"Proper"-Helix

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1 UCN LD2 Calculations: Helical Groove

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[2]:
```
#!/usr/bin/python3.7

from math import *
from mpl_toolkits import mplot3d
from mpl_toolkits.mplot3d import Axes3D
import matplotlib.pyplot as plt
import matplotlib.patches as patches
import numpy as np
from numpy import *
```

[23]:
```
p_psi=20. # PSI
p=p_psi*6894.76 # Pa
kt=0.104 # W/(m*K) a

T=Tin=23.4 # (K) inlet temp
Tw=20.7 # (K) temperature of cold wall

mdot=0.004 # kg/s
mu=3.5e-5 # Pa*s viscosity

L=10*0.0254 #m length of tube

rho=163.0 # kg/m^3


Cp=6565.4 # J/(kg*K)

Ngrooves=1 # number of grooves

D=4.76*0.0254 # 0.015949 #m diameter of tube, 0.015949 from optimizing dp in␣
↪backwards-hex-turbulent-tube.py
```

```
R=D/2

wprime= 0.015 #m width of groove

uprime= 0.01 # m width between grooves

depth=0.015 # m depth of groove

sinalpha=(Ngrooves*(wprime + uprime))/(pi*D) #pitch angle

alpha=arcsin(sinalpha)

print('The pitch angle is %f' %sinalpha)

print('Alpha is %f' %alpha)

Lprime=L/sinalpha #m length of wound groove

print('The length of the groove is %f m.' %Lprime)

turns=Lprime/(pi*D)

print('Coiling around a Cu rod of diameter %f m would require %f turns'%(D,turns))

#based off of sketch w/ jeff

w=wprime/sinalpha # m

ahelix=Ngrooves*wprime*depth #Arect+2*Atri ?? m^2 area of one helical groove/fin thing

print('The area of the helical fins is %f m^2.'%ahelix)

phelix=Ngrooves*(2*depth+2*wprime) #m

print('The perimeter of the helical grooves is %f m.' %phelix)

Dh=4*ahelix/phelix #m

print('Hydraulic diameter %f m'%Dh)
print()

G=mdot/ahelix # (kg/(m^2*s)) mass flow rate per unit area

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

```
The pitch angle is 0.065819
Alpha is 0.065866
The length of the groove is 3.859084 m.
Coiling around a Cu rod of diameter 0.120904 m would require 10.160000 turns
The area of the helical fins is 0.000225 m^2.
The perimeter of the helical grooves is 0.060000 m.
Hydraulic diameter 0.015000 m

Mass flux per area (G) is 17.777778 kg/(m^2*s)
```

The Reynolds Number is found from:

$$Re = \frac{4\dot{m}}{\pi D\mu} \tag{1}$$

[4]:
```
Re=Dh*G/mu # should be dimensionless
print('The Reynolds number is %f'%Re)
```

```
The Reynolds number is 7619.047619
```

The Deans Number is found from:

$$De = Re\sqrt{\frac{D_h}{D}} \tag{2}$$

[11]:
```
De=Re*sqrt(Dh/D)
print('The Deans number is %f.' %De)
```

```
The Deans number is 2683.650667.
```

The friction factor is found from:

$$f = 4fc\left(0.00725 + 0.076\left(Re\left(\frac{D}{D_h}\right)^{-2}\right)^{-0.25}\right)\left(\frac{D_h}{D}\right)^{1/2} \tag{3}$$

[13]:
```
f = 0.00725 + 0.076*(Re*(D/Dh)**(-2))**(-0.25)
fc = 4*f*(Dh/D)**(1/2)
print('f is %f'%fc)
```

```
f is 0.042753
```

The friction factor is also found from:

$$f_2 = 4fc_2\left(0.084\left(Re\left(\frac{D}{D_h}\right)^{-2}\right)^{-0.2}\right)\left(\frac{D_h}{D}\right)^{1/2} \tag{4}$$

[14]:
```python
Cpw=5974.156073133989
muw=3.68e-5
Pr=Prw=(muw*Cpw)/(kt)
Prb=(mu*Cp)/kt
f2 = 0.084*(Re*(D/Dh)**(-2))**(-0.2)
fc2 = 4*f2*(Dh/D)**(1/2)
print('f2 is %f'%fc2)
```

```
f2 is 0.045638
```

The Nusselt number is found from:

$$Nu_c = \left(1 + 3.4\left(\frac{D_h}{D}\right)\left(\frac{Pr_b}{Pr_w}\right)^{0.25}\right)(jHRePr^{1/3}) \tag{5}$$

[15]:
```python
Nu = (1 + 3.4 * (Dh/D))*(Prb/Prw)**(0.25)
print('This is Nuc/Nus %f' %Nu)
B1=1.174*((3.7e-5)/(3.68e-5))**(0.14)
jh=0.023*Re**(-0.2)*B1
Pr=(mu*Cp)/(kt)
Nus = jh*Re*Pr**(1./3.)
print('Nuc is %f' %(Nu*Nus))
```

```
This is Nuc/Nus 1.437628
Nuc is 64.514577
```

The flow velocity is found by:

$$u = \frac{G}{\rho} \tag{6}$$

[16]:
```python
u=G/rho #m/s
print(u)
```

```
0.10906612133605999
```

The pressure drop for the first friction factor is found by:

$$\Delta P = \frac{fcL'\rho u^2}{2D_h} \tag{7}$$

[19]:
```python
dp = (fc*Lprime*rho*u**2)/(2*Dh)
print('the pressure drop is %f Pa from f' %dp)
```

```
the pressure drop is 10.663483 Pa from f
```

The pressure drop for the second friction factor is found by:

$$\Delta P = \frac{f_2 L' \rho u^2}{2 D_h} \tag{8}$$

[20]:
```
dp2 = (fc2*Lprime*rho*u**2)/(2*Dh)
print('the pressure drop is %f Pa from f2' %dp2)
```

```
the pressure drop is 11.382942 Pa from f2
```

The heat transfer coefficient is found by:

$$hc = \frac{Nukt}{D_h} \tag{9}$$

[9]:
```
h = Nus*Nu*kt/Dh # (mu*Cp*Pr**(-2/3)*Re*0.023*Re**(-0.2))/(Dh)
print('The heat transfer coeff is %f W/m^2K.' %h)
```

```
The heat transfer coeff is 447.301068 W/m^2K.
```

The number of transfer units is found from:

$$Ntu = \frac{hA_w}{\dot{m}C_p} \tag{10}$$

where

$$A_w = N(w' + 2depth)L' \tag{11}$$

[21]:
```
Aw=Ngrooves*(wprime+2*depth)*Lprime
print('Area of cold wall %f m^2'%Aw)
Ntu=h*Aw/(mdot*Cp)
print('The number of transfer units is %f'%Ntu)
print()
```

```
Area of cold wall 0.173659 m^2
The number of transfer units is 2.957846
```

The total heat transfer is found from:

$$Q = \dot{m}C_p(T_1 - T_2) \tag{12}$$

[22]:
```
T1=Tin
T2=T1-(T1-Tw)*(1-exp(-Ntu))
T2=Tw+(T1-Tw)*exp(-Ntu)
Qtotal=mdot*Cp*(T1-T2) # Eq. (6.43) of Barron
print('For inlet temperature %f K and wall temperature %f K'%(T1,Tw))
print('the outlet temperature is %f K'%T2)
```

```python
print('and the total heat transfer rate is %f W'%Qtotal)
```

```
For inlet temperature 23.400000 K and wall temperature 20.700000 K
the outlet temperature is 20.840213 K
and the total heat transfer rate is 67.224107 W
```

[ ]:

```python

```