d2-hex-calcs

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UCN LD2 Calculations

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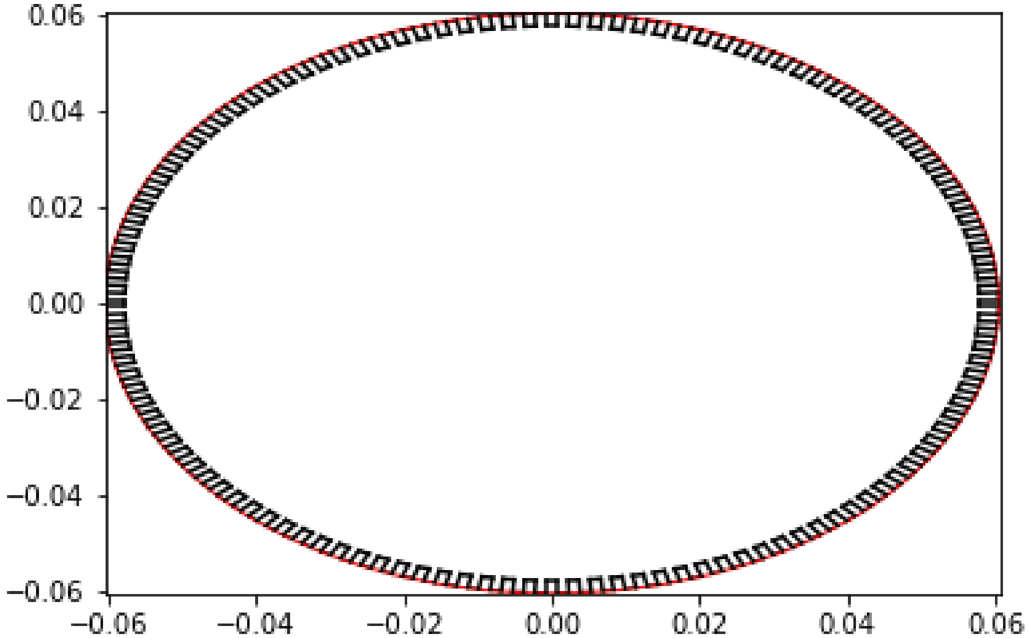
[4]:
```
#!/usr/bin/python3
from math import *
import matplotlib.pyplot as plt
import matplotlib.patches as patches
```

[22]:
```
d2=4.76*0.0254 # (m) inner diameter of the outer tubular housing
d1=4.75*0.0254 # (m) diameter of the inner cold cylinder before
               # cutting any grooves

print('d 2 is %f.' %d2)
print(' and d 1 is %f' %d1)

fig,ax=plt.subplots()

ax.set_xlim([-d2/2,d2/2])
ax.set_ylim([-d2/2,d2/2])

# outer housing
circle1=plt.Circle((0,0),d2/2,color='r',fill=False)
ax.add_artist(circle1)

groove_depth=0.1*0.0254 # m
groove_width=0.06*0.0254 # m
n=ngrooves=124

print('goove depth %f' %groove_depth)
print('goove width %f' %groove_width)

# shorter names
r=d1/2
w=groove_width
d=groove_depth
```

```python
for groove in range(ngrooves):
    theta=360./ngrooves
    center_angle=groove*theta

    alpha=center_angle*pi/180
    x=r*cos(alpha)
    y=r*sin(alpha)

    dalpha=asin(w/2/r)

    xsl=r*cos(alpha+dalpha)
    ysl=r*sin(alpha+dalpha)
    xel=xsl-d*cos(alpha)
    yel=ysl-d*sin(alpha)

    xsr=r*cos(alpha-dalpha)
    ysr=r*sin(alpha-dalpha)
    xer=xsr-d*cos(alpha)
    yer=ysr-d*sin(alpha)

    # draw line at edge of each groove
    line=plt.plot([xsl,xel],[ysl,yel],color='black')
    line=plt.plot([xsr,xer],[ysr,yer],color='black')
    # and bottom of groove
    line=plt.plot([xel,xer],[yel,yer],color='black')

    alpha_deg=alpha*180/pi
    dalpha_deg=dalpha*180/pi
    arc=patches.
 ↪Arc((0,0),2*r,2*r,0,alpha_deg+dalpha_deg,alpha_deg+theta-dalpha_deg)
    ax.add_patch(arc)

# Calculation of perimeter of all those grooves
pgroove=2*d+w # inner "U" of a groove
parc=(theta-2*dalpha_deg)*pi/180*r # outer arc length between two grooves
perimeter=ngrooves*(pgroove+parc)

print('The length of the inner U of a groove is %f m'%pgroove)
print('The length of an arc between two grooves is %f m'%parc)
print('The length around all those fins and grooves is %f m'%perimeter)

print()

# Calculation of area for flow
annulus=pi*(d2**2-d1**2)/4
agroove=d*w # area of one groove # approximately
aeps=((2*dalpha)/(2*pi))*pi*r**2-2*0.5*(w/2)*(r*cos(dalpha)) # area
```

```
                                                              # between
                                                              # the arc
                                                              # and the
                                                              # area of
                                                              # the
                                                              # groove
                                                              # on the
                                                              # previous
                                                              # line
agroove_total=agroove+aeps
agrooves=agroove_total*ngrooves
area=annulus+agrooves


print('Area of annular region between cylinders %f m^2'%annulus)
print('Additional area cut out by each groove %f m^2'%(agroove+aeps))
print('Area of all the grooves %f m^2'%agrooves)
print('Total flow area %f m^2'%area)
print()
```

```
d 2 is 0.120904.
 and d 1 is 0.120650
goove depth 0.002540
goove width 0.001524
The length of the inner U of a groove is 0.006604 m
The length of an arc between two grooves is 0.001533 m
The length around all those fins and grooves is 1.008948 m

Area of annular region between cylinders 0.000048 m^2
Additional area cut out by each groove 0.000004 m^2
Area of all the grooves 0.000481 m^2
Total flow area 0.000529 m^2
```



