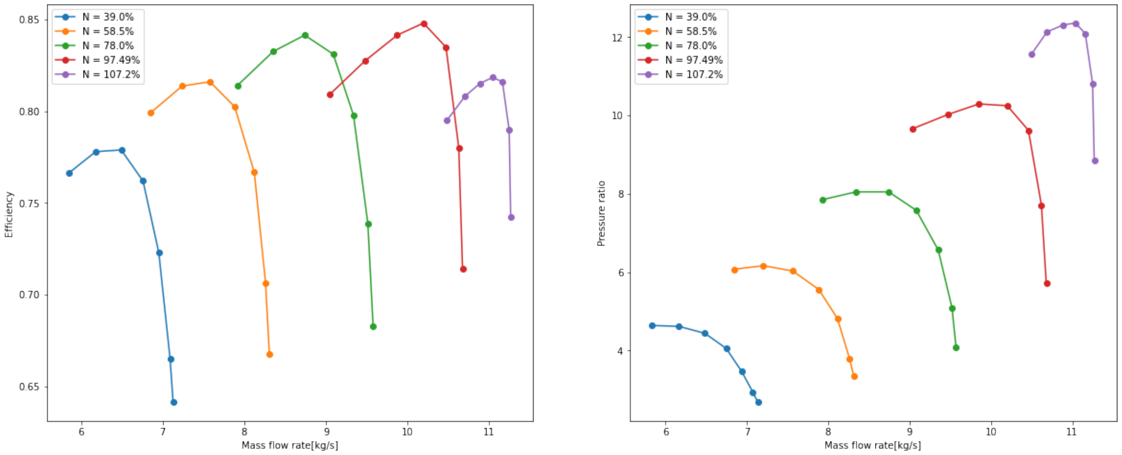
```
[12]:                 39.0%                                   58.5%                    \
       Mass flow rate[kg/s] Pressure ratio Mass flow rate[kg/s] Pressure ratio
     1             5.836295       4.638404             6.844791       6.074813
     2             6.165804       4.615960             7.204255       6.164589
     3             6.485327       4.436409             7.563719       6.029925
     4             6.744940       4.054863             7.883242       5.558603
     5             6.934657       3.471322             8.112900       4.817955
     6             7.074449       2.932668             8.262676       3.785536
     7             7.134359       2.685786             8.312602       3.359102

                      78.0%                                   97.49%                   \
       Mass flow rate[kg/s] Pressure ratio Mass flow rate[kg/s] Pressure ratio
     1             7.923183       7.847880             9.041515       9.665835
     2             8.342557       8.049875             9.470874      10.024938
     3             8.741962       8.049875             9.850309      10.294264
```

```
4           9.081455    7.578554         10.199787    10.249377
5           9.351053    6.568579         10.459400     9.620948
6           9.520800    5.087282         10.619162     7.713217
7           9.570725    4.077307         10.679072     5.715711

               107.2%
  Mass flow rate[kg/s] Pressure ratio
1            10.499340      11.573566
2            10.689058      12.134663
3            10.888760      12.314214
4            11.038536      12.359102
5            11.158358      12.089776
6            11.248224      10.810474
7            11.268194       8.857855
```

[13]:

```
def plt_func(Efficiency ,PR):

    fig = plt.figure(figsize=(20, 8))

    plt.subplot(1, 2, 1)
    Counter = [0, 0, 1, 1, 2, 2, 3, 3, 4, 4]
    counter = 0

    for column, S in Efficiency.items():

        s = np.array(S)

        if counter%2 ==0:

            X1 = np.array(s)

        else:

            Y1 = np.array(s)
            plt.plot(X1, Y1, marker = "o", linestyle = "solid", label=f'N =␣
↪{column[0]}')
            plt.xlabel('Mass flow rate[kg/s]')
            plt.ylabel('Efficiency')
            plt.legend()

        counter += 1

    plt.subplot(1, 2, 2)

    for column, S in PR.items():

        s = np.array(S)
        if counter%2 ==0:

            X2 = np.array(s)

        else:

            Y2 = np.array(s)
            plt.plot(X2, Y2, marker = "o", linestyle = "solid", label=f'N =␣
↪{column[0]}')
            plt.xlabel('Mass flow rate[kg/s]')
            plt.ylabel('Pressure ratio')
            plt.legend()

        counter += 1
```

