In [ ]:
```
import STARTG01_AVLmodel
import numpy as np
import Drag_Build_Up # python file that calculates individual components zero lift drag
import MiscDrag
import matplotlib.pyplot as plt
# import FlapDrag
```

$$C_{D_0} = \frac{1}{S_{\text{ref}}} \Sigma_{c=1}^{n_{\text{component}}} \left(C_{f_c} F F_c Q_c S_{\text{wet}} \right) + C_{D_{\text{mis}}} + C_{D_{L\&P}}$$

S_{ref} : Wing reference area

C_{f_c}: Skin friction coefficient for component c

FF_c: Form factor for component c

Q_c: Interference factor for component c

S_{wet}: Wetted surface area of component c

$C_{D_{\text{mis}}}$: Missing drag due to components with large form drag

$C_{D_{L\&P}}$: Leakage/protuberance drag

In [ ]:
```
CL1=[]
CD1=[]
for i in range(-15,15+1):
    CL,CD = STARTG01_AVLmodel.STARTG01_AVL(1,i,1)
    CL1 += [CL]
    CD1 += [CD]

CL2=[]
CD2=[]
for i in range(-15,15+1):
    CL,CD = STARTG01_AVLmodel.STARTG01_AVL(2,i,1)
    CL2 += [CL]
    CD2 += [CD]

CL3=[]
CD3=[]
for i in range(-15,15+1):
    CL,CD = STARTG01_AVLmodel.STARTG01_AVL(3,i,1)
    CL3 += [CL]
    CD3 += [CD]

CL4=[]
CD4=[]
for i in range(-15,15+1):
    CL,CD = STARTG01_AVLmodel.STARTG01_AVL(4,i,1)
    CL4 += [CL]
    CD4 += [CD]

CL5=[]
CD5=[]
for i in range(-15,15+1):
    CL,CD = STARTG01_AVLmodel.STARTG01_AVL(5,i,1)
    CL5 += [CL]
    CD5 += [CD]
```

```
P2_A-15.out does not exist, running . . .
P2_A-14.out does not exist, running . . .
P2_A-13.out does not exist, running . . .
P2_A-12.out does not exist, running . . .
P2_A-11.out does not exist, running . . .
P2_A-10.out does not exist, running . . .
P2_A-9.out does not exist, running . . .
P2_A-8.out does not exist, running . . .
P2_A-7.out does not exist, running . . .
P2_A-6.out does not exist, running . . .
P2_A-5.out does not exist, running . . .
P2_A-4.out does not exist, running . . .
P2_A-3.out does not exist, running . . .
P2_A-2.out does not exist, running . . .
P2_A-1.out does not exist, running . . .
P2_A0.out does not exist, running . . .
P2_A1.out does not exist, running . . .
P2_A2.out does not exist, running . . .
P2_A3.out does not exist, running . . .
P2_A4.out does not exist, running . . .
P2_A5.out does not exist, running . . .
P2_A6.out does not exist, running . . .
P2_A7.out does not exist, running . . .
P2_A8.out does not exist, running . . .
P2_A9.out does not exist, running . . .
P2_A10.out does not exist, running . . .
P2_A11.out does not exist, running . . .
P2_A12.out does not exist, running . . .
P2_A13.out does not exist, running . . .
P2_A14.out does not exist, running . . .
P2_A15.out does not exist, running . . .
P3_A-15.out does not exist, running . . .
P3_A-14.out does not exist, running . . .
P3_A-13.out does not exist, running . . .
P3_A-12.out does not exist, running . . .
P3_A-11.out does not exist, running . . .
P3_A-10.out does not exist, running . . .
P3_A-9.out does not exist, running . . .
P3_A-8.out does not exist, running . . .
P3_A-7.out does not exist, running . . .
P3_A-6.out does not exist, running . . .
P3_A-5.out does not exist, running . . .
P3_A-4.out does not exist, running . . .
P3_A-3.out does not exist, running . . .
P3_A-2.out does not exist, running . . .
P3_A-1.out does not exist, running . . .
P3_A0.out does not exist, running . . .
P3_A1.out does not exist, running . . .
P3_A2.out does not exist, running . . .
P3_A3.out does not exist, running . . .
P3_A4.out does not exist, running . . .
P3_A5.out does not exist, running . . .
P3_A6.out does not exist, running . . .
P3_A7.out does not exist, running . . .
P3_A8.out does not exist, running . . .
P3_A9.out does not exist, running . . .
P3_A10.out does not exist, running . . .
P3_A11.out does not exist, running . . .
P3_A12.out does not exist, running . . .
P3_A13.out does not exist, running . . .
P3_A14.out does not exist, running . . .
P3_A15.out does not exist, running . . .
P4_A-15.out does not exist, running . . .
P4_A-14.out does not exist, running . . .
P4_A-13.out does not exist, running . . .
P4_A-12.out does not exist, running . . .
P4_A-11.out does not exist, running . . .
P4_A-10.out does not exist, running . . .
P4_A-9.out does not exist, running . . .
P4_A-8.out does not exist, running . . .
P4_A-7.out does not exist, running . . .
P4_A-6.out does not exist, running . . .
P4_A-5.out does not exist, running . . .
```

```
P4_A-4.out does not exist, running . . .
P4_A-3.out does not exist, running . . .
P4_A-2.out does not exist, running . . .
P4_A-1.out does not exist, running . . .
P4_A0.out does not exist, running . . .
P4_A1.out does not exist, running . . .
P4_A2.out does not exist, running . . .
P4_A3.out does not exist, running . . .
P4_A4.out does not exist, running . . .
P4_A5.out does not exist, running . . .
P4_A6.out does not exist, running . . .
P4_A7.out does not exist, running . . .
P4_A8.out does not exist, running . . .
P4_A9.out does not exist, running . . .
P4_A10.out does not exist, running . . .
P4_A11.out does not exist, running . . .
P4_A12.out does not exist, running . . .
P4_A13.out does not exist, running . . .
P4_A14.out does not exist, running . . .
P4_A15.out does not exist, running . . .
P5_A-15.out does not exist, running . . .
P5_A-14.out does not exist, running . . .
P5_A-13.out does not exist, running . . .
P5_A-12.out does not exist, running . . .
P5_A-11.out does not exist, running . . .
P5_A-10.out does not exist, running . . .
P5_A-9.out does not exist, running . . .
P5_A-8.out does not exist, running . . .
P5_A-7.out does not exist, running . . .
P5_A-6.out does not exist, running . . .
P5_A-5.out does not exist, running . . .
P5_A-4.out does not exist, running . . .
P5_A-3.out does not exist, running . . .
P5_A-2.out does not exist, running . . .
P5_A-1.out does not exist, running . . .
P5_A0.out does not exist, running . . .
P5_A1.out does not exist, running . . .
P5_A2.out does not exist, running . . .
P5_A3.out does not exist, running . . .
P5_A4.out does not exist, running . . .
P5_A5.out does not exist, running . . .
P5_A6.out does not exist, running . . .
P5_A7.out does not exist, running . . .
P5_A8.out does not exist, running . . .
P5_A9.out does not exist, running . . .
P5_A10.out does not exist, running . . .
P5_A11.out does not exist, running . . .
P5_A12.out does not exist, running . . .
P5_A13.out does not exist, running . . .
P5_A14.out does not exist, running . . .
P5_A15.out does not exist, running . . .
```