They hydraulic diameter was found by:

$$D_h = \frac{4A}{P} \tag{1}$$

[21]:
```
a=area # (m^2) area for fluid flow
p=perimeter+pi*d2 # (m) perimeter of flow region

dh=4*a/p # (m) hydraulic diameter

print('The flow area is %f m^2, A.'%a)
print('The flow perimeter is %f m, P.'%p)
print('The hydraulic diameter %f m, Dh.'%dh)
print()

L=10.*0.0254 # (m) length of tube(s)
Aw=perimeter*L
print('The length of tubes is %f m, L.'%L)
print('The area of cold wall is %f m^2, Aw'%Aw)
print()
```

```
The flow area is 0.000529 m^2, A.
The flow perimeter is 1.388779 m, P.
The hydraulic diameter 0.001523 m, Dh.

The length of tubes is 0.254000 m, L.
```

```
The area of cold wall is 0.256273 m^2, Aw
```

G is found from:

$$G = \frac{\dot{m}}{A} \tag{2}$$

[6]:
```
mdot=0.004 # (kg/s) mass flow rate
G=mdot/a # (kg/(m^2*s)) mass flow rate per unit area

print('G is %f kg/(m^2*s)'%G)
```

```
G is 7.564393 kg/(m^2*s)
```

The Reynolds Number is found from:

$$Re = \frac{D_h G}{\mu} \tag{3}$$

[7]:
```
mu=3.5e-5 # Pa*s

Re=dh*G/mu # should be dimensionless
print('The Reynolds number is %f'%Re)
```

```
The Reynolds number is 329.168843
```

The Prandelt Number is found from:

$$Pr = \frac{\mu C_p}{k_t} \tag{4}$$

[8]:
```
# thermal conductivity

kt=0.104 # W/(m*K)
p_psi=20. # PSI
p=p_psi*6894.76 # Pa

Tin=23.4 # (K) inlet temp
Tw=20.7 # (K) temperature of cold wall
Ts=(Tw+Tin)/2 # (K) temperature of film, with which we will exchange heat.

T=Tin
Cp=5841.605609

Pr=(mu*Cp)/(kt)
print('The Prandtl Number is %f.'%Pr)
```

```
The Prandtl Number is 1.965925.
```

The heat transfer coefficient is found from:

$$hc = \frac{Nuk_t}{D_h} \tag{5}$$

[9]:
```
Nu=4.8608 # circular duct Barron Eq. (6.30)
fRe=96.00 # circular duct Barron Eq. (6.27)
hc=Nu*kt/dh
print('The heat transfer coefficient is %f W/(m^2*K)'%hc)
```

```
The heat transfer coefficient is 331.916164 W/(m^2*K)
```

The Ntu is found from:

$$Ntu = \frac{hcA_w}{\dot{m}C_p} \tag{6}$$

[10]:
```
Ntu=hc*Aw/(mdot*Cp)
print('The number of transfer units is %f'%Ntu)
```

```
The number of transfer units is 3.640313
```