[14]:
```
plt_func(Efficiency_prototype1 ,PR_prototype1)
```



3 Part 2

3.1 Conditions

[15]:
```
T_a     = 15+273.15    #kelvin
P_a     = 101          #kPa
D1_p    = 0.8          #meter
P01_p   = P_a
T01_p   = T_a
gama_p = gama_air
R_p     = R_air
```

[16]:
```
Efficiency_prototype2 ,PR_prototype2 = data_generator(
    Efficiency_model, PR_model, gama_p, gama_m, P01_p, T01_p, P01_m, T01_m,␣
↪R_p, R_m, D1_p, D1_model, N_m
)
```

[17]:
```
Efficiency_prototype2
```

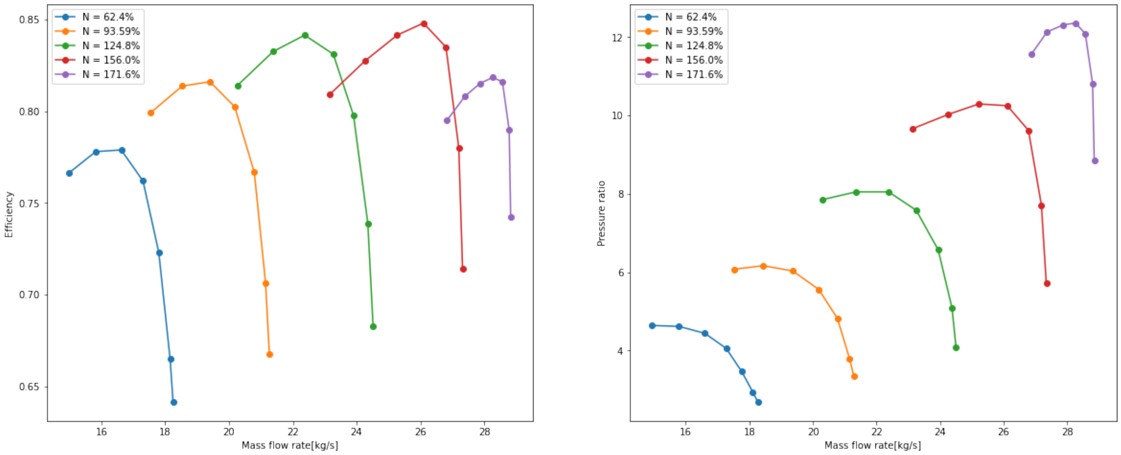
[17]:
```
                 62.4%                          93.59%             \
  Mass flow rate[kg/s] Efficiency Mass flow rate[kg/s] Efficiency
1            14.969318   0.766144            17.538855   0.799060
2            15.817972   0.777900            18.528951   0.813636
3            16.619479   0.778840            19.401179   0.815987
4            17.303117   0.761912            20.179112   0.802351
5            17.798166   0.722884            20.792029   0.766614
6            18.151772   0.665047            21.145635   0.706426
7            18.246066   0.641536            21.263504   0.667868

                124.8%                          156.0%             \
  Mass flow rate[kg/s] Efficiency Mass flow rate[kg/s] Efficiency
1            20.273407   0.814107            23.149402   0.808934
2            21.381372   0.832445            24.257367   0.827273
3            22.371469   0.841379            25.271038   0.841379
4            23.267271   0.831034            26.096118   0.847962
5            23.903761   0.797649            26.803330   0.834796
6            24.351662   0.738871            27.204084   0.779781
7            24.516678   0.682915            27.321952   0.713950

                171.6%
  Mass flow rate[kg/s] Efficiency
1            26.826904   0.794828
2            27.392673   0.807994
3            27.864148   0.815047
4            28.264901   0.818339
5            28.571360   0.815987
6            28.783523   0.789655
7            28.830671   0.742163
```