In [ ]:

```
# Define parameters
S_ref = 826.13454               # reference area

'''
Legend for flight_stg:

1 = clean
2 = takeoff flaps, gear up
3 = takeoff flaps, gear down
4 = landing flaps, gear up
5 = landing flaps, gear down

'''
flight_stages = [1, 2, 3, 4, 5]

# Flight conditions for each flight condition
M =     [0.457, 0.183, 0.183, 0.15, 0.15]                                       # Mach Numbers
rho =   [0.1152e-02, 0.0023769, 0.0023769, 0.0023769, 0.0023769]                # Densities
V =     [275*1.6878099,  1.3*157.3,  1.3*157.3, 1.3*128.4, 1.3*128.4]     # Velocities
mu =    [3.246e-7, 3.784e-7, 3.784e-7, 3.784e-7, 3.784e-7]                      # Dynamic Viscosities



'''
We need to put the following code into a for loop to get an array of Cd0 values that correspond
to the five flight stages. Then we can combine the CD0 values with the avl values to get our full
drag polars
'''


# Loop that ouputs an array of CD0 values corresponding to our 5 flight stages
CD0s = []
for i in range(len(flight_stages)):
    all_components = Drag_Build_Up.dragDragComponents(M[i], rho[i], V[i], mu[i])
    Sumcomps = (1/S_ref) * sum([component.CalculateDrag() for component in all_components])
    C_D_leakpro = 0.07 * Sumcomps
    C_D_missing = MiscDrag.miscDrag(M[i], flight_stages[i])

    # print("Flight Stage", flight_stages[i])
    # print("Wing: ", all_components[0].CalculateDrag() / S_ref)
    # print("hTail: ", all_components[1].CalculateDrag() / S_ref)
    # print("vTail: ", all_components[2].CalculateDrag() / S_ref)
    # print("Fuselage: ", all_components[3].CalculateDrag() / S_ref)
    # print("Nacelle: ", all_components[4].CalculateDrag() / S_ref)


    CD0s.append(Sumcomps + C_D_leakpro + C_D_missing)
print(CD0s)

# for i in range(len(flight_stages)):
#     Cdflap = FlapDrag.flapDrag(flight_stages[i])

# Cl's corresponding to the flight stages defined above
# cl1 =
# cl2 =
# cl3 =
# cl4 =
# cl5 =
```

```
Flight Stage 1
Wing:  0.004500176399830272
hTail:  0.0006055446619394421
vTail:  0.0007271689644441155
Fuselage:  0.003949889105481129
Nacelle:  0.000474344642571512
Flight Stage 2
Wing:  0.004069897697126311
hTail:  0.0005488124364364549
vTail:  0.0006562864215442628
Fuselage:  0.004161369172221671
Nacelle:  0.0005008745831006049
Flight Stage 3
Wing:  0.004069897697126311
hTail:  0.0005488124364364549
vTail:  0.0006562864215442628
Fuselage:  0.004161369172221671
Nacelle:  0.0005008745831006049
Flight Stage 4
Wing:  0.00409801868193114
hTail:  0.000553710435462744
vTail:  0.0006595433776780898
Fuselage:  0.004292851405932295
Nacelle:  0.0005176099232073313
Flight Stage 5
Wing:  0.00409801868193114
hTail:  0.000553710435462744
vTail:  0.0006595433776780898
Fuselage:  0.004292851405932295
Nacelle:  0.0005176099232073313
[0.011187813102627408, 0.0108013460742324, 0.011890757007226438, 0.011776775603126384, 0.01286618653612042]
```

