MAE 158 Drag Calculator

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Skin Friction Drag Coeff

Setup

```
hp_aircraft = 1;
T = 400;
%P = 1;  % via Table A.2
R = 1716;
rho = 0.0008754;

speedSound = sqrt(1.4*R*T)
```

```
speedSound = 980.2857
```

```
V = [230:10:880]%765;
```

```
V = 1×66
   230   240   250   260   270   280   290   300   310   320   330   340   350 ···
```

```
M = V/speedSound    % Mach Number
```

```
M = 1×66
    0.2346    0.2448    0.2550    0.2652    0.2754    0.2856    0.2958    0.3060 ···
```

```


Sref = 1000;

%CRexp = [];
%K = [];
%Cf = [];
%f = [];

%% Characteristic Lengths
MACexpW = 0;
MACexph = 0;
MACexpv = 0;
Lc = [MACexpW, MACexph, MACexpv, 16.2, 16.8];

%% Ratios
Lf = 119;
Df = 11;
ratios = [0.12, 0.09, 0.09, 0.06, Lf/Df, 5]  % Thickness and Fineness
```

```
ratios = 1×6
    0.1200    0.0900    0.0900    0.0600   10.8182    5.0000
```

```
sigma = [0.2, 0.35, 0.8, 1] % Taper
```

```
sigma = 1×4
    0.2000    0.3500    0.8000    1.0000
```

```
%% Sexp
Sexpw = 0;  % Defined Later on
Sexp = [Sexpw, 261, 161]
```

```
Sexp = 1×3
     0   261   161
```

```
%% Swet
Swet = [0, 0, 0, 117, 0, 455]
```

```
Swet = 1×6
     0     0     0   117     0   455
```

Wing

```
bW = 93.2;                          % Span
tcW = 0.18;
sweepangleW = 28;                   % Sweep Angle
sigmaW = 0.2;                       % Taper Ratio: cT/cR
CRW = 17.8;                         % Root Chord
Coverage_wing = .17;                % Percent Covered
Rfuse = 11/2;

% Getting Swet %
SexpW = (1-Coverage_wing)*Sref;
SwetW = SWET(SexpW);

% Getting Skin Friction Coefficient %
CTW = sigmaW * CRW;
CRexp_wing = CREXP(CRW, CTW, Rfuse, bW);
MACexpW = MAC(CRexp_wing,CTW)
```

```
MACexpW = 11.1755
```

```
RNw = ReynoldsNumber(V, MACexpW);
Cf_w = CF(RNw);

% Getting Form Factor %
Kwing = Kairfoil(tcW, M, sweepangleW)
```

```
Kwing = 1.4572
```

```
% Calculating f and adding to array %
fwing = F(Kwing, Cf_w, SwetW)
```

```
fwing = 1×66
    7.7743    7.7206    7.6696    7.6210    7.5746    7.5304    7.4880    7.4473 ···
```

Horizontal Tail

```
SexpH = 261;
```

```
tcH = 0.09;
sweepangleH = 31.6;              % Sweep Angle
sigmaH = 0.35;                   % Wing Taper Ratio
CRH = 11.1;                      % Root Chord

% Getting Swet %
SwetH = SWET(SexpH);

% Getting Skin Friction Coefficient %
CTH = sigmaH * CRH;
MACexpH = MAC(CRH,CTH)
```

```
MACexpH = 8.0715
```

```
RNh = ReynoldsNumber(V, MACexpH);
Cf_h = CF(RNh);

% Getting Form Factor %
Khoriztail = Kairfoil(tcH, M, sweepangleH)
```

```
Khoriztail = 1.1720
```

```
% Calculating f and adding to array %
fhoriztail = F(Khoriztail, Cf_h, SwetH)
```

```
fhoriztail = 1×66
    2.0744    2.0598    2.0459    2.0327    2.0200    2.0080    1.9964    1.9854 ···
```