[18]:
```
PR_prototype2
```

[18]:
```
                 62.4%                                  93.59%                 \
  Mass flow rate[kg/s] Pressure ratio Mass flow rate[kg/s] Pressure ratio
1            14.940916       4.638404            17.522665       6.074813
2            15.784458       4.615960            18.442893       6.164589
3            16.602438       4.436409            19.363120       6.029925
4            17.267047       4.054863            20.181100       5.558603
5            17.752722       3.471322            20.769023       4.817955
6            18.110588       2.932668            21.152452       3.785536
```

```
7              18.263960         2.685786              21.280261         3.359102

                   124.8%                                 156.0%                   \
  Mass flow rate[kg/s] Pressure ratio Mass flow rate[kg/s] Pressure ratio
1              20.283348         7.847880              23.146278         9.665835
2              21.356947         8.049875              24.245439        10.024938
3              22.379422         8.049875              25.216790        10.294264
4              23.248525         7.578554              26.111455        10.249377
5              23.938696         6.568579              26.776064         9.620948
6              24.373248         5.087282              27.185054         7.713217
7              24.501057         4.077307              27.338425         5.715711

                   171.6%
  Mass flow rate[kg/s] Pressure ratio
1              26.878312        11.573566
2              27.363987        12.134663
3              27.875225        12.314214
4              28.258653        12.359102
5              28.565395        12.089776
6              28.795452        10.810474
7              28.846576         8.857855
```

[19]:
```
plt_func(Efficiency_prototype2 ,PR_prototype2)
```



4 Part 3

4.1 Conditions

[20]:

```
T_a     = 25+273.15    #kelvin
P_a     = 2*101.325    #kPa
D1_p    = D1_model     #meter
P01_p   = P_a
T01_p   = T_a
gama_p  = gama_argon
R_p     = R_argon
```

[21]:

```
Efficiency_prototype3 ,PR_prototype3 = data_generator(
    Efficiency_model, PR_model, gama_p, gama_m, P01_p, T01_p, P01_m, T01_m,␣
 ↪R_p, R_m, D1_p, D1_model, N_m
)
```