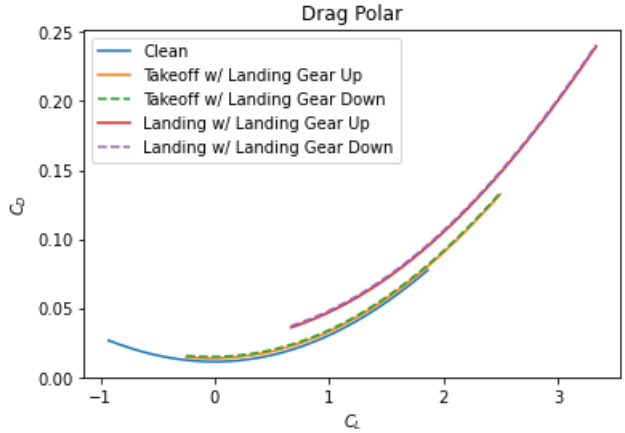
In [ ]:

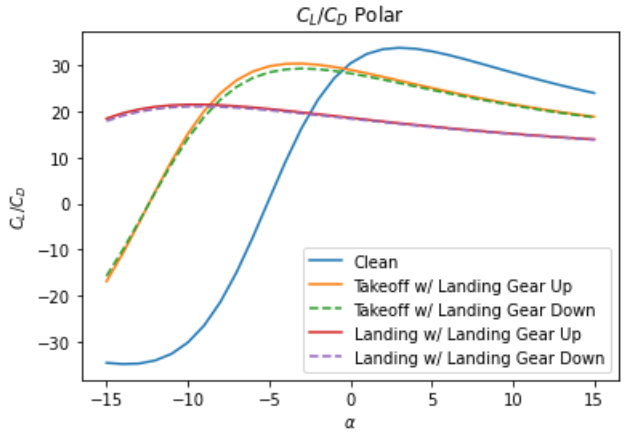
```
# plt.plot(CL1,CD1)
# plt.plot(CL2,CD2)
# plt.plot(CL3,CD3)
# plt.plot(CL4,CD4)
# plt.plot(CL5,CD5)

# plt.figure()

plt.plot(CL1,(CD0s[0]+CD1),label='Clean')
plt.plot(CL2,(CD0s[1]+CD2),label='Takeoff w/ Landing Gear Up')
plt.plot(CL3,(CD0s[2]+CD3),'--',label='Takeoff w/ Landing Gear Down')
plt.plot(CL4,(CD0s[3]+CD4),label='Landing w/ Landing Gear Up')
plt.plot(CL5,(CD0s[4]+CD5),'--',label='Landing w/ Landing Gear Down')
plt.xlabel('$C_L$')
plt.ylabel('$C_D$')
plt.title('Drag Polar')
plt.legend()
plt.savefig("Drag Polar.svg")


plt.figure()
plt.plot(range(-15,15+1),CL1/(CD0s[0]+CD1),label='Clean')
plt.plot(range(-15,15+1),CL2/(CD0s[1]+CD2),label='Takeoff w/ Landing Gear Up')
plt.plot(range(-15,15+1),CL3/(CD0s[2]+CD3),'--',label='Takeoff w/ Landing Gear Down')
plt.plot(range(-15,15+1),CL4/(CD0s[3]+CD4),label='Landing w/ Landing Gear Up')
plt.plot(range(-15,15+1),CL5/(CD0s[4]+CD5),'--',label='Landing w/ Landing Gear Down')
plt.xlabel('$\\alpha$')
plt.ylabel('$C_L/C_D$')
plt.title('$C_L/C_D$ Polar')
plt.legend()
plt.savefig("LD Polar.svg")
```


Drag Polar
Clean
Takeoff w/ Landing Gear Up
Takeoff w/ Landing Gear Down
Landing w/ Landing Gear Up
Landing w/ Landing Gear Down
C_D
C_L
0.25
0.20
0.15
0.10
0.05
0.00
−1
0
1
2
3


C_L/C_D Polar
Clean
Takeoff w/ Landing Gear Up
Takeoff w/ Landing Gear Down
Landing w/ Landing Gear Up
Landing w/ Landing Gear Down
C_L/C_D
α
30
20
10
0
−10
−20
−30
−15
−10
−5
0
5
10
15