Vertical Tail

```
SexpV = 161;
tcV = 0.09;
sweepangleV = 43.5;              % Sweep Angle
sigmaV = 0.8;                    % Wing Taper Ratio
CRV = 15.5;                      % Root Chord

% Getting Swet %
SwetV = SWET(SexpV);

% Getting Skin Friction Coefficient %
CTV = sigmaV * CRV;
MACexpV = MAC(CRV,CTV)
```

```
MACexpV = 14.0074
```

```
RNv = ReynoldsNumber(V, MACexpV);
Cf_v = CF(RNv);

% Getting Form Factor %
Kverttail = Kairfoil(tcV, M, sweepangleV)
```

```
Kverttail = 1.1354
```

```
% Calculating f and adding to array %
fverttail = F(Kverttail, Cf_v, SwetV)
```

```
fverttail = 1×66
    1.1328    1.1251    1.1177    1.1107    1.1041    1.0977    1.0916    1.0858 ···
```

Pylons

```
SwetP = 117;                    % Wetted Area
tcP = 0.06;
sweepangleP = 0;                % Sweep Angle
sigmaP = 1;                     % Taper Ratio: cT/cR
chordP = 16.2;                  % Chord

% Getting Skin Friction Coefficient %
RNp = ReynoldsNumber(V, chordP);
Cf_p = CF(RNp);

% Getting Form Factor %
Kpylon = Kairfoil(tcP, M, sweepangleP)
```

```
Kpylon = 1.1514
```

```
% Calculating f and adding to array %
fpylon = F(Kpylon, Cf_p, SwetP)
```

```
fpylon = 1×66
    0.3998    0.3971    0.3945    0.3921    0.3898    0.3875    0.3854    0.3833 ···
```

Fuselage

```
Lf = 105;
Df = 11;

% Calculating Swet %
SwetF = 0.8 * pi * Df * Lf;

% Getting Skin Friction Coefficient %
RNf = ReynoldsNumber(V, Lf);
Cf_f = CF(RNf)
```

```
Cf_f = 1×66
    0.0022    0.0022    0.0022    0.0022    0.0022    0.0022    0.0022    0.0022 ···
```

```
% Getting Form Factor %
ratioF = Lf/Df
```

```
ratioF = 9.5455
```

```
Kfuse = KFR(ratioF);            % Via Digitized Figure 11.4

% Calculating f and adding to array %
```

```
ffuselage = F(Kfuse, Cf_f, SwetF)
```

```
ffuselage = 1×66
    7.1882    7.1447    7.1033    7.0638    7.0261    6.9901    6.9556    6.9224 ···
```

Nacelles

```
% Swet %
SwetN = 455;

% Getting Skin Friction Coefficient %
Ln = 16.8
```

```
Ln = 16.8000
```

```
RNn = ReynoldsNumber(V, 16.8);
Cf_n = CF(RNn)
```

```
Cf_n = 1×66
    0.0030    0.0029    0.0029    0.0029    0.0029    0.0029    0.0028    0.0028 ···
```

```

% Getting Form Factor %
ratioN = 5;
Knacelle = KFR(ratioN);           % Via Digitized Figure 11.4

% Calculating f and adding to array %
fnacelle = F(Knacelle, Cf_n, SwetN)
```

```
fnacelle = 1×66
    1.7339    1.7222    1.7111    1.7006    1.6905    1.6809    1.6716    1.6628 ···
```

Total Skin Friction

```
ftotal = fwing + fhoriztail + fverttail + fpylon + ffuselage + fnacelle;
CDP_total = ftotal./Sref
```

```
CDP_total = 1×66
    0.0203    0.0202    0.0200    0.0199    0.0198    0.0197    0.0196    0.0195 ···
```

Induced Drag Coeff

```
% Getting CL %
W = 98000;                % Aircraft Weight
q = 0.5 * rho * (V.^2);   % Dynamic Pressure
CL = W ./ (q * Sref)      % Coeff of Lift
```

```
CL = 1×66
    4.2325    3.8871    3.5824    3.3121    3.0713    2.8558    2.6623    2.4878 ···
```

```

% Getting Aspect Ratio %
ARw = (bW^2)/Sref
```

```
ARw = 8.6862
```

```
% Getting CDi %
e = 1;                              % Oswald Efficiency Factor
CDi = (CL.^2) / (pi * ARw * e)    % Coeff of Induced Drag
```

```
CDi = 1×66
    0.6565    0.5537    0.4703    0.4020    0.3457    0.2989    0.2597    0.2268 ···
```