[22]:

```
Efficiency_prototype3
```

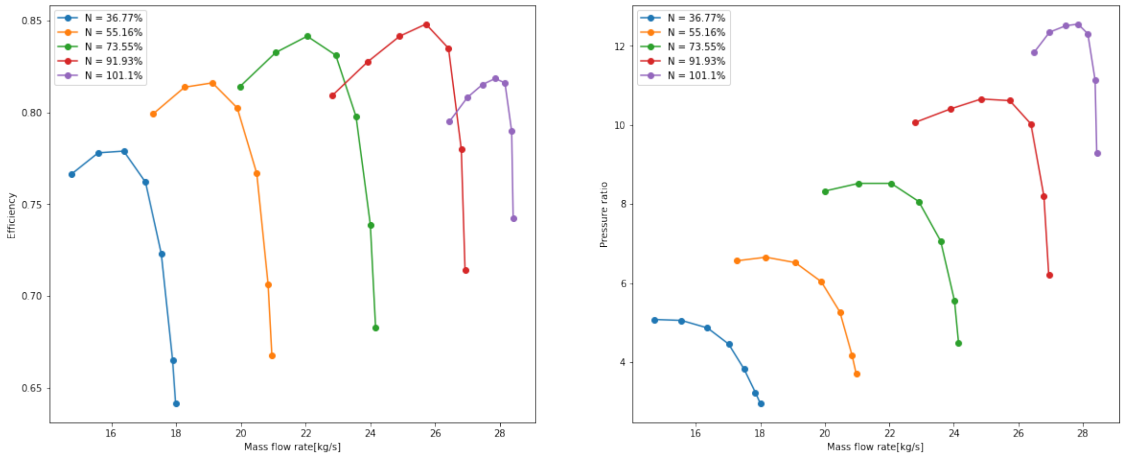
[22]:

```
                 36.77%                          55.16%             \
  Mass flow rate[kg/s] Efficiency Mass flow rate[kg/s] Efficiency
1            14.752937   0.766144            17.285331   0.799060
2            15.589324   0.777900            18.261116   0.813636
3            16.379245   0.778840            19.120736   0.815987
4            17.053002   0.761912            19.887424   0.802351
5            17.540894   0.722884            20.491481   0.766614
6            17.889389   0.665047            20.839976   0.706426
7            17.982320   0.641536            20.956141   0.667868

                 73.55%                          91.93%             \
  Mass flow rate[kg/s] Efficiency Mass flow rate[kg/s] Efficiency
1            19.980356   0.814107            22.814779   0.808934
2            21.072306   0.832445            23.906728   0.827273
3            22.048091   0.841379            24.905746   0.841379
4            22.930944   0.831034            25.718900   0.847962
5            23.558234   0.797649            26.415889   0.834796
6            23.999660   0.738871            26.810850   0.779781
7            24.162291   0.682915            26.927015   0.713950

                 101.1%
  Mass flow rate[kg/s] Efficiency
1            26.439122   0.794828
2            26.996714   0.807994
3            27.461373   0.815047
4            27.856334   0.818339
5            28.158362   0.815987
6            28.367459   0.789655
7            28.413925   0.742163
```

```
[23]: PR_prototype3
```

```
[23]:                36.77%                                    55.16%                 \
       Mass flow rate[kg/s] Pressure ratio Mass flow rate[kg/s] Pressure ratio
     1            14.724946       5.077043            17.269376       6.562533
     2            15.556294       5.053367            18.176302       6.653568
     3            16.362450       4.863401            19.083227       6.516941
     4            17.017452       4.456324            19.889384       6.035131
     5            17.496108       3.824234            20.468808       5.265904
     6            17.848801       3.229714            20.846694       4.166068
     7            17.999955       2.953420            20.972656       3.701283

                     73.55%                                    91.93%                 \
       Mass flow rate[kg/s] Pressure ratio Mass flow rate[kg/s] Pressure ratio
     1            19.990153       8.326302            22.811700      10.069396
     2            21.048233       8.523005            23.894972      10.406935
     3            22.055928       8.523005            24.852282      10.658737
     4            22.912469       8.062763            25.734016      10.616849
     5            23.592663       7.060819            26.389017      10.027056
     6            24.020934       5.547411            26.792096       8.194716
     7            24.146896       4.480401            26.943250       6.196371

                      101.1%
       Mass flow rate[kg/s] Pressure ratio
     1            26.489787      11.839844
     2            26.968442      12.350542
     3            27.472290      12.513072
     4            27.850175      12.553639
     5            28.152484      12.309842
     6            28.379215      11.138228
     7            28.429600       9.302040
```

```
[24]: plt_func(Efficiency_prototype3 ,PR_prototype3)
```



5 Part 4

5.1 Conditions

[25]:

```
T_a     = 25+273.15    #kelvin
P_a     = 2*101.325    #kPa
D1_p    = 0.8          #meter
P01_p   = P_a
T01_p   = T_a
gama_p = gama_argon
R_p     = R_argon
```

[26]:

```
Efficiency_prototype4 ,PR_prototype4 = data_generator(
    Efficiency_model, PR_model, gama_p, gama_m, P01_p, T01_p, P01_m, T01_m,␣
 ↪R_p, R_m, D1_p, D1_model, N_m
)
```

[27]:

```
Efficiency_prototype4
```

[27]:

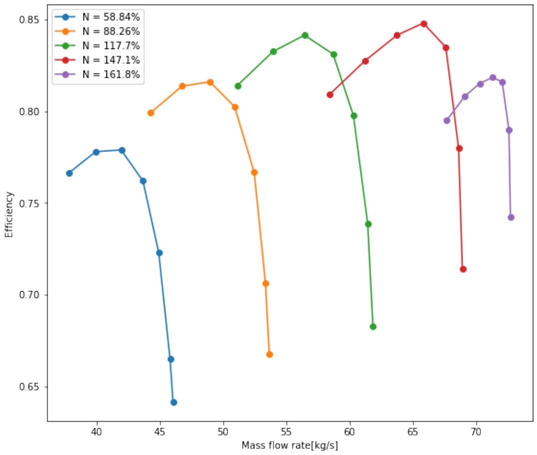
```
              58.84%                          88.26%                \
  Mass flow rate[kg/s] Efficiency Mass flow rate[kg/s] Efficiency
1            37.767520   0.766144            44.250448   0.799060
2            39.908670   0.777900            46.748457   0.813636
3            41.930868   0.778840            48.949084   0.815987
4            43.655684   0.761912            50.911806   0.802351
5            44.904689   0.722884            52.458193   0.766614
6            45.796835   0.665047            53.350339   0.706426
7            46.034740   0.641536            53.647721   0.667868

              117.7%                          147.1%                \
  Mass flow rate[kg/s] Efficiency Mass flow rate[kg/s] Efficiency
1            51.149712   0.814107            58.405833   0.808934
2            53.945103   0.832445            61.201225   0.827273
3            56.443112   0.841379            63.758710   0.841379
4            58.703215   0.831034            65.840384   0.847962
5            60.309078   0.797649            67.624677   0.834796
6            61.439130   0.738871            68.635776   0.779781
7            61.855465   0.682915            68.933158   0.713950

              161.8%
  Mass flow rate[kg/s] Efficiency
1            67.684153   0.794828
2            69.111587   0.807994
3            70.301115   0.815047
```

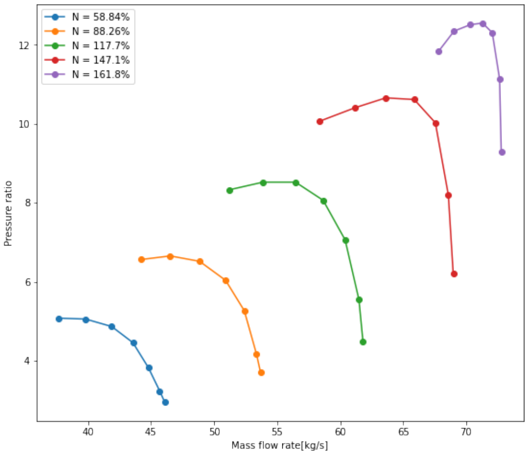
```
4             71.312214   0.818339
5             72.085407   0.815987
6             72.620695   0.789655
7             72.739648   0.742163
```

```
[29]: PR_prototype4
```

```
[29]:             58.84%                                88.26%                 \
        Mass flow rate[kg/s] Pressure ratio Mass flow rate[kg/s] Pressure ratio
      1            37.695861       5.077043            44.209603       6.562533
      2            39.824113       5.053367            46.531333       6.653568
      3            41.887873       4.863401            48.853062       6.516941
      4            43.564678       4.456324            50.916822       6.035131
      5            44.790035       3.824234            52.400149       5.265904
      6            45.692930       3.229714            53.367537       4.166068
      7            46.079885       2.953420            53.689999       3.701283

                  117.7%                                147.1%                 \
        Mass flow rate[kg/s] Pressure ratio Mass flow rate[kg/s] Pressure ratio
      1            51.174792       8.326302            58.397951      10.069396
      2            53.883477       8.523005            61.171128      10.406935
      3            56.463176       8.523005            63.621843      10.658737
      4            58.655921       8.062763            65.879080      10.616849
      5            60.397218       7.060819            67.555885      10.027056
      6            61.493591       5.547411            68.587765       8.194716
      7            61.816053       4.480401            68.974720       6.196371

                  161.8%
        Mass flow rate[kg/s] Pressure ratio
      1            67.813855      11.839844
      2            69.039212      12.350542
      3            70.329062      12.513072
      4            71.296449      12.553639
      5            72.070359      12.309842
      6            72.650792      11.138228
      7            72.779777       9.302040
```

```
[30]: plt_func(Efficiency_prototype4 ,PR_prototype4)
```


N = 58.84%
N = 88.26%
N = 117.7%
N = 147.1%
N = 161.8%
Efficiency
0.85
0.80
0.75
0.70
0.65
40
45
50
55
60
65
70
Mass flow rate[kg/s]


N = 58.84%
N = 88.26%
N = 117.7%
N = 147.1%
N = 161.8%
Pressure ratio
12
10
8
6
4
40
45
50
55
60
65
70
Mass flow rate[kg/s]