The total heat transfer rate is found from:

$$\dot{Q} = \dot{m}C_p\Delta T \tag{7}$$

[11]:
```
T1=Tin
T2=T1-(T1-Tw)*(1-exp(-Ntu))
Qtotal=mdot*Cp*(T1-T2) # Eq. (6.43) of Barron

print('The inlet temperature is %f K and the wall temperature is %f'%(T1,Tw))
print('The outlet temperature is %f'%T2)
print('The total heat transfer rate is %f'%Qtotal)
```

```
The inlet temperature is 23.400000 K and the wall temperature is 20.700000
The outlet temperature is 20.770859
The total heat transfer rate is 61.433616
```

The friction factor is found from:

$$f = \frac{fRe}{Re} \tag{8}$$

The pressure drop is found from:

$$\Delta P = \frac{fLG^2}{2D_h\rho} \tag{9}$$

[20]:
```
f=fRe/Re
print('The friction factor is %f'%f)
rho=163.292488
print('The density is %f kg/m^3'%rho)
dp=(f*L*G**2)/(dh*2*rho) #(Pa)
print('The pressure drop is %f Pa'%dp)
```

```
The friction factor is 0.291644
The density is 163.292488 kg/m^3
The pressure drop is 8.521685 Pa
```

To verify that our calculations were somewhat correct, the HEX was simulated as many rectangular channels running in parallel.

[13]:
```
Af=w*d # (m^2)

Pf=2*w + 2*d # (m)

Dh=4*Af/Pf # (m)

print('The hydraulic diameter for one rectangular channel is %f m.' %Dh)

#all

Afall=d*(n*w) # (m^2)

#Pfall=2*d + 2*n*w # (m)
Pfall=2*n*d + 2*n*w # (m) # Jeff edited

Dhall=4*Afall/Pfall # (m)


print('The flow area for all the rectangular channels is %f m^2.' %Afall)
print()

print('The hydraulic diameter for all the rectangular channels is %f m.' %Dhall)
```

```
The hydraulic diameter for one rectangular channel is 0.001905 m.
The flow area for all the rectangular channels is 0.000480 m^2.

The hydraulic diameter for all the rectangular channels is 0.001905 m.
```

The Reynolds Number is found from:

$$Re = \frac{D_h G}{\mu} \tag{10}$$

```
[15]: #Mass flux

Grect=mdot/Afall

Rerect=Dhall*Grect/mu # should be dimensionless

print('The Reynolds number for the rectangles is %f'%Rerect) #still laminar!
  #albeit larger
  than                                                    #the cylinder
```

```
The Reynolds number for the rectangles is 453.572336
```

The heat transfer coefficient is found from:

$$hc = \frac{Nuk_t}{D_h} \tag{11}$$

```
[16]: ba=w/d #dimentionless
print('The b/a is %f.' %ba) # b/c 0.600 I am using C1, C2, from Table 6.2

fRerect=C1=59.94
frect=fRerect/Rerect

print('The friction factor is %f.'%frect)

Nurect=C2=3.205

hcrect=(Nurect*kt)/Dhall # W/(m^2*K)

print('The hc of the rectangles is %f W/(m^2*K)' %hcrect)
```

```
The b/a is 0.600000.
The friction factor is 0.132151.
The hc of the rectangles is 174.971129 W/(m^2*K)
```

The number of transfer units is found from:

$$Ntu = \frac{hcA_w}{\dot{m}C_p} \tag{12}$$

```
[18]: #Wetted area of duct

#Awrect = 2*(w + d)*L # (m^2)
Aw_wet=(2*n*w+2*n*d)*L # (m^2) # Jeff edited # entire wetted wall area -- for
  friction losses
Aw_heat=(n*w+2*n*d)*L # (m^2) # Jeff edited # area for heat transfer

print('Wetted area of duct is %f' %Aw_wet)
```

```python
print('Area for heat transfer is %f' %Aw_heat)

#transfer units

Nturect=(hcrect*Aw_heat)/(mdot*Cp)

print('The transfer units is %f' %Nturect)
```

```
Wetted area of duct is 0.255999
Area for heat transfer is 0.208000
The transfer units is 1.557531
```

The pressure drop is found from:

$$\Delta P = \frac{f L G^2}{2 D_h \rho} \tag{13}$$

[23]:
```python
#heat transfer

Qrect=mdot*Cp*(T1 - Tw)*(1 - exp(-Nturect)) #W

print('The heat transfer is %f W' %Qrect)

#pressure drop

dprect=(frect*L*Grect**2)/(Dhall*2*rho) #Pa

print('The pressure drop is %f Pa.' %dprect)
```

```
The heat transfer is 49.799219 W
The pressure drop is 3.746726 Pa.
```

[ ]:
```python

```