Total Drag & Lift/Drag Ratio

```
ProfileDrag = CDP_total .* q .* Sref
```

```
ProfileDrag = 1×66
10^3 ×
    0.4701    0.5085    0.5483    0.5894    0.6319    0.6758    0.7211    0.7677 ···
```

```
InducedDrag = CDi .* q .* Sref
```

```
InducedDrag = 1×66
10^4 ×
    1.5200    1.3960    1.2865    1.1895    1.1030    1.0256    0.9561    0.8934 ···
```

```
CDtotal = CDP_total + CDi
```

```
CDtotal = 1×66
    0.6768    0.5739    0.4903    0.4219    0.3655    0.3186    0.2793    0.2463 ···
```

```
TotalDrag = CDtotal .* q .* Sref
```

```
TotalDrag = 1×66
10^4 ×
    1.5670    1.4468    1.3413    1.2484    1.1662    1.0932    1.0282    0.9702 ···
```

```
L = W
```

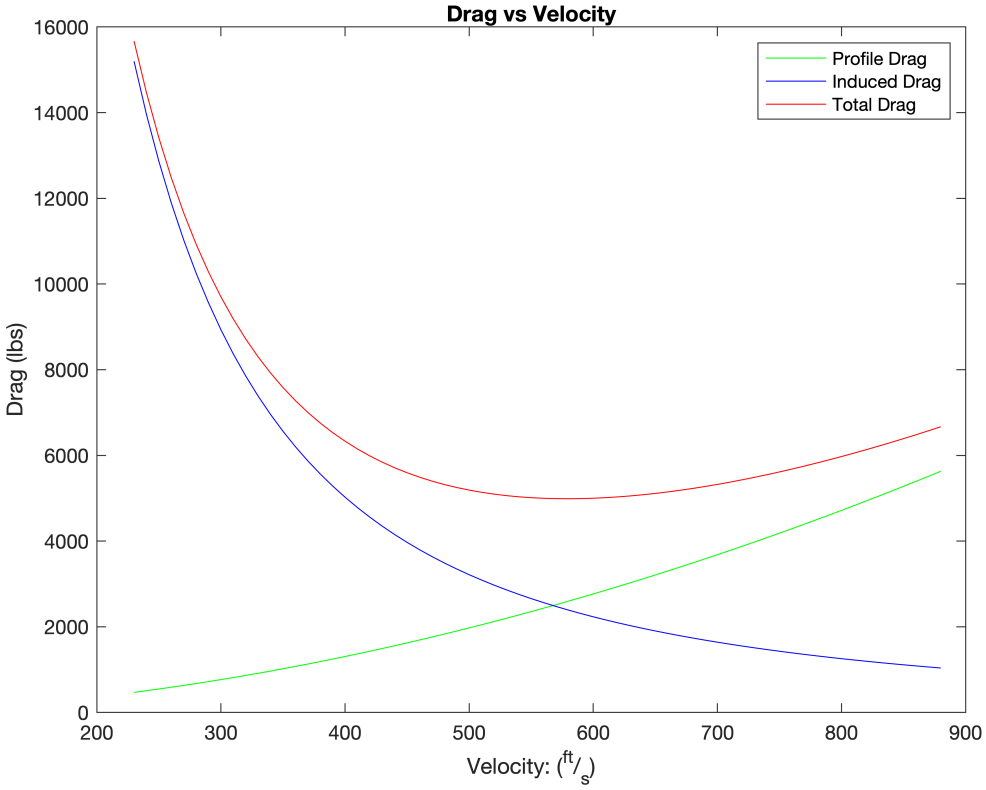
```
L = 98000
```

```
LiftToDrag = L ./ TotalDrag
```

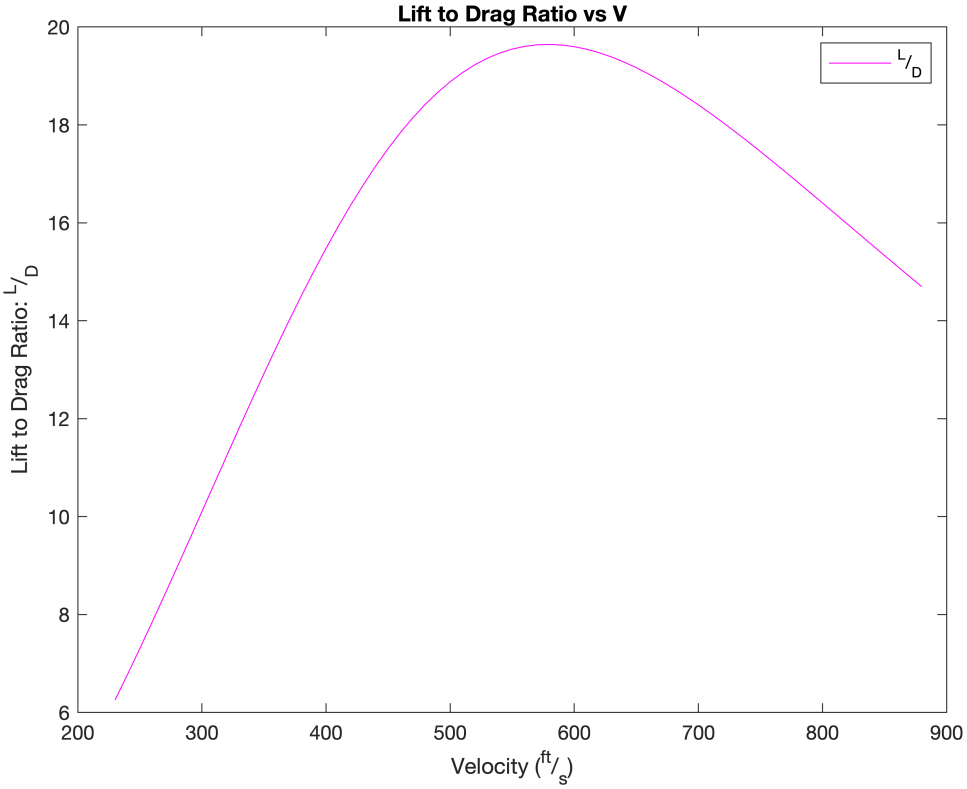
```
LiftToDrag = 1×66
    6.2540    6.7735    7.3061    7.8501    8.4036    8.9646    9.5313   10.1013 ···
```

Plots

```
hold off;
plot(V, ProfileDrag, 'g', V, InducedDrag, 'b', V, TotalDrag, 'r')
title("Drag vs Velocity")
ylabel("Drag (lbs)")
xlabel("Velocity: (^{ft}/_{s})")
legend("Profile Drag", "Induced Drag", "Total Drag")
```




```
plot(V,LiftToDrag, 'm')
title("Lift to Drag Ratio vs V")
ylabel("Lift to Drag Ratio: ^{L}/_{D}")
xlabel("Velocity (^{ft}/_{s})")
legend("^{L}/_{D}")
```



Functions

Reynolds Number Function

```
function RN = ReynoldsNumber(Velocity, characteristicLength)
    mu = 3.025E-7;
    rho = 0.0008754;
    V = Velocity;
    Lc = characteristicLength;
    RN = (rho * V * Lc)/mu;
end
```

Swet Function

```
function Swet = SWET(Sexp)
    Swet = 2 * 1.02 * Sexp;
end
```

MAC Function

```
function cbar = MAC(cR, cT)
    cbar= (2/3) * (cR + cT - ((cR*cT)/(cR+cT)));
end
```

CR Exposed Function

```
function crexp = CREXP(cR, cT, y, b)
    crexp = cR - ((cR- cT)*(2*(y/b)));
```

```
end
```

Skin Friction Coefficient

```
function Cf = CF(RN)
    Cf = 0.455 ./ ((log10(RN)).^2.58);
end
```

Form Factor for Airfoils

```
function K = Kairfoil(tc, Mo, sweepAngle)
    numTerm = (2-Mo.^2) * cosd(sweepAngle);
    denTerm = sqrt(1-(Mo*cosd(sweepAngle)^2));
    Z = numTerm/denTerm;
    K = 1 + (Z * tc) + (100*tc^4);
end
```

Form Factor via Fineness Ratio

```
function K = KFR(LbyD)
    K = 1.991*LbyD^-1.024+0.9084;
    % General model Power2:
    % Coefficients (with 95% confidence bounds):
    %    a =       1.991  (1.882, 2.101)
    %    b =      -1.024  (-1.091, -0.9582)
    %    c =      0.9084  (0.8888, 0.9279)
end
```

F Function

```
function f = F(K, Cf, Swet)
    f = K * Cf * Swet;
end
```